Stone is a durable and naturally occurring material used by humans throughout the world from the birth of humankind up to the present day. In prehistoric times stone was used to make simple tools, jewellery and even musical instruments, later to construct buildings for dwellings, tombs or for ceremonial/religious purposes and fortifications leading to modern uses of stone in today’s infrastructures. Carefully preserved stone objects may therefore provide a historic record of the cultural and social development of human societies in each country of the world and representative examples of such objects are all elements of a ‘stone heritage’ which varies from country to country. In this book, each chapter describes various examples of objects which contribute to the stone heritage of a specific country in East and Southeast Asia (i.e., chapters on Cambodia, Indonesia, Japan, Korea, Malaysia, Papua New Guinea, Philippines, Thailand and Vietnam).

Many of the stone heritage objects and sites described in this book attract international and domestic tourism and so can make an important contribution to the local economy. In turn, the tourist’s visit may be enriched by learning more about the origin and source of the stone used in the object’s construction. In these ways CCOP hopes that this book will help to improve the quality of life in the region as well as encouraging public interest in geology and its significance in the region’s cultural and economic development.

This book was prepared with strong support from the Japanese government through the Geological Survey of Japan (GSJ), National Institute of Advanced Industrial Science and Technology (AIST), from the initiation of the project to the publication. We are more than happy to see this book assist people to learn how geology contributes to our daily life.
STONE HERITAGE

OF

EAST AND SOUTHEAST ASIA
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Angkor Thom South Gate, Cambodia (photo by Shinji Tsukawaki).
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FOREWORD

It is with great pleasure that I write this “Foreword” to the first volume dedicated to the stone heritage of East and Southeast Asia.

Through reading the papers from each contributing country it is quickly possible to appreciate many unique aspects of stone use in this region. Consequently knowledge of such stone use and the geology of the rock involved are most valuable from an international perspective.

Intriguing examples of stone utilisation from the region include the manufacture of stone musical instruments or lithophones in Vietnam, the construction of stone ice storage structures in Korea to preserve ice over summer, the application of truly massive granite blocks in the 16th century castle walls in Japan and the targeted use of meteorite impact rock by prehistoric man in Malaysia.

Notable also are the wide ranging use of certain stone types across the region such as weathered laterite for routine construction in Cambodia, Thailand, Vietnam and Malaysia. Many ancient temples were constructed using laterite. Volcanic rocks also have wide cultural significance amongst these countries. In Indonesia such use of volcanic stone ranges from prehistoric megalith sites such as Gunung Padang in west Java, built about 6000 years ago, whilst similar stone also predominates in the famous Borobudur Temple compound, where construction commenced in the 8th century. In the Philippines, hard volcanic tuff, especially in the region of Manila, has long been quarried, under the label of “adobe”, and used for building throughout the country. The utilisation of volcanic rocks also has significance in Papua New Guinea in the production of stone axes.

In contrast, Japan has developed, over thousands of years, the mining of ornamental stones such as the Shirataki obsidian and Itoigawa jadeite with the consequent manufacture of ornaments and simple implements.

Since its establishment in 2012, the Heritage Stone Task Group (HSTG) of the International Union of Geological Science with further association, since 2015, with International Geoscience Programme (IGCP) Project 637, are dedicated to the establishment of the first international standard for building and ornamental stones via extensive documentation of those stones that have been significant in human culture.

This volume represents an excellent pioneering foundation for such documentation in East and Southeast Asia.

I anxiously await further research into the stone heritage in this region.

Barry Cooper
Secretary General
Heritage Stone Task Group
PREFACE

In 2008, CCOP published “Geoheritage in East and Southeast Asia”. The aim of this first book, written for the general public, was to promote interest in the earth sciences by introducing and explaining some of the many wonderful geological sites to be seen in the various countries of the region. Three years later, “Geological Museums in East and Southeast Asia”, which introduces museums of earth sciences in eight of the CCOP member countries was issued to further encourage public education in geoscience within the region.

In 2012, Dr. Hirokazu Kato, Honorary Advisor to CCOP and Vice President (East Asia) of the Heritage Stone Task Group (HSTG), a group established within the International Union of Geological Sciences (IUGS), made a presentation on the Global Heritage Stone Resource (GHSR) project at the Thematic Session of the 48th CCOP Annual Session at Langkawi, Malaysia. Here he suggested that ‘stone heritage’ in the CCOP region would be an interesting topic for the CCOP series of books. His presentation was warmly welcomed and a project to publish a book on stone heritage in the region was proposed and endorsed at the next CCOP Steering Committee Meeting at Ubon Ratchathani, Thailand in March 2013.

The words “stone heritage” collectively denote the stone constructions or objects made by human society and recognised, regardless of size or rock types, as significant symbols of a societies’ cultural development. Throughout human history, we have used a variety of rocks and stones in many ways, both practically and aesthetically: prehistoric stone tools and megalith tombs, ancient marble sculptures, medieval castles and stone bridges, modern architecture, gorgeous accessories and for many other artifacts. Stones have been a very familiar material to all of us.

From the geological point of view, “stone heritage” reflects more or less the geological characteristics and geodiversity of the region. Most of the rocks used in ancient large structures such as the Egyptian pyramids came from the vicinity, since rock is difficult to transport long distances on land. In every region of the world, local rocks and stones have been used in our daily life. So familiar are rocks to us that their very presence can trigger public awareness about geology.

There is a rich store of stone heritage in the CCOP region and many of the places of archaeological and historical importance have been developed as popular tourist sites, attracting vast numbers of both domestic and foreign visitors. Tourists enjoy the beautiful features and hidden history of stone structures and architecture, and admire the sophisticated technology of the ancient people, but often seem to have little interest in the geology of the heritage. This is partly because there is little scientific information available for tourists, though even a little knowledge about geology can make their visit more interesting and enjoyable.

This book covers some of the representative examples of stone heritage in East and Southeast Asia (the CCOP region) regardless of their size, scale and age; miniature or gigantic; from ancient to modern. The editors hope that the book will help readers to
learn about the geological background of the heritage of the CCOP region and extend their interest in the local geology and eventually the history of our planet.

We also expect that this book will be a contribution to the GHSR project under the IUGS, which was proposed at the 33rd International Geological Congress (IGC) in Oslo, Norway in 2008 and whose task group, HSTG, was formally established within the IUGS on the occasion of the 2012 IGC meeting in Brisbane, Australia. The project aims to “facilitate formal designation of those natural stone types that have achieved widespread recognition in human culture” (Cooper et al., 2013*).

As the designation “heritage stone”, similar to that of world heritage, will provide natural stone resources with international recognition, it will prevent them from depletion, and enhance the local stone industry. The collaboration with the GHSR project is expected to bring benefits to CCOP, which seeks to improve the regional quality of life with earth scientific knowledge and technology. It will help to get its people interested in local geology using the material familiar to them, i.e. stones, and encourage local stone industry by obtaining international recognition.

In publishing this book, there are many people we have to acknowledge and thank for their invaluable contributions. First of all, we would like to thank all the National Coordinators and their colleagues, who spared no effort to look for both famous and unknown heritage artifacts all over their country, search huge amount of references, and wrote very fascinating accounts of their national stone heritage. Special thanks should be given to Ms. Sumiko Miyano of the Geological Survey of Japan, for her excellent support in organizing the manuscripts for publication. We also thank the staff of CCOP Technical Secretariat and the Chairman and Members of the CCOP Steering Committee for their support for this project.


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Cover photo: Angkor Thom West Gate (photo by Shinji Tsukawaki).
1. Introduction

The Kingdom of Cambodia is located in the southern part of Indochina Peninsula. With a total land area of 181,035 square kilometers, the country is bordered by Thailand to the northwest, Laos to the northeast, Vietnam to the east and south, and the Gulf of Thailand to the southwest (Figure 1). Cambodia's landscape is characterized by a low-lying central plain, which occupies about two thirds of the country. The Mekong River flows across the country from north to south. To the east of the Mekong River transitional plains gradually merge with the eastern highlands to region of forested mountains and high plateaus that extend into Laos and Vietnam. In the west, the Kravanh (Cardamom) mountain forms a western highland region that covers much of the land area between the Tonle Sap and the Cambodian-Thailand border.

![Figure 1. Geographical map of Cambodia.](image)
Cambodia is one of the most appreciated tourist sites in the World thanks to its hundreds of attractive ancient temples dedicated to Hindu gods and their reincarnations, built since the foundation of the Indianized state of Chenla in the 6th Century (Figure 2). These temples were found scattered within a large territory of the Indochina Peninsula, from south Vietnam to southern Lao PDR and central Thailand.

Figure 2. The Bayon temple is one of the marvelous ancient temples of Cambodia (photo courtesy of Shinji Tsukawaki).

2. The use of stone material in prehistoric times

The use of stone in the life of people living in the area of the present Cambodia has been recorded since prehistoric times. Tools of quartz and quartzite pebbles, indicating human presence, were found in Mekong River Pleistocene terraces in Stung Treng and Kratie provinces of Cambodia (Figure 3). At the Samraong Sen prehistoric archeological site in central Cambodia, excavations revealed stone necklaces, bracelets, ear stretching plugs and jade ornaments, which were dated back to the Bronze Age (Figures 4). The use of stone materials for jewelry continued to flourish into the Iron Age as proven by archeological excavations in Phum Snay of Banteay Mean Chey province in northeastern Cambodia. Unfortunately, the origin and source of these stones are not yet determined.
Figure 3. Location map of prehistoric archeological sites.

