DIGITAL TECHNOLOGY FOR THE
RECONSTRUCTION AND INTERPRETATION OF
SUNGAI BATU ARCHAEOLOGICAL SITE

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DIGITAL TECHNOLOGY FOR THE
RECONSTRUCTION AND INTERPRETATION OF
SUNGAI BATU ARCHAEOLOGICAL SITE

by

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LIST OF ABBREVIATIONS

2D Two-Dimensional
3D Three-Dimensional
AI Artificial Intelligence
AR Augmented Reality
ARCO Augmented Representation of Cultural Objects
BCE Before Common Era
CE Common Era
GIS Geographical Information System
GPS Global Positioning System
ICOMOS The International Council on Monuments and Sites
ICT Information and Communication Technology
ISIS Islamic State of Iraq and Syria
LiDAR Light Detection and Ranging
.jpg Joint Photographic Experts
OSL Optically Stimulated Luminescence
RADAR Radio Detection and Ranging
SB Sungai Batu
TEM Transient Electromagnetic
UAV Unmanned Aerial Vehicles
UCLA University of California, Los Angeles
UNESCO The United Nations Educational, Scientific and Cultural Organization
USGC United States Geological Survey
USM Universiti Sains Malaysia
VR Virtual Reality
XRF X-ray fluorescence
DIGITAL TEKNOLOGI UNTUK REKONSTRUKSI DAN INTERPRETASI
TAPAK ARKAEOLOGI SUNGAI BATU

ABSTRAK

DIGITAL TECHNOLOGY FOR THE RECONSTRUCTION AND INTERPRETATION OF SUNGAI BATU ARCHAEOLOGICAL SITE

ABSTRACT

The archaeological complex of Sungai Batu revealed the evidences of early civilisation in Bujang Valley which have been excavated since 2009. Researchers have identified each of the site by four different functions. They are the ritual monument, iron smelting site, jetty and the jetty administration/ supporting structure. Although the discovery of Sungai Batu is significant, the sites condition in the ruins which causes most of the artefacts were broken in fragments and the sites can only be seen from limited viewpoint. In this regard, it is hard for the visitor to have complete understanding of the sites from these fragmented evidences. Thus, this study aims to explore the practice of digital technology in representing the archaeological interpretation based on four selected sites at Sungai Batu Archaeological Complex. Through computer-based visualisation method, the study intends to promote the aspect of intellectual and technical rigour, by adopted several recommended guidelines from the London Charter. The outcomes visualise four 3D reconstruction of archaeological sites by each of them represents each of the functions, three complete reconstruction of either missing/fragmented or broken artefact and one prototype of holographic visualisation. The 3D virtual reconstruction appears as valuable digital methods which it can produces variety of other media thus it create more inovative and effective presentation and dissemination of the archaeological knowledge.
CHAPTER 1
INTRODUCTION

1.1 Introduction

The research presented in this thesis explored the use of digital technology for 3D virtual/digital reconstruction to increase the understanding of the archaeological interpretations at Sungai Batu sites. In this chapter, it briefly describes the definitions of key concepts or specific terms applied for this study and summarisation of guidelines by The London Charter (Denard, 2009) regarding computer-based visualisation. Following this, the chapter explains the general background of Sungai Batu Archaeological Site in Bujang Valley as sites study for this research including the issues that interconnect the motivation of research work for digital reconstruction. The chapter also defines the research gaps, research aim and questions along with the objectives of this study. Furthermore, it also describes summary of the research methodology, the scope of work, and the research contribution. Finally, the structure of each chapter in this dissertation is presented at the end of the chapter.

1.2 Key Concept and Recommended Guidelines

Digital technology is related to the creation and practical use of digital or computerised devices, methods, systems, etc. The process of digitalisation is the method of generating the computer databases through the application of digital devices. It also includes digital representation of an object, image, sound, text or any forms of digital format which are applicable to utilise in a computer and other supportive devices. Digital devices that have been applied in archaeological field such as GPS, total stations, laser scanning, and computer or even digital camera, has
provided an unlimited amount of data which we can elect and make best use of it (Lafrance, 2016). Nowadays, with the emerging technologies applied in cultural heritage sector, they have welcomed the new concepts for representation, reconstruction and interpretation of reality particularly by using various application of graphical software and hardware installation. This concept established using several terms such as virtual heritage, digital heritage, digital archaeology, virtual museums and cyber-archaeology (e.g. Barceló, 2001b Bendicho et al., 2017; Hugget, 2015; Kolay, 2016; Evans & Daly, 2006; Rahaman & Tan, 2011; Morgan & Eve, 2012; Sanders, 2006).

According to UNESCO (2003), ‘digital heritage’ is any digital content that possess cultural value both in the form of 2-Dimensional such as text, image and motion pictures; and 3-Dimensional such as navigational virtual environment and three-dimensional objects. It comprises the uniqueness of human knowledge and expression where the information created digitally or converted into digital form from existing analogue resources (UNESCO, 2003). The term ‘heritage’ alone refers to the study of human activity where in archaeology field, it does not limit to the recovery remains, but also through tradition, art and cultural evidences and narratives (Rahaman & Tan, 2011).

In other words, the contents of digital heritage consisting the information on history and cultural value that represents and interprets in digital form. Although digital heritage often associates with the state-of-the-art digital data such as 3D model or virtual environment, it also includes 2D graphic and processing as well as image captures by digital camera. Besides, they can also originate from the sources that physically available such as old hand-drawn drawing and can be converted into digital form.
Since 1973, the Computer Applications in Archaeology (CAA) conference has been held annually (Huggett, 2013), has proved the long establishment regarding the practice of computer and information science to represent and interpret the archaeological data. The digital interpretations of the cultural heritage are the practice using the computer-based visualisation method that function as tool for archaeologists to increase their capacity to understand the site (UNESCO, 2003).

The ICOMOS has highlighted ‘interpretation’ as range of potential activities intended to heighten public awareness and enhance understanding of cultural heritage site (Silberman, 2008). Rahaman and Tan (2011) also believed that the interpretation in archaeology as “an effective learning, communicating and management tool that increases visitors’ awareness and empathy to the site and artefacts”.

In addition, Silberman (2008) suggested that interpretation does not limit to the type of programmes or activities such as public lectures, educational and communities programme, it also can be made in print and electronic publications, ongoing research and training, including the evaluation of the interpretation process itself. In this regard, digital interpretation by computer-based visualisation as an educational tools or practices for both archaeologist and the public that improves their understanding to the historical objects and sites.

Gabellone & Scardozzi (2007) explained that the virtual reconstruction of objects or sites does requires sufficient and details presentation and contextualisation in order to appear not only as artistic, but the fundamental value on the historical and cultural evidence can be understood by the public. Earl (2013) deliberately agreed that archaeological interpretation with rich textual narrative and description provides the identical reciprocity, creating engagement with the visual simulation thus it will encourage critique and discussion. Meanwhile Rahaman and Tan (2011) urged for the
digital interpretation of the past should comprehensively portrays multiple viewpoints to cater the understanding of the users from diverse backgrounds.

Computer-based visualisation according to the London Charter (Denard, 2009) is the practice of representation information virtually with the help of advanced computer technologies. Since it has been evolved over the years, currently there are various version of graphics software and modelling tools at the market which offer variety of outcomes in the form of digital media. The creation of 3D model, animation, holographic presentation and virtual reality are among digital materials that can be developed through the applications of computer-based visualisation. Generally, all abovementioned concepts and theoretical definitions are the domains under the broad application of digital archaeology that associates the uses of digital technology in the study of archaeology.

As discuss above, all the definitions were explained to establish the understand of the key terms and concept that applied in this research context. Table 1.1 below presents the definition of above matters.

<table>
<thead>
<tr>
<th>Key Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital technology</td>
<td>Related to the creation and practical use of digital or computerised devices, methods, systems, etc</td>
</tr>
<tr>
<td>Digitalisation</td>
<td>Method of generating the computer databases through the application of digital devices. It also includes digital representation of an object, image, sound, text or any forms of digital format which are applicable to utilise in a computer and other supportive devices.</td>
</tr>
<tr>
<td>Digital Heritage</td>
<td>Any digital content that possess cultural value both in the form of 2 Dimensional such as text, image and motion pictures; and 3 Dimensional such as navigational virtual environment, three dimensional objects.</td>
</tr>
<tr>
<td>Digital Interpretations</td>
<td>Range of potential activities particularly by using the computer-based visualisation method intended to heighten public awareness and as tools for both archaeologist and public to increase their capacity to understand the site.</td>
</tr>
<tr>
<td>Computer-based visualisation</td>
<td>The process of representation information visually with the help of advanced computer technologies.</td>
</tr>
</tbody>
</table>
Table 1.1 Continued

<table>
<thead>
<tr>
<th>Computer-based visualisation outcome</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>An outcome of computer-based visualisation, including but not limited to digital models, still images, animations and physical models.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3D Virtual Reconstruction/ 3D Digital reconstruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reconstruction of 3-Dimensional model that generated by computer graphic and modelling technique.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Virtual Archaeology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The representation of landscapes, objects, or sites of the past and the overall process of visualization of archaeological data with the use of VR technology.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Digital Archaeology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The uses of digital technology to study the past. Digital archaeology has both enabled archaeological theory and correlates with particular types of theory</td>
<td></td>
</tr>
</tbody>
</table>

1.2.1 The London Charter

This research work focuses on digital archaeology as its theoretical standpoint where it provides a way of approaching the archaeology with digital techniques and demonstrating the method. Digital archaeology as described by Evans & Daly (2006), function as ‘tool’ that give archaeologist an opportunity to explore and understand its strengths and limits of computer and information technology, particularly in process of creating the interpretations.

Regarding this, many of the scholars (Sanders, 2006; Rua & Alvito, 2011; Pujol, 2004; Barceló, 2001) have supported the 3D reconstruction and visualisation of heritage sites into practice. One of the main reasons is because this method has allowed various experimentation and hypotheses for better analysis and increase the ability for spatial exploration of the structure without disturbing the physical or original site/structure. Simultaneously, this practice in the contexts of research, communication and preservation of cultural heritage led to establishment of various digital archives particularly for 3D visualisation or 3D digital model on important world heritage sites.

Hence, since the digital methods are now employed in a wide range of conservation and preservation efforts, the question on the ‘transparency’ of 3D visualisation application has been constantly debated among the cultural heritage
professional (Beacham et al., 2006). The issues such as reliability of the archaeological data that has been portrayed in films or games based on historical themes is one of the concerning issues of digital reconstruction. In addition, the problem of indicating the different types of reality in visualisation for popularisation of archaeology in either tourist or the entertainment industry should be taken into consideration (Evans & Daly, 2006). Therefore, the implication on transparency for digital interpretation and presentation has encourage heritage professionals to form the guidelines to address several complexity issues and defining the purpose, method and outcomes of the digital interpretation and the practice of computer-based visualisation.

For instance, worldwide heritage organisations such as UNESCO and ICOMOS have collaboratively supported the digital empowerment to protect and interpret the tangible and intangible cultural heritage. For examples, The ICOMOS Charter has established guidelines that encourage effective communication to address the importance of heritage preservation. This nature of public communication has described as “dissemination,” “popularization,” “presentation,” and “interpretation” is part of important act of the conservation process (Silberman, 2008). Similarly, UNESCO (2003) also has provided the Charter on the Preservation of Digital Heritage which emphasised the measures needs to be taken throughout the digital information life cycle, from the creation to the continuity of the digital heritage.

Therefore, the continuing research interest in application digital technology has encouraged researcher to observe necessary recommended principles from ICOMOS and UNESCO Charter and into practice. Similarly, this research believes it is important to implement these guidelines to ensure the relevant of research sources, the methods and outcomes are documented in a way for the work-flow of visualisation is properly
presented. Among other recognised documentation of guideline in this field of interest is *The London Charter*.

The Charter established the fundamental objectives and principles of the 3D visualisation methods to ensure the practice is intellectually and technically rigorous (Beacham *et al.*, 2006). In addition, it defines the strategies for application of the visualisation method which aims to serve the whole range of Arts, Humanities and Cultural Heritage disciplines (Beacham *et al.*, 2006). Although it does not describe specific methods and techniques (Denard, 2009), since the technologies are constantly changing and develop, the charter particularly established what is required for 3D visualisation to be and to be seen to be. The main objectives of the London Charter (Denard, 2009) document as stated below:

i. **Provide a benchmark** having widespread recognition among stakeholders.

ii. **Promote intellectual and technical rigour** in digital heritage visualisation.

iii. **Ensure** that computer-based visualisation **processes and outcomes** can be **properly understood and evaluated** by users.

iv. Enable computer-based visualisation authoritatively to **contribute to the study, interpretation and management** of cultural heritage assets.

v. **Ensure access and sustainability strategies** are determined and applied.

vi. **Offer a robust foundation** upon which communities of practice can build detailed London Charter Implementation Guidelines.

From these objectives, The London Charter formulated six principles to define the use of computer-based visualisation methods in research and dissemination of cultural heritage across academic, educational, curational and commercial domains. Thus, several points of references from these principles were applies to understand the
reconstruction and interpretation of archaeological data in this study. In following Chapter 3, these respective points have been elaborated to justify the methods of 3D digital reconstruction in this study. Table 1.2 comprises the general summary for all six principles presented in the London Charter (Denard, 2009).

Table 1.2: Principles in The London Charter (Denard, 2009).

<table>
<thead>
<tr>
<th>Principle</th>
<th>General Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Implementation</td>
<td>The principles of the London Charter are valid wherever computer-based visualisation is applied to the research or dissemination of cultural heritage</td>
</tr>
<tr>
<td>2  Aims and Methods</td>
<td>A computer-based visualisation method should normally be used only when it is the most appropriate available method for that purpose.</td>
</tr>
<tr>
<td>3  Research Sources</td>
<td>In order to ensure the intellectual integrity of computer-based visualisation methods and outcomes, relevant research sources should be identified and evaluated in a structured and documented way.</td>
</tr>
<tr>
<td>4  Documentation</td>
<td>Sufficient information should be documented and disseminated to allow computer-based visualisation methods and outcomes to be understood and evaluated in relation to the contexts and purposes for which they are deployed.</td>
</tr>
<tr>
<td>5  Sustainability</td>
<td>Strategies should be planned and implemented to ensure the long-term sustainability of cultural heritage-related computer-based visualisation outcomes and documentation, in order to avoid loss of this growing part of human intellectual, social, economic and cultural heritage.</td>
</tr>
<tr>
<td>6  Access</td>
<td>The creation and dissemination of computer-based visualisation should be planned in such a way as to ensure that maximum possible benefits are achieved for the study, understanding, interpretation, preservation and management of cultural heritage</td>
</tr>
</tbody>
</table>

To conclude, the digital archaeology has utilised the advancement in digital technology to allow archaeological knowledge to be represented and interpreted in a way that it useful to provide understanding for general audience. It often portrayed through virtual representation or reconstruction with purpose for heighten the awareness and create the empathy for the historical sites, monuments or artefacts. At
the same time, it can be powerful tools communication and knowledge transition between research communities. However, without proper standard to define this method, the 3D digits model often views as no more than artist impression that does not promote academic and technical rigour. Therefore, this study adopts several strategies highlighted by The London Charter to justify the methods and techniques of digital interpretation that appropriate with the aim of reconstruction.

1.3 Research Background

Sungai Batu archaeological sites located in historical territories of the Bujang Valley in northern state, Kedah (Figure 1.1). Upon discovery, they were situated at private oil palm plantation before the area has been gazetted as Malaysian’s heritage site under the authorisation of Jabatan Warisan Negara (National Heritage Department). This property received recognition by Ministry of Information, Communication and Culture (KPKK), which currently the department known as Ministry of Tourism and Culture (MOTAC). The area extends as far as 1000km² compared with 400km in the early estimation (Mokhtar et al., 2011).
Figure 1.1: The location of Sungai Batu Archaeological Complex, bordered by Merbok, Bedong and Sungai Petani area.

The excavations have started since 2009 and all these integrated sites have revealed to be a large archaeological complex. Thus far, there are 57 excavated sites out of 97 potential sites mapped at the initial field survey in 2007. Through excavation and archaeological research, these sites were identified and have been categorised into four different functions. The four functions were represented by a ritual monument, riverside jetties and iron smelting sites and a structure to be believe as the jetty administrative monuments. At present, the complete excavated sites are sheltered by adjustable open-air structure and they are open to visit by the public but with certain limitation access.

The study area situated at two separated sides one at the north and another at south which both separated by the main Merbok -Semeling road, 10km to the northwest of Sungai Petani town. The prominent sight of Mount Jerai at the north
indicates the nearby mount range in the region of Bujang Valley. Sungai Batu area bordered by fertile lands ranging from tropical forest of Gunung Jerai, oil palm plantation, rubber estate and paddy field. The Merbok river provides an inlands waterway of Sungai Batu tributary, which flows from north to south before heading to the west towards the sea. At present, the topography of the surrounding area is flat landed and gradually increasing towards north then declining and sloping to the west of the study area, approximately 8km to the mouth of Merbok river (Sarmiza, 2011).

Series of excavations have revealed two main features of for Sungai Batu site, one is structural site and the other is non-structural site. Structural site is referred to the excavated site containing several constructed building elements such as floor, walkways, wall and stairs that made by clay-baked bricks. The ritual monument, jetty and administration/supporting building are categorised as the structural sites. Whereas the non-structural site is characterised by iron smelting site that appears as traces of smelting activity. Non-structural site is the excavated site without any elements of building construction and the site is represented by evidence of main activity or indicated the production work of Sungai Batu past community. Sungai Batu Archaeological Complex can be seen as an advanced civilisation hub following the evidence of ancient smelting site which complete with other structural facilities such as riverside jetty.

1.3.1 Structural Site: Ritual, Jetty and Administration Structure

The structural sites referred to the finding of ruinous structure made by bricks as main construction material. Thus far, they are three types of sites listed under this category. They are the ritual monument, jetty and jetty’s administration. Currently there only one structural site which identified to be a religious or ritual monument at
Sungai Batu. It is known as SB1B which SB refer for Sungai Batu, 1 to indicate the northern part of Sungai Batu area, and B as the sequence of excavated sites in alphabet order. The SB1B was excavated in 2009 and the dating by the OSL (Optically Stimulated Luminescence) has shown to be 110 CE (Mokhtar et al., 2011) thus making this structure to be the oldest religious monument in Southeast Asia.

Additionally, this ritual monument site also accompanied by four other structures namely SB1C, SB1D, SB1E and SB1F that adjacent with the main structure SB1B. These sites served as the supporting structure for the ritual monument. Unlike SB1B, these four sites do not have any distinctive form of brick arrangement, however these bricks ruins appear as several large mounds. Besides, there are also several visible small circle structures on ground found particularly at SB1D and SB1E (Siti Nurul Siha, 2014).

The second structural site in Sungai Batu was identified as a jetty structure. The jetty structure is undeniably among important site for Sungai Batu which in the past it had provided a way of transportation and a means of communication with neighbouring jetty or port. The function of jetty implies to the structure that built near the river or stream of the ancient Sungai Batu. The data on stratigraphy, ground drilling and electric imaging at the jetty sites such as SB2B and SB2D suggested that a long time ago there was a large ancient river flowing directly to the main Merbok river (Iklil Izzati, 2014). As such, Sungai Batu Complex in the past also has been considered functioned as a feeder point, where they gather the goods for export before took it to another headwater port near the sea (Iklil et al., 2011).

The jetty structure usually constructed in simple yet efficient in design as it responds to the location and instability of river’s border and water levels (Mohd Hasfarisham, 2014). The fired-clay brick was a main construction material at most of
the sites in the complex. Generally, it is a dominant material for jetty structures and similar regardless location of the sites. Although they used same brick material, but the size or the compound of the jetty, design pattern and structural elements appeared to be varied at each of the location.

In addition, studies at jetty of Sungai Batu have discovered the use of natural resin or gum-like material to hold or to cement the bricks together. For instance, some of the bricks from SB2E and SB1K had traces of *damar* gum which naturally can be obtained from tree (Mohd Hasfarisham, 2014), however, no scientific analysis has been conducted to the sample (Nurashiken, 2016). In contrast, the XRF (X-ray fluorescence) analysis on sample of adhesive or cement material on brick from SB2B revealed the mixtures of mud and silt (Iklil Izzati, 2014). Thus, these jetty structures exhibited the brilliant improvement in construction method inspired from the natural material and locally available.

The third structural site in Sungai Batu that constructed using bricks material other than a jetty and monument site, has acknowledged to functioned as a jetty’s administration or the supporting structure for jetty. The administration structures were identified by their architecture elements and the design for circulation areas that larger than the jetty structure. Furthermore, their location which not in the track of ancient river also plays an important role to identify the site as the administration/supporting structure.

For instance, the jetty oriented towards the ancient river, meanwhile the supporting structure for the jetty provides more floor area and passageway of an areas or spaces if compared with the jetty (Shamsul, 2015). As both structures could be found situated next to each other and sometimes appear as one whole building, they
seemingly operated for same purpose which a place for daily communal area for managing trade goods and river transportation.

However, there are several sites (SB1P, SB1R, SB1S and SB1W) which suggested had served for two purposes. Originally, they were built as the river’s jetty and later were used as the supporting building for the jetty (Suhana, 2016 & Nurashiken, 2016). This interpretation made based on the element of walkway or the footpath pattern and the orientation of administration/ support structures similar with the jetty sites (Suhana, 2016 & Nurashiken, 2016), but these structures accommodate more larger space han jetty. In the past, after long periods, the width of Sungai Batu’s ancient river getting smaller and the earlier built jetty was kept getting far from the river, thus the origin structure eventually converted into the administration for the jetty (Shamsul, 2015).

Similar with other structure, clay-fired brick was the main material used to construct the floor, wall, corridor and the walkway. Although most of the structures were destroyed, several others such as wall and floor are still visible after excavated. The findings on pillar base and fragments of the roof tile have indicated that some of the areas within the sites once were covered with roof (Suhana, 2016 & Nurashiken, 2016).

1.3.2 Non-Structural Site: Iron Smelting Site

Iron smelting sites at Sungai Batu Complex was the first ever discovery in Bujang Valley (Naizatul et al., 2011) that indicated the blooming of large iron industry in Malay Peninsula during early historical period. Based on the finding alone, this structure-less revealed plentiful evidences ranging from the raw mineral, processed iron and traces of smelting and refinery activities. As such, the dominant findings are
iron ore, iron slags, tuyere, charcoal and fragments of furnace remains (Nordianah, 2013).

Furthermore, based on the area distribution of the findings, they have suggested the iron sites at Sungai Batu implemented a very efficient operational/working system. According to previous researcher, the labour distribution was important working practice in the smelting workshop at Sungai Batu. They have proposed the possibility of certain allocations of working area by looking at the association of the artefacts found within the site (Naizatul Akma, 2012 & Nordianah, 2013). The main working area determined by deep dark soils that represents the firing and smelting process, while the other stations were categorised as an area for preparing the raw iron mineral, the separated waste area for tuyere and iron slag and random associations area for the other artefact (Naizatul Akma, 2012).

The chronology of iron smelting activity has proved this activity had continuously being occupied in a single locality as demonstrated at SB2A and SB2C site. The method used the OSL (Optically Stimulated Luminescence) dating clearly shown the area had intensively been using since 3rd CE until 11th CE (Nordianah, 2013). Thus, based on this chronometric dating alone, the evidence suggested that the large iron industry continuously took place before and throughout the existence of various ports in Bujang Valley. Hence, the discovery of smelting iron site in Sungai Batu also proven that this communities were well-developed and civilised during the early historical period. This evidence has marked a new phase for archaeological study regarding early civilisation in Malaysia.
1.4 Issues and Challenge at Sungai Batu Archaeological Complex.

Although Sungai Batu represents significance finding that can attract visitor to discover more on historical chronology of infamous Bujang Valley, there are issues and challenges concerning the site’s condition, the absence of important information and challenge in site preservation and accessibility. These issues and challenges are the main motivation for the aim of this research; to develop the 3D reconstruction for interpretation of the sites at Sungai Batu Archaeological Complex. The implementation of 3D reconstruction method is purposely to enhance site’s understanding and promote dissemination of knowledge in the effort for these sites to receive appropriate acknowledgement for its historical value. Thus, it is important to improve in medium to convey the knowledge between archaeologist to the public whereby it should provide an innovative and effective way to visualise the archaeological interpretation.

1.4.1 Ruinous Site Condition: Incomplete Understanding of the Site

Upon discovery, the whole complex of Sungai Batu was buried under the ground before finally being revealed. Thus, when these sites were exposed, the structural condition appears in ruins and in fragile condition (Figure 1.2). Normally what left after the excavations were only destroyed structures or remains. The construction material such as bricks barely in good form and they rarely found at their original location. For instance, a small and fragile component such as roof and small bricks were broken or most likely washed-out during whatever causes that brought them to collapsed Therefore, it is impossible for the visitor to organise these fragmented evidences and to have complete understanding of the sites. Although the
historical value of the site is significant, considering on poor representation of \textit{in-situ} sites, they might have failed to capture the visitor's interest and their understanding.

Figure 1.2: Scattered bricks and ruinous site structure are common appearance of sites at Sungai Batu Complex.

If looking into other archaeological site at Bujang Valley, for instance; the temples at Bukit Batu Pahat, they had rebuilt and restored the structures for public display. However, not in the case for Sungai Batu. The discoveries remained \textit{in-situ}, as the condition of the sites are beyond restoration. Moreover, not all archaeological sites need to be restored because this would disturb the original structure thus prevent any future archaeological investigation or effort.

Therefore, other strategies need to be implemented to provide a visitor a portion of incomplete understanding due to poor site condition. While the actual nature of archaeological data is fragmentary and remain speculative, archaeologists, in contrast as they study the sites, they should have their own theories and better interpretation regarding the structure of the sites. Their knowledge, archaeological data and evidences prepared by the archaeologists are among the important factor that
contribute to enrichment of archaeological knowledge. Thus, the 3D digital reconstruction somehow functions as the archaeologist’s representation tool that connected archaeological information for public to allow them to have better understanding of the site.

1.4.2 The Absence of Main Artefact: Insufficient In-situ Archaeological Evidence

Apart from fragmented information or incomplete understanding due to the collapsed structure, the missing or lack of evidences on the archaeological sites is also another issue happened at Sungai Batu site. This referring to the missing furnace structure at the iron smelting site. A furnace or relau is enclosed structure with controlled air ventilation which the structure used to smelt the certain mineral using firing at high temperature technique (Naizatul Akma, 2012). Although there are evidences of furnace residue and traces of burning clay that can be found almost at every smelting sites within the complex, however, the excavation failed to uncover the complete structure of furnaces. The shape or physical appearance of furnaces can have a variety in form however, the data for Sungai Batu’s iron sites somehow incapable to provide such information as no furnace structure can be found here apart from broken pieces of furnace remains.

Meanwhile, at Jeniang, a small town in Gurun district situated not too far from Sungai Batu, is well-known for archaeological finding on group of ancient furnaces (Figure 1.3). Up until now, the Jeniang’s furnaces are the only ancient furnaces in complete form or still physically intact which discovered in Malaysia (Norhidayahti, 2015). Although the Jeniang’s furnaces at Kampung Chemara and Kampung Sungai Perahu structurally complete, yet no findings on artefact made by iron found at both sites (Norhidayahti, 2015).
Ironically this totally opposite with the findings of countless iron’s artefact and tuyere (cylinder air pipe used together with furnace) at Sungai Batu, but none of their working furnace survived (Figure 1.4). The studies on Jeniang and Sungai Batu agreed that there is high possibility that structure of furnaces similar at both location (Norhidayahti, 2015 & Naizatul Akma, 2012). Hence, there should be a way to build a connection between the archaeological data which representing the interpretations and their tangible reality that exist on site.
1.4.3 On Going Site Degradation & Prevention Measure: Limitation of Visitor Accessibility and Viewpoint.

Similar with other archaeological sites, the in-situ structure after excavation will naturally experience the degradation process. The degradation will accelerate if the site is frequently accessed, constantly having disturbance or have been exposed to the natural element (Paquet & Viktor, 2005). The archaeological sites that are too fragile should remain protected from dangerous elements such as weather degradation, animal disturbance and vandalism. Regarding site preservation, Sungai Batu sites are sheltered by open-air roof structure and bounded by safety ropes to indicate the limit for public access (Figure 1.5). The safety ropes prevent domestic animal like a cow and goat from entering the site. In addition, the visitors are given trails to follow and they can only observe the site from specific viewpoint.

Figure 1.4: Distribution of countless tuyeres at SB2A, Sungai Batu Complex.
Figure 1.5: An open-air roof structure with safety rope at site SB2B & SB2D.

These restrictions are necessary to reduce the impact or disturbance made by the public that not only their presence can be harmful for a site, but it could be dangerous to them as well if they are not following the safe trails. This is because certain sites or part of the sites are inaccessible and cannot be closely observe due to unfitting path, existence body of water or they are too remote for public to visit. Thus, it could be harmful for public if they wander away from available trails. It may a good site preservation method, but the situation often halts the visitor’s curiosity to observe the whole site. It is harder for them to have a closer look and to understand the structure due to limitation of the view. This is one of the challenges of Sungai Batu sites need to overcome in order to improve the visitor understanding about the site and also to provide satisfaction in their visit.
1.5 Research Gap

Sanders (2008) stated that there has been increasing numbers of those in archaeology who have acknowledge the use of computer graphic and modelling in assisting them to understand the data collected. Likewise, there are quite number of studies on this topic and variety of the digital tools are now widely used by museums and archaeological sites, although they were in an extremely disorderly and random manner (Costa & Melotti, 2011). However, the heritage sector in Malaysia seems lack of approaches regarding utilisation of digital technology, especially the computer-based visualisation in documentation, interpretation and representation of archaeological data.

In Bujang Valley for instance, this area is recognised for its Candis’ and abundant of trade-wares artefact including religious relics and inscriptions. Several local folktales such as Merong Mahawangsa and Raja Bersiong also featured as famous legendary anecdotes making this area rich with cultural and heritage. In almost 180 years, numerous archaeological researches have been conducted by foreign as well local researchers that came across the Malaysia to Bujang Valley to unravel its long-lost history. Although the research conducted at Bujang Valley that started since 1840s (Mokhtar et al., 2011), there are only few studies addressing on computer technology and its application on the historical sites/monuments.

Undeniably, more recent studies on Bujang Valley and Sungai Batu especially have conducted their research scientifically which adopting the usage of advance technologies, either for site survey, documentation or analysis of artefact. Thus far in general, this practice is clearly limited as none of these studies focus solely on the usage of computer-based visualization in an archaeological research specifically the 3D reconstructions and or virtual representation of the sites/monuments. Table 1.3
shows the list of the previous researchers and their focus of studies at Sungai Batu Archaeological Complex.

Table 1.3: List of researchers and their focus on Sungai Batu Archaeological Complex.