Figure 4. Bronze Age stone necklace (left) and jade ring (right) found in Samrong Sen prehistoric archeological site by Jean Moura in 1876 (e.g., Heng, 2008).
3. Stone heritage of historic times

Since the 6th Century, stone was used in huge quantities in the construction of infrastructure, monuments and in sculpture. Based on their construction materials, it can be seen that earlier temples were built from laterite blocks and bricks, while sandstone was used for some parts of the construction such as entrance columns or lintels or in sculpture. In contrast, although bricks were still used in later built temples in the Angkorian period (approximately from the 9th to 15th Centuries), most of such temples were built from sandstone, while laterite blocks were used for walls or base support.

3.1 Brick materials for temple building

Some good examples of brick temples are the temples of Prasat Sambor Prei Kuk Group located about 30 km north of the Kampong Thom town (Figure 5), in an area which was one of the old capital cities known as Isanapura, and Prasat Phnom Da in Ankor Borey district of Takeo province (Figure 6). At the latter, bricks were used to build the upper half (the roof) part of the temple (Figure 7). The bricks were made from burnt clay and have a rectangular shape with dimension of approximately 20 x 30 cm (Figures 8 and 9).

As central Cambodia is covered by a large area of lowland and flood plain, clay deposits are abundant and easy to mine. They are made into bricks for use in construction. However, until now no ancient brick kilns have been discovered in the area.

Figure 5. Temple of Sambor Prei Kuk, which was built of brick.
Figure 6. Location map of Phom Da and Sambor Prei Kuk Group of brick temples.

Figure 7. Phnom Da temple was built of brick and laterite.
Figure 8. Brick temples are not strong as compared to laterite or sandstone counterparts.

Figure 9. Brick of Phnom Da temple.
3.2 Laterite stone heritage

Laterite is a rock type rich in iron and aluminium and formed from intensive and long-lasting weathering of the underlying parent rock in hot and wet tropical areas. In ancient Cambodia, laterite was widely used in building temples (Figure 10). As well as temples, laterite was also used in construction of infrastructure such as bridges and roads (Figure 11). For some temples, laterite was the main construction material, but for many others, laterite was used only in less important parts such as external walls or to cover the base of the temples (Figure 12). Nowadays, laterite blocks are still mined and used in the construction (Figure 13).

Figure 10. The 7th Century Asram Moha Russey temple built of laterite.
Figure 11. The Prah Toes (or Kampong Kdei) bridge, the longest corbelled stone-arch bridge in the world was made of laterite.

Figure 12. At Phnom Bakheng temple, laterite is used as base support of the temple and is covered by sandstone blocks.
According to the studies carried out on laterite materials used in the buildings of ancient monuments, we can conclude that laterite was mined from deposits located in the vicinity of the construction sites. Three groups of temples can be recognized according to the type of laterite used in their construction: they are 1) the southern group consisting of temples found in Takeo province, 2) the southeastern group that includes temples of Kampong Cham and Baray district of Kampong Thom, and 3) the central and northern group that includes temples in central and northern part of Cambodia.

In Cambodia, laterite was artisanally mined by using home-made tools such as hoes and picks. After clearing the vegetation, local miners removed the overburden composed of 20-30 cm of soil and the upper weathered layer of laterite crust. The underlying fresh but soft laterite is then cut using picks to make blocks at the dimension ordered by customers (Figure 14). The lower part of the laterite crust normally contains pebbles of the underlying parent rock and is not the target of mining due to its hardness.
Laterite of the southern group temples

The laterite used in building temples in southern Cambodia, such as Phnom Chiso, Tonle Bati, Phnom Da and Phnom Bayang temples, was mined from deposits located in Kirivong district of Takeo province (Figure 15). The area is well known for its laterite block mining heritage that is passed from generation to generation. Laterite deposits are found covering large areas around the foot hills of Tapok Taing Dong- Ream Andoeuk-Chroah Proos mountain group and its annexes at altitudes between 100 meters to 150 meters. The thickness of the laterite layer is from 1 to 3 meters. The country rock, which is also the parent rock of the laterite, is the Devonian-Carboniferous formation consisting of the sequence jasper-shale-sandstone (Figure 16). The laterite crust is covered by thin soil and lateritic pisolithic layers. Near the foot hill, laterite is exposed at the surface (Figure 17).
Figure 15. Geological map of the laterite mining area (UTM Zone 48, Datum Indian 60).

Figure 16: The parent rock consists of jasper, sandstone and shale of Devonian-Carboniferous age.
To the naked eye, the laterite is a brownish red color and contains some partially disintegrated fragments of jasper and sandstone (Figure 18). The size of the fragments varies from 3 to 20 mm. The laterite is soft when moist and becomes very hard when it dries out on the surface.

Few old quarries for laterite are found in the area (Figure 19). These pits have an average dimension of 8 x 10 meters and are filled with water. Big square laterite columns of 0.6 x 0.6 x 5 meters are seen in and around the pits. Based on the information provided by the indigenous people, these are ancient quarries, where laterite was mined to build the temples found in the area.
Laterite of the southeastern group temples

In contrast to those used in construction of temples in southern Cambodia, laterite blocks found in the southeastern group of temples are of iron rich laterite originating from the weathering of the Quaternary basaltic lava found in the area (Figures 20). The laterite is characterized by its dark brown color and its high density with fine cavities and the presence of small round-shaped concretions of hematite of diameter ranging from 1 to 3 mm (Figures 21 and 22). The content of iron in this laterite is high and can reach up to 44%. These young basaltic flows cover the old alluvium and have a low and flat topography about 1 meter higher than the surrounding flood plain (Figure 23).

Several deposits are found scattered and around the basaltic bodies covering a large area of Baray and Chamkar Leu districts of Kampong Thom and Kampong Cham provinces respectively. These are being mined for road construction and as building materials.
Figure 20. Location map of Baray laterite deposits.

Figure 21. A temple in southeast Cambodia built by blocks of iron rich laterite mined from deposits found in the area.
Figure 22. The laterite has a dark brown color due to rich iron content.

Figure 23. To acquire agricultural land and make cultivation possible, local people have to remove the shallow laterite layer.

Laterite of the central and northern group temples

Several ancient laterite mining pits from which Khmer people mined laterite to use in construction of ancient temples in central and northern Cambodia are found in the area of Andong Roy (in English "Hundreds pits") located in Kok Thlork Leu commune of Chikreng district, Siemreap province (Figures 24 and 25). Laterite occupies an area of about 20 ha and forms a high topography covered by small trees and bushes, within the surrounding rice fields. The laterite crust is covered by a layer of residual soil about 0.7 to 1 meter thick (Figures 26 and 27).
Figure 24. Laterite mining sites for the temples of central and northern Cambodia.

Figure 25. The Angkor Wat temples as well as other temples in central and northern Cambodia used unique laterite materials found in the area (photo courtesy of Shinji Tsukawaki).
Presently, in response to the need of laterite blocks for the restoration of ancient monuments in Siemreap province, the APSARA Authority has opened new quarries for laterite at two sites; one in Kok Thlork Leu commune of about 6 km to the east of an ancient quarry and another in Kvao commune of Sotr Nikum district (Figure 28). In the two areas, very shallow laterite layer occupies a large territory within a sparsely forested area.

Although, there are not any outcrops of the country rocks to be seen in these two mining sites, the presence of weathered sandstone fragments found in the residual soil
indicates that the substratum and parent rock is sandstone of Jurassic-Cretaceous age. Except its reddish orange color and absence of jasper fragments, this laterite has a vesicular texture similar to that of laterite of Takeo province in southern Cambodia (Figure 29).

![Laterite mined by local people and sold to APSARA Authority for the restoration of the monuments in Siemreap.](image)

Figure 28. Laterite mined by local people and sold to APSARA Authority for the restoration of the monuments in Siemreap.

![Vesicular reddish orange laterite of Siemreap province.](image)

Figure 29. Vesicular reddish orange laterite of Siemreap province.

### 3.3 Sandstone stone heritage

Sandstone is a popular stone material used not only in ancient times but also in modern buildings. In the construction of ancient monuments, three types of sandstone are used: the greyish blue arkosic sandstone, red fine-grained sandstone and bluish grey quartzitic sandstone.

**The greyish blue arkosic sandstone**

Among the three types of sandstone materials, the greyish blue arkosic sandstone was commonly used in many of the monuments of Cambodia (Figures 30 and 31).
Several abandoned ancient quarries for grayish blue sandstone were opened on a sandstone outcrop covering an area of about 6 km$^2$ located 2 km to the northeast of Boeung Meala temple of Svay Leu district, Siemreap province, where the grayish sandstone forms a small hill of about 15 m high at the southern foothill of Kulen mountain at an altidude between 90-100 m above sea level (Figure 32). The biggest pit is 300 meters long, 60 m to 70 m wide and 4 to 5 m deep (Figure 33). Two new quarries for sandstone to use in restoration of ancient monuments were opened about 1 km east of the above ancient quarries (Figure 34).

This sandstone is compact and contains a few thin conglomeratic beds. The grayish blue sandstone layer occupies the lower part of the J3K1 sandstone formation and, in most places, does not appear to the surface.

**Figure 30.** This Chao Say Tevada temple, like many other temples, is built from grayish blue arkosic sandstone.

**Figure 31.** Bas relief of Bayon temple scupted on grayish blue sandstone blocks.
Figure 32. Location map of grayish blue sandstone quarries.

Figure 33. Ancient quarry for sandstone.
Figure 34. Sandstone mining for the restoration of ancient monuments.

Red fine-grained sandstone

A good example of ancient monuments built from red sandstone is the Banteay Srey temple, located in Banteay Srey district of Siemreap province, which is very famous for the intricacy of its beautiful carving (Figure 35). The red arkosic sandstone is from a stratigraphic sequence of the Upper Jurassic-Lower Cretaceous sandstone formation that forms the massif of Kulen, Dangrek, Tbeng and the Cardamoms mountain range of Cambodia (Figure 36). Outcrops of the red sandstone sequence are well exposed at the Phnom Chunhchaing sandstone quarry of Banteay Mean Chey province. No ancient quarry for this red sandstone has been observed in Cambodia.