<table>
<thead>
<tr>
<th>Year</th>
<th>Researcher</th>
<th>Thesis Title</th>
</tr>
</thead>
</table>
(Excavation on Iron Smelting Site SB2A, Sungai Batu, Bujang Valley). |
(Iron Smelting Technology at SB2C site of Sungai Batu, Bujang Valley, Kedah). |
(Archaeological Study of Jetty sites SB2B and SB2D in Sungai Batu Complex, Bujang Valley). |
|      | Mohd Hasfarisham Bin Abd Halim | *Ekskavasi Tapak Senibina Jeti SB2E, SB1H, SB1J, SB1K dan SB1L, di Kompleks Sungai Batu, Lembah Bujang, Kedah.*  
(Excavation Jetty Structure of SB2E, SB1H, SB1J, SB1K and SB1L site in Sungai Batu Complex, Bujang Valley, Kedah). |
|      | Siti Nurul Siha | *Ekskavasi Tapak SB1C, SB1D, SB1E dan SB1F di Sungai Batu, Lembah Bujang, Kedah.*  
Excavation of SB1C, SB1D, SB1E and SB1F site in Sungai Batu, Bujang Valley, Kedah). |
| 2015 | Norhidayati Mohd Muztaza | *Kajian Arkeologi di Tapak Kampung Chemara dan Kampung Sungai Perahu, Jeniang, Kedah*  
Archaeological Study at the site of Kampung Chemara and Kampung Sungai Perahu, Jeniang, Kedah. |
|      | Shamsul Anwar Bin Aminuddin | *Kajian Arkeologi di Tapak SB1M dan SB1N, Kompleks Sungai Batu, Lembah Bujang, Kedah.*  
(Archaeological Study of SB1M and SB1N site, Sungai Batu Complex, Bujang Valley). |
| 2016 | Nurashiken Binti Ahmad | *Kajian Arkeologi di Tapak SB1R, SB1S, SB1U, SB1V dan SB1Z DI Kompleks Sungai Batu, Lembah Bujang, Kedah.*  
(Archaeological Study of SB1R, SB1S, SB1U, SB1V and SB1Z site, Sungai Batu Complex, Bujang Valley). |
As demonstrated on the list above, in general the research at Sungai Batu have focused on the excavation and archaeological studies at their respective site. Although some of the sites at Sungai Batu have been given the theoretical interpretation in a form of 2D site plan and an attempted reconstruction in 3D models but they are appeared not in proper 3D visual reconstruction. The point is that, their main study on respective site was to discuss on the excavation process and to elaborate archaeological finding. Thus, no particular attention on whether the 3D reconstruction following the recommended guideline on the methods and outcomes or the representation is sufficient to promote intellectual and technical rigour in digital heritage visualisation.

Therefore, this study deliberately emphasises on the application of 3D digital reconstruction to illustrate the interpretation of the archaeological site and describe the methods and outcomes of representation and how this study builds the connection between actual archaeological data and the proposed 3D visualisation.

### 1.6 Research Aim and Questions

The overall aims for this research project was to explore the practice of digital technology for represent the archaeological interpretation from selected sites at Sungai Batu Archaeological Complex through computer-based visualisation method. The research questions apply for this study are:
i. How to represent the ruinous archaeological site/structure?

ii. How to represent the evidence on missing, fragmented and broken artefacts?

iii. What is the appropriate medium for presentation and dissemination of archaeological data at Sungai Batu?

1.7 Research Objectives

The objectives of this study were formulated to achieve the research aim. The specific research objectives are listed below:

i. To represent the interpretation of archaeological site by using 3D virtual reconstruction.

ii. To represent the complete visualisation of artefacts by using 3D virtual reconstruction.

iii. To establish application of digital media as appropriate medium for presentation and dissemination of archaeological material at Sungai Batu.

As abovementioned, the actual nature of archaeological data is based on fragmentary information and they are remained speculative until the factual validation of the data can be presented. It is important to address here that 3D reconstructions of the archaeological sites in Sungai Batu are the result of the hypothetical interpretation made over the fragmented information. Like many other studies on computer-based visualisation of historical/archaeological sites or monuments, the method of 3D virtual reconstruction purposely applied to investigate the hypothesis of their interpretation.

Hence, the 3D reconstruction in this study in other way, proposing the virtual hypothesis of the structures, and not the accurate reconstruction of original structure
which it impossible to identify in their ruinous condition. To strengthen the research value and promote intellectual and technical rigour in digital heritage visualisation, this research adopted the recommended guidelines by the London Charter. For instance, the guidelines in London Charter assists on how the research sources are defined, selected, analysed and evaluated to current understanding so that the hypothetical visualisation appears to be as accurate as it can be. Further discussions are presented in the following Chapter 3 and Chapter 4.

1.8 Research Methodology

This research was structured based on qualitative study in the form of exploratory research. It comprises several methods to be implemented at various stages to gather, examine and build the data to assist in the process of digital interpretation. Overall, the research involves with following methodology:

1.8.1 Documentary Research

Prior to documentary research, appropriate sites need to be selected from the 57 excavated sites at Sungai Batu to demonstrate the 3D reconstruction. As mentioned previously, the research at Sungai Batu complex categorised the excavated sites into four functions. The sites study of this research was carried out at four selected archaeological sites in Sungai Batu – SB1B, SB2A, SB2B and SB2G (Figure 1.6). Each of them represents one of the four functions of the site that currently have been found at Sungai Batu:

i. SB1B for ritual monument,

ii. SB2B for jetty structure,

iii. SB2G for administration/supporting jetty structure,

iv. SB2A for the iron smelting site.
After the sites were selected, the information about the sites were gathered either in both primary and secondary data. This research identified two sources for the gathering the information. First was from the records and documentary study and second from the site investigation and documentation. Both sources of data were gathered to decide on the aim of 3D reconstruction as recommended in the London Charter; whether for represent the structure’s existing state, an evidence-based restoration or a hypothetical reconstruction of the site (Denard, 2009).

The primary resource of this study was collected through field survey by gathering information analyse the structural remains and in-situ artefact. The on-site works included recording the measurement of structural elements (eg: size of bricks and areas) taking photograph of in-situ artefact and the whole site and document other important remarks based on close inspection and observation. The site investigation is important in order to create the hypothesis of the structure, and to analyse or validate the interpretation made by previous research especially focused to the document.
related to the SB1B, SB2A and SB2B. As for SB2G, at present there is no available documentation regarding excavation and archaeological data of this site.

1.8.2 Computer Graphic and Visualisation

After all the required data completed, the work continues by digitalises the data collected. In this study, the models were created based by interpretation made from actual archaeological data and any factual uncertainty regarding the structure or archaeological evidence were represented by hypothetical reconstruction.

Several computer software has been identified to utilise in the phase of digital production. The computer graphic application such as Adobe Photoshop and Illustrator used for editing and assembling the photographed images. Most the 3D model work from the modelling phase, texturing, rendering and animation process were created in modelling software, 3Ds Max. The digital reconstructions and interpretations of this research project are represented by the 3D models of each selected sites.

1.8.3 Holographic Video Presentation

This is experiment model to demonstrate the practicability of application digital media produces by using the 3D reconstruction of an object/artefact related from selected sites. The method is carried out to propose the appropriate 3D outcomes or digital media that cost effective and as the alternative way of presentation and dissemination of the archaeological knowledge. The prototype of holographic video was selected to present the 3D model of rooftile as the digital presentation. The 3D model of rooftile was selected as it represents a single object which suitable to produce and visualise in holographic installation. As matter of fact, this is only small prototype which requires only one single object to test the operation of proposed digital media,
hence it only appropriate to use small object rather than the 3D reconstruction of the site.

Initial 3D model from the reconstruction of rooftop has been transformed into video presentation using Adobe Premier Pro. The method of holographic installation in this study only requires a transparent pyramid projection, smartphone and the 3D video. Further discussion on methodologies of this research will be elaborate in Chapter 3.

1.9 Scope of Work

The groundwork of this research will focus on the Sungai Batu Archaeological Site in Bujang Valley. The sites which were selected to demonstrate the 3D reconstruction and visualisation are Sungai Batu 1B (SB1B), Sungai Batu 2A (SB2A), Sungai Batu 2B (SB2B) and Sungai Batu 2G (SB2G). Each of the site is represented each one from four different functions of archaeological sites at Sungai Batu. First, this research reviews the archaeological research at Bujang Valley as well to address the significant of Sungai Batu Archaeological Site. These include the description of several existing digital technology used in cultural heritage sector particularly in archaeology discipline and emphasis for the computer-based visualisation.

To assure the accuracy of details and data, this study analysed archaeological material left on the excavation sites through the documentary research and field survey. The important part of this research work is the process to transform the data collected from both field survey and existing archaeological records for 3D visualisation of each sites. This done by demonstrated the method and process applied using several computer graphic and modelling software; namely, Adobe Photoshop and Illustrator, AutoCAD, 3ds Max and Adobe Premier Pro. Finally, from the 3D
outcomes of four of the case studies (SB1B, SB2A, SB2B and SB2G) and one 3D model of reconstructed artefact from the study was selected to use as prototype of holographic presentation. Only one outcome or object from 3D reconstruction was chosen for holographic presentation to demonstrate the practical implication of digital media in presentation and dissemination of archaeological knowledge. Besides, the method of holographic installation requires one single object as this only experimental model to achieve the objective; which to establish the application of digital media in archaeological field.

1.10 Research Contribution

This research will benefit for those who interested in application of digital technology either involved directly or indirectly with heritage sector and not limits for the archaeology field. The methods of computer visualisation in this study provide a recommended plans or guidelines that can be applied for any 3D reconstruction especially for cultural heritage object in the future. The contents of this study encourage for further improvement and improvise available digital data for better documentation and presentation. And lastly, for tourism sector, particularly the archeo-tourism; the outcome of study can be useful material and instrument to establish application of digital technology, corresponding to era of ‘digital and media convergence’ in the field of cultural heritage sector in Malaysia.

1.11 Structure of the Thesis

The current chapter introduces the background of the research and describes the issues and challenges, research gap, aim and objectives of the study. It also explains the scope of work involved in this study and give an overview of research methodology.
which will further describe in Chapter 3. The remaining chapters of the thesis are described as follows:

**Chapter 2: Literature Review**

This chapter provides highlights on the main classifications of digital technology and utilisation in the archaeology field and study; especially in the context of virtual/digital reconstruction. It also comprises some general reviews on historical documentation and archaeological research in Bujang Valley particularly on monument sites. This chapter then elaborates the archaeological research at Sungai Batu Complex and particularly discusses the four selected sites study.

**Chapter 3: Research Methodology**

This chapter intends to describe the methodology for computer-based visualisation as the practice of digital archaeology. The research methodology explains the research approach based on the study purpose and describe the methods related to research objectives formulated in Chapter 1. It describes the site study (documentary research and site investigation), the method and process of computer graphic and modelling, and practice of holographic visualisation.

**Chapter 4: Analysis & Finding**

This chapter elaborates the analysis on data, methods and process on individual site studies well as final outcomes that established from the 3D reconstruction. The last section of this chapter presents the experimentation work using the holographic video presentation of SB2B rooftile as proposal for digital media created from the 3D outcome.
Chapter 5: Conclusion

The final chapter discusses the finding gained from the formulated objectives. The discussion also includes limitation, future research and suggestion which apply for the research at Sungai Batu and Malaysia heritage sector generally regarding the application of digital archaeology.
CHAPTER 2
LITERATURE REVIEW

2.1 Introduction and Overview

This chapter continues from the previous introductory chapter and discusses overall fundamental subjects of this research obtained from the literature studies. Firstly, in this section, it highlights the main classifications of digital technology and how they have been utilised in the archaeology field and study. From the classification, the next section emphasis on general purposes of application digital technology as instrument for archaeological research and discoveries, for sustainable tourism and heritage preservation and lastly for business and entertainment. This chapter also highlights example of its application in the context of virtual reconstruction on several heritage sites in the world.

Then, the next section introduces the site study which includes the brief history relates to the area where the research studies conducted. This comprises some general reviews on historical documentation and archaeological research in Bujang Valley which focusing on the structural remains or monumental site. This chapter then elaborates the archaeological research at Sungai Batu Complex and particularly discusses the four selected sites study. The chapter concludes with a brief discussion on the general application of digital technology in research at Bujang Valley and quick review on the implication of the digital archaeology for Sungai Batu sites. The literature research of this thesis hopes to illustrate the general ideas of digital technology in connection with archaeological field, the application and how it can be implemented. Figure 2.1 presents a graphical summary of the contents for literature review of this study.
Graphical Summary of Literature Review

**Digital Technologies**
Classification of the digital technological methods

- 3D Laser Scanner
- Space Archaeology and Aerial Investigation
- Virtual Technology

**Case Study:**
Kedah Tua in Sungai Batu as the Oldest Civilization in Southeast Asia

- Origin and Historical Records of Kedah Tua
- Archaeological Research at Bujang Valley
- Sungai Batu Archaeological Complex
  - SB1B: Ritual Monument
  - SB2A: Iron Smelting Site
  - SB2B: Jetty Structure
  - SB2G: Supporting Jetty Structure

**Implementation of Digital Technology in Cultural Heritage Sector**

- Archaeological Research and Discoveries
- Sustainable Tourism & Heritage Preservation
- Business & Entertainment

**3D Visual Reconstruction at the World Heritage Site**

- Ancient Greece: Athens
- Roman Civilisation: Ancient Rome
- Ancient Palmyra: Syria
- Angkor Wat: Cambodia

**Issues and Challenge:**
Ruinous site condition, broken and missing artefacts and challenge in site preservation and accessibility

**Implication of 3D Reconstruction on archaeological sites at Sungai Batu**

---

Figure 2.1: Graphical summary of the literature review
2.2 Digital Technology in World of Archaeology

This research employed the digital tools and computer software as the main structure of the research framework. In general, any digital and computer software and instruments classify as the digital technology. Thus, this section reviews several state-of-the-arts related to digital technologies and several examples regarding their implementation in the archaeology field. Various digital technology can be integrated together depending on the purpose of utilisation. Nevertheless, digital technology in the context of computerised visualisation can be classified into three main technology; 3D laser scanner, aerial investigation and virtual technology. Following Table 2.1 describes on how these technologies applied in archaeology field.

Table 2.1 Classification of the digital technology methods.

<table>
<thead>
<tr>
<th>Digital Technology</th>
<th>Application</th>
</tr>
</thead>
</table>
| 3D Laser Scanner: 3D Digitalisation of Historical Monument | • An efficient and accurate tool for documentation especially in historical architecture and archaeology field.  
• Solution for the issues such as site monitoring, accessibility and preservation of heritage sites (Paquet & Viktor, 2005). |
| 3D Digitalisation of Artefact | • 3D scanner allowing artefacts to be brought into the virtual workroom for conducting the analysis digitally to avoid more unnecessary intervention on the object’s fragile state. |
| 3D Replication of Archaeological Material | • Helps to digitalise the object and then by using the similar scan data, a mould for replica or missing part of artefact can be constructed.  
• Replicas are perfect substitute for fragile and valuable artefact that use in research, exhibition and restoration. |
| Space Archaeology and Aerial Investigation | • Satellite imagery that provide more intensive information needed in archaeological surveys particularly in the aspect of observing the differences in texture, moisture content, topography, vegetation covers as well as geological composition. |
### Table 2.1 Continued

| **Google Earth** | • High resolution satellite images provide moving aerial view of the entire planet earth and featured with web-based geographical information system (GIS) and supports the other external data format and sources.  
• Users also able to explore other functions such as virtual tours, image overlays, place markers, imagery form multiple time periods and 3D buildings that integrated with the software (Welham et al., 2015). |
| **Drones** | • Unmanned Aerial Vehicles (UAV) that use in aerial survey.  
• Widely used to identify the possible new excavation sites and give the wider view and multiple shots from various angles above the ground.  
• Images from drone are also easy to access and interpret by the non-specialists and can be sent up at specific times more easily than satellites. |
| **Virtual Technology** | • Virtual and Augmented Reality | • Artificial environment that allows user to experience the scene and sounds in a way that they accept as a real environment, depending on the degree of immersion (Chavan, 2014).  
• VR and AR that mainly use in the museum exhibition provide a visitor with extra visualisation experience as it intended to enhance their learning and interaction with the cultural object. |
| **Online Virtual Tour** | • Way of interaction using wide range of platforms and digital contents that are available for internet users.  
• Users can access a virtual visit and browse the virtual contents on museum catalogue that complete with descriptive information (Signore, 2007). They can be either in virtual reality or augmented reality that provide a tour in various digital approaches using diverse media presentation. |
| **Hologram and Holoraphic** | • A holographic image that often associated with the term ‘hologram’, and hography is defined as a method of producing a three-dimensional (3-D) image of an object.  
• Bimber (2005) defined a common optical hologram as a photometric emulsion that records interference patterns of coherent light, resulted in projecting the three-dimensional appearance that can be observed from different perspectives. |
2.2.1 3D Laser Scanner

One of the most popular digital technologies in cultural heritage is the application of three-dimensional (3D) laser scanners especially for recording the archaeological sites and historical buildings. When it first came to prominence, 3D scanning technology was used mainly by the engineers for reverse engineering purposes (Petrov et al., 1998). With continuous improvements in laser scanning technology, the laser scanner instrument is now considered as an appropriate tool for the whole process of digitisation for cultural heritage.

The term ‘laser scanner’ refers to a range of instruments that function on different principles, in different environments and with different levels of precision and resulting accuracy that will define the surface of the scanned feature (Barber & Mills, 2011). In other words, the scanner device captures an existing exact size and shape of the physical object and stores digitally in computer as 3-Dimensional representation. There are many types of 3D laser scanning technology. Nevertheless, in general, there are three technical principles of laser scanner use in heritage sector namely; triangulation, time of flight and phase comparison (Reznicek & Pavelka 2008). Further explanations are being describes in the table below:

<table>
<thead>
<tr>
<th>Scanning system</th>
<th>Use</th>
<th>Typical accuracy / operating range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Triangulation-based Artefact Scanners</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Rotation stage | • scanning small objects (that can be removed from site)  
• to produce data suitable for a replica of the object to be made | 50 microns / 0.1m–1m |
| Arm mounted | • scanning small objects and small surfaces  
• can be performed on site if required  
• can be used to produce a replica | 50 microns / 0.1m–1m |
Table 2.2 Continued

<table>
<thead>
<tr>
<th>Mirror/prism</th>
<th>Terrestrial time-of-flight Laser Scanners</th>
<th>Terrestrial Phase-comparison Laser Scanners</th>
</tr>
</thead>
</table>
| • scanning small object surface areas in situ  
  • can be used to produce a replica |  
  • to survey building façades and interiors, resulting in line drawings (with supporting data) and surface models |  
  • to survey building façades and interiors resulting in line drawings (with supporting data) and surface models – particularly where rapid data acquisition and high point density are required |
| sub-mm / 0.1m–25m | 3–6mm at ranges up to several hundred metres | 5mm at ranges up to 50–100m |

Table 2.2 describes the different type of laser scanning provide various usability which also determined by their operating range or their accuracy. To summarise, the whole digitalising work using 3D laser scanner involves with scanning process, digital data processing, archiving and management and well as representation and reproduction. Hence, because of the scanner capable to gather extensive and highly accurate data sets for 3D model, a representation of virtual world for rapidly deteriorating sites that frequently accessed or exposed to natural degradation can be reconstruct. The representation in digital form is important as it can digitally preserve the endangered sites that highly exposed to natural disasters, human violence or deteriorate over the time.

Among the pioneering projects by using 3D laser scanner in Malaysia for documentation was research work at A’Famosa fortress in Melaka. This research evaluated the capability of terrestrial laser scanning (TLS) technology for documenting complex building features. This project has combined the 3D point clouds captured by scanner with the photogrammetric technique by digital camera to produce photorealistic model in 3D environment (Wei et al., 2010). The data presented
has found that the combination of TLS and photogrammetric provide a better solution for documentation (Figure 2.2) especially for preserving complex heritage features such as the A’Famosa (Wei et al., 2010).

Figure 2.2: The quality of 3D visualised model using Terrestrial Laser Scanning integrated with the photographing image (Wei et al., 2010).

Other than it becomes great tools in documentation, principle of 3D laser scanner helps to produce the physical object by using three-dimensional printing technologies. With 3D printing, archaeologist can produce the precise museum quality replicas of artefacts to conduct the analysis without further intervention on the original relics (Henderson, 2016). The 3D printed replica also suitable as substitute of museum display whereas the original artefact needs to be kept away from visitor as safety or preservation purpose.

Besides, visitor of museum and gallery also enjoy the benefit of this technology as the replicas usually allow visitor to touch and feel the physical shape and texture. Consequently, it enhances their experience and knowledge of the artefact. Wachowiak & Karas (2009) also states that the 3D scanning data can be scaled by its original size,
smaller or larger thus the replicas can be constructed easily according to desired scale in almost any material. Moreover, the fabrication apparently has encouraged improvement in knowledge sharing activities as it easier to distribute the scanned and fabricated data for research purpose. To conclude, the various potential and opportunities with the application of 3D scanner such as the improvements in techniques, scanning programs, and printing machines they are now moving rapidly in the archaeological sector.

2.2.2 Space Archaeology and Aerial Investigation

One of the ground-breaking archaeological explorations nowadays is the application of ‘space-operated’ platforms to locate and map the ancient sites around the world from aerial view. Darrin, & O'Leary (2009) referred space archaeology is the study of ‘the material culture that found on earth and in outer space and that is clearly the result of human behaviour through relevant space exploration’. This revolution of digital imaging has extended the use of satellite images which at first place only available for military purposes. The archaeological space exploration or aerial investigation has been developed towards the end of 19th century. Since then, the aerial photography has been widely used to provide the view of the earth taken higher above the ground. This conventional technology of aerial photography has been evolved into more sophisticated remote sensing technologies such as airborne remote sensing and LiDAR (Light Detection and Ranging) technologies.

Among the first archaeological sites to be photographed from the air was the mysterious stone circle at Stonehenge in 1906. The remote sensing imagery produce the digital data through variety of platforms such as satellite, aircraft, remotely pilot vehicles, handheld radiometers or even bucket trucks (Yadav et al., 2013). There are
various methods for remote sensing technologies which combining the multi-disciplinary techniques such as spectroscopy, photography, computer, electronics and telecommunication, satellite launching etc (Aggarwal, 2004). LiDAR, for example; when combined with other data, the LiDAR generates accurate topographical maps of areas, even when that area is covered with dense vegetation (Kiger, 2015).

By using this method, there have been some major finds in recent years. Using this method, there have been some major finds in recent years, including lost information about the New England colonies could be obtained, dating back to 18th Century CE (Vergano, 2014) and the discovery of Cambodia's vast medieval cities near Angkor Wat (Evans, 2016). This has brought a new effective way to explore the archaeological landscapes. Thus, looking at the recent finding and development, the aerial investigation can be described on three distinguish approaches; categorised as remote sensing technology, Google Earth and Unmanned Aerial Vehicles (UAV) or better known as a drone.

Recently, the drone imagery technology or UAV is widely used to identify the possible new excavation sites and give the wider view and multiple shots from various angles above the ground especially for the user with limited investment. Besides, the recording technique using UAV usually incorporated with photogrammetric technique, terrestrial laser scanning (TLS) or 2 and 3D data sets such as GIS and CAD to further visualise, interpret and analyses the archaeological structure or site. Example of integration with different 3D recording techniques and instruments is demonstrated through the survey work conducted at archaeological area of Paestum in Italy. In order to obtain detailed 3D textured models, Fiorillo et al (2013) integrated the collected aerial image that already made with a geo-referenced point of the cloud data from the laser scanner (Figure 2.3).
In summary, the specific applications of different type of devices and methods from aerial survey and investigation involved with numerous procedures and process. Particularly, among the common practice in archaeological aerial survey helps to locate sites, record and analyse the data and help to monitoring the area. Moreover, the application in archaeology survey helps to discover the archaeological remains at the earth surface as well as to reveal land alterations and detecting underground archaeological structures.

Most importantly, the digital image and data produced from this practice provide a diverse set of data and outcomes thus their implications are useful in various fields of study. Hence it is common for archaeologist to working alongside with other expert from different department such as geologist or environmentalist for integrated projects that can benefit all.
2.2.3 Virtual Technology

The virtual technology in archaeological study refers to the representation of landscapes, objects, or sites of the past and the whole process of visualisation of archaeological data with the use of 3D digital technology particularly the virtual reality technology. It often labelled as virtual heritage that describe the inventive methodologies and their utilisation within technological domain, particularly use in cultural heritage, museums, historical and archaeological research (Gabellone, 2015).

According to Roussou (2002), virtual heritage relates to the advanced virtual reality imaging technology for the cultural evidence and facilitate synthesis, conservation, reproduction, representation and digital reprocessing of the subject (as cited in Tan & Rahaman, 2009). Gabellone (2015) explained that the category of cultural heritage not only includes tangible objects such as buildings, sites with archaeological, anthropological and special natural value, works of art and human ingenuity, but also intangible heritage that closely related with historical and cultural identity such as dance, song and oral traditions. Virtual, augmented and mixed reality are examples of the virtual technology applies in exhibition at museums, galleries and heritage sites.

There is notable discrepancy exists in view the concept describing the virtual technology. Some of the scholar agreed that the virtual reality (VR) and augmented reality (AR) are totally different concept while the others considered that the both can be accepted as collectively idea in broad definition of VR (Guttentag, 2010). Virtual reality (VR) is the computer-generated simulation of a 3D image or environment that can be interact with in a seemingly real or physical way by a person using their five senses (Guttentag, 2010). In contrast with virtual reality, the augmented reality (AR) overlays the live direct or indirect view of real world with virtual objects thus creating
new layers of interaction with user. The blending of digital contents in the real world requires display technology that allows the user to simultaneously see the combination of virtual and real information in a 3D view (Olwal 2009). However, the combination works only to enhance the physical world without having any interaction with user. Hence, the mixed reality (MR) encompassed both VR and AR as it works by combining the virtual objects and real world and allows interaction on both real and virtual environment. This recent development in virtual technologies can be considered an advanced form of AR (Datta, 2017). Although it seems some long discussions generated on both opinions, in terms of technologies; VR and AR are both aim to immerse the user by enhancing their experience, although the execution of the processes might be different.

Returning to the application of virtual technology in heritage sector, Djindjian (2007) described the appearance of virtual museum signifies the combination of traditional concept of a museum with the computerised digital media and communication technology. That kind of concept has dematerialised the object and all its intrinsic and extrinsic information for better presentation and knowledge guidance (Djindjian, 2007). The virtual technology has been applied in the cultural heritage both as virtual and augmented reality such as online virtual tours, hologram or holographic representation and various interactive exhibition. The arrival of technological instruments in enhancing the experience; the immersive technologies (VR/AR/MR) including other interactive multimedia and gamification technology have demonstrated their competency to define history and heritage as enjoyment but also educational in museum environment.
For example, in representing particular historical events, technology such as VR in case study that exhibit 9th Century Viking encampment (Figure 2.4); would unlock the human stories around them, enabling visitors not only to understand that specific archaeological site at winter camp of Viking’s army in Torksey but also allow the visitor to experience real world elements such as sight and sound (Schofield, 2018).

![Figure 2.4: A still from VR experience Viking VR. (Schofield, 2018)](image)

### 2.3 Implementation of Digital Technology in Cultural Heritage Sector

The availability of variety digital instruments, media and communication technology has revitalised the archaeology field which brings the new method of representation, interpretation and dissemination of archaeological knowledge. Digital archaeology is currently being applied for research, documentation and as main tools to discover the archaeological sites. The implication of this technology also has proven useful for heritage site management and simultaneously has encouraged the growth of sustainable heritage tourism. More recently, the interest of digital technology in archaeological study has demonstrated positive potential in commercial business and
entertainment. Since the co-existence of authentic historical objects and sites with digital technologies to disseminate the cultural information, the researchers are mobilised the research projects into the world of business and entertainment. Thus, this situation has welcomed another opportunity for the academic research in cultural heritage sector to generate incomes.

2.3.1 Research and Discoveries

The new digital media studies; including the visual studies in archaeology are blooming in academic institutes as well as growing interest in the archaeological literature (Morgan & Eve, 2012). Now and then with the advancement in technology and innovative instruments, the researchers have been working to utilise the available technologies for the benefit of archaeological study and its dissemination in education.

For instance, a team of researcher and student University of California (UCLA) have founded The Cultural Virtual Reality Laboratory / CVRLab (http://www.cvrlab.org/) in 1997. Their aim is to create the scientifically authenticated 3D computer models of cultural heritage sites that designed to be compatible with virtual reality hardware systems (Frischer, 2003). Among their major project is the Rome Reborn (Figure 2.5) that aims to create a model of the entire ancient city of Rome from the Iron Age (ca. 900 BCE.) to the Gothic Wars (535-553 CE.) in which the task could take many decades to complete (Sullivan, 2003). While, the lab’s completed projects include a villa in Pompeii, a medieval Armenian church in Turkey, one of Rome’s first Christian churches, England’s Beaumaris Castle and a 3,000-year-old horse stable that may have belonged to King Solomon. (Frischer, 2003).
Besides, the project also serves as educational tools which have been used in the classes and for empirical study of archaeological research. Other than representing the historical structure, this also encourage analysis on related study thus allowing various hypotheses on architectural history of the structure. As pointed out by Frischer (2003), through 3D modelling work, they can estimate the structural capacity of Colosseum, study on the circulation of people through Roman Forum and other studies regarding interaction of the buildings with their past environment or possible natural disaster.

The research using digital technology not only limits for the archaeologist, but also stimulates serious application in the methods of archaeological visualisation for interpretation, such as 3D virtual reconstruction. This also has encouraged learning environment with different media to engage and attract the interest related to historical and cultural contents especially for younger generation. Furthermore, through implementation of this technology in archaeological research, it enables new possible hypothesis and improved the way to analyse and supervise the archaeological data for better understanding of the past.
The digital technology in research and education also leads to many great archaeological discoveries. For instance, there was one remarkable discovery in 2016 which has revealed a massive monument buried under sands at the Petra World Heritage site in southern Jordan, by using Google Earth (Dunne, 2016). Since Google Earth becomes more prominent for professional as well for the public, correspondingly the imagery from this application keeps on improving. This site has been discovered by using the Google Earth’s high-resolution satellite imagery as well as aerial drone photography and ground surveys, to find and document the structure (Figure 2.6). Dunne (2106) roughly described the site is long as an Olympic swimming pool and twice as wide. Nowadays it’s provided more high-resolution image, thus hopefully this free-platform continues to develop and featuring more innovative tools for archaeological research and discoveries.

Figure 2.6: Detail of monumental platform from UAV (Unmanned Aerial Vehicle) composite, with architectural details and measurements shown. (Dunne, 2016)
2.3.2 Sustainable Tourism & Heritage Preservation

Tourism plays the vital part to keep the economic growth and provide numerous job opportunities especially in the cities that generously abundant with heritage, arts and culture aspects. The growing of cultural heritage tourism encourages the local communities to become aware of their local historical features, culture and tradition as they learnt that this knowledge could provide the source of income for them. On the negative side, the tremendous amount of visitor to the significant historic and cultural sites has triggered other issues especially when it threatens to damage the building’s fabric or site and devalue the quality of visitor experience (United Nations Environment Programme, 2005).

Gabellone (2015) expressed the damage as a ‘light concern’ but generates consistently over time thus inadvertently creates prolonged harm to the sites, for example in the case of Pompeii and Herculaneum. Too many visitors all year around, the higher risk of these sites exposed to constant threat. Thus, it is necessary to set a proper policy into cultural heritage tourism for effective heritage management and preservation of these sites. Sustainable tourism is a condition of tourism that based on the principles of sustainable development which according to World Tourism Organization, it can be defined as:

"Tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities"

(United Nations Environment Programme, 2005)
Guttentag (2010) emphasised, there are six areas of tourism that may prove the application of digital technologies is particularly valuable. The planning and management, marketing, entertainment, education, accessibility, and heritage preservation are the six areas that could demonstrate the usefulness of digital technologies in enhancing the heritage tourism (Guttentag, 2010).

For examples, the laser scanning project for documentation of heritage monument and sites is practically a common practice as an effort for site conservation and preservation and to encourage sustainable tourism at world heritage sites. Among the most ambitious laser scanning project and currently still active is ‘Cyark’, a non-profit organization founded by Ben Kacyra (Masinton, 2009). Cyark uses scanner technology to create a 3D data set and generates the comprehensive 3D model representations of important heritage sites before they are lost to natural disasters, destroyed by human violence or withered by the passage of time. Their missions are to record and therefore digitally preserve as many as possible important heritage sites around the world and to allow free access on their online library at (http://www.cyark.org). The digital preserved data such as photo-real 3D model is valuable achieves for historical monument and site and among the effort for the sustainable measure for site preservation.

Museums, galleries and heritage sites are a familiar place to visit when discussing on heritage tourism. Today, museum plays important roles in tourism sector that denotes the knowledge on country identities and history especially for the foreign visitor. Nowadays, many heritage and museum authorities of the world heritage sites slowly embrace the virtual technologies as communications tools to provide an effective support; to transmits the cultural message and awareness of the sites’ existence (Gabellone, 2015). The application of digital technologies in museum sector
can be traced back since 1970s, when the museum started to manage and record their collection by digitalised their inventories through *museographic* databanks (Djindjian, 2007). Subsequently, the application of virtual technologies appears gradually in museum tours. It intended to provide a modern and attractive presentation that appealing for museum visitor with detailed information of the objects.

For instance, the ARCO project which stands for Augmented Representation of Cultural Objects implemented the practice of VR system in museum sector, (Wojciechowski *et al.*, 2004). The project offers the virtual exhibition in a selection of alternative representations of digital contents, where the data accessible at both inside and outside museums. They aim to develop the whole chain of technologies which help museums to create, manipulate, manage and present digitised cultural objects in their virtual system (Wojciechowski *et al.*, 2004).

The ARCO project utilised the both Virtual Reality (VR) and Augmented Reality (AR) interfaces using the Web-based form of presentation. Normally the web-based interface allows user to search and browse the database contents. However, with the addition of the VR and AR exhibitions (Figure 2.7), it let the visitor to examine virtual reconstructions of selected objects in 3D environments (Wojciechowski *et al.*, 2004). This system has transformed visitors from typically passive viewers into active players as they take part to interact with digital reconstruction of the object and at the same time it can stimulate and enhance their learning experiences.
Figure 2.7: In ARCO the real scene augmented with superimposed virtual models (Wojciechowski et al., 2004).

With digital interpretive of archaeological knowledge, museum has transformed into informational and communicational hub for public thus making it as significant place to visit during travel. The online virtual tour is another way of interaction for historical enthusiastic. The online tour provides a wide range of platforms and contents that available for internet users. For instance, virtual museum allows the cyber users to access virtual visit, where they can browse the virtual contents on museum catalogue and complete with descriptive information (Signore, 2007).

Among well-known museums for online visit are The Louvre, Paris; British Museum, London; Smithsonian National Museum of Natural History (Figure 2.8), Washington D.C; and the list goes on. Meanwhile, there is also a tour through You Tube 360º platform which presently being utilised by Metropolitan Museum of Art for their online tour. This series of online video allows viewer to control the move of the camera angle from viewing screen during virtual museum tour.
Other than museum tour, several other online programs offer the exploration of world heritage sites such as using the Google’s apps and platform namely Google Street View, Google Arts & Culture, Google Earth and Google Expeditions. On top of that, application such as Google Expeditions make possible for VR tours in a group with guide to direct the tour or self-guided exploration into historical significance places like Machu Picchu or Collosseum of Rome (Matney, 2017). Another significant advantage of these applications is the viewer can ‘walk’ through endangered sites or monuments which they could have eroded beyond recognition or deteriorated and destroyed altogether (Sullivan, 2003). Moreover, the features such as annotations tool allow the respective guide to emphasise important factor during their tour by draws inside the virtual scene and it can be received by another explorer who tour together in the same group.

Kalay et al., (2008) stated that the alternative approaches using the emerging technological advancement of digital media in preserving the cultural heritage has demonstrated solutions beyond the static display. The technological platform such as virtual copy used to display the unattainable or valuable artefacts or as substituted
model when the sites condition is inaccessible, closed or the structures are unfit for visit. For instance, the display on the interior of an Egyptian tomb in museum at Iceland and the exhibition on a site that has been sealed, like the prehistoric cave; Grotto of Lascaux which was closed in 1963 (Paquet & Viktor, 2005). After all, the integration between online virtual technology brings the digital visitor to places they might never have a chance to visit in real life.

Besides, the representation important historical sites in the context of ‘virtual archaeology’ not only can sustain for long period of time but they also can be upgraded, correspond with development of technologies. This is a notion of sustainable tourism where it also helps to build up and boost the new phase in the economic and cultural history of tourism as affirmed by Costa and Melotti (2012).

2.3.3 Business & Entertainment

Lately, the virtual technology for cultural heritage not only subject within academic institution, tourism and heritage sector, but also penetrate the world of business and entertainment. The dissemination of virtual contents apparently has been circulated in various publications, Internet, TV shows and documentary. As previously discussed on UCLA’s Cultural Virtual Reality Laboratory, their modelling project enabled them to gain incomes by featuring in the commercial and entertainment production. Apart from appeared in newspapers, magazines, and scholarly books; the lab has licensed the fly-through of models to the TV show and been used as backdrops in virtual set shoots for documentary programme like The Discovery Channel (Frischer, 2003).

The virtual models have started to become common when movies, game industries, and TV documentaries used to demand for 3D models of historical sites,
simultaneously allowing historians and archaeologists gained a new medium for disseminating their projects (Sequeira & Morgado, 2013). For instance, Second Life (http://secondlife.com/) is among online virtual platform that includes 3D contents of historical monuments and sites where the users participate with their own avatar in “gamification” environment (Figure 2.9). According to Sequeira & Morgado (2013), apart from virtual visit, Second Life explores the whole concept of virtual archaeology as it allows visitors and the researcher without technical ability to do the modelling themselves.

![Figure 2.9: One of the historical destination available in Second Life, a representation of Viking village. (Source: https://secondlife.com)](https://secondlife.com)

The outburst of demands for digital technology in recent years has resulted in the growth archaeological research that eventually turned into business prospect for academician. Costa & Melotti (2012) revealed that the recent drastic declines in humanistic sector partly due to insufficient funding at mostly European countries which have brought many sectors of academic research closer together towards business world.
One recent example, in September 2016, Simon Young and Dr M. Hamdi Kan from University of Melbourne set up a virtual reality company inspired from their research related to 3D visualisation software packages (Wong, 2017). Apart from presenting their research in archaeology by submitted thesis, they decided to extend the research by start-up a fully operational VR content production and distribution company. Wong (2017) recently reported that the company better known as Lithodomos VR (https://lithodomosvr.com/); has secured $900,000 seed funding from investors which embarking their first commercial project to re-create part of the Roman settlement of Mellaria in the Guadiato Valley.

Young, one of the founders of Lithodomos often emphasised that their approach in VR contents are different from others in the market place as they committed to ‘archaeological accuracy’. This indeed true as both founders came from an academic background which they dedicated the capability in technological innovations and humanistic knowledge into something that beneficial for public and private sector.

The blooming of digital technology along with the new media convergence somehow affecting the archaeology in various ways. Due to technological advancement, the digital media such as virtual technology and other interactive multimedia have demonstrated their competency to enhance the experience. Simultaneously, this new technology helps to define the new heritage experience as effective learning in entertaining environment which not only promoting cultural heritage context but also encourage business opportunity.
2.4 3D Virtual Reconstruction at the World Heritage Site

In the previous discussion, the implementations of digital technology serve for various purposes and utilisation. This section intended to provide a brief clarification on how the practices of digital technology for reconstruction and interpretation have been applied at archaeological sites. As discuss in Chapter 1, there are issues and challenge that motivate for 3D virtual reconstruction of Sungai Batu sites. Similarly, the archaeological sites at different location experience different of circumstances that encourage the work of computer visualisation. The following contents discuss on representation of several famous UNESCO world heritage sites that have been visualised in 3D virtual reconstruction. Although digital representations of these selected UNESCO sites were visualised for different reasons and purposes with various 3D outcomes (e.g. VR presentation, video animation, etc), but they generally aim for better understanding and enhance the experience of the past to the public. Consequently, these examples demonstrate the importance of digital technology in representing historical monument or site, help to illuminate the archaeological interpretation and to disseminate the information of archaeological sites.

2.4.1 Ancient Greece: Athens

The Acropolis of Athens is one of the archaeological sites listed by UNESCO. The site comprises notable monuments and ancient building from the Greek Civilisation. Nowadays, visitor can experience how the iconic Parthenon and other ancient building at the city of Acropolis appear in 2000 years ago. The virtual reality (VR) technology presents the visual reconstruction of ancient city Acropolis (Figure 2.10) and has been offered for the tourist while tour on site. The VR gadget allows
user to explore in outdoor historic site but experience a virtual world of ancient city, thus provide extra satisfaction in their visit.

![Acropolis Virtual Reality Experience](http://scooterise.com/scooterise-tours/acro{

Figure 2.10: Part of reconstruction scene that can be view through VR headset. Source: http://scooterise.com/scooterise-tours/acro{

2.4.2 Roman Civilisation: Ancient Rome

Presently, many of the effort of virtual project featured the reconstruction of the Ancient Rome. One of them is The Rome Reborn, the project features 3D digital model on ancient Rome leads by Dr. Bernard Frischer, professor emeritus at the University of Virginia. The project intended to create a model of the entire ancient city of Rome from the Iron Age Gothic Wars that designed to be compatible with virtual reality hardware systems (Frischer, 2003).

Another example of virtual tour has been offered as online course by University of Reading for those who interested in the city to explore its temples, monuments, shops and back streets, through the most detailed digital model of the ancient city ever created (Kennedy, 2017). The model of the city appeared in 315 CE and gives the
viewers 3D panoramic views with the landmark’s sites, such as Colosseum and Capitoline Hill (Figure 2.11).

![Figure 2.11: Sample of video tour of Capitoline Hill in ancient Rome. Source: YouTube Guardian Science and Tech.](image)

### 2.4.3 Ancient Palmyra: Syria

Eastern archaeologist Paolo Matthiae remarked that 70% of the city's monuments in ancient Palmyra which located the conflict country of Syria were destroyed by ISIS (Bond, 2017). The Palmyra was an ancient city and major trade location that associated with Assyrians, Parthians, Greeks and Romans. Currently, there have been efforts to digitally reconstructed the city and its monument which have been destroyed by the terrorist since 2015 (Denker, 2017).

The data for reconstruction mainly obtained from the excavation records and documentation such as in the case of Temple of Allat (Figure 2.12), since the physical structure was destroyed by terrorist assault (Denker, 2017). The digital data have been
collected from individual and organisation to build the digital archive which mainly in the form of 3D reconstruction/visualisation of the destroyed sites.

![Figure 2.12: One of the 3D reconstructions of Temple of Allat at the western and of Palmyra. Source: Denker (2017)](image)

2.4.4 Angkor Wat: Cambodia

The virtual reconstruction called Digital Angkor is one of the effort of 3D virtual reconstruction to represent the archaeological interpretation of the Khmer civilisation. The project presents the reconstructed Angkor Wat and its surrounding environment complete with depicting the daily life in the past at the ancient complex (Figure 2.10). The outcome was developed in the form of 3D video animation which includes three-dimensional landscape with people, animals, temples and vegetation resembling what they may have looked like in ancient times (Karasavvas, 2017). This representation was created by the Fine arts and archaeology PhD student; thus, this project tries to depict as realistically and historically accurate as possible, by using historical and archaeological data.
2.5 Case Study: Kedah Tua in Sungai Batu as the Oldest Civilization in Southeast Asia

In Southeast Asia, the infamous Borobudur in Central Java and Angkor in Cambodia are often referred as among the greatest structure of brilliant architecture and top-notch adaptation of technology during ancient time. Borobudur now is one of the greatest Buddhist monuments in the world and included on the UNESCO World Heritage list in 1991. It was built during Golden Age period of the Sailendra dynasty between 750 and 842 CE (Soekmono, 1976). The majestic temple of Angkor Watt that previously hidden in the jungle stand as the greatest legacy from Khmer Empire and presently defines as the world’s largest religious complex; covering 200 hectares land (Plubins, 2013). Nowadays, both archaeological monuments crowded with visitor as the ruins has seen as glorifying trace of early empires in Southeast Asia.

Up to the northwest shore of Malay Peninsula (Figure 2.14); there is an area whereby the estuary of Sungai Merbok (Merbok River) provides a safe anchorage and
beautiful panoramic mountain for seafarer along the coastline of the Straits of Malacca (Wales, 1940). It is the land situated in district of Kedah which practically owed its significance credit to its geographical position to attract the traders along the Silk Road. Historical document had recorded several names (such as Chieh-ch’ a, Kalah, Kadaram) addressing the ancient Kedah and its involvement with trade activities which extended beyond regional territories since early historic period.

Figure 2.14: The location of Bujang Valley at west coast of Kedah state in Peninsula Malaysia.
Bujang Valley of South Kedah now is historical complex, well-recognised on the discoveries of historical remains ranging from trading artefact, religious pieces and the ruins of historical Hindu-Buddhist temples locally called as *Candi*. The recent research studies frequently address these archaeological remains as the physical evidences that signify the existence of *Kedah Tua* or Ancient Kedah kingdom.

Nearly a decade ago another discovery unearthed an evidence of civilised community situated at Sungai Batu. The discovery simultaneously strengthens the historical chronology in Bujang Valley territories. The Sungai Batu Archaeological Complex was discovered in 2007 by the Centre for Global Archaeological Research, University Sains Malaysia. The early survey in 2007 identified 97 mounds in a 3km area (Mokhtar *et al.*, 2011); consisting structural monuments and iron smelting sites.

As the excavation started in 2009, the only ritual site/monument was among the significance discovery found in the complex. The structure dates 110 century CE which recorded as the earliest dating for ritual monument in Southeast Asia earlier than Borobudur in Java (9th century) and Angkor Wat, Cambodia (12th century). Moreover, several brick structures (SB1R, SB1S, SB1W) which found at Sungai Batu had given dating as early as 487 century BC (Nurashiken, 2016 & Suhana, 2016). With the latest finding and ongoing research, it is believed that Sungai Batu Complex would reveal more data to stand as the earliest civilisation ever existed at the Southeast Asian region.

2.5.1 **Origin and Historical Records of Sungai Batu Civilisation (*Kedah Tua*)**

Before the discovery of Sungai Batu Complex, many of early researcher believed the area of Bujang Valley existed since 2nd century CE and continue to rise until 14th century CE. Bujang Valley or *Lembah Bujang* is infamous area for
archaeological research as it rich with historical and cultural significance. It covers the coastal plain of south Kedah, over 400 squares which extending from Bukit Choras at the north and Bukit Mertajam at South (Adi, 1998). Moreover, it surrounds by majestic mount Mount Jerai, which also known previously as Kedah Peak, the highest landform in Bujang Valley (Sanday, 1987).

Geographically strategic, Mount Jerai provides helpful landmarks for ships or vessel in the Strait of Malacca and navigating them into the harbour (Figure 2.15). Apart from played the important role in trade and commercial centre, the major river such as Muda and Merbok rivers supply good inland waterways for lands cultivation especially rice agriculture and perfect place to build a sanctuary for religious obligation. Hence, the archaeological evidences were obtained mostly along the rivers of Bujang Valley, which formed by the drained of the Muda, Trus, Merbok and the Sala rivers and their tributaries (Adi, 1998).

The past records from China, Arab, Tamil and India frequently mentioned on the existing of Ancient Kedah by various names such as Chieh-ch'a by I- ching of China, Ko-lo, or Ko-lo-fu-sha-lo, of the T'ang annals; Kalah by the Arabic geographical texts; Kadaram by Tamil records and Kataha in Sanskrit (Blagden, 1920; Winstedt, 1920; Briggs, 1950; Allen, 1988; Allen, 2008). These names even though were cited in different chronology and from varied sources, nevertheless from the narrative aspect related to the region of ancient Kedah or Kedah Tua in Malay Peninsula.
Although no written documents or inscriptions had described in depth concerning the historical context of Ancient Kedah and its origin, however many researchers favour the abovementioned names that appeared in foreign records indeed referred to the old Kingdom in Kedah. Most probably the prominent sources generally used by the researcher in unfolding the historical anecdote of Kedah would be the infamous Kedah Annals or *Hikayat Merong Mahawangsa*. However, the Kedah Annals contains historical anecdote which mainly based on folktales or legendary chronicle thus the credibility might be questioned in research and academic writing.

Besides, scholars believe that the evidences from Guar Kepah prehistoric sites in possibly suggested the social culture and population of Ancient Kedah evolved from local settlements (Nik Hassan Shuhaimi, 1998). Guar Kepah is Neolithic site situated at north Seberang Prai district, between boundary of Penang and Kedah state and 8 km away from the coastal area on the west bank of Sungai Muda (Muda River). Recent discovery has revealed the full skeletal of upper body buried in shell midden at Guar Kepah excavation site. This finding marked the first Neolithic human remains...
uncovered by Malaysian archaeologist since the site was first discovered. At present, it has been reported that the state government of Penang is in the midst of talks to bring back the remaining 37 bones found during the first excavation conducted by British archaeologist G. W Earl in 1851 and to preserve them in the upcoming archaeology gallery (Lee, 2017).

Although the ancestry links between the Neolithic people in Guar Kepah with Bujang Valley region is scientifically yet to be proven, however the local linkage hints by the fact that geographical distribution of human activities related to the geomorphological phenomenon. As mentioned by Allen (2008), the main trade centre for the old Kingdom of Kedah had to shift location through time as responded to coastal transformation and river captures. Hence, this resulted several sites relocation started long before the period of 12th century from Sungai Mas to Pengkalan Bujang in and back again to Sungai Mas and later for brief of time, around 14th century the main trade centre shifted to Kampung Sireh, the inland on the Muda River (Allen, 2008).

Moreover, the current chronometric record as explained by Bulbeck (2014) concluded that the transition of settlement and burial site from closed site to the open-air indicated the two components of Holocene period. According to Bulbeck (2014) this evolution along with evidences on which they had already implies the hierarchical status through richness of burial material that subsequently leading to the early state formation in this region. Furthermore, the later establishment of coastal empire mentioned by Ptolemy's *Golden Khersonese* (Golden Peninsula) during first half-millennium CE has proven by the existence of iron industrial sites and ancient bricks technology at Sungai Batu archaeological sites (Bulbeck, 2014).
As cited, the geomorphological phenomenon such as coastal progradation, sea level changes and river capture encourage people to shift location for suitable place to dwell in and contributes to the development of human activities and cultural growth (Allen, 1988; Bulbeck, 2014). Accordingly, looking from this perspective, recent studies at Sungai Batu also has demonstrated the continuity of sites movement which were likely navigated by the ancient riverine transformation as responded to sea level changes. As Mokhtar et al. (2011) elaborated; the only area suitable for settlement around Merbok River during 1st to 3rd century was Sungai Batu since the other sites; Sungai Mas and Sungai Bujang were still under the sea or swampy areas.

Meanwhile, the aspects of social structures such as establishment of settlement, political structure and social-culture of Ancient Kedah remain among the speculative theories that lacking in solid evidences (Nasha et al., 2015). Researcher such as Quaritch Wales emphasised the concept of ‘Indianisation’ or the Indian colonisation in Kedah thus focused mainly on the relations between India and Malay Peninsula regarding the stylistic elements of sculptures, inscriptions and religious monument (Wales, 1940). In contrast, Allen (1988) used the geomorphology data to analyse the location of the sites and function of individual sites thus given the interpretation on interaction between landscape evolution, trade exchange and settlement distribution that formed social structure of Ancient Kedah.

To date, regardless of discovery on countless archaeological materials, the identity of the early communities who inhabit the area and who the one built numerous structures in Sungai Batu and entire Bujang Valley is presently remains vague. However, looking at the evidences of early settlement since Neolithic period in this region until the reign of Sultanate era, it is reasonable to regards the ruler of ancient Kedah was then a Malay. This is due to the people from the early settlement could
evolved into maritime state and later under Malay Sultanate reign which the lineage exists until today. The Malay historically recorded as seafaring people who participated in local and overseas trade and established internal and external trade exchange as well as cultural adaptation. Thus, it is only natural to presume that they are capable in such skills thanks to long life experiences that inherit from their ancestor. Furthermore, many Malay villager still resides at majority of historical sites within Bujang Valley which they have had occupant the area long since olden times.

Although many earlier researchers also believed that the Chinese and Indians ruled the trading alliance during early historic period especially there are many elements of Hindu-Buddhist were found throughout the regions of Malay Archipelago. However existing evidence referred to Malays as the long-established initiators, regulators, and controllers of both internal and external exchange in the Malay Peninsula (Allen, 1988). In fact, Kedah was among the renowned entrepôt apart from Srivijaya and Melaka that signified the major centres of Malay power (Matheson-Hooker, 2003). All these statements suggest that, during the ancient times, the Malay seemingly dominated the population, political and cosmopolitan area in Bujang Valley (Nik Hassan Shuhaimi, 1998), yet the traders especially from India and China brought the cultural dynamic and influences thus integrated with local elements.

2.5.2 Archaeological Research at Bujang Valley

The earliest archaeological report of Bujang Valley was recorded in the 1840s when Colonel James Low, a government official in Penang discovered the remains of ancient monument (Supian, 2002). Somehow, the earliest archaeological excavations particularly during the period before 1970s were monopolised by the researchers from
the western countries. Presumably, at that time they did have an upper hand and relatively enough resources to support the expedition.

Moreover, the approaches and aims for archaeological research in Bujang Valley were varied through time. For instance, the pioneers in archaeological sites exploration namely James Low, Irby and Evans who apparently were the colonial officer in Malay Peninsula. They initial interest was to collect the valuable artefacts and treasures from the historical period since Bujang Valley primarily rich with Hindu-Buddhist site (Nasha *et al.*, 2015). After years of Malaysia’s independence, the studies in Bujang Valley have focussed to strengthen the national data on our cultural heritage.

Nevertheless, it started with Low’s sporadic archaeological findings which have guided more research and investigation to study the Bujang Valley area. Eventually, there were a quite number of researchers that attracted by its rich historical and cultural features to conduct the archaeological study more intensively rather than just site exploration. Table 2.3 lists all the researchers in the Bujang Valley since the 1840s:

<table>
<thead>
<tr>
<th>Researcher</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>James Low</td>
<td>1840s</td>
</tr>
<tr>
<td>F W Irby</td>
<td>1894</td>
</tr>
<tr>
<td>I.H.N Evans</td>
<td>1920s</td>
</tr>
<tr>
<td>H.G Quaritch-Wales</td>
<td>1930s-1940s</td>
</tr>
<tr>
<td>K.G Tregonning</td>
<td>1950s-1960s</td>
</tr>
<tr>
<td>M. Sullivan</td>
<td>1950s-1960s</td>
</tr>
<tr>
<td>Alastair Lamb</td>
<td>1950s-1960s</td>
</tr>
<tr>
<td>Peacock</td>
<td>1960s</td>
</tr>
<tr>
<td>Al-Rashid</td>
<td>1970s</td>
</tr>
<tr>
<td>Leong Sau Heng</td>
<td>1970s</td>
</tr>
<tr>
<td>Adi Taha</td>
<td>Since 1970s</td>
</tr>
<tr>
<td>Nik Hassan Suhaimi Abdul Rahman</td>
<td>Since 1970s</td>
</tr>
<tr>
<td>Jane Allen</td>
<td>1980s</td>
</tr>
<tr>
<td>Kamarudin Zakaria</td>
<td>1990s</td>
</tr>
<tr>
<td>Supian Sabtu</td>
<td>1990s</td>
</tr>
</tbody>
</table>
Local archaeologist also actively involved in archaeological research and excavation at Bujang Valley, among them are Al-Rashid, Adi Taha, Nik Hassan Shuhaimi, Kamaruddin Zakaria, Leong Sau Heng and Supian Sabtu (Mokhtar et al., 2011). The first group of local researchers in Bujang Valley focused more on enhancing the archaeological data obtained from the previous researcher (Nasha et al., 2015). For instance, in the early 1992, Nik Hassan Shuhaimi from Universiti Kebangsaan Malaysia and Kamarudin Zakaria from National Museum collaborated with western researcher, Michel Jacq Hergoualc’h to review and conduct site survey based on the existing data of archaeological sites including excavation for Site 23 at Pengkalan Bujang (Nasha et al., 2015). The research helps enriched the museum collection as well as encouraged more academic writing on the Bujang Valley to construct the historical significance of Malay Peninsula. Nowadays, more scientific approach as well as variety of specific research subjects have been conducted for studies at Bujang Valley.

2.5.2(a) Excavation and Findings

The growth of entrepôt during the glory era in Bujang Valley has been proven by a lot of archaeological discovery that found near the bodies of water. Generally, for the ancient harbour; the physical archaeological evidence of trading centre in ancient Kedah pointed towards the discovery of massive quantities of the trading artefacts such as of porcelain, ceramic, earthenware and more. These trade-ware items mostly have been identified originated from the outside of locality range. For instance, Pengkalan Bujang where located at the west banks of Bujang river once served as a main harbour as a place to load, collect and distribute the trade commodities Bujang due to its suitable geographical landscape (Nasha, 2011).
Lamb (1961) who excavated Pengkalan Bujang described it was ‘once a very cosmopolitan trading centre’ based on countless of trade-items deposit that he found. The excavation area covered 100 square feet revealed approximately 10,000 fragments of porcelain, group of larger fragments of earthenware and glass, as well terra cotta and glass beads. The collection of findings came from various parts of world; such as Thailand, China India, Persia and Middle East as well as a locally produced trade-ware (Lamb, 1961).

Apart from trading artefact, the most well-known archaeological finds that relates the Bujang Valley with historical and cultural significance is the existence of monuments that either built for religious purposed or to function as secular used. Most of the early archaeological findings scattered along two rivers tributaries of Merbok river; Bujang river and Merbok Kecil river (Wales, 1940). The structural remains of temple in Bujang Valley have either element of Hinduism or Buddhism and relatively small compares to the other ancient temples found in Southeast Asia. Archaeological evidences in Bujang Valley also have recorded the traces of local manufactured sites also found in the immediate neighbourhood. It included the beads manufacture sites at Sungai Mas and recently discovered sites of iron making industry at Sungai Batu Archaeological Complex.

Excavations at Sungai Batu have revealed the community that once involved with the iron smelting technology, having a means of communication and transportation as well as the capability to build structure from clay fired bricks. These sites altogether are better known as Sungai Batu Archaeological Complex consist of several structures with each served for different functions namely as a ritual monument, riverside jetties and iron smelting sites and a supporting structure for the jetty/port administration. In addition, the findings of jetty structure and iron industry
have strengthened the archaeological data on Ancient Kedah as the trading centre and actively participated in producing their own trade material, which is an iron.

2.5.2(b) Ruins and Monuments of Bujang Valley

Through the early series of archaeological expedition, researchers had revealed numbers of temples or Candi have been found from various sites within the Merbok and Muda river estuary in Bujang Valley territories (Figure 2.16). They could have indicated the dispersion of settlements that once existed in the old kingdom in Bujang Valley. According to Lamb (1961), the remains of the ancient temples along the banks near the Pengkalan Bujang site presumably indicated a large settlement covering the area. In fact, in the modern-day settlement, the villagers from the neighbouring kampung (village) took the bricks from these temples to use as bases for house’s timber supports (Lamb, 1961).

Figure 2.16: Reconstruction work on Tapak 8, Candi Bukit Batu Pahat. (Source from Straits Times Annual, 1968; after Matheson-Hooker, 2003)
As shown in following tables (Table 2.4, 2.5, 2.6 and 2.7), are the list of monument and potential ruins’ sites sorted based on their location; the area at Mount Jerai and two main rivers (Merbok and Muda river). These tables briefly describe the functions, structures, construction materials and the associated finds that combined published data from Wales (1940) and Allen (1988). The shrines listed below may contains more than two functions based on the researchers’ interpretation regarding their structural formation, location and its associated finds. Several of the documentation contained site drawing plan of these structure. Whereas the others apparently never had a record either were destroyed or basically based on surface finding and survey without proper excavation and documentation.

Table 2.4 lists the site number 1, 9, 49, 64 and 65 which situated at the Mount Jerai area mostly at hilltop, upper slopes and near the stream channel. The locations covered Bukit Choras, the summit of Mount Jerai, Telaga Sembilan and Sungai Batu Pahat.

Table 2.4: Site, location and description of sites at area of Mount Jerai (Wales, 1940 and Allen, 1988)

<table>
<thead>
<tr>
<th>Site &amp; Location</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1, Bukit Choras</td>
<td>Date: 4th CE</td>
<td>*Assumed as fort due to location of site found on summit of Bukit Choras.</td>
</tr>
<tr>
<td></td>
<td>Function: Shrine, Fort*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Structure: A laterite stairway and basement with platform 15sq feet at the centre.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Material: Laterite</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Finds:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>i Undecorated pottery fragments</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ii Ancient type iron nails</td>
<td></td>
</tr>
<tr>
<td></td>
<td>iii Inscription on rectangular bar stone</td>
<td></td>
</tr>
<tr>
<td>Site 9, Summit of Mount Jerai</td>
<td><strong>Date:</strong> 8th or Later</td>
<td><strong>Function:</strong> Shrine, Lighthouse</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td><strong>Structure:</strong> Platform with hole in the centre containing the ring stone inside.</td>
<td><strong>Material:</strong> Granite block, clay bricks</td>
<td></td>
</tr>
<tr>
<td><strong>Finds:</strong> Ming’s blue and white porcelains (as reported in Evans 1927)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 49, Telaga Sembilan</th>
<th><strong>Function:</strong> Shrine</th>
<th>--</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure:</strong> Remnants granite and pegmatite outcrops on the east bank of first stream east of Batu Pahat river with few socles (base of column; plinth)</td>
<td><strong>Construction Material:</strong> Laterite, granite blocks, cobbles, boulders (rock slab).</td>
<td></td>
</tr>
<tr>
<td><strong>Finds:</strong> Fragments of stone (yoni) associated with Saivite tradition.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 64: Sungai Batu Pahat</th>
<th><strong>Function:</strong> Shrine or secular used</th>
<th>--</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure:</strong> Boulder foundation of square corners structure, remains of east wall approximately 7m length and a fragment granite column.</td>
<td><strong>Material:</strong> Bricks, granite cobbles and blocks, boulders.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 65: Sungai Batu Pahat</th>
<th><strong>Function:</strong> Shrine or secular used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure:</strong> Rectangular granite building, 15 m east-west and 11 m north-south. Wall remnants on south and east.</td>
<td><strong>Material:</strong> Granite,</td>
</tr>
<tr>
<td><strong>Finds:</strong></td>
<td></td>
</tr>
<tr>
<td>i Modern midden</td>
<td></td>
</tr>
<tr>
<td>ii 19th century European and blue and white Ming wares, brown-glazed ceramic</td>
<td></td>
</tr>
<tr>
<td>iii Stoneware shreds tempered with grog (crushed fired pottery high with silica and alumina)</td>
<td></td>
</tr>
<tr>
<td>iv Middle eastern glass, blue and green</td>
<td></td>
</tr>
<tr>
<td>v Iron rod</td>
<td></td>
</tr>
<tr>
<td>vi Cobble carve with bird’s footprint</td>
<td></td>
</tr>
</tbody>
</table>
Merbok River areas comprise 34 sites (Table 2.5) of sites 2-8, 10-23, 25, 30, 33-35, 50, 68, 71, 77, 79-81 and 87, that mainly found at the northern side of river. These locations include Kg. Bendang Dalam, Kg. Sungai Batu, Bukit Gajah Mati, Bukit Batu Pahat, Bukit Tupah estate, Kg. Bendang Dalam, Bukit Pendidat, Pengkalan Bujang, Bukit Penjara, Kg. Pasir and Bukit Batu Lintang.