Figure 35. Banteay Srey temple is made from red sandstone (photo courtesy of Shinji Tsukawaki).
Bluish grey quartzitic sandstone

The use of bluish grey quartzitic sandstone in building ancient monuments was very limited. In the Angkor Wat Monument complex, this sandstone can be seen only in towers of the Prasat Takeo temple in the Angkor Wat monument complex area (Figures 37 and 38).

To the naked eye, the rock is a light bluish grey, fine grained and compact sandstone. Under the microscope, the sandstone is a quartzitic sandstone with cement composed mainly of microcrystals of quartz and a small amount of clay minerals. This sandstone is strongly resistant to weathering and very hard for carving.

Bluish grey quartzitic sandstone occupies the lowermost part of the Upper Jurassic sandstone series and might be overlain by the above cited greyish blue arkosic sandstone. An outcrop of this quartzitic sandstone is observed near Tbeng Mean Chey town, where it overlies the red series (Terrain Rouge) of carbonaceous shale, sandstone and marl of Lower-Middle Jurassic.

Figure 36. Location maps of the three sandstone type outcrops.
Figure 37. Prasat Takeo, in which quartzitic sandstone was used in building of its towers.

Figure 38. Towers on top of Prasat Takeo temple. The upper part made from quartzitic sandstone is more resistant to weathering than the lower part, which was built from common arkosic sandstone.
3.4 Black slate materials

Beside sandstone, black slate was also used by ancient Khmer people in making different objects and carving. In some temples, in particular, those of the southern group of temples (Phnom Da, Phnom Chiso, Tonle Bati), the black slate was sculpted into Yonis and Linga and also used as pedestals for statues (Figure 39). This black slate is a hornfelsic shale originated from contact metamorphism. A deposit of this black slate is observed in Angkor Borei mountain, where a granitic intrusion is seen in the Triassic sandstone and shale series.

![Figure 39. Yonis made from black slate found in Prasat Phnom Da.](image)

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Cover photo: Borobudur Temple, Central Java.
Stone Heritage of Indonesia

Sinung Baskoro

1. Introduction

The Indonesian Archipelago comprises a vast group of islands and islets strung out along the equator, spanning the Asian and Australian continents and extending between latitudes 6° north and 11° south, and longitudes 95° and 141° east. The many islands stand like sentries guarding the sea avenues that link the Pacific Ocean with the Indian Ocean. Due to the archipelago’s location above a zone of the earth’s crust where two of the world’s great mountain belts -the Circum-Pacific and the Tethyan (Mediterranean-Himalayan) Mountain Systems- meet, the Indonesian Archipelago occupies one of the most active volcanotectonic regions in the world where, even today, active mountain-building still takes place. Indonesia possesses more than 400 volcanoes, 127 of which are still active.

Indonesia is the largest archipelago in the world to form a single state. According to the current official count it consists of 13,466 islands and islets, with a land area of 1.92 million km² and sea area of 3.26 million km² (after Geospatial Information Agency), which stretches from west to east for 6,400 km. It is flanked by the Asian and Australian Continents and the Pacific and Indian Oceans.

Located in one of the earth’s most geologically active zones in the earth at the confluence of the Eurasian, Pacific and Indo-Australian Plates, Indonesia is very vulnerable to the motion and collision between the plates which can result in earthquake and volcanic activity. A great variety of rocks and minerals are found within the country. The geology of Indonesia is summarized on the map below (Figure 1).

The cultural history of Indonesia can be said to have begun at least two million years ago, for that is the date ascribed to the hominid fossils found in 1809 by Eugene Dubois near the village of Trinil, East Java. Java Man, as the remains were called, was allotted by the German zoologist Ernst Haeckel, later in the 19th century, to the genus Pithecanthropus, meaning ‘ape-man’ but; once it was established that Java Man was part of the ancestral tree of modern human beings, Homo sapiens, the fossils were reclassified as belonging to the species Homo erectus.

Indonesia has a long history of stone usage from 2,000,000 BC until the present day. The pre-historic ages can be divided into the Paleolithic Age until the Neolithic Age.
The megalithic culture appeared after the Neolithic Age and thrived in the Metal Age. The subsequent historic ages began to emerge with a stone inscription in AD 400.

There are so many amazing temples found in Indonesia, largely concentrated on Java Island (Figure 2). Although the exact number cannot be determined, it certainly exceeds 1000 so Indonesia deserves a nickname as “the land of 1001 temples”. Those temples are evidence of the Hindu-Buddhist cultural period of civilization experienced by Indonesia. This period is often referred to as the Indonesian Classical Culture Period. The temples are spread across several regions of the country. In Java there are Batu Jaya Temple, Borobudur Temple, Prambanan Temple, Candi Ijo Temple, Candi Lumbung Temple, Sewu Temple, Jago Temple, Kidal Temple, Panataran Temple, and many others. In Sumatra there are also several temples such as Bareleng Temple, Bahal Temple, and Muara Jambi Temple. In Bali, there is Gunung Kawi Temple.

The native Indonesians have their own distinct tribal stone sculpture styles, usually created to depict ancestors, deities and animals. Pre-Hindu-Buddhist and pre-Islamic sculptures can be traced in the artworks of indigenous Indonesian tribes.

The stone sculpture art form particularly flourished in the eighth to tenth centuries in Java and Bali, which demonstrate the influences of Hindu-Buddhist culture. Both stand-alone works of art and also those incorporated into temples are widely evident. The most notable sculptures of the classical Hindu-Buddhist era in Indonesia are the hundreds of meters of relief and hundreds of stone Buddhas at the temple of Borobudur in central Java. Approximately two miles of exquisite relief sculpture tell the story of the life of Buddha and illustrate his teachings. The temple was originally home to 504 statues of the seated Buddha. This site, as with others in central Java, shows a clear Indian influence. The examples of notable Indonesian Hindu-Buddhist
sculptures are; the statues of Hindu deities; Shiva, Vishnu, Brahma, Durga, Ganesha and Agastya enthroned in rooms of the Prambanan Temples, the Vishnu mounting Garuda statue of king Airlangga (Garuda Wisnu Kencana), the exquisite statue of Eastern Javanese Prajnaparamita and 3.7 meters tall Dvarapala dating from the Singhasari period, and also the grand statue of Bhairava Adityawarman discovered in Sumatra.

![Figure 2. Location map of stone heritage sites in this chapter.](image)

Chapter 2. Stone Heritage of Indonesia

2. Stone Heritage of the Pre-historic Age (2,000,000 BC – 400 AD)

2.1 Paleolithic (Old Stone) Age

*Homo erectus* is known to utilize simple coarse Palaeolithic stone tools and also shell tools, discovered in Sangiran and Ngandong. Cut mark analyses of Pleistocene mammalian fossils documented 18 cut marks inflicted by tools of thick clamshell flakes on two bovid bones created during butchery and found in the Pucangan Formation (1.6 and 1.5 million years old) in Sangiran. These cut marks record the use of the first tools in Sangiran and the oldest evidence of shell tool use in the world.

**Sangiran Early Man Site**

Excavations here from 1936 to 1941 led to the discovery of the first hominin fossil at this site. Later, 50 fossils of *Meganthropus* palaeo and *Pithecanthropus erectus/Homo erectus* were found - half of all the world’s known hominin fossils. Inhabited for the past one and a half million years, Sangiran is the most complete archaeological site of ancient humans in Asia with an area of 56 square kilometers situated at the foot of Mount Lawu in the Solo river valley in Sragen Regency, Central Java. It is one of the key sites for understanding early human evolution.

**Pacitanian**

In 1935, Ralph von Koenigswald and M. W. F. Tweedie undertook intensive research on the Solo River upstream in a southern mountainous area of Java. They discovered
an abundance of tools that appear to have originated from the Paleolithic age in the Baksoka riverbed and in a boulder conglomerate in the bank of the river, 3-4 meters above the bed, assigned to an industry widely known as the Pacitanian.

The Pacitan tools comprise many choppers and chopping tools, made of silicified tuff, fossil wood and silicified limestone (Figure 3). Hand axes are also present as well as flakes, which are generally of large dimensions and, rarely, a hand-held chisel. The age of these tools is based on subsequent research that concluded that Pacitan tools are derived from Upper Pleistocene time about 50,000 years ago. Wajak Man could very well have been the manufacturer of the Pacitanian tools (Bartstra and Basoeki, 1989).

Figure 3. Pacitanian tools, Baksoka River, Pacitan, East Java (photo courtesy of Awang Satyana).

2.2 Mesolithic (Middle Stone) Age

After the turn of the Pleistocene epoch to the age of the Holocene epoch, Palaeolithic culture did not just disappear, but experienced further development. In Indonesia, the Palaeolithic culture gained a new influence by the flow of a new culture from mainland Asia. The New culture that arose is called Mesolithic. The evidence of its influence is found in many places: Sumatra, Java, Kalimantan, Sulawesi and Flores. From these relics it can be seen that at that time people still lived by hunting and fishing (food-gathering). But some people already had a permanent home, so it could be possible to live though simple small-scale farming. Traces of dwellings are found on the beach (Kjokkenmoddinger) and in caves (Abris sous roche) with traces of many cultures.

Research on shell mounds produced many results in which different types of hand-held axes and choppers (hand-held axes of the Paleolithic) were discovered. Handheld axes found in the shell mounds are called pebble-axes in Sumatra. The shape of the
Mesolithic pebble-axes is much more elaborate than those of the Palaeolithic Age and proves the development of the technique for shaping stones.

**Sumatralith (Pebble Culture)**

In 1925, Dr. P.V. Van Stein Callenfels undertook research on the shell mounds and found handheld axes. The axes found in the shells of the hill are called pebble/handheld axes of Sumatra (Sumatralith) (Figure 4, left) according to the location of the discovery in Sumatra Island, Indonesia. The material to make these axes is from broken river stone.

**Toalian (Flakes Culture)**

Two researchers from Switzerland, Frits Sarasin and Paul Sarasin conducted research in the caves of Lamoncong, South Sulawesi, in 1893-1896. The caves were still inhabited by Toala tribes. They both managed to find tool flakes, jagged arrowheads (Figure 4, right) and other tools of bone.

Based on the tools found, Van Stein Callenfels concluded that Toala culture is a Mesolithic culture. Tools that resemble Toalian are also found in Flores, Rote and Timor (East Nusa Tenggara).

**Bandung Microlith Culture**

In Bandung, West Java, in Pawon Cave, Dago, and Karsamanik Hill some small backed flakes of beautiful black stone, obsidian, were found from the well-known sources of Gunung Kendan in Nagreg and Kampung Rejeng in Garut.

![Figure 4. Left: Sumatralith stone tools, right: Maros point, Toalian (Soebadio et al., 2002).](image)

**2.3 Neolithic (New Stone) Age**

The polished stone tools of the Neolithic culture, such as polished stone axe and stone hoe, were developed by Austronesian people in the Indonesian archipelago. Also during this period in Indonesia, large stone structures of a megalithic culture also flourished in the archipelago.

The New Stone Age in Indonesia has long been recognized to have produced stone tools such as axes and hatchet shaped square tools with high-grade grinding and polishing techniques replacing cut and flake methods. This resulted in Neolithic rectangular axes (Figure 5, left) found in Sumatra, Java, Bali, Kalimantan, Nusa
Tenggara, and Maluku. While the oval axe (Figure 5, middle) is found in Eastern Indonesia, like Papua, Leti, Tanimbar, Seram, Gorong and Minahasa. The Neolithic jewelry made of precious stone in the form of bracelets (Figure 5, right) has been found in Tasikmalaya, Cirebon and Bandung amongst other types of jewelry such as bracelets, necklaces, beads and earrings. The materials used to make these are beautiful stones, like agate, chalcedony and jasper.

![Figure 5](image_url)

**Figure 5.** Left: Rectangular axe is made of precious stone, middle: Oval axes are made of green/black stone, right: Stone bracelets are made of chalcedony (Soebadio et al., 2002).

### 2.4 Megalithic Culture

Megalithic culture is a culture that produced the larger stone buildings that appeared since the Neolithic Age and thrived in the Metal Age. According to Von Heine Geldern, megalithic culture spread to Indonesia in two waves: Old Megalith, spread to Indonesia in the Neolithic Age (2500 - 1500 BC) and was brought by supporters of the Square Axe Culture (Proto-Malay), with structures such as menhirs, step pyramid structures and static statues; Young Megalith, spread to Indonesia in the Bronze Age (1000 - 100 BC) brought by supporters of Dong Son Culture (Deutero Malay), with grave stones, dolmens, sarcophagus and dynamic statues. Megalith sites such as menhirs, dolmens, statues, burial sites, and paintings in caves cliff niches are scattered across Indonesia, from west to east. Stone tomb or a sarcophagus can be found in Sumatra, Bali, Kalimantan, Sulawesi, Bali and Nusa Tenggara.

The Indonesian archipelago is the host of Austronesian megalith culture in the past and present. Megalith culture that still exists can be found in Nias, an island off the west coast of North Sumatra, Batak culture in the interior of North Sumatra, Sumba Island in East Nusa Tenggara, as well as Toraja culture in the interior of South Sulawesi. Megalith culture is maintained, isolated and undisturbed until the late 19th century. Several megalith sites and structures are also found throughout Indonesia. Menhirs, dolmens, stone tables, ancestral stone statues, and step-pyramid structure were discovered in various sites in Java, Sumatra, Sulawesi, and the Lesser Sunda Islands.

“Punden Berundak” (step-pyramid structure) and menhirs can be found in Paguyangan Cisolok and Gunung Padang, West Java. Cipari megalith site also in West Java displayed monolith, stone terraces, and sarcophagus. “Punden Berundak” is believed to be the predecessor and basic design of later Hindu-Buddhist temples structure in
Java after the adoption of Hinduism and Buddhism by native population. The 8th century Borobudur and 15th-century Candi Sukuh featured the “Punden Berundak”.

Lore Lindu National Park in Central Sulawesi houses ancient megalith relics such as ancestral stone statues. Most of them are located in the Bada, Besoa and Napu valleys. Living megalith cultures can be found on Nias, an isolated island off the western coast of North Sumatra, as well as among the Batak people in the interior of North Sumatra, on Sumba Island in East Nusa Tenggara and Toraja people from the interior of South Sulawesi. These megalith cultures remained, preserved, isolated and undisturbed well into the late 19th century. One example of the megalithic heritage is monolith from Toraja (Figure 6).

![Figure 6. Torajan Monolith, Rantepao, Tana Toraja, South Sulawesi (Wikipedia).](image)

**Waruga Cemetery, Sawangan, Minahasa, North Sulawesi**

Waruga are stone sarcophagi used by the Minahasa tribes in which to place their dead in a squatting position. The Waruga Park is located in the village of Sawangan (Figure 7), and at the Airmadidi sub-district, some 40 kilometers from Manado. Based on local belief, these graves are made of stone carved to resemble a house, a tradition kept since 1600 AD. The graves vary, depending on the profession or social status of the person buried.

There are 144 “dotu” or clans gathered together at the waruga park in Sawangan, whose original locations were previously spread out throughout several villages in the Minahasa district, but these have now been gathered in the waruga compound at Sawangan (Figure 7) and nearby Airmadidi.
Waruga is the grave or tomb of the ancestors of Minahasa. Made of stone and they consist of two parts; the top is shaped like a triangle and the lower box-shaped section contains an empty space (the body cavity). Each part is made of a single stone (monolith). Inside the body cavity a grave waruga contained the body of the deceased person with the corpse in a squat position like a baby in the mother's womb before birth. If the remains are male, the arms are in the locked position (key hand) and for females in a fist.

Figure 7. Waruga, Sawangan, Minahasa, North Sulawesi (photo courtesy of Deni Sugandi).

Pasemah Megalithic Site, Pagaralam-Lahat, South Sumatra

The Pasemah (Besemah) Megalithic Site, located in the Pasemah Highlands in the Bukit Barisan Range, South Sumatra, reflects megalithic cultural traditions. It is considered to be one of the most remote and mysterious sites of Southeast Asia. In the area between Pagaralam and Lahat, there are about 26 sites that include stone tombs (Figure 8, left), carved boulders and terraced sanctuaries. The structures which date back to AD 100 are a collection that demonstrates the monumental symbolic culture of the Sumatrans. The stone art in this area is unique, rare and consists of heroic figures with dramatic facial expressions (Figure 8, right). The megalithic heritage in Pasemah displays many variations. Based on a survey conducted by researchers from the Archaeological Center in Palembang, Budi Wiyana, nineteen megalithic sites either, clustered or dispersed, have been found.
Figure 8. Stone tomb (left) and stone art (right) made of andesite stone in Tanjung Aro Site (photos courtesy of Oki Oktariadi).

Napu - Besoa - Bada Valley Megalithic Sites, Poso, Central Sulawesi

One area with a sufficient distribution of artifacts of the rich megalithic cultural legacy is Lore Lindu National Park, which stretches along the Napu Valley, Besoa Valley and Bada Valley - Central Sulawesi. Here the testimony of history demonstrates that high culture has colored the life of the peoples in the archipelago.

Central Sulawesi has some 1,451 statues from around 4000-3000 BC still in their natural sites scattered in the Napu Valley, Besoa Valley and Bada Valley in the District of North Lore and South Lore, Poso Regency. This megalithic area is estimated as the most extensive and diverse in Indonesia. Here we can witness the statues or the unique stone sculptures from prehistoric times sprawling in the savanna. For examples, Pokekea site in Napu Valley (Figure 9, left); Tadulako statue in Besoa Valley (Figure 9, middle); and Palindo statue in Bada Valley (Figure 9, right).

Figure 9. Pokekea Site in Napu Valley (left) and Tadulako Statue in Besoa Valley is made of granite and is 196 cm high (middle) (photos courtesy of Tubagus Dedi). Right: Palindo/Sepe Statue in Bada Valley made of granite and 4.1 m high (photo courtesy of Titi Bachtiar).

Bena Megalithic Village, Ngada, Flores, East Nusa Tenggara

Bena Village is one of the megalithic villages located in Ngada District, East Nusa Tenggara. Its presence at the foot of Mount Inerie, is a hallmark of the old society as a devotee of the mountain of the Gods. According to the villagers, they believe in the existence of Yeta, god of the mountain who protects their village. With its impressive
stone formations and ancestral shrines (Figure 10), as well as traditional houses, Bena has turned into a signpost for Ngada culture.

The village currently comprises approximately 40 houses that surround each other. The village stretches from north to south and the entrance to the village is only from the north. The southern end is at the top edge of a steep cliff. Amidst the village or nearby fields, there are several buildings that villagers call bhaga or ngadhu. Bhaga looks like a small cottage (without occupants), while Ngadhu are single colonnaded buildings and fiber-roofed huts shaped like a palm for shade. Ngadhu usually have a pole of a special type of hard wood because this also functions as a sacrificial animal gallows during traditional feasts.

Figure 10. Bena Megalithic Village with stone formations and ancestral shrines (photo courtesy of Deni Sugandi).