Table 2.5: Site, location and description of sites at area of Merbok river (Wales, 1940 and Allen, 1988)

<table>
<thead>
<tr>
<th>Site &amp; Location</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| Site 2: Kg Bendang Dalam | Date: 6th CE  
**Function:** Buddhist Shrine  
**Structure:** Square structure with small basement for small Stupa  
**Material:** Laterite (red shale slabs)  
**Finds:**  
i. Sanskrit inscription on rectangular tablet made by hard sun-dried clay  
ii. Gold leaf  
iii. Iron finial fragment (part of ornament) either Stupa itself or inner reliquary (relic’s container) | Destroyed by excavations and quarrying activities for construction purposes  
Sun-dried tablet is preserved in National Museum Singapore |
| Site 3: Kg Sungai Batu | Date: 5th-6th CE  
**Function:** Shrine  
**Structure:** Approximately 9 feet square in rectangular structure of laterite blocks and forming four courses. Deep basement for small stupa probably in early Buddhist period.  
**Material:** Laterite | Located close together with *Site 11*.  
Reconstructed by Museum Department in 1973 |
Table 2.5 Continued

<table>
<thead>
<tr>
<th>Site 4: Sg Batu Estate</th>
<th>Date: 6th-7th CE</th>
<th>Function: Saivite Shrine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>One of largest excavated area in the area by Wales</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Structure: Enclosed wall with stone (boulders) foundation. Cut granite socles as entrance, one main shrine and two subsidiary structure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Material: Laterite and granite blocks, bricks and river boulders.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Finds:</td>
</tr>
<tr>
<td></td>
<td>i</td>
<td>Roof of miniature bronze shrines in river</td>
</tr>
<tr>
<td></td>
<td>ii</td>
<td>Granite river boulder represent Ganesa simple and plainly carved</td>
</tr>
<tr>
<td></td>
<td>iii</td>
<td>Fragment of Linga that made of granite</td>
</tr>
<tr>
<td></td>
<td>iv</td>
<td>Carved granite lamp stand found at basement</td>
</tr>
<tr>
<td></td>
<td>v</td>
<td>Fragments of red-brown undecorated pottery and almost complete earthenware- pot</td>
</tr>
<tr>
<td></td>
<td>vi</td>
<td>Glass beads and vessel shreds</td>
</tr>
<tr>
<td></td>
<td>vii</td>
<td>Iron knife, head of arrow and iron nails</td>
</tr>
<tr>
<td></td>
<td>viii</td>
<td>Fragments of bronze bell, ring and staple</td>
</tr>
<tr>
<td></td>
<td>ix</td>
<td>Sharpening stone with convenient grab form</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 5: Kg Sungai Batu</th>
<th>Date: 6th-7th CE</th>
<th>Carved granite block was located by Allen (1988). Site reconstructed by Museums Department in 1974</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Structure: Enclosure wall of boulders, opening at east with laterite plinth. Narrow bricks path at the middle leading to the entrance of the shrine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Material: Laterite, boulders, bricks, stone socles and square mortise.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Finds:</td>
</tr>
<tr>
<td></td>
<td>i</td>
<td>Two fragments of “coarse” brown pottery with pattern of ornamentation and one fragment yellowish crazed glaze</td>
</tr>
<tr>
<td></td>
<td>ii</td>
<td>Iron nails</td>
</tr>
<tr>
<td></td>
<td>iii</td>
<td>Sharpening stone</td>
</tr>
</tbody>
</table>
Table 2.5 Continued

<table>
<thead>
<tr>
<th>Site 6: Kg Sungai Batu</th>
<th>Date: 6th-7th CE</th>
<th>Function: Shrine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure:</strong> Two adjoining enclosures measuring 21.3m and 32.3m along the river, 26m wide. Boulder foundation, with opening at eastward of shrine.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Granite, laterite and bricks</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Finds:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Fragments of red earthenware</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. Amber glass with pontil mark</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iii. Rim of bronze bowl</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 7: Bukit Gajah Mati</th>
<th>Date: 6th-7th CE</th>
<th>By 1979, the location was hardly known by neighbouring resident.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function:</strong> Shrine (probably Saivite)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Structure:</strong> Once reported at the summit of the hill but disappeared before Wales (1940) survey.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Granite and laterite blocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Finds:</strong> Stone with spiral marking</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 8: Candi Bukit Batu Pahat</th>
<th>Date: 7th – 8th CE</th>
<th>Reconstructed at original place, adjacent to Bujang Valley Archaeology Museum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function:</strong> Saivite Shrine</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Structure:</strong> Oriented north-south, opening at south. Enclosure wall built by rock such as water-worn schist, granite boulders &amp; cobbles. Basement of granite blocks and stairs led to platform and interior of sanctuary that projected toward southeast. Stone socles with square mortises surround the outer platform.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Granite blocks and boulders, stone socles/plinth, cobbles.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Finds:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Silver capsule with polished sapphire and pyrope (gems)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. Grey or red unornamented potsherds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iii. Ancient nails</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iv. Fragments of bronze base</td>
<td></td>
<td></td>
</tr>
<tr>
<td>v. Quartzite reliquaries</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 2.5 Continued

<table>
<thead>
<tr>
<th>Site 10: Bukit Tupah Estate</th>
<th><strong>Date:</strong> 9th CE</th>
<th>As reported by Treloar (1980), gold and silver disc contain mercury probably used in metalworking at Pengkalan Bujang (as cited in Allen, 1988)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function:</strong> Buddhist Shrine (probably Mahayanist)</td>
<td><strong>Structure:</strong> Remnants of alignments of enclosure of boulder walls around 15.8m². Plinth of moulded brickwork at entrance gateway at the west.</td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Laterite, brick, cobbles, boulder and stone socles</td>
<td><strong>Finds:</strong></td>
<td></td>
</tr>
<tr>
<td>i Six silver discs, plain on one side, inscribed on the other</td>
<td>ii One gold inscribed at the centre</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 11: Kg Sungai Batu</th>
<th><strong>Date:</strong> 8th-9th CE</th>
<th>Associated with Site 3.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function:</strong> Shrine or secular used-royal audience hall or council chamber</td>
<td><strong>Structure:</strong> Comprises two component, main hall and double wall porch with boulder foundation. Stepped rectangle at narrow east end. Six to eight courses of water-worn cobbles and pebbles.</td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Granite, laterite, block boulders, stone socles.</td>
<td><strong>Finds:</strong></td>
<td></td>
</tr>
<tr>
<td>i Fragments of ornamented earthenware and greenish glazed Chinese ware (Tang ceramic)</td>
<td>ii Three glass fragments, one wick tube of greenish glass Arab lamp</td>
<td></td>
</tr>
<tr>
<td>iii Piece of flat, tapering iron (probably broken sword), 3 old type nails</td>
<td>iv Plain square image bronze</td>
<td></td>
</tr>
</tbody>
</table>

Demolished by land developer in 2013.
Table 2.5 Continued

<table>
<thead>
<tr>
<th>Site 12: Kg Sungai Batu</th>
<th>Date: 8th – 9th CE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function:</strong> Secular structure- Royal audience hall.</td>
<td></td>
</tr>
<tr>
<td><strong>Structure:</strong> Brick and laterite block was built inside the 1m-thick wall enclosure and in-situ pillar socles. Oriented facing the river to its east-south. Boulders at lower course at the middle on enclosure.</td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Laterite, bricks, boulders and once a timber.</td>
<td></td>
</tr>
<tr>
<td><strong>Finds:</strong></td>
<td></td>
</tr>
<tr>
<td>i Iron dagger with bronze hilt shapes like serpents’ heads with eyes</td>
<td></td>
</tr>
<tr>
<td>ii Fragments; corroded bronze vessel</td>
<td></td>
</tr>
<tr>
<td>iii Two fragmented Chinese mirrors (Tang Dynasty, 618-907 AD)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 13: Kg Sungai Batu</th>
<th>Date: 8th – 9th CE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function:</strong> Mahayanist Shrine</td>
<td></td>
</tr>
<tr>
<td><strong>Structure:</strong> Comprises 5 components of Site 13, Site13a, Site 13b, Site 13c and Site 13d. Plinth at north wall and portion of walls made of bricks and unspecific ‘rubble’. Rectangular stone platforms, 13b, 13c and 13d constructed of water-worn boulders and cobbles.</td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Bricks, rubble, cobble, boulders (13a), and stone socles (13b).</td>
<td></td>
</tr>
<tr>
<td><strong>Finds:</strong></td>
<td></td>
</tr>
<tr>
<td>i Earthenware jars (Site 13a) at each of four corners, beneath floor level which contained:</td>
<td></td>
</tr>
<tr>
<td>a. Molluse shells Variety of colour and size of glass beads</td>
<td></td>
</tr>
<tr>
<td>b. Fragment of bronze ring and bronze bowl.</td>
<td></td>
</tr>
<tr>
<td>c. Small polished sapphire gems and quartz crystal</td>
<td></td>
</tr>
<tr>
<td>d. Fragments gold earring, some ornamented with beads</td>
<td></td>
</tr>
<tr>
<td>e. Rim of silver bowl</td>
<td></td>
</tr>
<tr>
<td>ii Shreds of plain reddish earthenware with impressed design (stamped/ pressing surface with something)</td>
<td></td>
</tr>
</tbody>
</table>
Table 2.5 Continued

<table>
<thead>
<tr>
<th>Site 14: Kg Bendang Dalam</th>
<th>Date: Late 9\textsuperscript{th} CE</th>
<th>Excavated by Quaritch Wales. Disturbed by irrigated rice field</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Function: Shrine</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Structure:</strong> Platform with floor made of laterite blocks. In-situ granite socles, including two on platform at eastern end had triangular mortises. Stairway of stone and brick led up to platform.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Material:</strong> Laterite, stone, bricks</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Finds:</strong></td>
<td></td>
</tr>
<tr>
<td>i.  Two of earthenware jars contained:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.  Two silver coins dated 234AH from Abassid Caliphal Mutawakil (847-861AD) with small square hole through it</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.  Inscribed rim of small river vessel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.  Bronze finger ring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.  Polished gems, amethyst quartz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.  Milky quartz and blue short beads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. Undecorated potsherd, probably from late Tang period.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 15: Kg Bendang Dalam</th>
<th>Date: 9\textsuperscript{th} -10\textsuperscript{th} CE</th>
<th>Excavated by Quaritch Wales</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Function: Shrine</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Structure:</strong> Square sanctuary with parallel outer ground level laterite. Small stones were scattered in between two enclosures. In situ stone socles at the edge of inner compartment and opening towards the east. Outer entrance bordered by low laterite, the right side to entrance indicated the foundation of chamber</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Material:</strong> Laterite, small stones, stone socles and bricks.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Finds:</strong></td>
<td></td>
</tr>
<tr>
<td>i.  Two fragments of green glazed Chinese ware and ornamented shreds of jar possibly Indian origin.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. Green glass beads and smaller blue glass bead</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iii. Green-tinted clear glass</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2.5 Continued

<table>
<thead>
<tr>
<th>Site 16: Kg Bendang Dalam</th>
<th>Date: 9th - 10th CE</th>
<th>Function: Buddhist Shrine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Structure: Stepped rectangle structure smaller but resembled Site 15. Opening at east, with laterite block forming the floor and chamber which situated beside the entrance.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Material: Laterite, Clay brick</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Finds: Bronze relic casket contained:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Golden bowl inside it was small pearl, gold silver-alloy, metallic substances at bottom of bowl.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. Gold: bow, two arrows, sword, a dagger, a noose, a staff or spear, shield, damaru drum, golden lotus, and a rectangular piece representing a book</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. Silver: a bell (or seal), a ploughshare and yoke (crosspiece connected to plough)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. Nine gems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>e. Fragment of bronze lamps and bronze bell</td>
<td></td>
</tr>
<tr>
<td></td>
<td>f. Rusted iron ring and iron tubing</td>
<td></td>
</tr>
</tbody>
</table>

Reconstructed and relocated at Bujang Valley Archaeology Museum

Site 16a: Found red earthenware jar shreds, 5th CE type of standing Buddha image on Bronze

<table>
<thead>
<tr>
<th>Site 17: Bukit Pendiat</th>
<th>Function: Shrine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure: Octagonal site at the summit of the hill, the enclosure wall structure by laterite blocks and clay brick at inner hallow segment</td>
<td></td>
</tr>
<tr>
<td>Material: Bricks, laterite</td>
<td></td>
</tr>
<tr>
<td>Finds:</td>
<td></td>
</tr>
<tr>
<td>i Earthenware pots</td>
<td></td>
</tr>
<tr>
<td>ii Jewellery and beads</td>
<td></td>
</tr>
</tbody>
</table>

Excavated in 1977 and was reconstructed in situ around 1979-1980. An elephant trap recorded 0.4km south.
<table>
<thead>
<tr>
<th>Site 18: Pengkalan Bujang</th>
<th>Date: 11&lt;sup&gt;th&lt;/sup&gt; - 12&lt;sup&gt;th&lt;/sup&gt; CE</th>
<th>Function: Royal audience hall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure:</strong> Rectangular structure of two compartments. The smaller one situated at north with brick floor, laterite blocks of three courses wall and few stone socles with square mortises. Lintel made of granite and moulded doorframe, unglazed roof tiles with hook for attachment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Granite, bricks, laterite, unglazed ceramic tiles</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Finds:</strong> i Fragments of Song porcelain: Longquan celadon, olive-green glaze ware and few earthenware ii Mother-of-pearl spoon iii Iron nails iv Small bronze discs, bronze coins and fragments of bells/vessels v One carnelian beads and a stone bead vi Numerous fragments of glass, some with pontil marks and bubbly. vii Glass fragments of two Arab lamps.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 19: Pengkalan Bujang</th>
<th>Date: 11&lt;sup&gt;th&lt;/sup&gt; - 12&lt;sup&gt;th&lt;/sup&gt; CE</th>
<th>Function: Hindu Shrine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure:</strong> Vaulted shrine probably built entirely by bricks with porch and opening to the east. Thick wall height almost 1.5m from foundation of small water-worn stones.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Bricks and water-worn stone.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Finds:</strong> i Rough pottery fragments and Longquan celadon ii Old types iron nails and iron ladle iii Pointer bronze object with crenulated edges (scalloped or notched outline) iv Statue of Ganesa in fragmentary weathered terracotta and missing head v Broken portion of nine-chambered reliquary</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Resemblance the structure at Site 11 and 12 but in absence of ritual objects.

Reconstructed site at its original location. Several artefacts from here at Bujang Valley Archaeology Museum.
| Site 20: Pengkalan Bujang | **Date:** 11th – 12th CE  
**Function:** Saivite Shrine  
**Structure:** Remains of lower courses of a porch brick shrine, resemble Site 19  
**Material:** Bricks  
**Finds:** Fragments of Song Dynasty celadon |
|---|---|
| Sites 21, 22, 23: Pengkalan Bujang | **Date:** 11th- 12th CE  
**Function:** Shrine  
**Structure:** Site 21, rectangular form measuring 6.4m x 3m opening at south. Remains of brick walls and few stone socles. Site 22 consisted two main structure. Site 22 and 23 left with traces of broken bricks and tiles in site 22.  
**Material:** Bricks, stone socles (Site 21) and tiles (Site 23)  
**Finds:**  
i Fragments of Sung celadon.  
ii Beads  
iii Ring or earring  
Bronze and sandstone sculptures  
Site 21 reconstructed at Bujang Valley Archaeology Museum while Site 22 reconstructed in-situ  
Site 21 and 22 might stood as a single complex. Site 23 probably site 22 and Site 21 probably 23 |
Table 2.5 Continued

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Function</th>
<th>Structure</th>
<th>Material</th>
<th>Finds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 25: Bukit Penjara</td>
<td>11th - 12th CE</td>
<td>Shrine</td>
<td>Small structure opening to the west at located near of the summit.</td>
<td>Bricks</td>
<td>Associated with prison (penjara) that built by Rajaseger in Kedah Annal where the hill derives name from it.</td>
</tr>
<tr>
<td>Site 30: Sg Batu Estate</td>
<td>14th CE or later</td>
<td>Shrine/secular</td>
<td>Destroyed site with evidence of brickwork</td>
<td>Bricks and tiles</td>
<td>Ground been levelled suggested that elevation of the area probably several meters higher.</td>
</tr>
<tr>
<td>Site 33: Kg Pasir</td>
<td></td>
<td>Shrine</td>
<td>No surface material found during Allen’s (1988) survey.</td>
<td>Bricks</td>
<td>Wales (1940) suggested that this site was ‘comparatively modern’</td>
</tr>
<tr>
<td>Site 34: Bukit Batu Lintang</td>
<td></td>
<td>Shrine</td>
<td>Remnants of bricks fragments and sunken landform (depression).</td>
<td>Bricks, shale (rock) and laterite blocks</td>
<td>Likely been exploited by the treasure hunters during 1950s who disguised as ‘Museum staff’ to the villagers.</td>
</tr>
<tr>
<td>Site 35: Bukit Batu Lintang</td>
<td></td>
<td>Shrine/ Habitation</td>
<td>Large depression likely excavated area with well and fragments of granite.</td>
<td>Laterite, earth</td>
<td>Ceramics and sculpture relief.</td>
</tr>
<tr>
<td>Site 50: Kg Bendang Dalam</td>
<td><strong>Function:</strong> Shrine</td>
<td>Partially excavated for reconstruction purposed by 1980</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------------------</td>
<td>----------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Structure:</strong> Two component consisted petroplinthite (laterite) blocks. Granite slab fragments inside the northern component. Three style granite socles with vertical side: circular with square mortise, square with square mortise and square stepped with round mortise.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Material:</strong> Laterite, Granite socles, stone pillar.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Finds:</strong> Local tools <em>batu menggiling-</em> a roller used to grind food substance, in form of granite.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 68: Kg Sungai Batu</th>
<th><strong>Function:</strong> Shrine or secular place</th>
<th>Located in estate rubber (now oil palm plantation)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Structure:</strong> Remains of main structure 15m east-west x 10m north-south. Second component contained alignment of mix rock concrete floor locater beside the site.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 71: Sg Batu Estate</th>
<th><strong>Function:</strong> Secular used</th>
<th>Current area of Complex Sungai Batu Sites at south east of the river. Most likely SB2A, the iron smelting site</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Structure:</strong> Three of mound with buried small bricks</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Material:</strong> Brick</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 77: Kg Bendang Dalam</th>
<th><strong>Function:</strong> Shrine or secular used</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Structure:</strong> Gathering of water-worn cobbles and boulders measuring 5m east-west and 7m north-south</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Material:</strong> Granite, pegmatite, cobbles, boulders and clay brick.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 79: Pengkalan Bujang</th>
<th><strong>Function:</strong> Shrine or secular used</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Structure:</strong> 5m x 6m partially buried clay bricks at near the eastern edge of river’s ridge</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Material:</strong> Bricks</td>
<td></td>
</tr>
</tbody>
</table>
Table 2.5 Continued

<table>
<thead>
<tr>
<th>Site 80: Pengkalan Bujang</th>
<th><strong>Function:</strong> Shrine or secular, habitation site</th>
<th>Likely an extension site of Lamb’s deposit P, 100m northwest of Site 18</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Finds:</strong> Shreds of ceramic</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 81: Pengkalan Bujang</th>
<th><strong>Function:</strong> Shrine or secular used</th>
<th>Probably Lamb’s deposit K, which subsurface finding of various shreds</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure:</strong> An area measured 9m x 6m contains of petroplinhte block and brick fragments</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Laterite, clay bricks</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 87: Pengkalan Bujang</th>
<th><strong>Function:</strong> Shrine or secular used</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure:</strong> Occupies stream levee (wall to prevent flooding or to control flow of river), remains of foundation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Brick and granite boulder</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.6 shows the sites at Muda river area which comprises six structural remnants at sites Site 31 and 37-41, at areas of Matang Pasir, Kg Jawa, Matang Kedungdong, Pinang Tunggal and Kg Seberang Tok Soh.

Table 2.6: Site, location and description of sites at area of Muda river (Wales, 1940 and Allen, 1988)

<table>
<thead>
<tr>
<th>Site &amp; Location</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 31, Matang Pasir</td>
<td><strong>Date:</strong> 13th CE</td>
<td></td>
</tr>
<tr>
<td><strong>Function:</strong> Shrine</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Structure:</strong> Excavated by Wales and Sullivan but not reconstructed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Laterite, gravel, rubble and red stone socles.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Finds:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i Olive green glazed bricks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii Song Dynasty type of porcelain.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2.6 Continued

<table>
<thead>
<tr>
<th>Site</th>
<th>Function</th>
<th>Date</th>
<th>Structure</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>37: Kg Jawa</td>
<td>Shrine or secular used</td>
<td>9th CE</td>
<td>Mound remnants, 17m in diameter</td>
<td>Brick</td>
</tr>
<tr>
<td>38: Matang Kedungdong</td>
<td>Shrine or secular used</td>
<td>Date: 9th CE</td>
<td>Structure: Mound remnants, 17m in diameter</td>
<td>Material: Brick</td>
</tr>
<tr>
<td>39: Pinang Tunggal</td>
<td>Shrine/ secular</td>
<td></td>
<td>Structure: Mound remnants, 17m in diameter</td>
<td>Material: Laterite, granite</td>
</tr>
<tr>
<td>40: Pinang Tunggal</td>
<td>Shrine/ secular</td>
<td></td>
<td>Structure: Mound remnants, 17m in diameter</td>
<td>Material: Laterite, petroplinthite block</td>
</tr>
<tr>
<td>41: Kg Seberang Tok Soh</td>
<td>Shrine</td>
<td></td>
<td>Structure: Mound remnants, 17m in diameter</td>
<td>Material: Brick, granite</td>
</tr>
</tbody>
</table>

Gold was claimed to be found here.

Material such as granite lintel currently placed at Surau.

Table 2.7 comprises an area between Merbok and Muda river which found 14 remains of possible structure whereby 9 remaining sites scattered within Kg Sungai Mas, and the rest located at Tikam Batu, Bukit Meriam, Kg Tambang Simpor and Kg Seberang Terus. These sites are 24, 26, 43, 46, 47, 51-57 and 60-62.
<table>
<thead>
<tr>
<th>Site &amp; Location</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 24, Tikam Batu</td>
<td><strong>Function:</strong> Hindu shrine <strong>Structure:</strong> Built on terraced hill with enclosure wall approximately 19m east-west and 9m north-south. Sandstone ‘image’ base that surrounded by a low mud wall. At centre, square pit with smaller and deeper rectangular hallow of each side of square, creating cruciform appearance. <strong>Material:</strong> Bricks, laterite, quartzite pillar capitals <strong>Finds:</strong> i Sandstone pedestal ii Kendi iii Chinese trade ware from late Song or Yuan Dynasty iv Jewellery</td>
<td>Fairly late dating of Hindu shrine Excavated by Sullivan. Now destroyed during the construction of the factory Image base was known locally as ‘Raja Bersiong’ Flagstaff”. However, it resembles closely to Cham’s pedestal.</td>
</tr>
<tr>
<td>Site 26: Bukit Meriam</td>
<td><strong>Function:</strong> Shrine <strong>Structure:</strong> Remains of damage bricks surround a large and shallow earth depression- probably trace of past excavation <strong>Material:</strong> Brick</td>
<td></td>
</tr>
<tr>
<td>Site 43: Kg Tambang Simpor</td>
<td><strong>Function:</strong> Exchange site and shrine <strong>Structure:</strong> Discovered at west bank of Sungai Simpor which served as trade channel. Consisted one or more structures. <strong>Material:</strong> Brick, laterite <strong>Finds:</strong> i Caledon wares, other trade ceramics and earthenware ii 14 glass vessel shreds, middle eastern types iii Two beads</td>
<td>Involved in exchange with China, Vietnam and Middle East same time as Pengkalan Bujang. Served as second order trade transfer point</td>
</tr>
</tbody>
</table>
### Table 2.7 Continued

<table>
<thead>
<tr>
<th>Site</th>
<th>Function</th>
<th>Structure</th>
<th>Material</th>
<th>Finds</th>
</tr>
</thead>
</table>
| 46: Kg Seberang Terus | Trade exchange point, shrine or secular used.                             | Extensive surface remains of clay bricks and laterite block on mound; scatters and along the path at its western edge. | Laterite, bricks | i Trade ceramics from Song to Yuan Dynasty  
ii Southern Song celadon  
iii 12th -13th CE creamware of Vietnamese manufacture |
| 47: Kg Seberang Terus | Shrine or secular used.                                                   | Old bricks were reported had been removed from the river cliff            | Brick          |                                                                      |
| 51: Kg Sungai Mas | Shrine or secular used.                                                   | Remnant of petroplynthite block that gathered mainly at one part of mound | Laterite       |                                                                      |
| 52: Kg Sungai Mas | Exchange point, Shrine or secular used.                                   | Petroplinthite block outline the main mound which probably once was a basement. Remnant was measured 6m east-west x 3m north-south | Brick, laterite | Ceramic shreds and non-trade objects of earthenware                  |
| 54: Kg Sungai Mas | Shrine or secular used.                                                   | Petroplinthite block outline the main mound which probably once was a basement. Remnant was measured 6m east-west x 3m north-south | Brick, laterite, rock | The evidences suggested that the site likely was existed for two periods in early historic sequence, before external trade and period when Chinese ware came to the area. |
| 55: Kg Sungai Mas | Shrine or secular used.                                                   | Slightly over a meter in height, 200m south of Site 53. Length over 14m x 10m. Mount composed of shale fragments and clay bricks | Brick, sedimentary rock-shale, granite |                                                                      |
Table 2.7 Continued

**Finds:**

i White-ware shred, probably Song Dynasty

ii White and red glass

iii Yellow beads in the mound

<table>
<thead>
<tr>
<th>Site 56: Kg Sungai Mas</th>
<th><strong>Function:</strong> Shrine or secular used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure:</strong> Mound that revealed the remnants of shale fragments and clay bricks. Formed two structures.</td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Bricks</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 57: Kg Sungai Mas</th>
<th><strong>Function:</strong> Shrine or secular used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure:</strong> Structure or structures was estimated 22m east-west and 14m north-south. A well 2m from mound, lined with petroplinthite block and brick. Brick alignment formed as pavement for 12m at northern side while laterite found mostly at the south.</td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Bricks, laterite and shale</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 60: Kg Sungai Mas</th>
<th><strong>Function:</strong> Shrine or secular used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure:</strong> Occupied 20m north-south and 15m east-west.</td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Bricks, laterite block</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 61: Kg Sungai Mas</th>
<th><strong>Function:</strong> Trade exchange and habitation site, shrine or secular used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure:</strong> Mound with diameter 15m² with 0.75m high.</td>
<td></td>
</tr>
<tr>
<td><strong>Material:</strong> Bricks, laterite block</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Finds:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>i 7 earthenware, 10 trade-ware from 12th to 14th Chinese, and Khmer, and 19th European wares</td>
</tr>
<tr>
<td>ii Olive glass shred</td>
</tr>
<tr>
<td>iii 29 glass beads</td>
</tr>
<tr>
<td>iv Shells/midden and nonhuman bone</td>
</tr>
<tr>
<td>v Vessel shreds</td>
</tr>
</tbody>
</table>

Incomplete beads and melted glass suggested the bead manufacture in the area.
Table 2.7 Continued

<table>
<thead>
<tr>
<th>Site 62: Kg Sungai Mas</th>
<th>Function: Shrine or secular used</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Structure:</strong> Located in house compound with visible bricks fragments scattered continuously in 12m² areas. Alignment of petroplinthite block at western edge. Two square granite blocks that may functioned as part of doorway or sculpture pediment</td>
</tr>
<tr>
<td></td>
<td><strong>Material:</strong> Bricks, laterite block and granite</td>
</tr>
</tbody>
</table>

As demonstrated in Table 2.4 -2.7, the location of these monuments was found scattered at the area of Muda and Merbok river as well as at the slope of Jerai Mount. Among the notable archaeological works was made by Alastair Lamb, who excavated and reconstructed Candi Bukit Pahat in Merbok that has left significant impact on later development of Bujang Valley (Adi, 1998). The early studies on the monuments in Bujang Valley illustrated various functions associate with religious structure of Hindu-Buddha, a fort, secular structure and a lighthouse (Allen, 1988).

The religious structures were in the forms of stupa linked with Mahayana Buddhism and the other was the vimana-mandapa for devoted Hindu Siva (Shaivism) religious group (Adi, 1998). Although there are some of monuments dated as early as 2nd CE, however most of the ruins discovered dated around 6th century CE until 13th century CE (Supian, 1998).

Most of the structural monuments were destroyed and the evidences of the remnants were identified by the mound formation and surface finding such as bricks, laterite and granite block. Some were excavated and reconstructed and few were relocated to the Bukit Batu Pahat within the proximity of Bujang Valley Archaeology Museum, for preservation purpose. Whereas the other are still unaccounted for the heritage inventory. Probably due to many of them were destroyed, lost track or hard to
access. Unfortunately, many valuable archaeological findings at several of these sites have been reported either stolen by treasure hunters or exploited by group of ‘antiquarian’ colonial officers.

To summarise, the early archaeological findings in historical area of Bujang Valley can be classified into two main findings, which are structural remains and artefacts. The remaining structures came in variety of shape and sizes were identified as religious edifices or Candi (Adi, 1998). The discoveries are the result of the trading relationship which promoted different cultural influence and development at the old Malay Kingdom of the Bujang Valley (Sanday, 1987) or the Kingdom of Ancient Kedah.

The dynamic development in terms of research approach and wide range of research studies has proven that Bujang Valley is worth research attention and for future potential studies. Another extra point added; the area also abundant with remarkable elements of nature, ecosystem and geographical factors allowing possible collaboration between archaeology with other branch of study.