Gunung Padang Megalithic Site, Cianjur, West Java

Gunung Padang Megalithic Site is located in Cianjur regency, West Java Province (Figure 11). It constitutes the remains of the largest ancient megalithic site in all of Southeastern Asia. The stones used here are andesite and columnar jointed basalt. The age is about 4000 BC.

The existence of the site was mentioned in Rapporten van de Oudheidkundige Dienst (ROD, “Report of the Department of Antiquities”) in 1914. The Dutch historian N.J. Krom also mentioned it in 1949. Employees of the National Archeology Research Centre visited the site in 1979 to study its archaeology, history, and geology.

According to ancient beliefs stretching back to antiquity, Gunung Padang is a sacred place. Gunung Padang means in the local Sundanese language “Mountain of Light” or “Mountain of Enlightenment.”
The megalithic complex – arranged across five terraces – is covered with strikingly shaped and massive columns of volcanic rock, in complicated patterns of lines and shapes. The columns – perfectly suited for the creation of even giant structures – represent a unique geological formation of columnar basalt occurring in only a few places in the world.

Located at 885 metres above sea level, the site covers a hill in a series of terraces bordered by retaining walls of stone that are accessed by about 400 successive andesite steps rising about 95 metres. It is covered with massive rectangular stones of volcanic origin. The Sundanese people consider the site sacred and believe it was the result of King Siliwangi’s attempt to build a palace in one night. The asymmetric “Punden Berundak” faces northwest, to Mount Gede and was constructed for the purpose of worship. It is located in a position that has been noted for its geomantic and astrological factors. Based on various dating techniques, the site was completed by 5000 BC and quite likely much earlier. There are even preliminary indications that the hill site may itself be an ancient pyramid construction.

Building materials at the site are large boulders of andesite, basaltic andesite, and naturally occurring basalt pillars with a length of about one meter and dominant diameter of 20 cm. The multi-sided rock pillars have the dominant form of four-sided (tetragonal) or five-sided (pentagonal) stone pillars. Each terrace has a different stone building pattern intended for various functions. The first terrace is the widest terrace with the most number of rocks, following which, as terraces reduce so do the number of rocks, with terraces 3 to 5 having few rocks.

Figure 11. Gunung Padang Megalithic Site, Cianjur, West Java (photo courtesy of Oki Oktariadi).

Mount Padang megalithic site has been built in harmony with geology; because it is built utilizing the local hill ridge/peak basaltic andesite and basaltic lava of Pliocene age (2.1 million years ago), which includes columns of andesite and basalt that have
detached naturally along the columnar joints which were formed when the original lava cooled. The stones were then mined by humans of that time to build “Punden Berundak”

Site “Punden Berundak” of Mount Padang is asymmetric, in contrast to the symmetrical “Punden Berundak” of Borobudur, also in contrast to other symmetric “Punden Berundak” found in West Java as at the site of Sibedug in Lebak, Banten. A symmetrical “Punden Berundak” does not indicate that development is concerned; “Punden” indicates only the direction in which the building is facing.

3. Stone Heritage Sites of Historic Age (AD 400 – Present)
3.1 Ancient Age (Early Kingdoms): Hindu-Buddhist Civilizations

Kutai Kingdom, East Kalimantan (4th Century)

Of the early influences that have made their impact felt on almost every aspect of life, at least in parts of Indonesia, one of the most important was that of Hinduism. In a number of regions such as Bali and Java, that influence is clearly discernible even today in the traditional ceremonies and customs as well as in the various artistic and cultural expressions of those areas.

Some of the oldest relics attesting to the early influence of Hinduism in Indonesia are found in the Kutai regency of East Kalimantan. Stone statues and inscriptions found near Muarakaman on the bank of the Mahakam, dating from around 400 AD (Figure 12), provide evidence of the existence of early Hindu settlements in that area. One of those inscriptions, in Sanskrit and written in the old Palawa script of India, proclaims that Mulawarman, one of the first Hindu kings to have ruled over the area, at one time presented 1,000 head of cattle as well as parcels of land to his priests. The Muarakaman inscriptions make it clear that the kingdom was established by Mulawarman’s father, Asyawarman, who had a father by the name of Kundungga. Scholars believe those early kings to be indigenous Indonesians, despite the fact that, with the exception of Kundungga, they carried Indian names.

From an account by Prapanca, chronicler to the court of Majapahit, it is evident that in later centuries Kutai became part of the power sphere of that mighty East Java based empire.

Tarumanegara Kingdom, West Java (4th – 6th Century)

As far as is known, Tarumanegara was the oldest kingdom to have wielded power on the island of Java. It probably had its center in the Bogor area of West Java, where stone inscriptions were found in Ciaruteun (Figure 13). One of those stones bears the imprint of a huge foot and the legend, “This footprint, alike to the footprint of the God Wisnu, belongs to Purnawarman, the courageous ruler of Tarumanegara who dominates the world”. Like his Kutai counterpart, Purnawarman also donated 1,000 head of cattle to his priests. Another inscription proclaims that on the king’s orders a 20 kilometer long ditch was dug and completed in 21 days. It probably served for irrigation and to prevent floods.
Most of the population of Tarumanegara worshipped the Hindu God Wisnu, the savior. A curious fact is that in West Java no major Hindu or Buddhist temples or monuments were ever found.

**Figure 12.** Kutai inscription, Muarakaman, East Kalimantan. This is the oldest Indonesia written record extant, dating from AD 400 (Soebadio et al., 2002).

**Figure 13.** Ciaruteun inscription stone of the Tarumanegara Kingdom in 5th century, found in Bogor, West Java (Wikipedia).
Medang (Old Mataram) Kingdom, Central Java (7th – 10th Century)

The old kingdom that existed on Central Java was Kalingga, established at around AD 600 and ruled by a queen named Sima, who embraced the Hindu faith. The kingdom was, however, short-lived and by AD 700 it had ceased to exist.

At the beginning of the 8th century, a new kingdom rose in Medangkamulan, in the area of what is now Semarang. Bearing the name of Mataram, it flourished under a succession of rulers, one of the best known of whom was Sanjaya. The son and heir to the throne of Sahana, a king known for his fairness and wisdom, Sanjaya later made himself remembered by subjugating Bali and other regions. Upon his death somewhere in the middle of that same century, Sanjaya was succeeded by Rakai Panangkaran.

The Hindu kingdom of Mataram reached the pinnacle of its greatness under the rule of the kings of the Sailendra dynasty, when the people lived in peace and prosperity. The Sailendra’s were Buddhists and under their reign, some of Central Java’s most beautiful temples and monuments dedicated to the glory of Buddha were built. Among the best known today are Candi Kalasan and Candi Sewu, near Prambanan, Yogyakarta. The crowning glory of them all, however, is Borobudur in the Magelang highlands. All these shrines are believed to have been built from the year AD 825 onwards, during the reign of King Samaratungga.

Borobudur Temple Compounds, Magelang, Central Java

Many Hindu and Buddhist heritage structures for religious rituals can be found in Indonesia, particularly in Java. These include structures for sacred ritual activities, called “candi”, sacred ponds called “patirhan” and hermitage caves. One of the most important heritage sites, not only for Buddhists but also for the entire nation of Indonesia, is a sacred structure known as Candi Borobudur. It was declared a World Cultural Heritage site by UNESCO in 1991.

This famous Buddhist temple, Borobudur Temple Compounds (Figure 14), dating from the 8th and 9th centuries, is located in Magelang, Central Java. It was built in three tiers: a pyramidal base with five concentric square terraces, the trunk of a cone with three circular platforms and, at the top, a monumental stupa. The walls and balustrades are decorated with fine low reliefs (Figure 15, left), covering a total surface area of 2,500 m². Around the circular platforms are 72 openwork stupas, each containing a statue of the Buddha (Figure 15, right). The monument was restored with UNESCO’s help in the 1970s.

Candi Borobudur overall is very special in terms of size, stone formation techniques, quality and quantity of sculptural reliefs, the choice of stories, as well as its statues. The temple layout is square with an overall size of 123 x 123 meters, the original height (including chattra or the upper part of the peak chaitya) is 42 meters, without chattra it is only 31 meters.
Temples are usually constructed on either compacted soil foundations, or on specially made foundations often sunk into the ground, such as Prambanan Shiva Temple. However, the foundation of Candi Borobudur is different. The temple was constructed right on top of a hill, which is formed according to the desired shape of the temple. The outer part of the temple foundation was constructed at approximately one meter depth in the ground resting on a coral layer, while the structure above rests on several layers of stone.

There is tremendous technological progress in construction techniques indicated at this world cultural heritage site. The temple is composed of andesite blocks joined together
with “swallow tail” or “butterfly” pegs, and a thin layer of plaster between stones. Stones are strongly attached to each other. A weak foundation can have a detrimental effect on such a temple as well as the impact of weather and lichen on stones, thus Candi Borobudur has had to be restored twice.

Borobudur basic constituent materials, approximately 55,000 cubic meters of andesite, were taken from neighbouring stone quarries to build the monument. The andesite was a product of Merapi Volcano. The stone blocks were cut to size, transported to the site and laid without mortar. Knobs, indentations and dovetails were used to form joints between stones. Reliefs were created in situ after the building had been completed.

Prambanan Temple, Yogyakarta

Built in the 10th century Prambanan Temple (Candi Prambanan) is the largest temple compound dedicated to Shiva in Indonesia (Figure 16). It a compound consisting of three concentric courtyards and rising above the centre of the last of which are three temples decorated with reliefs illustrating the epic of the Ramayana, dedicated to the three great Hindu divinities (Shiva, Vishnu and Brahma) and three temples dedicated to the animals who serve them. Candi Prambanan is also known as Candi Rara Jonggrang, the local name for the Durga Mahisasuramardini statue (Figure 17, left), located in the entrance pavilion on the northern side of the temple. The other famous statue inside the temple is a Ganesha, son of Shiva and Durga (Figure 17, right). Ganesha is widely revered as the remover of obstacles, the patron of arts and sciences, and the deva of intellect and wisdom.

The central courtyard (110 x 110 metres) is surrounded by an enclosure fence and four entrance gates. contains eight temples including Candi Shiva the biggest temple facing east, flanked by Candi Wisnu on the north and Candi Brahma on the south. In front of the three temples are three smaller temples, initially called wahana temples, representing the ride of each god. The stones used to build the temples are andesite from the eruption of Merapi Volcano.

Figure 16. Prambanan Temple Compounds, Yogyakarta (Photo courtesy of Oki Oktariadi).
Gunung Kawi Temple, Tampaksiring, Bali

Gunung Kawi is a temple complex centered around royal tombs carved into stone cliffs in the 11th century (Figure 18). It is located amid scenic rice terraces in the Pakrisan river valley, Tampaksiring, Bali, near Ubud. There are more than 300 steps to climb.

The complex comprises 10 rock-cut candi (shrines). They stand in 7-meter-high (23 ft) sheltered niches cut into the sheer cliff face. These monuments are thought to be dedicated to King Anak Wungsu of the Udayana dynasty and to his favourite queens.

Gunung Kawi temple shrines are carved within a thick layer of ignimbrite (pyroclastic volcanic rock), the product of a volcanic eruption 20,000 years ago. The huge,
caldera-forming eruption produced 19 km³ ignimbrite which is now seen in cliffs up to 20 meters thick. The active volcano of Mount Batur (about 21 km from Gunung Kawi) can now be seen rising above the lake formed in one of the calderas.

Singasari Kingdom, Malang, East Java (12th – 13th Century)

Not much remains of the once powerful 13th century East Java Kingdom of Singasari. Only remaining are an unfinished Singasari temple (Figure 19, left) built in 1304 and two giant guardian statues that once stood guard in front of the palace of this great kingdom known as Dvarapala.

Dvarapala Statue, Singasari, East Java

Dvarapala is a door or gate guardian often portrayed as a warrior or fearsome asura giant, usually armed with a weapon, the most common being a gadha mace (Figure 19, right). The statue of dvarapala is a widespread architectural element throughout the Hindu and Buddhist cultures, as well as in the areas, like Java, influenced by those cultures.

Dvarapalas as an architectural feature have their origin in tutelary deities, like Yaksha and warrior figures, such as Acala, of the local popular religion. Today some dvarapalas are even figures of policemen or soldiers standing guard.

These statues were traditionally placed outside Hindu or Buddhist temples, as well as other structures like royal palaces, to protect the holy places inside. A dvarapala is usually portrayed as a fearsome armed guardian looking like a demon, but at the gates of Buddhist temples in Sri Lanka, dvarapalas often display average human features. In other instances a fierce-looking nāga snake figure may perform the same function.

Figure 19. Left: Singasari Temple, Malang, East Java (photo courtesy of Oki Oktariadi). Right: Dvarapala Statue, Singasari Temple (Wikipedia).

The sculptures in Java and Bali, usually carved from andesite stone, portray the dvarapala as fearsome danavas or daitya (asura race) with a rather bulky physique in semi kneeling position and holding a club. The largest dvarapala stone statue in Java, a dvarapala of the Singasari period, is 3.7 meters tall. The traditional dvarapalas of
Cambodia and Thailand, on the other hand, are leaner and portrayed in a standing position holding the club downward in the center.

Batu Basurek, Tanah Datar, West Sumatra

Batu Basurek is a relic of history, which proves the past existence and glory of the Pagaruyung Kingdom in West Sumatra. It is an andesite stone with inscriptions in the old Palava script of India, bearing the legend of Adityawarman in the year 1347. Literally, "Batu Basurek" itself means "The Written Stone". The stone is 25 cm wide, 80 cm high, and 10 cm thick (Figure 20). Erected above King Adityawarman's resting place centuries ago, this stone was rediscovered in December 1880. The inscription tells about Adityawarman's heritage; due to his services to Majapahit Kingdom, Adityawarman became a king in Dharmasraya and moved his kingdom from Siguntur Sawahlunto to Pagaruyung.

Batu Basurek lies about 4 kilometers from Batusangkar the capital of Tanah Datar regency, in the West Sumatra Province.

Figure 20. Batu Basurek, Tanah Datar, West Sumatra.

3.2 New Age (Rise of Islamic States): Early Islamic Kingdoms

Siti Fatimah binti Maimun Graveyard, Gresik, East Java

According to archeological data, the tomb of "Siti Fatimah binti Maimun" is the oldest Islamic tomb in Southeast Asia. His tomb is unique because the shape of the cone of the walls and roof are all made of white limestone from the Paciran Formation of Pleistocene age (Figure 21).
Figure 21. Siti Fatimah binti Maimun Graveyard, Gresik, East Java.

Londa and Lemo Cemetery of Tana Toraja, South Sulawesi

Londa is a complex of ancient tombs located in a natural cave. On the outside of the cave are typical wooden dolls Toraja. Lemo are stone graves in the form of burrows carved in a cliff wall in which to bury the bodies of the dead. On the site that was built around the 16th century, there are approximately 75 lemo and 40 grave statues of people who have died (Figure 22).

Tana Toraja, the famed “Land of The Heavenly Kings”, lies about 328 km north of Makassar, in the central highlands of South Sulawesi. On the walls of a steep hill, coffins hang from cracks in the rocky face of limestone (karst). Lifelike wooden sculptures or effigies complete with clothes, stand in neat rows in cracks hollowed out in the cliff faces, very much like the windows & balconies of a house. These cave cemetery figures represent the dead who are buried there. Not far from this hanging grave lies a burial cave many hundreds of years old.

3.3 Modern Age (Colonization Era & Emergence of Indonesia)

Japanese Bunker, Bukittinggi, West Sumatra

The Japanese bunker in the town of Bukittinggi (Figure 23) was built by Indonesians under forced labor for the Japanese soldiers who occupied Indonesia from 1942 to 1945. This 1,470 meter long underground bunker is 40 meters below Ngarai Sianok (Sianok canyon). There are 21 tunnels in the bunker which were used to store ammunition and as residences, meeting rooms, the Romusha (forced labourer) dining room, kitchen, prison, hearing room, torture room, espionage room, ambush room, and the escape gate.
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Figure 22. Lemo Stone Cemetery, Makale, Toraja (photo courtesy of Oki Oktariadi).

Figure 23. Japanese Bunker, Bukittinggi, West Sumatra (Wikipedia).

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Cover photo: Stone wall of Kanazawa Castle, Ishikawa Prefecture (photo by Toshihiro Uchida).
1. Introduction

The Japanese Islands, composed of an extensive variety of rocks and minerals (Figure 1), are located in one of the most geologically active zones of the earth. Since ancient times, Japanese people have taken advantage of this geological environment by using various rock and minerals for small stone implements and ornaments as well as for tombstones, large stone walls of castles, temples, shrines and the facing for modern buildings.

Figure 1. Index geological map showing introduced stone heritage sites in Honshu (Main Island); pink: Cretaceous granite, green: mainly pre-Tertiary sedimentary rocks, yellow: Tertiary sedimentary rocks, red: Tertiary igneous rocks, brown: Quaternary volcanic rocks, light blue: Quaternary sediments.
Some typical objects and sites illustrating the stone heritage of Japan will be introduced in the following sections in temporal order and in the order of the size of the stones used from smaller to larger.

2. Stone Heritage in the Pre-historic Period

The Japanese Paleolithic period began around 50,000 BC, when the earliest stone tools were probably made, and continued to around 14,000 BC. First, we will introduce two examples of small but important examples of the stone heritage of this period.

2.1 Shirataki Obsidian in Hokkaido

During the Plio-Pleistocene epoch (5Ma-1.7Ma), large-volume pyroclastic flows had been erupted and a number of volcanic calderas formed in the northeastern part of Hokkaido, including the Shirataki area (Shirataki National Geo-park) in the Monbetsu-Kamishihoro Graben. Such volcanic activity formed the Shirataki obsidian, a product of monogenetic volcanoes in the E-W tensional stress field (Wada, 2011) (Figure 2).

In the late Pleistocene and early Holocene times, ancient people made small implements and ornaments of obsidian. Shirataki, Engaru Town, northern Hokkaido was the largest obsidian producer and implement factory in Paleolithic Japan where people made arrowheads, knives and so on (Figure 3). Obsidian implements from this area are found as far as in Sakhalin and along the Amur River in Siberia and are believed to have been used as a means of trade in a fashion similar to monies in later civilizations.

In this locality, effusion of dacite and rhyolite formed a caldera during the late Pliocene time, namely the Horoka-Yubetsu basin. Subsequently, volcanic activity of aphyric rhyolite magma started, and explosive eruption in the caldera formed several pyroclastic lake deposits. Then, aphyric rhyolite lava effused and flowed down into the caldera lake where it was autobrecciated by contact with water. The caldera lake
became buried by pyroclastic materials, and after that the volcanic activity changed to lava eruption on to a land surface. At and inside the caldera rim, obsidian lava flows were erupted some 2.2 million years ago. These obsidian lavas consist of ten flows called the Shirataki Obsidian Lava Complex. Shirataki obsidian is almost aphyric, composed of glass (> 98 vol%) and a small amount of crystalline minerals. The obsidian consists of two types; one is a jet-black lustre type without phenocrysts and the other is a perlitic type with rare plagioclase phenocrysts (0.4-1.0 mm) (Figure 4). Tiny minerals in obsidian are called microlites, composed of plagioclase (< 200 µm), magnetite (< 70 µm), and biotite (< 10 µm). The perlitic type contains 1-2 vol% plagioclase microlites and perlitic texture is due to the presence of such plagioclase microlites. Biotite is observed only in obsidian samples of the Tokachi-Ishizawa lava. Both types contain magnetite and < 20µm plagioclase microlites.