Furthermore, within archaeology study, a lot of research in recent years have demonstrated variety of approaches ever since the scientific methodology and technological advancement have been widely accepted in the field. Significantly, this allowed more discoveries to be made, theories to be proven, data could be enhanced, and several other hypotheses would enrich the archaeological research and study.
2.5.3 Sungai Batu Archaeological Complex

Sungai Batu is the archaeological site located within the historical area of Bujang Valley that discovered in 2007 by the Centre for Global Archaeological Research, Universiti Sains Malaysia. The archaeological sites at Sungai Batu were found based on evidence of paleo-sea level from geomorphological studies using geoarchaeological mapping, transient electromagnetic (TEM) and core drilling studies (Mokhtar et al., 2011). Based on the GPS (Global Positioning System) coordinate reading at the datum point, the area enclosed by longitude 100° 27,277' east and latitude 5° 41,651' north (Naizatul et al., 2011).

Upon discovery, the sites were buried in total ruins except for several structural elements that remained at their original place on the cultural layer. Most of excavated areas in Sungai Batu were identified by the small mounds and sometimes structural bricks can be spotted on the ground surface. There are several factors that cause the sedimentation built up that covering the whole sites, such as topography changes, weathering processes, flooding, rise and fall of sea level and so on (Yusoh et al., 2018). In the early centuries, before the sea-level decline, the whole of the coastal plain and the early entreport sites such as at Sungai Mas and Pengkalan Bujang were still under the sea or in swampy areas. During that period, the ancient shoreline placed at the more far inland areas therefore, making the part in the middle-west Kedah at present days, such as Sungai Batu the only suitable place to inhabit (Mokhtar et al., 2011).

As stated earlier, Sungai Batu Complex comprises two separated sides, one on the north and another at south which has been divided by the Merbok- Semeling road. Sungai Batu 1 (SB1) has been assigned to the whole sites located at the northern part and Sungai Batu 2 (SB2) for the sites at the southern area (Figure 2.17). The surrounding of SB1 is practically bordered by palm oil plantation and Jerai mountain
at the north as its background setting. Meanwhile at the SB2, the area also surrounded with the oil palm and there are some villagers who reside nearby, out of the unspecified border of Sungai Batu sites.

Figure 2.17: The location of all excavated sites in northern and southern sides at Sungai Batu

Centre for Global Archaeological Research (CGAR) from Universiti Sains Malaysia has long been involved with the research to investigate the civilisation at Sungai Batu since the early discovery and excavation works. At present, there are numerous research and publication either on the scientific and humanistic approaches that discussed on the findings and theoretical views regarding discovery at Sungai Batu. Most of the studies adopted the scientific methods by using specific experimentation as well as systematic excavation plans and procedures. Table 2.8 shows the list of excavated sites that already have been published in academic writings
Table 2.8: Lists of Sungai Batu sites including description on function and chronometric dating.

<table>
<thead>
<tr>
<th>Site</th>
<th>Year of Excavation</th>
<th>Function</th>
<th>Chronometric Dating</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB 1A</td>
<td>2009/2010</td>
<td>Jetty</td>
<td>3rd Century</td>
</tr>
<tr>
<td>SB1B</td>
<td>2009/2010</td>
<td>Ritual Monument</td>
<td>2nd Century</td>
</tr>
<tr>
<td>SB1C</td>
<td>2009/2010</td>
<td>Monument (Adjacent Structure for SB1B)</td>
<td>6th – 12th Century</td>
</tr>
<tr>
<td>SB1D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SB1E</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SB1F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SB1G</td>
<td>2010/2011</td>
<td>Iron Smelting Site</td>
<td>11th – 13th Century</td>
</tr>
<tr>
<td>SB1H</td>
<td></td>
<td>Jetty</td>
<td>1st Century BCE</td>
</tr>
<tr>
<td>SB1J</td>
<td></td>
<td>Jetty</td>
<td>1st Century BCE</td>
</tr>
<tr>
<td>SB1K</td>
<td></td>
<td>Jetty</td>
<td>1st Century</td>
</tr>
<tr>
<td>SB1L</td>
<td></td>
<td>Jetty</td>
<td>10th – 15th Century</td>
</tr>
<tr>
<td>SB1M</td>
<td></td>
<td>Supporting Structure/ Jetty Administration</td>
<td>1st Century BCE</td>
</tr>
<tr>
<td>SB1N</td>
<td>2011/2012</td>
<td>Supporting Structure/ Jetty Administration</td>
<td>2nd Century BCE</td>
</tr>
<tr>
<td>SB1P</td>
<td></td>
<td>Jetty, Supporting Structure/ Jetty Administration</td>
<td>3rd Century BCE – 3rd Century</td>
</tr>
<tr>
<td>SB1Q</td>
<td></td>
<td>Supporting Structure/ Jetty Administration</td>
<td>1st Century BCE – 2nd Century</td>
</tr>
<tr>
<td>SB1R</td>
<td></td>
<td>Jetty, Supporting Structure/ Jetty Administration</td>
<td>5th Century BCE - 4th Century</td>
</tr>
<tr>
<td>SB1S</td>
<td></td>
<td>Jetty, Supporting Structure/ Jetty Administration</td>
<td>5th Century BCE – 3rd Century</td>
</tr>
<tr>
<td>SB1T</td>
<td></td>
<td>Supporting Structure/ Jetty Administration</td>
<td>2nd Century BCE – 2nd Century</td>
</tr>
<tr>
<td>SB1U</td>
<td></td>
<td>Supporting Structure/ Jetty Administration</td>
<td>1st Century</td>
</tr>
<tr>
<td>SB1V</td>
<td></td>
<td>Supporting Structure/ Jetty Administration</td>
<td>3rd Century</td>
</tr>
<tr>
<td>SB1W</td>
<td></td>
<td>Jetty, Supporting Structure/ Jetty Administration</td>
<td>5th Century BCE – 1st Century</td>
</tr>
<tr>
<td>SB1X</td>
<td></td>
<td>Supporting Structure/ Jetty Administration</td>
<td>2nd Century</td>
</tr>
<tr>
<td>SB 2A</td>
<td>2009/2010</td>
<td>Iron Smelting Site</td>
<td>1st Century</td>
</tr>
<tr>
<td>SB2B</td>
<td></td>
<td>Jetty</td>
<td>5th - 7th Century</td>
</tr>
<tr>
<td>SB2C</td>
<td></td>
<td>Iron Smelting Site</td>
<td>8th - 11th Century</td>
</tr>
<tr>
<td>SB2D</td>
<td></td>
<td>Jetty</td>
<td>5th - 7th Century</td>
</tr>
<tr>
<td>SB2E</td>
<td>2010/2011</td>
<td>Jetty</td>
<td>6th Century</td>
</tr>
</tbody>
</table>

The series of excavations started since 2009 and have revealed a several types of structure; identified as a ritual monument, iron smelting sites, riverside jetty and its supporting structure or could be assumed as an administrative building. As explained in previous Chapter 1, Sungai Batu sites encompasses two different findings of excavation site, one is excavation on the structural site, secondly the excavation on the non-structural sites. With exemption of iron smelting site, all the other sites were constructed using brick material made by fired-clay brick.

From the list of the excavated sites, there are four sites have been selected as case study in this research. The following section describes each of these sites in which each one of them represents one of the four functions of the site in Sungai Batu. They are SB1B for ritual monument, SB2A for iron smelting site, SB2B for jetty and SB2G for supporting jetty structure or jetty administration.

2.5.3(a) SB1B: Ritual Monument

The Sungai Batu 1B (SB1B) is located at the northern area the complex. Presently, this is the only structure that signified the ritual monument found at Sungai Batu. The excavation began on 2nd March 2009 and continued until 30th June 2009 with total 150 trenches were excavated (Zolkurnain et al., 2011). Looking at the all sites in the complex, SB1B is significantly in much better condition in the aspect of structural integrity if compares with other structure found in this archaeological compound.

The distinguish features of the architectural style are portrayed by three distinct components of bricks arrangement that formed the circular base at the bottom, square structure at the centre and another circular arrangement on top of this monument. When it had first been exposed, the top bricks at the centre of the structure has appeared
to outline the circular arrangement (2.18A). Later, that area was dug-up to find further evidence of religious or ritual practice, but nothing significant can be found other that sediment and debris (Figure 2.18B).

![Figure 2.18: (A)Top surface of before the centre part was excavated. Source: CGAR. (B)The present condition of hollow excavated pit of SB1B.]

During the early excavation process, small quantity of broken bricks that circulate near to the surface, indicate that they are the remains of the top structure (Zolkurnain et al., 2011). After proper documentation, those bricks were taken out thus the excavation resulted the present structural monument. This monument also accompanied by four other sites namely SB1C, SB1D, SB1E and SB1F that assumed to form one unified compound (Figure 2.19). These sites play the roles as supporting structure or serve as additional components for main ritual monument (Siti Nurul Siha, 2014). None of these sites have had display any distinctive brick formation that on a par with SB2B structure. These areas mainly filled with mound of bricks in large quantity and most of them broken in small sizes. Other than these components, approximately 25 meters to the east from the ritual site, there is a jetty structure which simultaneously indicates that there was once an ancient river of Sungai Batu nearby the ritual monument.
Zolkurnain et al., (2011) believed that although the architecture of the monument is simple, yet it contains several distinctive meanings. It could be signified by the layers of bricks and their arrangement as well as environmental setting which can be symbolised as the concept of cosmology. The adaptation of this concept is portrayed by structure’s orientation which facing north, pointed into direction of Mount Jerai as it backgrounds landscape. Presumably in the past, the gigantic Mount Jerai appeared as majestic element and signify the mystical power for the ancient community. Therefore, they highly view the mountain as sacred entity and became part of their indigenous believe. The archaeological study on SB1B also revealed that this structure was once associated with the Buddhist influence based the finding on stone inscriptions in Sanskrit Pallava (Zolkurnain et al., 2011). Other findings also included several fragmented earthenware potteries and pieces of thin gold plat.

As different from the relative dates that previously applied to measure the dating of monuments at Bujang Valley, the dating for Sungai Batu’s monument has been established based on chronometric dating such as radiocarbon, accelerated mass spectrometry (AMS) and optical stimulated luminescence (OSL). From the result
presents at Table 2.9, SB1B to be believed as the earliest dated monument in Bujang Valley, that existed since 110 Century CE.

Table 2.9: Chronometric date of site SB1B

<table>
<thead>
<tr>
<th>Lad code</th>
<th>No. Sample</th>
<th>Dating (year)</th>
<th>AD/BC</th>
<th>Type of Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>UW2082</td>
<td>SB1B/S9/S9</td>
<td>1,900+/-100</td>
<td>110AD</td>
<td>Brick</td>
</tr>
<tr>
<td>UW2083</td>
<td>SB1B/S8/S9</td>
<td>1,900+/-100</td>
<td>110AD</td>
<td>Brick</td>
</tr>
</tbody>
</table>

Source: Zolkurnian et al. (2011)

Thus far, the SB1B is one of important archaeological discovery as the only ritual structure uncovered in Sungai Batu archaeological complex. The finding also marked a milestone for evidence of earliest ancient ritual monument which not only significant for Bujang Valley and Malaysia historical context, but also the South-East Asian regions.

2.5.3(b) SB2A: Iron Smelting Site

Early field survey conducted by Jane Allen between 1987 until 1988 (Allen, 1988) had located one of the expected-to-be monumental site which situated at Sungai Batu and recorded the area as Site 71. Years later, the same location of site turned out to be the current SB2A site. Sungai Batu 2A (SB2A) located at the other side from the SB1B crossways of Merbok-Semeling road. The SB2A is known as the iron smelting site by the presence of various iron-related artefact that functioned as tools or part of smelting component and mineral used for process and production of iron. Excavation at SB2A began on 26th January until 15 April 2009 and exposed 200 out of 501 trenches on 572m² area. According to Naizatul (2012), based on the Accelerator Mass
Spectrometry (AMS) and Optically Stimulated Luminescence (OSL), the site existed since 1\textsuperscript{st} Century CE but the smelting activity only started around 3\textsuperscript{rd} until 5\textsuperscript{th} Century CE.

The abundant archaeological findings of *tuyere*, iron ore and slag blocks indicated that this site had long been used as iron smelting inhabitation during the *proto-historic* period. *Tuyere* is long tubes function as an airway to supply air into the blazing furnace (Figure 2.20). Apart from that, variety of artefacts such as iron tools, bracelets made from iron and bronze, bricks, beads, fragmented mercury jar and pottery shreds were uncovered from the site. One significant feature of SB2A is the site has revealed hundreds of thousands of broken *tuyere* in one large mound. Moreover, the accumulation of artefacts that found dominant at certain location seemingly indicates that there had been division of working area within smelting site. As revealed in excavation data from Naizatul (2014) had proposed there could be several working zones which categorised by the dominant archaeological findings (e.g. *tuyere*, slag, charcoal and ashes, iron ore).

![Image](image.png)

Figure 2.20: One of thousands of in-situ broken *tuyere* at SB2A.
Stratigraphy method has been used to record the cultural layer and changes of soils at every excavated trench. It is important to identify the cultural layer by looking at the density of an artefact and soil’s textures of the site where they can specify more than one period of *in-situ* inhabitant. Result of excavation revealed that SB2A comprises up until seven to ten layers of soils, whereas the cultural layer had started at fifth and forth layer in between spit 5 to 6 (Naizatul, 2014). Moreover, from the excavation data, there are four cross section that represents soil textures, findings and entire position of an artefact for the whole site. The data particularly emphasise on the dominant area with raw ore, smelting zone, *tuyere* and non-smelting area (Table 2.10). These lines are 1. C8 – V8, north to south; 2. H3 – U16, the cross section; 3. P5 – P21, east to west; and 4. M2 –M23, east to west (Naizatul, 2014).

Table 2.10: Summary of the SB2A findings according to the cross-section (Source: Naizatul 2014).

<table>
<thead>
<tr>
<th>Cross Section</th>
<th>Trench</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>C8 – V8 (north to south)</td>
<td>C8 – K8</td>
<td>• Small and medium pieces of iron slags</td>
</tr>
</tbody>
</table>
| | L8 – O8 | • More refined and dark coloured types of soil as compared with previous trench.  
• Large and medium size of iron slag in less quantity, distant from each other.  
• L8 was excavated until spit 12.  
• Evidence of small iron slags, dark and fine soils, charcoal, ashes, fragments of *tuyere* and burned clay indicates that the area was once the smelting area. |
| | M8 – N8 | • Remains of *tuyere* was found arranged vertically at spit 8 |
| | O8 and P8 | • More condensed and darken soils |
| | P8 – Q8 | • Pile of bricks and sediment rocks  
• Abundant of *tuyere’s* fragments, fine and dark soils at R8- presumably traces from process of roasting to prepare the iron ore |
| H3 – U16 (cross section) | H3 – K6 | • Iron slag in variety of sizes and several fragments of *tuyere* |
| | L7 – O10 | • Flakier/refine iron slag (hammer-scale) along with fine and dark soils and burned clay, presumably to be the smelting area. |
Table 2.10 Continues

<table>
<thead>
<tr>
<th>O10 – P11</th>
<th>• Accumulation of bricks and sedimentary rocks.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q12 – U16</td>
<td>• Pile of fragments tuyere estimated around 90cm.</td>
</tr>
<tr>
<td><strong>P5 – P21 (east to west)</strong></td>
<td></td>
</tr>
<tr>
<td>P6 – P11</td>
<td>• Accumulation of bricks and sedimentary rocks along with iron artefact, fragments of tuyere and small quantity of iron slag.</td>
</tr>
<tr>
<td>P12</td>
<td>• Stone tool/ artefact at spit 12 associates with bits of tuyere and iron slag.</td>
</tr>
<tr>
<td>P15</td>
<td>• 190cm depth excavated pits. Ground level was decided start at 160cm depth.</td>
</tr>
<tr>
<td></td>
<td>• Insignificant quantity of small iron slag.</td>
</tr>
<tr>
<td>P20</td>
<td>• Excavated to 80cm, fragments of tuyere at spit 4 until spit 8.</td>
</tr>
<tr>
<td><strong>M2 - M23 (east to west)</strong></td>
<td></td>
</tr>
<tr>
<td>M2 – M6</td>
<td>• Abundant of iron slag</td>
</tr>
<tr>
<td>M7 – M11</td>
<td>• Main area for smelting activity. Identified based on hammer-scales iron slag, fine dark soils, charcoal and ashes.</td>
</tr>
<tr>
<td></td>
<td>• M7 was excavated until 190cm depth, different level of iron slag represented by varied size.</td>
</tr>
<tr>
<td>M12 – M23</td>
<td>• Pile of tuyere’s deposit.</td>
</tr>
</tbody>
</table>

Information from Table 2.10 is crucial as the findings from the iron site characterise the past activity and historical scenarios since the absence of structural remains is unable to directly interpret into computer visualisation. Therefore, this study of archaeological data and findings of what remains in-situ helps to construct proper interpretation of the site and develop the digital model for iron smelting setting.

2.5.3(c) SB2B: Jetty Structure

Sungai Batu 2B (SB2B) located at southern part together with site study SB2A and SB2G. Excavation conducted in 2009-2010 revealed a quay or jetty structure which is positioned near an ancient Sungai Batu river. Similar with other sites, the SB2B was identified as a potential area to excavate by appearance of small mound as
well as visible bricks fragments on the ground surface. Situated 13 metres above sea level the site can be seen gradually decreases from east to west orientation (Figure 2.21) and consists several distinctive structures namely a floor, platform, stairs, walkway and two mound-like which imitate a circular platform (Iklil, 2014).

![Figure 2.21: The present condition of the site, the orientation from east to west can be seen gradually decrease.](image)

Neighbouring SB2B by facing north orientation, another jetty structure known as SB2D. Although both appeared bordering each other, there are noticeable dissimilar in aspect of angle’s position, architectural features and brick arrangements which demonstrated that they were built as a different structure. Probably, both structures situated almost near to each other, but in different position is related to the suspected ancient river and its flow that keeps changing and moving (Yusoh et al., 2018). Thus, these sites were constructed or designated according to the ancient river meander.

A total of 190 trenches were excavated which revealed the condition of structure slightly higher at the east, gradually decrease toward west and the north of the site is lower than the south (Iklil, 2014). Although the radiocarbon dating received from the two charcoal samples unable to provide the accurate dating for this site,
however it appropriate to represent the continuation of site utilisation from 5th CE until 7th CE (Table 2.11). Technically, the OSL dating on the brick sample would provide more accurate details to reveal the construction dated of the site.

Table 2.11: Result of the radiocarbon dating of SB2B.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Spit</th>
<th>Radiocarbon Dating</th>
<th>Conventional Dates</th>
<th>Calibration Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (290605)</td>
<td>5</td>
<td>1450 ± 30 B.P.</td>
<td>560 CE - 650 CE</td>
<td></td>
</tr>
<tr>
<td>2 (290607)</td>
<td>8</td>
<td>1560 ± 30 B.P.</td>
<td>420 CE - 570 CE</td>
<td></td>
</tr>
</tbody>
</table>

Source: Iklil (2014)

Major indicator that suggested SB2B as riverside jetty is the site’s location situated along the suspected ancient river together with another jetty’s site such as SB2D and SB2E. Generally, the main structural element of jetty sites portrays by the brick on the ground floor that formed a footpath or walkway, which similar as a garden pathway in the modern-days. The bricks appear have been arranged vertically close together in a line, then the same patterns were paved along the pathway with certain obvious gaps in between every repeated pattern. Since the jetty was built close to the river, these gaps possibly functioned to let through the water and allow the stepping bricks to dried up even faster if the walkway happened to be flooded with water.

To conclude, SB2B comprises set of variety construction elements in one small area. It uniquely combines a platform, stairs, walkway or footpath and possible circular-mound of bricks to form the riverside jetty. This finding on jetty at Sungai Batu surpass the idea on how the ancient jetty looks like in the past. Because they usually depicted as small structure made from perishable material like wood for example. Moreover, the excavation also found fragmented rooftiles, hence indicates
that there was once a sheltered area. However, the architectural elements of the site might difficult to notice by the visitor unless they are physically reconstructed or restored to be presentable for visitors to have a good view. Thus, looking for the bigger picture, they in need for plan or strategies on how these characteristics can be presented to visitor of Sungai Batu without being physically disturbed.

2.5.3(d) SB2G: Supporting Jetty Structure/ Jetty Administration

SB2G situated not far from SB2B, after pass through two jetty structures, SB2D and SB2E respectively. This site to be believed functioned as administration building or supporting structure for jetty. In 2010, excavation had exposed a total of 414 trenches that almost twice larger than SB2B’s jetty site. This is due to the ‘administration’ building/structure generally comprises several floor areas or space as conjoined building element. The spatial context and circulation areas that occupied SB2G much bigger and consists variety of floor areas which set apart the administration building from the jetty structure (Figure 2.22).

Figure 2.22: Partial view of SB2G site which mainly consists floor areas.
It can be assumed, SB2G was built as supporting structure due to its location and traffic between jetty and iron site that approximately 170 metres from the nearest iron site (SB2H) and 50 metres from the nearest jetty structure (SB2J). The SB2G was selected as the site study because it is the only supporting structure neighbouring the jetty SB2B, therefore the digital reconstruction can deliberately narrate the presence of both the jetty and its jetty’s administration. The existence of both sites (SB2B and SB2G) probably to accommodate the communal need related to exportation of their own produce, which an iron as well as to supervise the activities of river transportation.

As mentioned in Chapter 1, previous researchers have suggested that several jetty administration sites possibly had served for two purposes, which earlier functioned as jetty, and later transformed into supporting structure for jetty (Suhana, 2016 & Nurashiken, 2016). This theory based on the pattern of the walkway and the its orientation that found at the administration/ supporting structure which keenly similar with the one constructed at jetty sites (Suhana, 2016 & Nurashiken, 2016). Most reliable reason of this situation happened due to the changes in river meander and or the size of river gradually getting smaller (Shamsul, 2015) consequently making the body of water getting further away from the jetty. Later, the site was no longer can be function as jetty therefore it converted and operated as the supporting structure with additional structural elements. It can be assumed that these sites which served both functions operated earlier than the jetty sites. As shows in the diagram below (Figure 2.20), the sites which served for both functions has recorded the dating much earlier than jetty site and supporting structure.
Based on this interpretation, the SB2G also having similar footpath element (Figure 2.24) and its orientation towards ancient river thus making this structure to considered as among the jetty-converted-into-supporting administration structure. Therefore, the SB2G was selected as it considers to be a representative for the supporting structure for jetty, however, this site also includes distinct footpath component which can be represent as jetty structure itself. Hence, the combination that represent both structural elements can be further discussed in this study to explore the actual function of SB2G.
2.6 Discussion

From the early archaeological exploration, it has been revealed the evidences of the kingdom based on the maritime trade and the existence of religious community that developed in within this region. Although the initial discovery omitted the principle of archaeological research and the survey conducted for the sake to track the ancient treasures, yet these early discoveries help to set Bujang Valley as Malaysia’s historical and cultural importance.

Compared with several archaeological structures that have been physically reconstructed at Bujang Valley, Sungai Batu sites have been presented as they are without an attempt to reconstruct. Despite having ruinous appearances, Sungai Batu Complex is still among the top heritage and historical tourist attractions in Bujang Valley region after the archaeological museum (Adnan & Yunus, 2017). Corresponding to this, the potential of Sungai Batu as the centre of archeo-tourism attraction is highly possible, with the help of future planning and technological development.

Nevertheless, the current development in science and ICT (Information and Communication Technologies) has largely contributed to the various implication and application of digital archaeology. However, the prospective effort for practical application in Malaysia mostly stayed on the theorisation of the framework rather than actual set of valid support for the archaeological study especially in presentation and dissemination.

As previously discuss in Chapter 1, the practice of computer-based visualisation that help to represent the archaeological structure or site is rarely being explored in research at Bujang Valley or Sungai Batu. Generally, the availability of digital technologies and their utilisation in cultural heritage in Malaysia, are scarce in
academic writing and digital outcome is hardly represented in exhibition in museums or gallery. Only few digital representations can be seen at museums in Malaysia such as at National Museum which depicts the holographic displays/diorama and Selangor State Museum with their 3D holographic of Malay weapon; Keris (Figure 2.25). Thus far, there is no representation of 3D archaeological site at local museum and gallery.

Figure 2.25: 3D Holographic display of Malay weapon; Keris at Selangor’s State Museum.

Digital archaeology is a subject area that develops much of its method as compared to other disciplines. According to Huggett (2013), as the subject area, the digital archaeology seems to promote practice-based technique and technology over theory which considered lacking in consistency of its own core subject identity. Thus, it constantly plays as supporting role in archaeology compared with the other allied disciplines, making it as a second-option to be considered.

However, many of advantages have been discussed above and the implication of digital archaeology seems to be interactive, practical and innovative. Therefore, it worth to consider the digital archaeology, especially for the computer-based visualisation as being part of any current and future attempts to present the
archaeological data and preserve its heritage values. Besides, having an opportunity to commercialise the research study in this subject is proven worth research attention.

Particularly in the case of Sungai Batu, the practice of 3D digital reconstruction should be applied to deliver the information on archaeological finding and interpretation of the ruinous site. Hence, the ultimate purpose for this study is to establish the method of computer-based visualisation to represent the virtual substitute for fragile sites. Consequently, this method also intends to demonstrate alternative medium of presentation in delivering the fragmented knowledge to public in more interpretative manner.
CHAPTER 3
RESEARCH METHODOLOGY

3.1 Introduction

This study was formulated to gain the further insight in what way and how the application of digital technology helps the interpretation and reconstruction of selected sites in Sungai Batu by using the excavation data and archaeological finding with computer graphic tools and methods. This chapter intends to describe the methodology for computer-based visualisation as the practice of digital archaeology for representation, interpretation and dissemination of archaeological knowledge about Sungai Batu sites. Overall, this chapter aims to define the research approach based on the study purpose and describe the methods related to research objectives formulated in Chapter 1.

3.2 Research Approach

This research was structured based on qualitative study in the form of exploratory research. Quantitative research applies the statistical analysis to acquire the outcomes of their research which can be measured to test the objective of the study whereas qualitative often used as a source of hypotheses without formal measurement (Marczyk et al., 2005). Since this research involves with a case study which researcher seek to understand the context and gathering information personally and do not attempt to quantify the result through statistical summary or analysis, hence it applicable to categorised as the qualitative study.

The main purpose of the exploratory research is to explore the new knowledge, ideas or insight and for more precise investigation from operational point of view. The
main characteristic of the study was formulated when the topic itself has not been studied more clearly or little or no knowledge on the topic exist. To sum up briefly, this research took the form of new research subject on the existing site studies that have been done by other researchers at Sungai Batu.

Emphasising on the operational point of view; this research seeks to validate the archaeological interpretation by demonstrating the computer reconstruction using 3-Dimensional model of selected sites at Sungai Batu. Referring to the research objective in Chapter 1, the 3D reconstructions of these sites are the representation of virtual interpretation from hypothesis made on the structure or site. They are not depicted the actual reconstruction of original structure/site since it is impossible to represent the destroyed archaeological structure or site. Moreover, as several times mentioned in this writing, archaeological data remains as fragmentary information if the discovery failed to reveal the any concrete evidence. Thus, it given that the computer reconstruction become as a tool to test various hypothesis, to explore new knowledge and enhance understanding about the study of the past.

3.3 Research Design

In this section, it describes on the general plan of the study to answer research questions. For this study, several appropriate recommended from the six principles in London Charter were implemented to describe the purpose, the aim and method of visualisation, the interpretation process, documentation, sustainable approach and dissemination plan for the outcome. Therefore, the framework presents below was constructed corresponding with the research approach and several points of principles recommended by the London Charter. The reason for only selected points of principles were applied is because the nature of this study was structured based on exploratory
research by demonstrating the new practice of 3D virtual reconstruction in the archaeological field. Since this study explore the new insight or ideas to establish serious consideration regarding this subject, therefore only selected points were applicable for this study. This framework is explained by three phases (Figure 3.1):

i) Sources acquisition phase,

ii) The production process and

iii) The information transition phase.

Figure 3.1: Framework for 3D reconstruction for Sungai Batu Archaeological Site

The framework (Figure 3.1) shows the summary of the research progress which describe how the sources regarding the site were obtained, the production progress to create the visual representation from the data acquired and transition of outcome (3D model) from the production phase into the medium for presentation and dissemination.
3.3.1 Phase 1: Sources Acquisition

The first step is to acquire all the sources, the process started with gathering the relevant information from digital and non-digital sources, including the primary and secondary data of the site. As stated in Principle 3: Research Sources (Denard, 2009):

3.1 In the context of the Charter, research sources are defined as all information, digital and non-digital, considered during, or directly influencing, the creation of computer-based visualisation outcomes.

(The London Charter)

The main points of reference in collecting the data are from topographical, archaeological and photograpical survey of the site. Topographical survey is to identify the location, contour of the ground and surrounding features such as mountain, river etc. Secondly, the archaeological survey was conducted to study of the architecture of the site or structure and its features such as the building element (type of floor, pathway, wall boundaries) and any other findings or evidence (artefact, archaeological/historical record, etc). And lastly the collections of photograph image were taken in references for the site and its surrounding, and as references for the shapes, spaces, texture and material of the structure. In general, the data can be obtained from integrated of the on-site documentation (primary) and the existing or available archaeological/historical records from previous researcher.

3.3.2 Phase 2: Production

In production phase, it demonstrated the progress to create the representation by the computer-based program. Firstly, the aim of the reconstruction of the site was
addressed before the reconstruction process begins to determine what type of 3D visualisation seeks to represent. This determination of the research aim is necessary as recommended by London Charter in Principles 4: Documentation (Denard, 2009);

4.4 It should be made clear to users what a computer-based visualisation seeks to represent, for example the existing state, an evidence-based restoration or hypothetical reconstruction of a cultural heritage object or site, and the extent and nature of any factual uncertainty.

From this statement, the charter implies that the 3D reconstruction must address how the site or structure to be represented by defining the purpose of the representation and the need to justify any reference on the data or sources that assists interpretation work. As aforementioned, the 3D model representations of archaeological sites at Sungai Batu were developed based on the hypothetical reconstruction which they simulated to propose interpretation made by the archaeological data from academic research and result of excavation. However, in certain limitation such as lack of evidence or information; the source of data that assists in hypothetical reconstruction of digital model need to be clarified to ensure the intellectual integrity of computer-based visualisation methods and outcomes. As stated in London Charter under principles 3: research sources (Denard, 2009):

3.2 Research sources should be selected, analysed and evaluated with reference to current understandings and best practice within communities of practice.

3.3 Particular attention should be given to the way in which visual sources may be affected by ideological, historical, social, religious and aesthetic and other such factors.
Therefore, particular research sources and justification on how it influences the interpretation and reconstruction need to address for the visualisation can be understood. After a series of digitalisation process using the methods operated by computer graphic and modelling, the 3D digital model of site/structure and artefact/object were produced. More information is provided in following Chapter 4.

3.3.3 Phase 3: Information Transition

The phase of information transition was carried out to maximise the outcomes of 3D visualisation work, whereas the digital object can be presented in other digital media as medium for presentation and dissemination of the archaeological finding. Corresponding to principle 5 and 6 regarding the value of sustainability and access in the London Charter (Denard, 2009):

**Principle 5: Sustainability**

5.2 Digital preservation strategies should aim to preserve the computer-based visualisation data, rather than the medium on which they were originally stored, and also information sufficient to enable their use in the future, for example through migration to different formats or software emulation.