**Figure 4.** Left: specimen and microscopic images of jet-lustre type and perlitic type obsidian. Right: oxidised obsidian “Hana-Tokashi” (Wada, 2011).

**Obsidian with jet-black lustre at Hachigo-sawa, Hokkaido**

In the Akaishiyama upper lava at Hachigo-sawa (Figures 5 and 6), tiny spherulites constitute the flow structure. At the front face of the outcrop, these spherulites are aligned horizontally, while at the back left side they are aligned vertically (Figure 5, right).

Vesicular obsidian increases toward the lava interior. Rhyolite layer can be observed in the interior parts. Obsidian of the Hachigo-sawa outcrop is a member of Akaishiyama series. This obsidian with its jet-black lustre and glassy composition indicates high Fe values (AK-B in Figure 4).
2.2 Jade/Jadeite at Itoigawa, Niigata Prefecture, central Japan

Jade, an ornamental stone, is a common name depicting two different minerals: jadeite, a sodium-aluminum pyroxene, and nephrite, a tight aggregate of actinolite. Jadeite has about the same hardness as quartz. The jadeite found in Itoigawa City was formed in a metamorphic body about five hundred million years ago (Figures 7 and 8). The Itoigawa area is the only place in Japan where abundant jade is produced. Ancient people had already collected and processed such jade into ornaments in spite of its hardness and traded them over a wide area more than several thousand years ago.
Figure 7. Geological map around Itoigawa area, Central Japan (Takenouchi, 2004).

Figure 8. The formation process of Itoigawa Jadeite (Takenouchi, 2008).
Kotakigawa’s riverbed at the foot of Mt. Myojosan is the very place of the ‘Home of Jade’ and is called Kotakigawa Jade Gorge (Figures 9 and 10). Until quite recently all excavated jade artifacts were thought to be foreign products, but the discovery of jade rock at Kotakigawa River in 1938 completely overturned that theory.

Among the earliest known jade artifacts excavated from prehistoric sites are simple ornaments with bead, button, and tubular shapes (Figure 11). Tools such as hammers made of jade are also excavated. As metal-working technologies became available, the beauty of jade made it valuable for ornaments and decorative objects.

It is interesting to note that, “magatama” (Figure 11, right), a comma-shaped gem comprising mostly jade or agate, together with a sword and bronze-copper mirror, was one of the symbols of power among the influential clans of various regions in ancient Japan. The “three divine instruments” of the Emperor also consisted of sword, mirror and magatama and these are said to have been passed down through generations of the Imperial Family.
3. Stone Heritage of Historic Times

3.1 Archaeological Remains

Asuka, Nara Prefecture was one of the ancient capital cities in central-Southwest Japan in the 7th Century. Stone structures such as tombs, monuments and also some artifacts of unknown usage, mainly made of Cretaceous granitic rocks, were widely distributed there. Some of these are described below.

3.1.1 Ishibutai Kofun (stone stage)

In the Kofun (old burial mound) Period of Japan (250 to 538 AD), stone burial chambers were constructed in mounds for preservation against decay and protection from theft. For example, Ishibutai Kofun at Asuka is the largest known megalithic structure in Japan (Figure 12). It is about 7.7 m long, 3.5 m wide and 4.7 m high, occupying a space of 54 m². Furthermore, the Kofun, platform and moat, now lost through erosion, have been estimated to have covered an area of 85 m long. It was constructed at the beginning of the 7th Century from 30 stone blocks whose total weight is 2,300 tons. They were transported for a distance of 3 km from the stone quarries. The tomb is believed to be that of Soga-no-Umako (551?-626), a noble man of those days.

Ishibutai Kofun is a side corridor-type tomb and has a particularly long entrance path of 38 m, originally covered by a stone ceiling which has been now removed. A shallow drainage channel runs on the floor of the path. The inner chamber is 7.5 m long, 2.55 m wide and 4.8m high. The ceiling is formed by two huge stones. The weight of the north ceiling is about 60 tons and that of the south one about 77 tons.
3.1.2 Sakafune-ishi Remains

These are stone objects found on the mountain east of the ancient palace which was described in the Chronicles of Japan (Nihon-shoki) in 8th Century. The Sakafune-ishi made of granite (Figure 13, left) is located on a hill at Asuka. It is about 5.5 m long, 2.3 m wide and 1m high. Plate shaped depressions and grooves are engraved on the upper surface of the stone. The exact purpose is unknown but it is inferred to be a part of sake brewery or a pharmaceutical laboratory. In 2000, a newer Sakafune-ishi was excavated near the older one. It consists of a tortoise-shaped stone tank (about 2.4 m long and 2 m wide) and a rectangular tank (about 1.65 m long and 1 m wide), they are both made of granite (Figure 13, right). Other pumping apparatus is made of sandstone. Spring water was channeled to the rectangular stone tank through wooden ducts and stored there, then small amounts of water were conducted through small holes and entered the nose of the tortoise and accumulated in the tank on its back.

Figure 13. Sakafune-ishi; left: the older one, right: newly excavated one (photos by H. Kato).

3.1.3 Oni (Devil) Stone Monuments

The Oni-no-setchin (devil’s toilet) stone is a portion of a stone chamber from the latter half of the 7th Century, the Asuka Period (Figure 14). Although its eastern mound is lost, the stone chamber is considered to consist of three huge pieces of finely crafted
granite, namely the base section, cover and the portal. The Oni-no-setchin stone is the cover portion, and is considered to have fallen from the base section, which is called the Oni-no-manaita (Devil’s Cutting Board) stone. According to a legend, there used to be devils who could generate mist in order to make travelers lose their way. The devils dismembered the captured travelers on the manaita stone, then cooked and ate them. After the meal, it is said that they used the Oni-no-setchin to relieve themselves. The stones of these monuments are local Cretaceous granite which includes many black xenoliths as shown in Figure 14.

![Figure 14. Oni Stone Monuments; left: the Oni-no-setchin, right: the Oni-no-manaita (photos by H. Kato).]

3.1.4 Kame-ishi (tortoise-stone)

The size of Kame-ishi stone monument composed of Cretaceous granite is about 3.6~4.5 m × 2.1~2.7 m × 1.8~2 m (Figure 15). The upper part is in its original natural state, but the lower part was sculpted to make its tortoise-like form. The name of this stone is found in a temple document written in 1116 AD, while its purpose is unknown.

![Figure 15. Kame-ishi (photo by H. Kato).]
According to a legend, a long, long time ago, when the Nara Basin was covered by a lake, a catfish living in the Kawahara area attacked some snakes in Taima on the opposite shore. The battle ended in victory for the snakes who had sucked up the whole of the lake water. As a result, the Kawahara area was dry and all the tortoises in the lake died out. Villagers took pity on them and erected this gravestone. The stone is said to have originally faced north, thereafter east, and now it faces southwest. As the legend goes, when the stone faces west towards Taima, the Nara Basin would be flooded, turning into a muddy lake again.

3.2 Ishigaki (stone walls) of Some Typical Castles

Castles in Japan underwent many changes since ancient times. Some 25,000 castles are estimated to have existed before 1615, when the Tokugawa Shogunate not only restricted restoring existing castles but also strictly forbid new construction. At the end of the Edo era (1867) the number of castles decreased to less than 200.

The major controlling factor in stone wall construction is the existence of large rock masses within a transportable distance. The rocks of the stone walls of Osaka Castle are of Late Cretaceous granitoids and exceed 500,000 in number with the largest block weighing 108 tons. Those of Hikone Castle are Paleogene Koto Rhyolite and the stones of Edo (nowadays Tokyo) Castle, the present Imperial Palace, consist of late Quaternary andesite of Hakone Volcano.

3.2.1 Osaka Castle

Osaka is presently the third largest city by population in Japan. In the middle of the city, stands Osaka Castle. The castle was originally constructed in 1583 by Hideyoshi Toyotomi, a feudal warlord who successfully subjugated the entire country after the death of his liege lord. After his death, the castle was burned down in the Osaka Summer War in 1615 and was subsequently reconstructed by the Tokugawa shogunate between 1620 and 1629. The Main Tower was burnt down again by lightning in 1665 and the present tower was reconstructed with funds raised from the citizens in 1931. However, the stone walls of the castle remain the original feature of 1620s (Figure 16).

Reconstruction of massive stone wall

The maximum height of the stone walls is about 32 m, and the total length is 12 km constructed with more than 500,000 stone blocks. On the reconstruction, the Tokugawa shogunate ordered 64 feudal lords (Daimyo) of western Japan to engage in the project, which caused them to develop good quarries for stone for the walls. The feudal lords engraved their own family crests and seals on some of the wall stones that they contributed and more than 2,000 kinds of seals have been found on over 50,000 stones. These provide valuable clues in helping to identify the original quarries today (Figure 17).

Among the stones, there are some exceptionally large ones. The most symbolic five stones are estimated to weigh over 100 tons each and another 16 blocks over 50 tons. Such blocks were placed in the walls of the courtyards by each gate (Figure 18).
Figure 16. Stone walls of Osaka Castle remained unchanged during almost four centuries since it was reconstructed between 1620 and 1629 (South Outer Moat; photo by M. Fujita).

Figure 17. Inscriptions engraved on the stones of the South Outer Moat. Feudal lords assigned for construction work engraved their own marks to show their contribution: two parallel lines in a circle is for the Honda family of Yamato Takatori (now Nara Pref.) and eight smaller circles arranged around a large central circle is for the Hosokawa family of Buzen Kokura (now Fukuoka Pref.; photo by M. Fujita).
Figure 18. Symbolic large stones of the Osaka Castle complex (photos by M. Fujita): (a) Octopus Stone at the courtyard of Sakura Gate is the largest stone. It was quarried on Inujima in the Seto Inland Sea, Okayama Pref., (b) Higo Stone at the courtyard of Kyobashi Gate is the second, quarried on an island in the Seto Inland Sea, and (c) Ote Mitsuke Stone at courtyard of Ote Mon Gate (Main Entrance) is the fourth, quarried on Shodoshima in the Inland Sea, Kagawa Pref.