**Principle 6: Access**

The creation and dissemination of computer-based visualisation should be planned in such a way as to ensure that maximum possible benefits are achieved for the study, understanding, interpretation, preservation and management of cultural heritage.

The Charter seeks to ensure the long-term sustainability when come to planning the strategies for digital material related to cultural heritage. Thus, computer-based visualisation outcomes in this study were created in a way that they can be
produced in other medium or transfer into different format to maximise utilisation of
3D model outcome. Currently there are lots of digital media which have been used in
museums and exhibition such as the interactive museum exhibition, online tour, virtual
reality, video games and others. For this research project, the application of video
presentation and holographic visualisation were applied as suitable means of
communication to introduce and educate the public about Sungai Batu archaeological
site.

3.4 Site Study

Currently there are 54 sites located at Sungai Batu Archaeological Complex
and four of them were selected as site study for this research. This study deliberately
chooses four respective sites as each of them represent the each one from four different
functions of site that have been identified at Sungai Batu complex. They are SB1B,
SB2A, SB2B and SB2G. As previously included at Chapter 2, all the important
component regarding these four sites have been discussed to address why they need to
be reconstructed using computer-based visualisation method.

Of many sites at Sungai Batu, SB1B is the only site that represent the ritual
monument and this structure is comparatively intact and distinctive from other
structural found within the complex. The discovery of SB1B also marked a milestone
for the evidence of ancient ritual monument which not only given the earliest dated
monument, but also different in terms of architectural design compares with others
monument found at Bujang Valley as presented in Table 2.4 -2.7.

Meanwhile at SB2A, the archaeologist found the iron smelting sites where the
physical traces of previous activities and the related artefacts was buried in-situ. The
archaeological information on this site has revealed several working zones or
distribution of work spaces by looking at the dominant findings at their respective area. Moreover, another significant feature of SB2A is the site has discovered the disposal area for hundreds of thousands of broken tuyere that accumulated up to 1.5m mound, which could not be found at any other iron smelting site in Sungai Batu.

As for the jetty structure, SB2B was chosen as the site demonstrates the variety structural design and situated along the ancient river of Sungai Batu. Given that SB2B has shown slightly visible in-situ remains of structural arrangement compares to other jetty site, thus it would have increased accuracy for interpretation. Meaning, the 3D reconstruction helps to emphasis the characteristics or features of the site, so it can be understood and easily connected with the physical site. Considering all these aspects as noted above, the selection of the SB2B certainly worth to be reconstructed in 3D representation.

Within SB2B’s proximally, there is SB2G which functioned as the jetty administrative or as supporting structure for the jetty. This is the nearest jetty administration structure that has been identified located neighbouring SB2B’s jetty site. Compared with other sites that mentioned previously, the SB2G has the least archaeological record and the details reports on the site has not yet presented in any publication to date. Based on archaeological records from other sites with similar function, there is an evidence of the structure could had served for two purposes. As mentioned in previous chapter, SB2G could be initially functioned as a jetty, and later it transformed into jetty administration. Thus, the combination that represent both structural elements can be discuss in this study.

Together all four respective sites have been chosen because they represent the variances in structural features as well as their differences in function. Above all, the four sites studies lack in details discussion on the reconstruction of architectural
element based on physical evidence and hypothetical setting which it will be further discussed in Chapter 4. In summary, the selection of individual site study is described in Table 3.1

Table 3.1: Justification of selecting the site study.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Reasons for choosing:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ritual Monument: SB1B</td>
<td>• The only ritual monument in Sungai Batu</td>
</tr>
<tr>
<td></td>
<td>• Different from other religious/ritual monuments that previously found at Bujang Valley in terms of chronometric dating and architectural elements.</td>
</tr>
<tr>
<td>Iron Smelting Site: SB2A</td>
<td>• Evidence of the division on working area, demonstrated by the distribution of the specific artefacts at their respective areas.</td>
</tr>
<tr>
<td></td>
<td>• The disposal area for hundreds of thousands of broken tuyere accumulated up to 1.5m mound, that could not be found at any other site.</td>
</tr>
<tr>
<td>Jetty Structure: SB2B</td>
<td>• SB2B significantly rich with diverse structural elements; namely a floor, platform, stairs, walkway and a circular platform that existed together in one site.</td>
</tr>
<tr>
<td></td>
<td>• The remains of structural arrangement also more visible compared with other jetty sites that would have increased accuracy for interpretation and emphasis the characteristics or features of ancient jetty.</td>
</tr>
<tr>
<td>Jetty Administration Structure: SB2G</td>
<td>• SB2G was selected as the site study because it is the only supporting structure neighbouring the jetty SB2B, therefore the digital reconstruction can deliberately narrate the presence of both the jetty and its administration building.</td>
</tr>
<tr>
<td></td>
<td>• There is evidence of the structure could had served for two purposes, which earlier functioned as jetty, and later transformed into supporting structure for jetty thus the combination that represent both structural elements can be discuss in this study.</td>
</tr>
</tbody>
</table>

3.4.1 Records and Documentary Study

The purpose for conducting the archaeological records and documentary research is to understand the conception of the research subject and to provide an overview of digital archaeology. The documentation and records are in form of
secondary data that exists in various sources, including reports, article, dissertation, journals, books, newspapers, online sources, historical documents and more. For this project, the sources for record and documentary mainly from previous academic research and excavation reports specifically related to the Sungai Batu archaeological site and Bujang Valley in general, local and university libraries and resources centre and online databases.

Since 2009, the Global Centre for Archaeological Research, USM has continuously conducted excavation project at the sites of Sungai Batu. Within that duration of time, several academic dissertations have been published in relation to the research and excavation works undertaken at Sungai Batu sites. Among them, Naizatul (2012) and Iklil (2014) are the key sources for this research which both theses provided the initial information on site studies of SB2A and SB2B respectively.

Naizatul (2012) reported on excavation at site SB2A that discovered the traces and evidence of iron smelting activities based on findings such as tuyeres, iron slag’s, iron ore and other artefacts. Meanwhile, Iklil (2014) writes on the archaeological study to investigate the jetty structure at SB2B and SB2D which the former has been chosen as the site study for this research project. Both documents provide the initial data for this study and served as reference and guidance for field survey at the physical site.

Other than focussing the academic research on Sungai Batu, the study extended into other records and reports on Bujang Valley to have an inclusive insight on archaeological and historical reference of whole study area. Numerous publications such as journals, books, articles, theses and field reports are available, which provided records or information on the early archaeological researches; during colonisation period until the recent studies. Furthermore, this documentary study helps to trace the development related to subject or the focus of archaeological research in historical area
of Bujang Valley. Meanwhile, the sources from online databases and libraries mainly contributed into the research regarding the application of digital technologies in heritage sector. Particularly the online databases, these sources are extremely crucial in providing the recent studies and the state-of-art of digital technologies particularly in the practice of 3D reconstruction of archaeological sites from around the world. Vast collections of article reviews, research papers, journals, conference papers, proceedings, case files and more were collected mostly from the foreign project’s records and research studies which the sources of data were accessed from USM library online database.

3.4.2 Site Investigation and Documentation

The fieldwork or field survey is one of several methods that used in collecting the primary data especially in archaeological studies. Gathering the primary data is essential to validate the research and presented the data in more conclusive manner. As important component for this research study, the site investigation and documentation aimed to collect the data through observation or close inspection on the site’s features especially on the structural elements of the excavation sites. The information was gathered and documented with field notes and digital camera for data such as the topographical features, archaeological structures, materials and textures. Physical evidences of the remains have been documented by digital camera, by notes and sketches as part of working practices and crucial references for interpreting the site’s structure for 3D reconstruction.

The sites which the present research work is concerned are situated within two of separated part (Post A/ SB1 and Post B/SB2) of Sungai Batu Archaeological Complex. There are total 4 sites, where the SB1B located at Post A, and the other three
(SB2A, SB2B, SB2G) sited at Post B. Prior commencement of the fieldwork, permission to enter the site was obtained from Department of National Heritage with supporting approval from Director of Centre for Global Archaeological Research, USM. All the sites that involved for this study have been completed in excavation phases and currently being preserved and maintained for visiting and research purposes.

The fieldwork began with the documentation of the structural features and physical settings of the sites including its current condition. All four sites study were covered by galvanized sheet as roofing material with gutter for rainwater access (Figure 3.2). The roofing installation took place after the excavation completed. Due to the nature of remains material, the site needs to be covered after it was exposed to prevent any further damaged. The galvanized sheet is carbon steel coated with thin layer of zinc for corrosion resistance which suitable for outdoor used. Digital camera, measuring tape, field notes and sketch book are mainly used in this phase for recording the structural features and necessary measurement. The measurements mostly taken for the size of bricks, roof tiles (if available) and the estimation dimensions of every structural elements. Apart from measurement, the amount of bricks placed for respective structure was recorded as replacement for size’s measurement. This applied on the element such as walkways or stairs since they were reconstructed based on the quantity of brick arrangements.
Although SB2A and SB2B have been previously studied and the archaeological reports have been published (Naizatul, 2012 & Ikilil, 2014), they only provide the initial data on archaeological information of these sites. The researcher personal observation, documentation and understanding are crucial in the process of interpreting the site for computer-based reconstruction. The documentation assessment of each of the sites also varied depending on their distinctive features that need to evaluate individually and photographed for comprehensive understanding of the sites. For instance, the SB2B has recorded a significant finding of the roof tiles. Notably most of the roof tiles have found in fragmented or in pieces as there are lots of the missing part, thus previous study unable to provide the information on rooftile in completed shape. Hence, direct observation and analysis on the shape of these fragments were necessary to provide understanding of the roof tiles in complete shape for digital visualisation.
3.5 **Computer Graphic and Visualisation**

It is important to point out that this research intended to give an insight on the application of computer graphic tools particularly from the operational point of view of the methods and outcomes of 3D visualisation to represent the archaeological sites. The purpose of the application computer graphic and modelling software is to develop the digital representation in this study based on interpretation made on structural and artefact from archaeological site. The process and development of the method used are necessary to be documented in practical and efficient manner as suggested by the London Charter (Denard, 2009) to ensure the sufficient understanding and evaluation of the research contexts.

Depending on what type of representation that the study seeks to generated, there are several considerations regarding on the outcomes of 3D visualisation. Either it should be photo-realistic or graphical representation; high or low in detail; representations of hypotheses or in the form of available evidence; “motionless” or interactive; “impressionistic” or precisely portray the real subject (Denard, 2009). In addition, the description or documentation of theories and method of respective 3D representation is necessary in order it can be widely understood within relevant communities of practice. The main reason behind this is, it will give an insight on the strengths and limitations of producing the 3D reconstruction using computers and technology.

Alternatively, as briefly describe in Phase 2 of research framework, the computer-based visualisation could be summed up into three main characteristic of 3D reconstruction for the archaeological sites;
1. 3D reconstruction based on existing state of the ruins or excavation sites where it was found.

2. Representation from the physical reconstruction of the sites which based on the restoration that made from available evidence found.

3. Hypothetical reconstruction of the site which the consideration should be given to what extent of the theoretical setting and any factual uncertainly involved in the interpretation.

As follows, the degree of the available tools and researcher’s technical knowledge in research subject should also be taken into consideration. The methods for computer graphic and representation is designed to provide explanation on the relationship between the research sources, the interpretative knowledge and techniques, reasoning behind such hypotheses and the outcomes of 3D works where the document of London Charter states (Denard, 2009):

4.6. Documentation of the evaluative, analytical, deductive, interpretative and creative decisions made in the course of computer-based visualizations should be disseminated in such a way that the relationship between research sources, implicit knowledge, explicit reasoning, and visualization-based outcomes can be understood.

As follows, this study intends to represent the 3D visualisation by adopting the hypothetical reconstruction in which the interpretation made based on the available structural remains that found at the respective sites to construct the interpretation of the site. Thus, the extent of hypothetical aspect might be varied between the sites, depending on the state of the sites. Some of the site, for instance, SB1B might give explicit understanding on its structural arrangement, while SB2G might take more effort and deeper observation to interpret the structural remains. Another example, the
methods of documentation and digitalisation of SB2A was different from the other as the iron smelting site does not featured any brick arrangements as it main structure.

Overall, this study used five computers graphic software to implement various task needed to develop the 3D visualisation or reconstruction of Sungai Batu. The programs that have been utilised are; AutoCAD, Adobe Photoshop, Adobe Illustrator, Autodesk 3ds Max and Adobe Premiere Pro. These computer applications were identified as appropriated to perform the digital techniques for documentation, analysis and visualisation of archaeological sites at Sungai Batu.

The scope of work also varied either they support the still images, video, or 3d model. The tasks included; i) picture editing arrangement, ii) mapping the site plan, and iii) 3d modelling, texturing and animation. All the materials and data that need to be digitised have been identified beforehand before assigned to respective application.

### 3.5.1 Picture Editing and Arrangement

The Adobe Photoshop mainly used for image editing meanwhile Adobe Illustrator (Figure 3.3) used for assembling the image from top view of each of excavated trench and any graphical work. The method of assembling every image of the trench (1meter x 1meter) to produce the top view image of whole site. This method was applied at structural site namely; SB1B, SB2B and SB2G. On the other hand, SB2A contains remnants of iron smelting activities, thus it not required for this method to be applied. The archaeological evidence for example, on where the traces of furnace and the other artefact were identified for placement of utilised space at SB2A. These evidences and records helped in creating simulated models for furnace, tuyere, other artefacts and setting for SB2A.
3.5.2 Mapping the Site plan

Prior the process of modelling 3D objects, the AutoCAD has been used to demonstrate the spatial arrangement of the structure or the distribution of the utilised space at site area. The AutoCAD produced a map or site plan of the case study sites which allowed a good reference for volume and spatial arrangement to use for modelling work 3ds Max application.

In the case of SB1B, the main structure is considerably intact with the distinguishable volume and shape thus the measurement record is relevant, and several measured drawings can be produced (Figure 3.4). While for the other sites as the remains mostly fixed on the ground surface, the measure drawing is not necessary to show the volumes of the structure.
Figure 3.4: Snapshot from AutoCAD application used for creating the drawing of the site plan

3.5.3 3d Modelling, Texturing and Animation

The 3ds Max was utilised for the main task to create the 3D model. The outcome of 3D object was result of construction of the structures’ volume and geometry, texturing and animation of respective site. The modelling phase, it gives an insight on the process to transmit the integrated interpretation derived from the both data from site investigation and existing data from previous research. In this stage, the study has demonstrated the extent of the relevant hypotheses and the reasoning underlying of why such interpretation was made.

In 3ds Max application, apart from modelling tool, there are several of other tools and different techniques can be applied to get the desired outcome. The main techniques or tools that have been utilised in this research project are modelling the polygon, material texturing and animation.
3.5.3(a) 3D Modelling

Georgopoulos (2014) described that 3D modelling involve the process of constructing the virtual three-dimensional (3D) representation of an object. Modelling tool allows the polygon to be modified using the available standard/setting tools to create desirable model. The process and selection of modelling tools are the important for develop a good 3D model (Figure 3.5). The 3D scene is where the work for 3D modelling took place which it can appear either an orthographic or perspective view (Connell, 2011). It provides scene for display the constructed object as well as produces variety form of desired outcomes of the 3D work, such as model, still image, animation and so forth. Models can be created from reference images, 3D scanning data, digital sculpting or simply start with basic geometric shapes (Beane, 2012).

![Figure 3.5: Snapshot from 3ds Max; showing the process in creating the 3D model of monument SB1B](image)

In most of 3D modelling software, the general functions such as dividing, smoothing, extruding, bevelling, deleting, combining, and separating are often used on polygons (Beane, 2012). The options of ‘dividing, extruding, bevelling’ are the process
to modify and manipulate the form of the 3D objects. The ‘smoothing’ use to refine the original geometry through different level of smoothing intensity into desired polygon object. Meanwhile, ‘deleting, combining and separating’ are mostly applied when the original shape of geometry does not require too much difference with the polygon object that needs to be created. Any polygon face can be deleted to create other form as well as combination and separating the polygons can be used to produce other objects (Beane, 2012).

The modelling characterised the physical form and structure of the objects to appear as three dimensional by understanding of its physical appearance. Barceló (2001b) considered three general reasons that underlying the modelling work in archaeology; the formation process of an archaeological artefact; the formation process of an archaeological site; and the formation process of a society. The visual model is a projection of archaeological data and properties that represented in geometrical context, which has been developed through relevant analyse and understanding of physical appearance in the real world. Likewise, the modelling work in this research has identified three different construction models:

i. Modelling work on the structural sites (SB1B, SB2B and SB2G)
ii. Modelling work on non-structural site; artefact (SB2A)
iii. Modelling work on contour and environment setting (Mount Jerai, SB1B, SB2A, SB2B and SB2G)

3.5.3(b) Materials and Textures

Next step after modelling work, was the process to apply materials and textures. One of the aspects to complete the modelling process, the surface characteristic can be illustrated by applying the material of the object to define their physical appearance and add realism to reflect the real world. Material would portray
a basic illustration of how the light interacts with a surface (Connell, 2011). A basic material appearance in modelling was explained by these main components; which are colour, reflection, transparency, refraction, absorption and emission of light. Connell (2011) described that the attributes of material can be attuned according to their percentage and the combination of these components can achieve a wide variety of looks and styles.

*Texture* is a bitmap image in material channels that applied to give additional details on surface’s appearance of the geometry or object (Danaher, 2001). Generally, the material and texture both used in the modelling process refer to the group of properties with their individual details which applied to the model’s surface to make 3D models appear close with real objects in life.

The *texturing* process resembles the surfaces and colour attributes of the object that they supposed to represent (Beane, 2012). The method of texturing applied to differentiate the surface properties from point to point, in order to understand the imitation of the objects when comparing with real ones (Barcelo, 2001a). In this texturing process, the material and texture were applied into the object by using the photographic material or graphic images to represent the material of structure.

This study using two different approaches in applying the material into the objects; first by creating digitally (Photoshop) and second by taken directly from original image of real material. Except for brick and furnace, all the other objects have applied the material directly from images of the object’s surface.
3.5.3(c) Rendering

Rendering in 3D production is the final step of modelling work to create the final look of the 3D models or scene that can be produce in 2D video or still images. The 3D models completed with their material and textures are integrate with 3D visual effect for render the final outputs. The visual effect in modelling software includes tools such as camera and lighting for illuminate the effect and the render engine will work together to create natural-seeming and complex motion of the final production (Beane, 2012).

There are various rendering plugins that integrated with 3D modelling software to achieve preferable visualisation. The render plugin used in this research project was Vray engine that usually used for architectural rendering and design visualisation. The scenes for each of finished reconstruction work was viewed through the composition of Vray physical camera (Figure 3.6).

As Earl (2013) elaborated, the final form of the virtual model that accomplish through virtual camera appear as the projections such as the orthographic and the isometric or it attempts to mimic human vision in the modelling scene. The virtual camera reflects the expression of space and form by modified field of view or perspective. The still image and 3D model and scene of the final prototype has been realized by rendering the model into .jpg image.
3.5.3(d) Video Animation and Editing

Animation according to Stevens (2002) is technically defined as:

“A graphic method that creates the illusion of motion by rapid viewing of individual frames in a sequence. Each frame has differences from the previous one in terms of position, shape, colour, transparency, structure, or texture of an object, so as to give the appearance when viewed of a real-life changing scene”

Barceló (2001a) clarified that the animation creates changes in the display data by specifying how physical properties change from frame to frame as means to improve the visibility of the features embedded during viewing time. The video animation tool in 3ds Max was used to helps in creating simulation or the movement of the rooftop object. The content of the video has displayed the 360° rotation of the 3D rooftiles and saved as video format.

The process of video editing allows the final outcome of the 3D model to be edited by Premiere Pro software (Figure 3.7). The purpose of this task is to produce the video to be used as holographic presentation to represent the 3D virtual
reconstruction from this study. Editing for the holographic video mainly involved with the scaling and rotating of the 3d model in order to generate the four-side image of the object on display. As mentioned, given that holographic projection works the best in portraying single object, the rooftile from of SB2B has been chosen to be presented in holographic video presentation as a proposed digital media created from 3D outcome of the studies.

Figure 3.7: Snapshot from Adobe Premiere Pro, showing the four-side image created using this application.

3.6 Holographic Visualisation

Method of holographic visualisation has been proposed to represent the production of digital media from the 3D reconstruction of archaeological information. The digital media such as holographic visualisation is one of many other interactive mediums for information and transition of the archaeological knowledge to the public. A hologram or holographic image is among the technology that represents 3D content
for visualisation without the need to wear the input devices (Chessa et al., 2015) thus making it appropriate and affordable choice for use in museum and gallery.

A holographic image that often associated with the term ‘hologram’, and holography is defined as a method of producing a three-dimensional (3D) image of an object (“Hologram and holography,” n.d.). Bimber (2005) defined a common optical hologram as a photometric emulsion that records interference patterns of coherent light, resulted in projecting the three-dimensional appearance that can be observed from different perspectives. The method would produce the holographic image which can be seen by either by looking into an illuminated holographic print or by shining a laser through a hologram and projected the image onto a screen (“What is a Hologram,” n.d.).

Rossi (2015) identified holographic image produces by the Pepper’s ghost technique previously used by illusionists in the 19th century as the other method to create a holographic image. Even though often misleading as holograms, this technique provides an optical illusion and spatial quality that uses partially reflective surface to mix a reflection with the scene beyond. In the modern term, it refers as ‘Holobox’ or ‘Holocube that operates using reflecting glass or transparent plastic plates rotated at 45° in direction. The projected views will produce the volumetric projection to make the visual object appears “float” in space (Rossi, 2015).

The holographic visualisation in this research was created as an experimental model which intends to demonstrate its operational aspects. The display model appears as small prototype which the main instruments are the transparent pyramid projection and a Smartphone. The pyramid projection was made from a thin acrylic sheet that can be cut by using craft knife. The size of the pyramid depending on the size of the device
used to project the video. In this experiment, the pyramid was cut into 6cm x 4.5cm x 1cm as shows at Figure 3.8 below:

![Figure 3.8: The size of cut out for pyramid pattern](image-url)

As abovementioned, the application of holographic visualisation in this research adapted the Pepper’s ghost technique that operates by reflected the image on glass or transparent pyramid. As illustrates in Figure 3.9, the transparent pyramid needs to be positioned upside down on the top of Smartphone’s screen to create the reflective visualisation of the 3D video inside the pyramid.

![Figure 3.9: The description on the operational process of holographic pyramid](image-url)
3.7 Summary

The research methodology described the overall method that constitutes the conceptual structure that has been formulated for collection, measurement and analysis of data. The important features of research design related to the efficiency of the methods and techniques that need to be applied, and adequate amount of data collected. Based on the exploratory research, the design in this study was structured to explore the method of 3D reconstruction for archaeological sites at Sungai Batu. It comprises several methods to be implemented at various stages to gather, examine and interpret the data for the computer graphic modelling. To facilitate this research operation, the collection of data was acquired through documentary research and fieldwork study and to established proper interpretation of the respective sites.

The research structure has adopted the guidelines from the London Charter for the use of computer-based visualisation in research and communication of cultural heritage. The Charter has emphasised several principles that define the basic objectives and demonstrate the guidelines for 3D reconstruction to establish the aspect of intellectual and technical rigorous in understanding the operational process. These principles concerning on the implementation, aims and the methods, research sources, documentation, sustainability and access of the computer-based visualisation (Denard, 2009). Most importantly, this study not only requires skills and knowledge in terms of utilisation of computer applications, but it also employed archaeological understanding in interpreting the data which those principles were established in London Charter document.
CHAPTER 4
ANALYSIS & FINDING

4.1 Introduction

Following the discussion of the research methodology in Chapter 3, this chapter provides details analysis and finding conducted from the site study. This chapter explains the process in developing the interpretation to understand the notion of research sources, types of data, the utilisation of specific computer software for creating the 3D reconstruction. The 3D model has been developed by using Autodesk 3ds Max as a main modelling software, and supported by other graphical application such as AutoCAD, Adobe Photoshop, Adobe Illustrator and Adobe Premiere Pro. Overall, the contents elaborate the analysis on data, methods and process on individual site studies as well as final outcomes that established from the 3D reconstruction. The last section of this chapter presents the experimentation work using the holographic video presentation of SB2B rooftiles as proposal for digital media from the 3D outcome.

4.2 Site/Structural Investigation, Interpretation and Reconstruction

This study aims to develop a reconstruction of 3D model by demonstrating the application of digital technologies, particularly computer-based reconstruction to enhance the understanding of archaeological data. Since this is exploratory study, it investigates from operational point of view on how the archaeological information on these four selected sites can be digitalised or interpreted using method of computer graphic and modelling.
Apart from documentary research form excavation record, the site investigation also helps to formulate interpretation and therefore assists reconstruction. The 3D reconstruction capable to display the interpretation that established from integrated information of archaeological and historical data for better understanding of the respective site study. Each of site’s 3D models were reconstructed according to their own characteristic and individual interpretation as each of them have varied condition that required different approach for the digital reconstruction. Hence, reconstruction process may or might not adopted the same methodology as every site study gives varied set of characteristic and their own rationalities behind it.

For instance, since the smelting site of SB2A does not have any structural form, thus digital reconstruction has been developed through previous archaeological for SB2A and other sources concerning ancient iron smelting especially in Bujang Valley and Southeast Asia generally. In that way, the absence of structure at SB2A could be reconstructed by recreating the hypothetical setting for ancient smelting scene.

On a side note, although of this study has provided relevant evidence on where the research source that influence the creation of 3D outcomes, however some aspects remain speculative. This refer to some of structure elements/evidence which appear uncertain due to undistinguishable structure and lack of physical evidence to support their characteristic. The following contents will further discuss rationalities behind the information and source of data used to reconstruct the 3D model according to individual case/site study.
4.2.1 SB1B

At the beginning of the reconstruction work of SB1B, the data from the fieldwork and the documented sources were gathered to transfer into digital data. The main instruments used in this stage are computer modelling software and other editing software. Essentially, the reconstruction for the case study of SB1B seeks to represent the whole in-situ structure including the ruined section. Most of the structural components of SB1B are moderately intact which made the reconstruction of 3D model relatively easy to recreate. However, there was uncertainty on certain structural part especially disintegration at the top component thus the reconstruction was relied on the hypothetical interpretation.

4.2.1(a) Structural Investigation and Interpretation

Site investigation was conducted to study the monument’s structural design and characteristic of the construction material including the size, colour and textures. Specifically, the measurement, layer and arrangement, amount of bricks for each layer, pattern and size and the main topographical features for SB1B were measured and recorded. Each of the features were intensively documented by digital camera and necessary measurement tool.

As previously discussed, the distinguish features of the SB1B’s architectural style are portrayed by three distinct components that formed the circle base at the bottom, square structure at the centre and another circular arrangement on top of this monument. The details analysis of each structures is shown below in Table 4.1.
Table 4.1: Documentation and analysis of SB1B structure.

<table>
<thead>
<tr>
<th>Image</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Foundation Image" /></td>
<td><strong>Foundation</strong></td>
</tr>
<tr>
<td><img src="image" alt="Circular Base: Floor Image" /></td>
<td><strong>Circular Base: Floor</strong></td>
</tr>
<tr>
<td><img src="image" alt="Circular Base: Holes Image" /></td>
<td><strong>Circular Base: Holes</strong></td>
</tr>
<tr>
<td><img src="image" alt="Square Structure: Elevations Image" /></td>
<td><strong>Square Structure: Elevations</strong></td>
</tr>
</tbody>
</table>

### Foundation
- The foundation of the structure was constructed by accumulation of laterite soil.
- Found at the very bottom of both circle and square component.

### Circular Base: Floor
- The circular base comprising five layers of brick arrangement.
- Bricks in random size were arranged to fit the motion of circle floor plan.
- Approximate 167cm for the width of the floor.

### Circular Base: Holes
- One of a hole found at Y12, with diameter approximately 10cm and 28cm deep.
- Several other holes also found situated at X12, V17, V8, U18, S16 and P16.

### Square Structure: Elevations
- Square component has seven elevation of layers that gradually tapering upward.
- Each elevation made up with following amount of brick (starting with the bottom layer):
  - 1st: 5 bricks
  - 2nd: 1 brick
  - 3rd: 4 bricks
  - 4th: 4 bricks
  - 5th: 1 brick
  - 6th: 1 brick
  - 7th: 4 bricks
Table 4.1 Continued

**Square Structure: Layers**
- On the 4th layer, the upper and lower bricks were arranged with bullnose brick which they have rounded outward edges. This arrangement creates semi-curved layer that notably distinct from the others.
- The 6th elevation consists only one-layer brick that protrudes outward.

**Top Structure**
- The top structural component barely appears in circular shape, where the wall collapsed inward.
- The pattern indicates that the top layer probably had been tapering towards the top.
- It made by eight layers of small size brick, 315cm in diameter.

The construction for foundation of SB1B was built on top of the embankment laterite soil thus it slightly raised above the ground surface. Probably it was intended to level the ground to ensure a stable construction. On circular base, the bricks were arranged randomly but fit in their position to create the formation of circle structural base. Separated square component on top of this foundation has a seven distinguish elevation of layers as described in Table 4.1.

The circle top component was constructed by small size brick that seemingly collapsed inwards. There could be possibility where the structure could be higher than the current position as there were a lot of collapsed bricks within its perimeter. It has been reported that the square component was made in different period or timeline, after the base was built. The feature of circular base and the existence of Mount Jerai to be believed has indicated the cosmological influence which had influenced the ancient
people at Sungai Batu. According to Aveni (1981), indigenous astronomical system and environmental affects might have developed fundamental reference to a circle symbol into a practical or religious motive especially to an ancient society in tropical latitude or zones.

Previous researchers also have proposed the past societies of Sungai Batu were profoundly influenced by cosmological representation of circular structure which probably depiction of the moon, sun or earth (Zolkurnain et al., 2011). In the context of practicability of the design, from the standpoint of the participant that occupying some sort of ritual event, the circle design enables the maximum visibility of those present for that occasion (Fleming, 1972). As such, it may be suggested that the vision of the circle base design of SB1B closely related to cosmology concept or from the ancient people’s observation on natural occurrences such as the sun and moon shapes and their movement and appearances at the horizon. Though, the researchers also suggested that the square structure with circle on top in might represents the influence from stupa of the Buddhism. In addition to this, seven inscriptions dated around 5th to 7th century CE that have been found on this site strengthen the relation of the structure with Buddhist’s architecture (Zolkurnain et al., 2011).

Both theories can be accepted as early Southeast Asian communities often merged traditional indigenous symbolism with incoming Hindu and Buddhist ideology. They often by integrated the element such as ancestor spirits, sacred mountains, cosmological symbol and local folk traditions and ritual practices (Hall, 2010) with religious influence that come later. Thus, it is safe to concludes that SB1B was the representation of transition and adaptation of local indigenous community that had been practicing cosmological spiritual practice and later embracing and merging the Buddhism philosophy with their indigenous tradition.
4.2.1(b) 3D Reconstruction

The first stage to prepare SB1B data using computer software was to combine all single photograph taken from the top view of each of excavated trench at SB2B (Figure 4.1). The goal of this process was to get the overall top view of the structure. This process using two computer graphic application which are Adobe Photoshop and Adobe Illustrator. This method using Illustrator helps to assemble every single photograph to create the whole top view or aerial view of the SB1B. The grid line shows at Figure 4.1 above represent the scale of 1meter x 1meter excavation trench or grid line at the site. This process also assisted by Photoshop application which used to edit the photograph and to achieve the correct quality of an image.

Figure 4.1: Top plan view of SB1B that produced by merge and overlay the images of every excavated trenches.
In this case study, the floor plan of the structure was produced in AutoCAD to demonstrate its spatial arrangement especially on size and dimension of the utilised space. The measured drawing (Figure 4.2) allowed a good control in constructing each of single layer of brick arrangement. Precisely, it used as a reference to reconstruct according their correct volumes and shapes during the modelling process.

Figure 4.2: Measured drawing of SB1B

After the drawing been imported unto 3ds Max scene, the modelling started with arranging the bricks at the structural base by following the outline and volume from measured drawing. The brick was arranged individually to fit the volume of the circular path for the outcome model to represent as close as possible with the real object. It was a long process since each of square brick with different sizes need to position according to the circle path by different angle and rotation. Next process was
to construct each elevations of square component on top of the circular foundation. The square contains different arrangement and specific number of layered bricks; thus, each layer also needs to create independently.

As for the top component of at SB1B, most of bricks arrangement on this segment were collapsed. Thus, it unable to provide definite information on its arrangement and how it originally built, therefore this structure was hypothetical reconstruct based on the pattern of fallen brick. For this reason, by looking at the present condition of the monument, the top structure has shown the hollow space at the middle which may or may not exist in the past construction. Although nothing was found during excavation process, this chamber or hallow space might always be there considering the bricks that form the circular structure were collapsed in direction into the empty space. Therefore, the top structure much likely has tapered upward in circle formation, before collapsed uniformly inward.

Figure 4.3: The phases for reconstruct the separate structure of SB1B as 3D model
The process in building part by part of individual bricks layer mostly done using geometric box to signify as brick. As shown in Figure 4.3, the foundation was created first, then followed by square structure and lastly the circular structure was placed on top. After the structure completed, the material of the monument need to be registered or applied by using texture and material that represent a clay fired brick. The complete model of SB1B in environmental setting presents in following section bellow.

4.2.2 SB2A

The absence of structural features at SB2A has resulted the study for SB2A to focus on developing digital model to replicate the scene of iron smelting site which contains numbers of artefact from ironworking. Thus, the archaeological findings and evidences of the smelting activity found at the excavated area are crucial to portray the the used area as work setting for the past community of Sungai Batu.

According to previous researcher of SB2A, due to restriction on budget and time constraint, not all excavation trench for SB2A were excavated. These trenches were selected for excavation based on anomaly of magnetite reading during the geophysics survey by magnetometer (Naizatul, 2014). From the result, a total of 200 from 501 labelled trenches has been exposed. Regardless only less than half of total area was excavated, it was sufficient to provide relevant interpretation of human activities that once happened at smelting site.

4.2.2(a) Site Investigation and Interpretation

A variety of metallic elements found at SB2A such as iron ores and slags that were associated with other artefact such as tuyeres and few small pieces that was
identified as remains of furnace. According to SB2A’s archaeological report, there was divisions on working areas at this iron smelting workshop. Presently, the *in-situ* artefact also able to show the evidences of clusters of an artefact at their respective location, as indicated by the previous report. They were circulated based on activity that once took place at their corresponding area. It is noted that although quite number of artefacts from SB2A which in total of 276215 pieces and weight roughly 2888kg (Naizatul, 2014) were took out for analysis purpose, the site still dense with archaeometallurgical remains especially the slags and *tuyeres*. The categorised zones are based on dominant findings which mainly include slag, iron ore and abundant broken *tuyere* and their interpretation are briefly presented in Table 4.2 and Figure 4.4.

Table 4.2: Interpretation of the working area based on the dominant archaeological findings and its distribution (Naizatul, 2014).

<table>
<thead>
<tr>
<th>Categorise of an area</th>
<th>Excavated Trench</th>
<th>Archaeological Findings</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Zone A</strong> Trench: 66</td>
<td>Depth: Between Spit (30cm - 40cm) to Spit 19 (190cm -200cm)</td>
<td>Various fragments of broken tuyeres</td>
<td>Based on the random position of the fragments, it assumed to be a disposable area for <em>tuyeres</em></td>
</tr>
<tr>
<td><strong>Zone B</strong> Trench: 19</td>
<td>Depth: Between Spit 4 (40cm -50cm) to Spit 13 (130cm -140cm)</td>
<td>Sedimentary rocks, Iron ore, slag pieces and remains of <em>tuyere</em></td>
<td>Preparation area for smelting material/ore dressing</td>
</tr>
<tr>
<td><strong>Zone C</strong> Trench: 32</td>
<td>Depth: Between Spit 6 (60cm -70cm) to Spit 19 (190cm -200cm)</td>
<td>Iron slag, remains of <em>tuyere</em>, iron ore, burned clay, charcoal and ashes.</td>
<td>Main smelting area based on the refined and darken soil which highly contains with Ferum (Fe) that was produced from active smelting process.</td>
</tr>
<tr>
<td><strong>Zone D</strong> Trench: 53</td>
<td>Depth: Between Spit 3 (30cm -40cm) to Spit 9 (90cm -100cm)</td>
<td>Various sizes of slag</td>
<td>Accumulation of iron slags resulted from smelting discard.</td>
</tr>
<tr>
<td><strong>Zone E</strong> Trench: 30</td>
<td>Depth: Between Spit 3(30cm-40cm) to 12 (120cm-130cm)</td>
<td>Association of random artefacts</td>
<td>Unspecified area of an artefact where their distribution distance from each other to categorise the dominant finding.</td>
</tr>
</tbody>
</table>
Zone A comprises a lot of broken tuyeres (long tubes to supply air into the furnace) either in the whole rings or partly broken two from their cylinder form. According to Harrisson & O’Connor (1969) the tuyere’s nozzles become unusable once passage of air was blocked from entering the furnace. It either causes by internal diameter sags, clogs, melts which obstructs the flow of the air consequently it become useless and need to be thrown away. Therefore, zone A was clearly depicted a disposable area for unworkable tuyere, whereby an excessive quantity of them had been piling up thus created a mound of tuyere disposal (Figure 4.4A). As compared to the nearby smelting site SB2C and others, the amount of tuyere present here is enormous where the mound accumulated up to 1.5-meter height (Figure 4.4B). Thus, it evidently shown that this the smelting activity was once running continuously longer and vigorously than the other sites.

Figure 4.4: (A)The mound of broken tuyeres with one trench was excavated deeper to find the exact height of mound. (B)Close up 1.5 meter height of broken tuyeres.
Meanwhile, the adjacent area of zone B is scattered with small size of ore as dominant finding. A visible dark coloured ground surface and ashes associated with small fragmentary tuyere and several baked clays can be seen in this area (Figure 4.5). This zone B has been categorised as an area for preparing the raw material for smelting or as part of the ore dressing process by previous researcher, Naizatul (2014). As stated by Humphris (2010) the traces of burnt soil can be assumed that the ore could be roasted before the smelting process to ensure successful smelting. Besides, an evidence of small fragments of ore also part of preparation process where the ores need to be broken in more refine pieces before smelting process. Similarly, as demonstrated in some part of India region the preparation process took place where the mixed ores were pre-heated to remove the excess moisture and to make the iron breaking easier (Prakash, 1997).

Figure 4.5: Noticeable dark coloured ground surface and ashes which associate with other artefact such as tuyere and several baked clay.
Zone C has been described as a main smelting area which locked in between southern zone B and northern zone D. This surface appears more darker and had been excavated deeper than other areas (Figure 4.6A), possibly they expected to find indication of furnace pit lining. However, no base or lining were found except for small pieces that identified as part of furnace’s debris. There are also remains the 5 part of broken tuyeres that fixed on the ground, which probably signified 5 standing tuyeres that arranged in a line as symbolic of the ritual practice by the ancient people in smelting the iron (Naizatul, 2014). Nevertheless, the soil samples on M7 and O10 were analysed, and the results found less level of oxide present in both samples which indicated the combustion had been occurred actively (Naizatul, 2014). There is also one slag block can be seen sat in between M9 and L9 (Figure 4.6B), which possibly flow out from the furnace station. Therefore, from scientific analysis of oxygen level and *in-situ* evidence, it proposedly supported the statement.

![Figure 4.6: (A)Overall view of zone C and the location of 5 remains broken tuyere (B)The *in-situ* slag block within zone C.](image-url)
Zone D initially claimed to be a discharge area for smelting production where the slags were found dispersed within this area. Several working stone tools that have been found nearby seems more likely indicates that this as a place for hammered the iron bloom of this smelting production. Next to this area is located zone E that comprises random artefact as well as fragmented tuyeres. It is noticeable that the quantity of excavated trench was fewer on this part of the site. This area interlocked with the bottom of tuyere’s mound and neighbouring the disposal area of iron slag. It can be presumed that although this area was unidentified working scene, it is part of smelting site which it could supposed to be an area for sorting out the iron production.

The smelting site SB2A has no trace of workshop building or structure and it highly possible to consider the overall smelting setting may happened in an open space. Since the findings SB2A reflect the production remains of the past, it is important to identified what artefact that need to be at each of the excavated area. Therefore, this categorised of working zone (Figure 4.7) greatly helps in recreating the simulation of smelting site to visualise the scene of the past activity in Sungai Batu. Apart from that, the photographic survey on field work also extremely useful to provides the extra details of the site, relating to location, space and texture to resemble the physical site.
Figure 4.7: The SB2A floor plan illustrates the of the areas that have been categorised in several working area zones based on the dominant archaeological findings and its distribution.

4.2.2(b) 3D Reconstruction: Furnace

The method for undertaking research for SB2A site was slightly different from the other sites as some of the components in 3D model were recreated with references from other archaeological sources. Due to the absence/missing important archaeological evidence and uncertainties on several main features in this iron smelting site, the study analytically seeks for other relevant hypotheses and archaeological information.
Hence, the data for support the SB2A’s 3D reconstruction was integrated between the actual archaeological data for SB2A with other reliable sources pertinent to the study. For instance, the disappearance of furnace from the smelting ground mainly because the furnace need to disassemble to obtain iron bloom that accumulated at the furnace pit (Bielenin & Suliga, 2008). Furnace, as in the aspect of this study applies to the refractory structure made by earth clay that resilient to the high temperature which usually used for smelting the iron. Based on the present archaeological records for ancient iron smelting in Bujang Valley, the smelting operation in SB2A consists of three important components; the furnace, tuyere and air bellows (Figure 4.8).

![Diagram of furnace, tuyere, and air bellows](image)

**Figure 4.8:** The proposed concept regarding on the operation of an air bellows and tuyere to supply the air into the furnace at SB2A site.

The information on furnace was acquired from local furnaces that discovered in Jeniang. The furnace from Jeniang came from the blomery type which is the closest existing monument that likely relatable with the iron industry at Sungai Batu in terms
of dating chronology as well as similar composition in sample analysis. Given that this type of structure was locally made and the mineral present from wall sample from both sites appears comparable (Nurhidayahti, 2015), this source of referencing seems plausible to provide a missing information on the morphology of smelting furnace at Sungai Batu.

In addition, the analysis of iron artefacts uncovered at SB2A has indicated that they were produced through bloomery smelting process, thus theoretically the furnace form and structure can be classified as bloomery type (Naizatul, 2014). Consider to this, a pair of the bloomery furnace dating from 1st Century BC to 13th CE that discovered at Kampung Chemara, Jeniang (Nurhidayahti, 2015) has been relocated to Sungai Batu Archaeological Site for public display (Figure 4.9). This relocation helps for better understanding on the smelting activity at Sungai Batu and establish the connection with the iron site at Jeniang.

Referring to Figure 4.8, the top part of these clay domed were left opened and both structures have protruding opening at the bottom; which functioned as mouth-like feature for slag discharge. Generally, in a case of Jeniang’s furnace, they have
frequently found constructed in a pair with no specific size, but in a domed shape and installed above the ground level (Nurhidayahti, 2015).

It has been noted there was no specific size and height of the furnace therefore the 3D model was reconstructed without having certain precision for the shape and size. Because in reality the variations happened in the craft or artwork created by human, thus similar with the construction of furnace which depends on the preference of the smelting group itself. Naizatul (2104) suggested that the furnace at SB2A could has more than one furnace with height more than 90 cm and they may operate at the same time.

With this information, proposed reconstruction for furnace 3D model has demonstrated a combination attributes of Jeniang’s furnace with SB2A smelting site. The model was created in 3ds Max by manipulating the circle spline and converted into editable polygon through some volume’s modification. This allowed the alterations on subdivision of polygons to create the surface of furnace’s mouth. After modelling phase, the texture of actual material was assigned to create realistic archaeological model. Figure 4.9 represent the 3D model of furnace which created based on the Jeniang’s reference.

Figure 4.10 (A & B): 3D model of the furnace completed with material and texture.
4.2.2(c) 3D Reconstruction: Tuyere

Another important component in smelting operation is the tuyere. The tuyere technically functions as a pipe which allow the air into the furnace either pumped manually or channelled in by natural draft made by specific clay (Humphris, 2010). Harris & O’Conner (1969) explained tuyere is a nozzle-like tool, facilitating between the cool-zone of an air-pressuring bellows and the harsh heat at the point of oxidisation over the ore and/or metal. The tuyere found at SB2A appears in cylinder form with a hallow tunnel that allows air to enter the blasting furnace to maintain the relevant firing temperature during the smelting process. Table 4.3 illustrates several images of in situ fragmented tuyere found in different conditions such as variation in coloured clay, length and evidence of the tint of iron slag at body of tuyere.

Table 4.3: The characteristic of tuyere found at SB2A

<table>
<thead>
<tr>
<th></th>
<th>Variety color of tuyeres, (a) light peach and (b) being more light greyish brown in colour.</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td><img src="image1.png" alt="Image of tuyere fragment" /></td>
</tr>
<tr>
<td>b.</td>
<td><img src="image2.png" alt="Image of tuyere fragment" /></td>
</tr>
</tbody>
</table>

157
Table 4.3 Continued

2. A cross section of fragments with opposite end fused with tint of iron slag.
   c. 
   d. 

3. A clean section of broken tuyeres.
   e. 
   f. 

4. Among the longest tuyere that demonstrated different diameter size at opposite ends.
   g. 
   h.
The longest part of broken tuyere has been recorded to be 27.06cm long and 11.15cm diameter with average thickness 3.84cm (Naizatul, 2014). It can be assumed that the whole size could be twice long or additional 1/3 from the recorded size. Through the field observation, there were noticeable difference in diameter of size from one end to another at several of exposed tuyeres. The tuyeres has a slightly tapered towards end which probably to distinguish their position at the furnace wall; probably one side as an outlet to release air and the other side as an inlet to secure the bellow pipe. Figure 4.11 illustrates the 3D model of tuyere in complete shape that has been reconstructed using geometrical cylinder in 3ds Max software. Then, the image depicted the real texture of tuyere taken from the excavation site and was applied for complete 3D model appearance of tuyere.

![Figure 4.11 (A& B): The 3D model of complete tuyere with actual material and texture applied.](image)

The air bellow is another component in ancient iron smelting which functions as some-kind of generator that connected with tuyere to pumping air into furnace. In fact, in many parts of Africa, the bellows regarded as the most important aspect in ancient iron smelting process whereby it required skilled smelters or smiths to produce and operate the bellows (Friede, 1977). According to Humphris (2010), tuyere function as the passageways for the air supply either by forced draft or by natural draft. This
force draft for the air supply required hard work where the air being blown in by manually powered bellows, hence it considered as important task in iron smelting.

The bellows can be made by variety of material such as animal skins, wood, clay and bamboo depending on what type of air mechanism used for operation. As such, the characteristic of operational air bellows could be influenced by the geographical and cultural setting. For instance, in African regions, the air bag bellows made by assortment of animal skins has been used by most of the tribes to perform the smelting process (Friede, 1977 & Humphris, 2010). Meanwhile the piston bellows made with bamboo may be the most common type of bellows used by the indigenous people in Southeast Asian regions (Hall, 2010).

Similar with the case of the furnace structure, there was no evidence of air bellows found here at SB2A to give some clues on the type of air bellows used for the iron smelting operation. However, unlike furnace which some of them can be found within Bujang Valley, this type of material culture left no other concrete evidence that can be correlate with the study. Despite of that, it has been known from archaeological research on Southeast Asian, the people in this region has developed their own sophisticated metallurgical techniques (Hall, 2010).

Especially for indigenous people in some part of Malaysia and neighbouring region such as in Thailand and Philippines, they have demonstrated the used of piston air bellows made with bamboo or other wood material (Figure 4.12). The similar type of material culture could be applied for this site. Referring to the geographical setting, this area rich with bamboo plant and it locally available (Naizatul, 2014). Looking at the amount of disposal tuyere, most likely the double-piston air bellow was used where it produces more air to cater the active furnace operation.
Figure 4.12: An example of double piston made by wood and bamboo originated from (Malayan forge/ penquudihan). It consists bellows base, a pair bellow tube with piston valve component and two small bamboo pipes. Source: http://collections.peabody.yale.edu/search/Record/YPM-ANT-230277

Therefore, to assist the virtual reconstruction of SB2A, the bellows can be assumed made of a pair large cylindrical bamboo with hand-operated valve fitted in bamboo hollow segments to compress air out. As shown through diagram in Figure 4.7, the pumping air run into another smaller bamboo pipes connected at the bottom, and their end meets with the tuyeres that carried air into the furnace. Additionally, it is possible to consider that the bellows need to work on more stable ground to keep them secured in place, thus the remains of bricks (Figure 4.13) near the main smelting area might be the working area to operate the air bellows. The completed final model of virtual simulation for smelting site is presented at following sub topic.
Figure 4.13: Remains of broken bricks discovered near the main smelting area.

4.2.3 SB2B

SB2B is among one of the sites that has simple, yet diverse jetty structure ever discovered at Sungai Batu Archaeological Complex. Although appears as ruinous structure like any other sites, it still enables to display its structural component which some persisted on the ground of the site. Upon discovery, there was no apparent body of water at the topography of site apart from the noticeable trail of drained puddle that occasionally filled with water after the rain. Later, after the excavation completed, the pond was artificially formed and enlarged based on existing trail to provide indication on formation of ancient river that justifies the site’s function and its landscape.

The purpose of digital reconstruction of SB2B is to reveal the unique structure for jetty in ancient Sungai Batu that clearly different from traditionally perishable river jetty which has been generalised as representation of early jetty structure. Thus, to allow proper implementation of 3D interpretation strategy, the natural topography such
as the site contour and the formation of the river also important be included into the hypothetical visualisation of SB2B structure.

4.2.3(a) Structural Investigation and Interpretation

Identification of the architecture component throughout the site survey has been assisted by study documented by the previous researcher, Iklil (2014). This is necessary to achieve highest accuracy and to justify the interpretation and information on both archaeological and architecture context. Since the excavation had been completed in 2009, the site has experienced several degradation issues especially at the westward area, near the reformation of ancient Sungai Batu river. Over a certain period, the water from rain or nearby artificial river regularly accumulated at this lowest part of the site and allows vegetation growth surrounding the area. Simultaneously this situation and present condition of the site leads to disintegration of bricks component on the area that could causes inaccuracy in the interpretation.

The site has revealed three main structures encompasses the platform, a pair of walkway and stairs. The highest structural level for SB2B can be seen positioned at the eastward of the site, consisted a levelled floor and a long rectangular platform. The orientation gradually declining westward that ended with two small mounds of bricks which it seems to appear like circular structure (Figure 4.14). A pair of footpath or walkway guarded both sides of the stairs that situated at the middle. The footpaths trailed to the direction of ancient river with obvious gaps in every arrangement. The gaps supposedly to let the water through and allow the stepping bricks to properly dried up when the area happened to be flooded with water from nearby river.
The SB2B’s bricks have several different sizes of rectangular(shape ranging from small, middle and big. From close observation, it can be seen that different sizes of brick were used for in specific structural elements thus it deliberately making the arrangement can be identified from each other. The archaeological data prepared by Iklil (2014) also discovered several other findings such as fragments of pottery and tuyere, iron ore, slag, iron and stone artefact as well as a bead. Apart from that, there is cluster of rooftiles fragments where mostly found at both left and right the site’s platform. For further description, the following Table 4.4 describes the structural features of SB2B.
Table 4.4: Documentation and identification of SB2B structure.

<table>
<thead>
<tr>
<th>No.</th>
<th>Image at Location</th>
<th>Details of Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>![Image]</td>
<td><strong>Eastern Floor</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• A layer of brick floor, measuring roughly 1.7m length at the east of the site.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The bricks were arranged horizontally on the ground in north-south direction.</td>
</tr>
<tr>
<td>2.</td>
<td>![Image]</td>
<td><strong>Platform</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• A raised floor or platform contains two to six layers of bricks.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Although the amount of layered bricks might not the same at certain part, but the it almost levelled at the uppermost layer.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The remaining structure is 5m long and approximately 80cm width which comprises four horizontal bricks.</td>
</tr>
<tr>
<td>3.</td>
<td>![Image]</td>
<td><strong>Stairs</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Located in between of two walkways from east to west</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Comprises nine steps in horizontal alignment and last step more extensive than the others</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Each step has two blocks of vertical brick in between of two sides step.</td>
</tr>
<tr>
<td>4.</td>
<td>![Image]</td>
<td><strong>Walkway/ Footpath</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Two main walkways at both sides that gradually declining from east to west of the site.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Eight bricks have been arranged vertically in line and paved repeatedly for total 8 footpaths with certain obvious gaps in between.</td>
</tr>
</tbody>
</table>
Table 4.4 Continued

<table>
<thead>
<tr>
<th>5.</th>
<th>Circular platform</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Appears like a two mound of bricks that located towards the end the site at the west direction.</td>
</tr>
<tr>
<td></td>
<td>Estimated around 2.2m in diameter</td>
</tr>
<tr>
<td></td>
<td>Big size brick found dominant at this area which stacked together creating a circular mound-like structure.</td>
</tr>
<tr>
<td>6.</td>
<td>Roof Tiles</td>
</tr>
<tr>
<td></td>
<td>Mostly found in fragmented pieces that gathered in certain area at the site</td>
</tr>
<tr>
<td></td>
<td>The arched bricks found in-situ that suspected to be the part of pillar base for roof structure.</td>
</tr>
<tr>
<td></td>
<td>Although no evidence of pillar or column, this evidence concluded that the SB2B was once covered by a roof.</td>
</tr>
</tbody>
</table>

4.2.3(b) 3D Reconstruction

The whole process of 3D reconstruction in SB2B utilised the techniques using Photoshop and Illustrator and main work implemented by using the 3Ds Max. As shown in top plan in Figure 4.15, the identified structural elements of SB2B have been labelled from 1 to 5. SB2B has revealed a prominent utilised space of footpath and stairs as the main structure of the jetty (no. 3 and 4). In addition to visible structure components such as platform and a paved ground floor (no. 1 and 2), there is also unidentified structure at both sides of the main structure. It might be just some remains of small floor or could be drifted bricks from other structures. Since no accurate information could be interpret from it and that possible structures not appear to be as
the main construction of the jetty, thus they did not include in the reconstruction of the site.

Another distinguish characteristic of this site is a presence of the two mound (no. 5) which to be believed functioned as some sort of platform to anchor the boat (Iklil, 2014). These structures highly likely were constructed to place a mooring device, to tie the boat during loading and unloading the trade item. On ancient quay or port, the mooring device usually used the pierced stone or sometimes be called as mooring ring in which the rope/cord of the boats or ships were tied to it (De Graauw, 2017).

Figure 4.15: The whole top plan view of SB2B.
Apart from the circular structure, the others have shown evident *in-situ* remains of their arrangement. For two circular mounds, in the 3D model, they have hypothetically represented as a circular arrangement with several layers of bricks and the hollow part at the centre as a place to put the mooring device (Figure 4.16). Therefore, the 3D reconstruction for SB2B has depicted these main 5 structural elements namely, floor, platform, stairs, footpath and circular platform.

![Figure 4.16 (A & B): Reconstruction of SB2B that displays the walkways, stairs and circular structure.](image)

All the modelling work was created in 3ds Max software wherein every part of the jetty was constructed individually using basic box geometry to represent as brick. Another thing to consider when recreate the site is to replicate of the site’s topography site. Thus, the visualisation has merged both jetty structure and contour or ground surface of SB2B site to give impression that this structure was build according to the natural riverside terrain. The full representation of jetty structure shown in Figure 4.17 without the details on its texture and colour.
4.2.3(c) 3D Reconstruction: SB2B Rooftile

Additionally, a study was conducted to analyse what type of rooftiles in terms of shape and constructed design that probably does not found elsewhere other than Sungai Batu. As described in Table 4.4, the evidence of rooftiles can be seen exposed together with bricks is major indication that jetty SB2B was once roofed structure. Iklil (2014) reported the total of 104443g fragments roof tiles and 31855g small shards/chip of rooftiles were taken out from excavated site. They are mostly found at spit 3 as this was a cultural layer for SB2B. However, the remains of pillar or column that supposedly supported and framed these rooftiles was nowhere to be found. Most probably it was constructed by the perishable or organic material such as wood thus it degraded over the times. Still, the evidence of several arched bricks found in-situ that suspected were used as pillar base (Figure 4.18), consequently have suggested the roofed structural element of SB2B.
Most of the rooftiles in SB2B were found in small fragments and clustered at specific area. From analysis thru Microscope Optic by thin section analysis, one of the main indicators for rooftiles is they have numerous layered in their structural thickness which different with other clay artefact such as bricks and pottery (Iklil, 2014). This layered thickness also can be identified by our physical eyes (Figure 4.19) and the thickness for fragments can visibly to be measured, however, for shards or chip of rooftiles the thickness was unidentified and cannot be measured.
There was no complete or perfect shape of rooftiles was found at SB2B, thus the actual size and shape cannot be identified by previous researcher. However, there was one evidence of complete length rooftile with two body part that represent a pointed curvature (Iklil, 2014). Previous analysis on the morphology of broken rooftiles at SB2B has recorded the average thickness of is 9.3mm, with minimum 3.7mm and 18.8mm maximum and it can be assumed that the length can be around 162.7 to 180.5 and 110mm width (Iklil, 2014).

From field survey, it can be concluded that not all the area in SB2B was covered by roof. This is based on *in-situ* evidences revealed that the distribution of roof tiles mostly found at northeast and southeast of the site and grouped together closely overlaid each. Again, despite of many were found, none of them preserved in their complete shape or form. Several *in-situ* rooftiles were photographed and documented (Table 4.5) for proper study on their specific profile/morphology.

<table>
<thead>
<tr>
<th>Image</th>
<th>Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Image" /></td>
<td><img src="measurement1.jpg" alt="Measurement" /></td>
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</tbody>
</table>

Table 4.5: Documentation of several *in-situ* rooftiles.
Table 4.5 Continued

<table>
<thead>
<tr>
<th></th>
<th>Image 1</th>
<th>Image 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>3.</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
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<tr>
<td>4.</td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
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<tr>
<td>5.</td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
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</tbody>
</table>
Table 4.5 Continued

6.

8.
As one of SB2B structural element, the 3D model for rooftiles has been created to recognise and to emphasise its significant characteristic of SB2B site. Considering none of the rooftiles were found in good condition or in completed form/shape. This analysis on their morphology intended to build information for the 3D reconstruction to be as accurate as possible. Based on close inspection of *in-situ* rooftiles, they have strong resembled of the ‘s’ shape in cross section which this shape divided by three body part and pointed curvature at the middle (Figure 4.20).

The rooftiles have an average of 20cm length and 4 to 5cm width for each segment of the rooftile. Moreover, the edge of the some of the curvature appears to be wavier than the others and the thickness of tiles varied from 0.6 cm to 1 cm. Thus, there may be more than one type of rooftiles in SB2B site. In addition, an approximately 1 cm to 1.2 cm diameter hole can be seen at one of the body segments. The hole most probably functioned to bond the rooftile together, to keep them secured in place (Iklil, 2014).

Figure 4.20 (A & B): The complete model of rooftiles, demonstrating the ‘s’ shape clay rooftiles with the bonding hole.
Since there is no information about the construction structure of the roof, it might had built in a standard open gable style like mostly applied for traditional terracotta roof. As usual, the modelling work employed in Autodesk 3ds Max using *editable splines* for easy rendition of curve. The volumes or the thickness was added after the curvature was properly shaped and the hole was formed at appropriate position according from various image reference taken during field survey. Then the texture and material of original rooftiles was applied onto the model to give the similar representation of the clay rooftiles.

Although the shape of rooftile has been studied and 3D reconstruction to visualise the complete SB2B rooftile has been created, the model was not included in the reconstruction of the site model. This is due to lack of evidence and documentary sources for the roof framed or the architectural roof structure that can assists to develop the hypotheses. Therefore, the final 3D representation of SB2B was reconstruct without element of roof structure.

### 4.2.4 SB2G

Although most of structural bricks of SB2G have been disintegrated, several remaining structural elements can be seen on the ground surface. Some of the brick had been swept away all over the place and the others might still be in their original position. Among them, the footpaths or walkways are still visible orientated from west to east, similar with the one found at the jetty sites within the complex. Hence, towards the process to investigate the structure of SB2G, there could be possibility that SB2G functioned as both jetty and supporting structure to administrate the jetty activity. More information is further discussed in following sub-topic.
4.2.4(a) Structural Investigation and Interpretation

SB2G comprises larger area of site than the previous case studies. Unlike the other selected sites, thus far there is no published archaeological data on SB2G that available for documented references. Hence this case study mostly relies on the field work to analyse and obtain the information concerning the structure of SB2G. The initial study has identified the presence of several types of floor at SB2G. The difference between the floor can be identified by the brick arrangement and orientation of the brick which vary at each of the floor. By observing the present condition of site, the whole SB2G areas may have constructed with different type of walkways, floor and there could be an area which bounded with low height of brick wall.

It can be seen from the plan view (Figure 4.21) that the site slightly tilted toward east and obvious traces of footpath dominating the one-third of the areas. During the field survey, most bricks can be seen were scattered in small size unless the ones that are fixed on the ground surface as part of the paved floor. To make it easier to understand the structure, SB2G has been divided into three main areas as shown in Figure 4.21.
Subdivision A encompasses several areas covered with brick floor, a walkways or footpath accompanied with several set of stairs and raised platform or corridor from A to B area. The B area consists of levelled floor and hallway which located in between A and C. Hence, this area has allowed circulation from A to C. The subdivision C having two levelled floor that linked to each other and an unpaved area which bordered by a wall structure. Overall, SB2G has been identified with a pair of walkways, stairs,
platforms, a wall and several open areas designated with different arrangement of floor structure. The description on the different characteristic of the floor also supported by excavation report made by previous researcher (Shamsul Anuar, 2015; Nurashiken, 2016; Suhana, 2016) on their respective sites. Meanwhile, the evidence of roof tiles fragments in SB2G are rarely can be seen *in-situ*. Table 4.6, 4.7 and 4.8 have listed the details of structure found at every division in SB2G.

Table 4.6: Area of division A

<table>
<thead>
<tr>
<th>Position of subdivision A:</th>
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<tbody>
<tr>
<td>1 2 3 4 5 6</td>
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Detail images:

<table>
<thead>
<tr>
<th>1 2 3</th>
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178
Table 4.6 Continued

<table>
<thead>
<tr>
<th>Image</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>4</td>
<td>A floor paved with brick in horizontal arrangement and it slightly on raised ground next to nearby floor no. 2.</td>
</tr>
<tr>
<td>5</td>
<td>Clear appearance of horizontal brick floor connected to structure no. 4 that resembles part of entranceway.</td>
</tr>
<tr>
<td>6</td>
<td>A set of footpath of walkways that directing towards floor area no.6. There are set on natural terrain that gradually rise at the middle of walkways and inclined towards floor no.6. The structure was accompanied by steps of stair (no.5) at that located at middle of walkways arrangement.</td>
</tr>
<tr>
<td>7</td>
<td>Unfamiliar structure at the sloping ground that could be a transition passageway or entranceway from bare ground to floor no.2. The structure was build by both side having a several brick placed together in straight up position and paved with brick floor.</td>
</tr>
<tr>
<td>8</td>
<td>Evidence of possible stairs structure that having similar pattern with the one found at SB2B’s jetty site. The sloping ground also making the remains were highly likely functioned as a step of the stair.</td>
</tr>
<tr>
<td>9</td>
<td>This floor area located at most lowest ground within the site compound and the floor seemingly sinking a little depth than the others.</td>
</tr>
</tbody>
</table>

Explanation of the images:

1. A floor paved with brick in horizontal arrangement and it slightly on raised ground next to nearby floor no. 2.
2. Clear appearance of horizontal brick floor connected to structure no. 4 that resembles part of entranceway.
3. A set of footpath of walkways that directing towards floor area no.6. There are set on natural terrain that gradually rise at the middle of walkways and inclined towards floor no.6. The structure was accompanied by steps of stair (no.5) at that located at middle of walkways arrangement.
4. Unfamiliar structure at the sloping ground that could be a transition passageway or entranceway from bare ground to floor no.2. The structure was build by both side having a several brick placed together in straight up position and paved with brick floor.
5. Evidence of possible stairs structure that having similar pattern with the one found at SB2B’s jetty site. The sloping ground also making the remains were highly likely functioned as a step of the stair.
6. This floor area located at most lowest ground within the site compound and the floor seemingly sinking a little depth than the others.
Table 4.7: Area of division B

Position of subdivision B

Detail images:

Explaination of images:

1. Small mound of bricks scattered across division A to B. This could be remains of a long rectangular platform or hallway that perhaps the structure was lifted up to 3 to 4 layer of brick from ground.
2. A clear arrangement of horizontal brick floor covered more than half area of division B.
3. A group of brick in straight up position that somewhat similar with entranceway structure no. 4 at division A.
4. Another type of floor whereas the brick arranged vertically and it connected to another floor in division C.
Table 4.8: Area of division C

<table>
<thead>
<tr>
<th>Position of subdivision C</th>
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</table>

Detail Images:

**Explanation of the images:**

1. The remaining of wall border and collapsed brick along the track. If compared with the other, this area contain less density of brick on the its surface, an area that most probably only bordered by the wall.
2. Another collapsed brick wall in between area no.1 and no.3.
3. An area with horizontal brick floor that provides circulation connected from floor in B and floor no. 4.
4. A floor area located at the end of eastern part of the site with short passageway that connected with floor no. 3.
4.2.4(b) 3D Reconstruction

As described, the reconstruction and arrangement of this site was based on the interpretation made from present evidence found at site. Like other site’s interpretation made at Sungai Batu, the theoretical descriptions on the structural arrangement were looking at the size of brick, the arrangement, their position whether fix to the ground or not and the possible used of space/area. As described in Table 4.6 - 4.8, SB2G was built on existing terrain thus the floors probably were arranged according to the natural contour. Therefore, it explains the differences in level of floor, although it barely visible yet noticeable.

In 3ds Max, there are various external plugins which can be used together to perform specific task in object modelling. Considering SB2G encompassed several constructions of brick floor, the free version plugin called Floor Generator has been used to generate the whole floor consisting individual bricks without need to arrange each one of them. This tool works by assigning the it to a planar object and can be modified with setting such as length, width, volumes and distribution pattern of the floor.

In the case of stairs structure, the actual location was situated probably in between a pair of walkways in Division A. Given that the indication of stair only can be seen at the surface of slopes, the stairs might be built only at certain location in between of the walkway. This set of steps having a similar pattern with the one found at SB2B’s jetty site. In 3D model, it was recreated at the surface with a steep slope particularly at location which directing to lowered floor area (Figure 4.22).
Figure 4.22: (A) The area in which the set of stairs were identified. (B) The proposed reconstruction of stairs at the slope directing to the lowered floor area.

Other than stairs structure, there is noticeable a pair of parallel brick arrangement at sloping surface, thus creating some sort of indication of entrance or passageway to another floor area (Figure 4.23A). And since the original arrangement of this structure were disturbed, by looking at present evidence, they could be built similarly on both sides. The idea of this structure in 3D model was reconstructed with the brick at both side having a straight up position and were arranged horizontally at higher level but positioned vertically along the slopes (Figure 4.23B).

Figure 4.23: (A) The structure resembles a pair of entranceways at sloping surface. (B) The 3D arrangement of entranceway from bare ground to paved floor.
Another visible structural evidence other than floor area is traces of the collapsed wall border in Division C which the bricks remained single line (as shown in Table 4.8, no1). This could be indicated part of wall original brick foundation on the ground. The construction can be assumed had consisted 4 to 5 layers of brick as the amount of collapsed brick does not indicates it belongs to higher wall. Though, it barely visible to identify, this perimeter seemingly does not accompany by any floor structure and only outlined by the wall border. Therefore, contrasting with the others, this area was visualised with only lower wall structure without floor. Generally, reconstruction of SB2G has presented indications of possible use of area whereby it encompassed a pair of walkways, stairs, platforms, a wall block and several floor arrangements (Figure 4.24).

Figure 4.24: The hypothetical reconstruction of SB2G which encompassed a pair of walkways, stairs, platforms, a wall block and several floor arrangements
4.2.5 3D Environment Scene

Likewise, 3ds Max has been used to recreate the details such as trees, river terrain and Jerai Mountain which they are necessary for developing the environment model. As background scene, this study used the Jerai Mountain as main setting for the environment reconstruction. The initial 3D model of landscape was decided to overview Jerai Mountain, because it always has been depicted in every scenery for this region. Not only that, many historical anecdotes and scientific research have been mentioned the importance of this mountain and as main identification for the area of the Bujang Valley. Hence, it is necessary for any historical/archaeological reconstruction to include the landscape this mountain into the scene.

The terrain model of Jerai mountain was created by using reference taken using 2D elevation image from USGC (United States Geological Survey) and Google Earth satellite imagery. The height data was downloaded from an online application called terrain.party where it provides a real heightmaps data from USGC typographic digital imagery (Figure 4.25A).

This online application is useful for 3D digital reconstruction as it provides the global elevation data or general contours at choice of location. Thus, this data can be used to generate surface of the landscape in the modelling software for any location at the world. The selection of background scene in this study consisted an area squared up for 24km². The selection just enough to cover the mount range, nearby coastal area and main Merbok river and the Sungai Batu Archaeological Site (Figure 4.25B).
The displace modifier as a ‘force tool’ has been applied to the heightmap image to reform the geometry of the surface. The function of *displace modifier* helps to manipulate the greyscale amount of the maps, thus creating difference level of volume or height on the surface model. Meanwhile the image references from Google Earth were used for controlling the height or the amount of displacement in imitating the physical silhouette of the Jerai terrain (Figure 4.26). This method not only provide accurate representation in digital scene but also ensures the significant aspect of historical and geographical elements which exist together into archaeological reconstruction.
4.3 Final Model and Rendering

After the modelling phase and before rendering the final model of 3D reconstruction, the representation or visualisation of the archaeological model need to observe the following processes:

1. Textualization or applying materials and textures into finished model.
2. Create the rendition of surrounding landscape with all the vegetation such as trees and grass.
3. Setup the light, camera and render setting.

The attribute of object in the reconstruction was demonstrated by these two components; the material and texture. Both material and texture incorporate the characteristic of the represented objects in digital scene to achieve the result that make them appear close with real life objects. This study preferred two approaches in applying the material into the objects; first by creating digitally using graphic software such as Photoshop, and second by taken the image directly from real material. Either way, the overall aim for textualization of the model is to stimulate the sense of lifelike to the object but at the same time it also can separated what is proposed from what is truly exists. As shown in Figure 4.25, it was a process whereby the portion of material that extracted from real object and were edited to produce the image to apply in 3ds Max. Meanwhile for other material such as brick, the textures fully produced in Photoshop software through layers of colours, textures and added effect as it intended to generate several variations among them.
In a way that the texture can be correctly scaled and positioned according to any aspect of material inputs, the *UVW Map* modifier has been applied. The *UVW Map* modifier controls how mapped and the procedural materials to be projected on the surface of an object (Autodesk, 2018). By default, the mapping coordinates the object in 2D textures, therefore this modifier governed the specific appearance of material, to ensure it fixed on the surfaces of 3D object.

Once the 3D models were ready, they need to be exported into larger environment model. Prior this phase, the rendition of surrounding landscape with the vegetation elements such as tree and grass need to be prepared. The trees were downloaded from the free version low-poly tree that readily available on internet. Additional feature such as a river was reconstructed by modified the attributes of the default material such as reflections, transparency and refraction to depict a water surface. It is quite time-consuming phase to setup the environment with all the elements involved.
After both the site model and the environment model were merged together in one scene, the only thing to do is to set the light, camera and render setting. The Vray was used in this study as the render productions engine. Vray benefits the model to be appeared more photo-realistic assisted by correct material and actual lighting effects as well as the specific parameters that provided together to achieve realism. Since the site models are the outdoor setting, the Vray Sun used as light to illuminate the environment by reproduce the real-life sun.

Finally, the setting for Vray render deliberately has been setup and adjusted the option and parameters of desirable output before the rendering production. Rendering process and setup can be time consuming as the material, colour and light need to be correctly depicted into composition and framing. This was done by trial and error until certain quality of the visualisation was produced through this process. The final 3D model reconstruction of selected site at Sungai Batu Archaeological Site is presented in 2D images visualisation in the following pages.
4.3.1 Ritual Monument (SB1B)

The 3D reconstruction of ritual monument SB1B is shown in Figure 4.28 and Figure 4.29. The virtual environment includes Mount of Jerai in the background and the monument is depicted built on the embarkment of laterite soil.
Figure 4.29: The 3D virtual reconstruction ritual monument of SB1B.

1. Perspective view from eastern side.
2. Bird’s eye view to show the full view of monument.
3. Eye level perspective view.
4. Close-up of the structural layers and elevations.
4.3.2 Iron Smelting Site (SB2A)

Iron smelting site SB2A represents as the simulation on the evidence of iron smelting activity with hypothetical furnace and several other artefacts such as air bellows and five standing tuyere to be believed as ritual practice in iron site (Naizatul, 2014). The 3D environment as shown in Figure 4.30 and Figure 4.31.

1. The view of the scene of smelting site.
2. Perspective view towards northern side facing the Jeral Mount.

Figure 4.30: The simulation of iron smelting site SB2A
1. Full view of the smelting site with the tuyeres, furnace, iron slags and ores.
2. The mound of broken tuyeres
3. Close-up to the double piston air bellows, made with bamboo. The bellows standing on arrangement of bricks as the platform for stability during the work operation.
4. The furnace with simulation of iron hot fluid flows out from its mouth.

Figure 4.31: The simulation of iron smelting site SB2A
4.3.3 Jetty Structure (SB2B)

SB2B depicted the type of ancient jetty structure for Sungai Batu. Figure 4.32 and 4.33 demonstrated 3D reconstruction of SB2B in digital environment together with formation of ancient river to portray its function as jetty structure.

1. The view of jetty with Jeraí Mountain at background setting
2. Front full view from the river

Figure 4.32: The 3D virtual reconstruction of jetty structure SB2B.
1. Bird eye view of full jetty structure
2. Perspective view from the platform towards river
3. Close-up of the stairs and walkways.
4. View of the jetty from the ancient river.

Figure 4.33: The 3D virtual reconstruction of jetty structure SB2B
4.3.4 Supporting Structure/ Jetty Administration (SB2G)

SB2G was identified as jetty administration building or supporting structure for jetty at Sungai Batu. However, this site also could possibly had served for two functions; utilised as jetty in the beginning, then was transformed into supporting structure. The 3D virtual reconstruction demonstrated in Figure 4.34, 4.35 and 4.36.

1. The bird's eye view of the whole jetty administration structure.
2. Perspective view towards northern side facing the Jera Mount.

Figure 4.34: The 3D virtual reconstruction of jetty administration structure SB2G.
1. Perspective view of division B from floor area in division C.
2. Close-up on the walkways structure.
3. The stairs and lowest floor area in division A.
4. The sloping entrance way from bare ground to the paved floor.
5. Perspective view on the area in division A and B.

Figure 4.35: The reconstruction of jetty administration structure SB2G
1. The whole perspective view of jetty administration structure and jetty SB2B far at the background.
2. Close view of an area which enclosed with lower wall and unpaved ground at division C.
3. The view from floor area in division A towards division B and C.

Figure 4.36: The 3D virtual reconstruction of jetty administration structure SB2G
4.4 Proposed Digital Media: Holographic Visualisation

As discussed above, the digital reconstruction in this research defines by implication of the 3-Dimensional (3D) visualisation to facilitate archaeological interpretation. This study not only offered the assembled model of end-product but, it explores various other techniques which describes the development of the 3D visualisation process.

In this era of advance information technology and communication (ICT) numerous other devices and application in variety of form are offered to provide an effective learning but also entertaining. Generally, digital data has been designed in a way that they can be integrated with each other and continues to generate other form of digital material. As Gillings (1999) has asserted that the final representation should not be treating it as definite end-product but as manipulative medium that could constantly modify, alter and added new interpretation if it available.

The following experimental model was intended to demonstrate what is the other way that the digital model can be presented and disseminated to public. The 3D reconstruction of SB2B rooftile was chosen to become holographic virtual representation of the outcome 3D model. This prototype only requires a small setting using an 360º view video presentation of the 3D model, portable pyramid projection and a Smartphone. As for the creation of the video, the motion or the 360º movement of the rooftile was captured in 3ds Max as an animation video. Then, the content of video was edited by seperated the video frame into four different view using the video editing software; Adobe Premiere Pro (Figure 4.37).
The video displays the four views of the object and by using the 45° transparent glass in form of pyramid, which helps the projection of the video image into the 3D holographic view. This is done by positioned the transparent pyramid on the top of Smartphone’s screen. From the video playing on the screen of the phone, it simultaneously draws the four versions of the view into one projected scene inside the upturned pyramid. This holographic method displays some sort of floating view of 3D object which has been reflected by the sloping angle of pyramid see-through glass.

Although the availability of virtual presentation is not always necessary for museums or heritage gallery, if that happens, museum need an efficient, cost effective and simple methods of creating virtual or augmented reality exhibitions on their collections. Hence, with this experimentation on holographic video presentation (Figure 4.38), it offers the possibility of creating a visual presentation which ease in technical ability and more importantly it cost efficient and avoid overstressing budget for the heritage sector.
Although the present study has shown the outcome of holographic presentation only operates in prototype sizes, the capability to produce the real exhibition with the same method and affordable is proven to be achievable. It is because, the method can be applied without much need of high cost device and advance system configuration. It is known that most of the heritage body such as museums and archaeology gallery are rarely making any income because they are non-profit organization, therefore to create something which low in cost production and easy to maintain is essential.

Moreover, the attractive and interactive digital medium is desirable in this new age of media convergence. Therefore, this kind of virtual reconstruction and presentation platforms are beneficial in tourism context especially for visitors at museums and archaeological sites. In addition, other than holographic presentation, many other digital media can be develop using the same 3D data, especially by using the virtual technology; such as virtual reality, augmented reality, online tour and even games or phone applications.
4.5 Summary and Discussion

From this chapter, issues such as information resources, alternative references, justification, authenticity of data, method and the process involved have been deliberately addressed. The four selected sites have displayed their own site’s condition and characteristic which has encouraged different approaches and studies to be taken. Although the areas of uncertainty exist in each model, due to missing information or fragmentary nature of archaeological evidences, the study has addressed the how the resource sources were taken for reference and how the evidence from archaeological data were integrated into the visualisation model. This is important to emphasis this aspect in order to establish the principles of archaeological reconstruction to ensure the academic or educational practice of computer-based reconstruction.

This chapter also proposed to explore an option for archaeological knowledge to be applied in computer graphic interpretation and how the best way to represent and reconstruct them. As mentioned by Gilling (1999), although virtual representations are fakes substitute of archaeological objects, but as an archaeologist, he utilised them as catalysts for exploration and interpretation. As proposed in the objective of studies, the holographic visualisation has utilised the outcome of 3D model and maximise the benefits of computer-based visualisation. This method proven as cost effective and the prototype model for this study has demonstrated on how it operates for presentation and distribution of archaeological data. Indeed, the future implementation of any computer-based reconstruction can be significantly improved to provide understanding and helps to explore the new idea and knowledge of the historical/archaeological materials.
CHAPTER 5
CONCLUSION

5.1 Discussion on the Findings

Returning to the four site studies of Sungai Batu, in discussing why these 3D visualisations of archaeological sites have been created, one of the clear advantages of 3D virtual model is the ability to test the theories/hypothetical interpretation without interrupting physical objects/site. The archaeological information continues to be speculative and fragmentary without factual data or evidence to support the theories or interpretation. Consequently, they keep changing when there is new information found or discovered which added and further enhance the previous interpretation or knowledge. In this regard, it is important to ensure any effort to interpret and demonstrate the archaeological information does not affecting current discovery of the site/monument or artefact.

Considering this, the practice of computer-based visualisation, has allowed archaeological knowledge to be studied and visualised in digital form without attempting to disturb the existing site/structure or an artefact. This study sought to explore the practice of digital technology to demonstrate the archaeological interpretation from selected sites at Sungai Batu Archaeological Complex through computer-based visualisation method.

The outcomes of computer-based visualisation were presented in the form of 3D virtual reconstruction by using several techniques in computer graphic and modelling software. Additionally, to promote intellectual integrity of digital heritage visualisation, this research applied several recommended guidelines by the London Charter. This is to ensure the 3D reconstruction is seen to be, or at least should accurately convey the knowledge that they represent such as distinctions between
evidence and hypothesis, and between different levels of probability (Denard, 2009). Thus, this study also has demonstrated the technical methods and how the research sources are defined, selected, analysed and evaluated to current understanding so that the hypothetical visualisation appears to be as accurate as it can be. The study revealed the final 3D outcome of virtual reconstruction of four archaeological sites, three complete reconstruction or visualisation of either missing/fragmented or broken artefact and one small prototype of holographic presentation created from the outcome of 3D model.

5.1.1 **Research Objective 1: To represent the interpretation of archaeological site by using 3D virtual reconstruction**

Among four selected sites, the approaches for reconstruction have been divided into two; for structural sites and non-structural sites. SB1B, SB2B and SB2G are the representation of structural sites which indicated by the finding on the structure made by bricks as main construction material. Meanwhile, the reconstruction of non-structural site of SB2A has depicted the archaeological evidences which appear as the traces of iron smelting activities. All completed models also represent in hypothetical environment setting that encompasses natural features such as tree, mountain and river.

SB1B has revealed a different layers and bricks arrangement that become the main point to record the details of the site. The modelling of SB1B assisted by the measured drawing which it allowed a good control in constructing each of single layer of brick arrangement. This method was applied during the modelling process to make the arrangement of bricks to individually fit the volume of the circular path, each layer of square structure and top structure. Thus, the 3D reconstruction enables to represent the model to be as close as possible with the real physical monument. As for the top
component of at SB1B, most of bricks arrangement on this part were collapsed, therefore this structure was hypothetical reconstruct based on the pattern of fallen brick. From the field study, the top structure was much likely had tapered upward in circle formation, before collapsed uniformly inward. Consequently, the 3D reconstruction has visualised the complete look for the top structure of SB1B monument as described (Figure 5.1).

![Figure 5.1: Final 3D model for SB1B](image)

The significant about SB2B site is although it bounded in small area, it has demonstrated a diversity in architectural components. This site has revealed a prominent utilised space of footpath/walkways, stairs with small rectangular platform and small paved floor area. Apart from that, one of the distinguish characteristic of SB2B is the presence of two mound which to be believed functions as platform to anchor the small boat on river side. Thus, the mound represented as a two-circular arrangement in the digital reconstruction. The location of SB2B suggested to be near the ancient river and the structural components were positioned according to the contour of close to riverside ground (Figure 5.2). Therefore, the recreating the natural
terrain in the 3D scene is important to support the function of site as the river jetty structure.

Figure 5.2: Jetty structure hypothetically constructed near the ancient river

SB2G appears as large excavated site that mainly consists several types of floor arrangements which also include transition passageway, a pair of footpath/walkway, stairs and platform (Figure 5.3). SB2G was built on existing terrain thus the reconstruction of the floor was arranged according to the natural contour, means that the floors or other structural components are represented in different level from each other. For instance, the footpath or walkway was constructed in two separated set. At the middle of them, there are the evidence of stairs which only can be seen at the surface of slopes. In addition, each set of steps seems lesser than the walkway. Thus, the stairs were reconstructed only at certain location of the walkways, more specifically at the slope of the ground contour.

Initial description on SB2G site was to represent the function of jetty’s supporting structure or jetty administration. However, through this study, the site
might as well have reflected two functions; as a supporting/administration structure and as a jetty itself. Mainly because the combination of walkways that usually identified as a main feature of jetty structure and large used areas which common for administration structure. This perhaps because at first SB2G site was built as jetty structure, as time goes by, and the river meander changed and getting far from the site. SB2G was then transformed into the administration structure with additional several floor and other structures.

Figure 5.3: Bird’s eye view of overall structure at SB2G

For non-structural site, the reconstruction needs to visualise the smelting activity or scene once happened in SB2A. Analysis and previous interpretation on the SB2A has proposed the site was divided by the working zones based on the archaeological findings. The present site condition does not clearly illustrate the main component of the smelting site because there are missing evidences regarding the main component for reconstruction of the model, such as the furnace and the air bellows. Thus, the reconstruction has been created hypothetically by referring from the other
relevant sources. Accordingly, the 3D models have portrayed the operation of main three components, namely the furnace, *tuyere* and air bellows.

The information of the *tuyere* can be acquired easily by the physical evidence on the site. Meanwhile the information on furnace was acquired from local furnaces that have been discovered throughout Jeniang to assist in the reconstruction. The recreation of 3D scene also has demonstrated the distribution of the artefact, particularly the mound of broken *tuyeres* which thus far, this type of evidence does not appear at any other sites in Sungai Batu (Figure 5.4). Therefore, the combination of these 3D models parallel with the purpose of study to demonstrate the virtual interpretation of different function of archaeological sites in Sungai Batu, regardless they are structural site or non-structural site.

Figure 5.4: Virtual reconstruction of SB2A depicts the furnace that associated with the mound of *tuyeres*.
5.1.2 Research Objective 2: To represent the complete visualisation of artefacts by using 3D virtual reconstruction

This research has identified three main artefacts that have been reconstructed in 3D models. The analysis undertaken to investigate the complete shape of these artefact. They are the tuyeres, furnace from SB2A and rooftiles from SB2B. Although it widely known that the tuyere is in the form of cylinder with the hollow tunnel that allows air to enter the blasting furnace, but the reconstruction can help to illustrate this artefact more clearly (Figure 5.5). In addition, the visualisation also interconnected with the main component of the smelting site, thus it significantly important to demonstrate in 3D reconstruction of SB2A site.

![Figure 5.5: 3D model of single tuyere](image)

The type of furnace structure was identified by studying the morphology of the iron products which were produced at SB2A site. The morphology analysis of iron artefacts uncovered at SB2A has indicated that they were produced through bloomery smelting process, thus theoretically the furnace structure can be classified as bloomery type. This type of furnace can be found at Jeniang in territory of Bujang Valley. Hence,
the reconstruction was based on Jeniang’s reference which also has validated the linking of these two locations of iron site in the region of Bujang Valley. In reality, there are variations on size and height of the furnaces as it depends on the preference of the manufacturer or who had built them. Thus, the 3D model was reconstructed without having certain accuracy for the shape and size. More importantly, the 3D model intends to demonstrate the shape of SB2A furnace which the evidence absence from excavated site (Figure 5.6).

Figure 5.6: The representation of the iron smelting furnace for SB2A Sungai Batu.

Meanwhile, analysis on the shape of rooftiles at SB2B was driven to reveal a complete form of this artefact. As SB2B site appears to be as old as 5th Century CE, the SB2B rooftiles were probably the oldest type of rooftiles found in this country. Representation of rooftile in 3D model has demonstrated the complete ‘s’ shape that divided by three body part with the small hole which probably functions to bond the tiles together (Figure 5.7). Nonetheless, the 3D reconstruction represents the thorough analysis on the rooftiles and has combined the fragmented pieces of rooftiles into whole complete shape.
5.1.2 *Research Objective 3: To establish application of digital media as appropriate medium for presentation and dissemination of archaeological material at Sungai Batu.*

The study also intends to demonstrate on how the production of 3D model outcome can be used for medium for presentation and dissemination. Throughout the end of research, the study has proposed the prototype of digital media created by the 3D outcome from case study of the SB2B’s rooftile. Main goal is to enhance the 3D data by providing interactive presentation of archaeological knowledge. Thus, the holographic video presentation (Figure 5.8) was proposed as an alternative medium to for presentation and dissemination, as it cost effective and does not requires any high-end system to operate.
Fundamentally, this research clarifies that 3D visualisation are not solely for archaeological interpretation, but it can be disseminated through application of various digital media which can be developed using the same digital material. As demonstrated in the prototype of holographic video presentation, the data can be improvised, reproduced and distributes by any means of new format and system. Therefore, the results from this study consolidates the integration of archaeological data and practices of computer visualisation method to further support the establishment the 3D virtual reconstruction for cultural heritage sector.

5.2 Limitations of the Study

Upon completing the research, it provides the insights into implementation of 3D reconstruction for archaeological interpretation and proposed the holographic visualisation for medium of presentation. Despite this study has identified specific framework that guide the progress on each phases of 3D reconstruction for Sungai Batu site, the study also had some limitations, which offers an opportunity for digital archaeology in the future research. In this current study, the framework was structured
into three phases in which the last stage requires the 3D outcome in the form of digital media to be evaluated by academician or heritage professional before presented to the end users (public/tourist). Although the holographic presentation has been created as proposed digital media from the outcomes of 3D virtual reconstruction, the final evaluation of abovementioned unable to be conducted to test the practicability and determine the employment of this practice is indeed noteworthy.

Moreover, this holographic presentation was only operated in small prototype thus it not adequate as proper medium for evaluation Consequently, since this only sample model, it does not ready to be used in real exhibition or display. It may be justified the research if the presentation could be assessed by demonstrate in appropriate devices that fully operational scale. Therefore, this limitation opened the new study to structure the quantitative research for measuring the perceptive on implication of virtual technology and its impacts towards the user.

5.3 Future Research & Suggestion for Sungai Batu Archaeological Complex

Nowadays countless of digital gadget and tools that keep decreasing in price and advance technology are now features in our daily used device. Technical aspect concerning digital technologies are getting less complicated, which provide easy to use application that specific for utilisation of non-technical person. For instance, people can make free website, apps and other digital content through user-friendly application that equipped with ready-to-use template. In future research, the archaeological data in Sungai Batu would become inclusive and can be gathered to provide a complete database or archive for Sungai Batu. The database can be stored in variety of method, for instance, an online collection or digital device such as mobile application. For example, the future digital empowerment for Sungai Batu site, the
available 3D models of respective site can be developed into mobile apps which containing description of the site and their archaeological findings (Figure 5.9)

Figure 5.9: The proposed mobile application can be integrated with the available 3D model and information from archaeological data (as illustrated).

The science and technology are moving forward in constant pace to satisfied human demands for improve lifestyle and unlimited digital interaction. It is noted that the new modes of engagement and interpretation could also instils some benefit towards the development of archeo-tourism. Especially when there are emerging media and digital tools which can improves the visitor’s experiences with 3D virtual reconstruction of historic sites or an artefact. It can be done by representation virtual
substitute for fragile or complicated sites in more interpretative manner using Virtual and Augmented Reality gadget such as VR headset, AR display, VR gloves which improve the way we utilise the virtual technology. For instance, using the technology of augmented reality incorporating with the application of artificial intelligence (AI). The application would automatically perceive the physical environment of the site and display the visual environment as alternative representation of the ruins using portable devices such as smartphone (Figure 5.10).

![Image](image.png)

**Figure 5.10:** Example of the proposed augmented reality technology which identified the physical site and view as 3D visualisation.

As numerous times mentioned throughout this study, Sungai Batu archaeological site, is a valuable historical property which significantly different from other archaeological sites found in Malaysia or even in Southeast Asia. Similarly, the digital archaeology can be useful in promoting the appreciation towards the heritage
value of this complex and displaying the archaeologist’s theorisation about the sites. For now, there should be encouragement for practice of computer-based visualisation and other digital application methods in archaeological study.

In broader perspective, the heritage and its substantial area should encourage the public interest, so it can continue to develop and be funded, especially if it gains support by the public involvement. The digital archaeology in near future can be main supporter for the growth of archeo-tourism, but recent interest in archaeological study also has revealed positive potential in commercial business and entertainment. In coming opportunity, the application could potentially become profitable for archaeology field. Therefore, this study hopes to strengthen the interaction between archaeological knowledge and digital technologies in becoming great tools in supporting the archaeological research as well as embracing archeo-tourism.

5.4 Conclusion

Nowadays, the adaptation of digital technologies in heritage sector is increasing rapidly around the world. International conferences on digital or virtual archaeology/heritage are being held almost every year especially in European countries. The conference is one of the ways on making the effort for support, improvement and promotion of digital heritage across the academic, business, education, cultural heritage, policy, and tourism sectors.

In Malaysia, we should accelerate the effort to implement the variation of digital technologies in heritage sector. It does not matter if we start with small approach by digitising the analogue or physical data and information such as old hand-drawn drawing of historical structure or old record of artefacts and digitally save or store it online. In the case of existing data lost or due natural disaster, human neglect,
war and so many other possibilities or simply disorganized information due individual mistakes, the digital and online data serves as archives which we could refer and accessed it anytime. The collaboration between heritage organization, academic institution and contemporary business organization should be encouraged to create fundamental interdisciplinary to support the efforts. Especially among the academic institutions, in between university departments, the familiarity with archaeology should be dispersed to student in various departments. It could promote the younger generation embracing the archaeology in different perspective on what they could do within their specialisation. Therefore, it will create the diversity of archaeological expertise.

Within the heritage sector, it is recommended that there should be an improvement regarding the approaches in digital heritage. They should be taking the digital matter seriously and maximise the effort to prove that they are committed to treat the heritage accordingly as valuable possession. As this study has demonstrated, digital literacy especially in computer graphic techniques should have been encouraged and cultivated and among the heritage professional as the potential offer by these technologies are evident. Undeniably, using digital tools and applications indeed requires specific skills, which mostly archaeologist assumes it beyond their capabilities, however, the motivation to challenge the techniques and to explore the various potential can be rewarding for archaeological field.
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