Many questions concerning the origin of the stones, how they were cut and transported, and how the stone walls were constructed have been well studied since 1959 (Osaka Castle Museum, 1988). The stone walls of Osaka Castle have great value in Japan’s cultural heritage, and display the most advanced construction techniques of the time.

Technical development of quarrying

Most of the stones used for the stone walls are granitoids which were quarried and transported from various areas in western Japan, not only on land such as Mikage, Ashiya, and Nishinomiya in the Rokko Mountains, Hyogo Prefecture, the Ikoma (Osaka and Nara Pref.) and Kasagi (Nara Pref.) mountains, but also from the islands of the Seto Inland Sea (Setonaikai), and some as far away as Kyushu (Figure 19). Most of them are Late Cretaceous, coarse-grained biotite granites and coarse-grained hornblende biotite granodiorites of the Sanyo and Ryoke belts which are widely distributed in Southwest Japan (Figure 19).
There is a geological reason why these granitoids were used: it lies in their weathering characteristics. Fresh granitoids contain micro-fractures which can be observed as systematic joints. Weathered granitoids, however, contain fresh granitoid cores surrounded by “lamination sheeting” (Figure 20) (Fujita, 2003). Fresh cores exposed by erosion were easily excavated by human power and could then be cut manually into rectangular blocks by experienced stonemasons who were well aware of systematic micro-cracks in the stones (Fujita and Yokoyama, 2010). The large rectangular stones were then transported from the quarries to the reconstruction site by Shura trailers on land and by ship (Figure 21).

The differences in stone walls dating from the Toyotomi and Tokugawa era respectively show that the technique of stone cutting greatly improved from 1580s to 1620s marking the changeover (Nakamura, 2005) (Figure 22) and thanks to the technical development, the stone walls of Osaka Castle still look beautiful and majestic.
Figure 20. Weathering structure of Yoshino Granodiorite, the Kamesaki Quarry in Iwagatani, eastern Shodoshima, Kagawa Prefecture (photos by M. Fujita).

Figure 21. Replica of "Shura" (wooden sled), a tool used to transport the stones in Osaka Castle Zanseki Memorial Park, northern Shodoshima (photo by M. Fujita).

Figure 22. Technical evolution of construction methods during four decades: (a) restored stone walls from the northern part of San-no-maru of Osaka Castle, Toyotomi Era in the 1580s, and (b) stone wall of the Kakushi-kuruwa Bailey of Osaka Castle, the Tokugawa Era in the 1620s (photos by M. Fujita).
Visiting the original quarry

There are quarries of the Tokugawa Era that still remain on islands of the Seto Inland Sea after four centuries. In particular, Shodoshima, Kagawa Prefecture is famous for producing high quality stone, and there are many quarry sites of the Tokugawa Era (Figure 23). The Iwagatani Quarry Ruins for Osaka Castle is the only ancient quarry site designated as a National Historic Relic Site in Japan (designated on Mar. 16, 1972) (Figure 24). A total of 1,612 cut stones with many chiseled pits, marks, and seals are abandoned in the quarries (Kitagaki, 2011).

**Figure 23.** Old quarry sites of Shodoshima shown on the geological map (modified from Yokoyama, 1984; Fujita, 2013). All the quarries coincide with the distribution of Late Cretaceous granitoids of the Sanyo and Ryoke belts and are located near the coast for transportation convenience.
Figure 24. Iwagatani Quarry Ruins for Osaka Castle, a national historic relic site, Shodoshima Island, Kagawa Prefecture (photos by M. Fujita). The quarry was used by the Kuroda family of Chikuzen (now Fukuoka Pref.). (a) Tofu-Ishi Quarry site, chiseled holes in a row and an engraved spiral (Kuroda’s family seal, seen on the right side of the rock), (b) Hachinin-Ishi Quarry site, (c) Tengu-Iwaiso Quarry site is located on the seashore, (d) Otengu Iwa, whose volume and weight are estimated 652m³ and 1,700t respectively, is the symbolic stone of the Tengu-Iwa Quarry site.

3.2.2 Hikone Castle

Hikone City, Shiga Prefecture, Southwest Japan was established as a castle town in the Edo era. With its twin moats and chalk-white walls it is a hilltop-type castle which has for long been a landmark on the shores of Lake Biwa, the largest lake in Japan. It is one of the four National Treasure Castles (Figure 25).
History of Hikone Castle

After the epoch-making battle which resulted in the decisive victory of Tokugawa over Toyotomi in year 1600 and which laid the foundation for the subsequent Tokugawa Shogunate (1600 - 1867), Hikone Castle, located at a strategically vital location, was given to Ii, one of his most trusted generals, as a reward for his distinguished contribution during the battle. Ii started to renovate the old castle in 1604 and completed it in 1622 (Figures 26-30).

Figure 25. Castle tower and base stone wall of Hikone Castle (photo by H. Kato).

Figure 26. Stonework of “Tenbin Yagura” (Balance Scale Turret; photo by T. Kohayakawa). It is said that these two-storied turrets were moved from “Otemon”, the front gate of Nagahama Castle, originally built for Hideyoshi Toyotomi, and were called “Tenbin Yagura” because it looks like a balance scale “Tenbin”. This structure is thought to be the only example of its type in Japan.
Figure 27. The stone wall of the right hand side of the gate was made in the original Gobozumi style of stone work (photos by T. Kohayakawa).

Figure 28. The stone wall of the left hand side of the gate was made in the new Otoshizumi style of stone work because it was destroyed by earthquakes and re-built (photos by T. Kohayakawa).

Figure 29. Tate-ishigaki or Nobori-ishigaki (photos by T. Kohayakawa). Vertical stoneworks run from the top to the bottom of a hill to prevent an enemy attack. The top of the stonework is surrounded by a wall with tiles on top.
Figure 30. Inner moat stonework (photo by T. Kohayakawa). Stonework encircling the lower part of the earthen embankment known as Hachimaki Ishigaki (headband stone wall, upper part) and Koshimaki Ishigaki (girdle-type women’s underwear stone wall, lower part). This type of stonework is rarely seen in this region, Southwest Japan.

Petrography of building stones

The main building stones were quarried from the Koto Rhyolites formed during the igneous activity of the Koto Cauldron of late Cretaceous to Palaeogene age (Figures 31 and 32). They are mainly distributed to the west of Suzuka Mountains and partly in the east plain of Lake Biwa. The rhyolites consist mainly of silicic pyroclastic flow deposits including welded tuff. The Koto Rhyolites can be divided into two groups corresponding to two igneous cycles. The older group is composed of welded tuff and quartz porphyry. The tuff overlay the basement of Mesozoic sedimentary rocks with a ship-bottom shaped boundary, and it appears have formed in a volcanic vent. The welded tuff erupted first as vesicular magma from the top of the magma reservoir and was followed by a co-magmatic intrusive phase represented by quartz porphyry. The younger group consists of pyroclastic rocks composed of volcanic breccia, rhyolitic welded tuff and pumice tuff, and granite porphyry which was the final igneous activity intruding along ring faults whose central block subsided stepwise and resulted in a double ring dyke about 30 km across.
Figure 31. Origin of stones used in Hikone Castle; red: granites, pink: diorites, yellow: Koto Rhyolites, black: dike rocks.

Figure 32. Outcrop and quarry of the Koto Rhyolites (photos by T. Kohayakawa).
3.2.3 Edo Castle

The Old Edo Castle was built in the 15th Century. About 150 years later, Ieyasu Tokugawa who unified the nation decided to rebuild the castle and to develop Edo Town (present Tokyo), which grew into a city of more than a million population in the early 18th century, arguably the largest metropolis in the world at that time. He enlarged the castle from 1604 to 1635. The scale of the castle tower was 38x34m and 61m high, however it burned down in 1657. The castle was also damaged severely by the Kanto earthquake in 1923. It was partly rebuilt and is now the residence of the Emperor, the Imperial Palace (Figures 33-35).

Figure 33. The keep (left) and stone wall (right) of Edo Castle around the moat (photos by H. Kato).

Figure 34. Structure of the stone wall.

Figure 35. Regular-cut blocks of the stone wall (photo by H. Kato).

Edo Castle stones

The main quarries for the Quaternary andesite lava used for the stone walls of this castle were located several tens to more than a hundred kilometers from Edo such as in Kanagawa and Shizuoka Prefectures (Figures 36-38). Manazuru-misaki (peninsula),
near Atami City, is located 70 km southwest from Tokyo (in Kanagawa Prefecture) and situated at the northeast end of the Izu Peninsula, which is the northern end of the Izu-Ogasawara Arc. In this area, Quaternary volcanic products are widely distributed and divided roughly into two groups; the Hakone Volcanoes comprising the Hakone Volcano (0.4 Ma to present) and Yugawara Volcano (0.4-0.2 Ma), and the slightly older Usami-Taga Volcanoes. The rock types are mainly olivine-clinopyroxene or olivine-clinopyroxene-orthopyroxene basalt to andesite, and clinopyroxene-orthopyroxene andesite to dacite. Some of them were used as building stones.

Hon-komatsu Lavas, consisting of dacite lava whose K-Ar age is 0.18~0.17Ma, 0.25±0.01 Ma, and Manazuru-misaki Lava, consisting of andesite lava and pyroclastics whose K-Ar age is 0.15±0.01 Ma, are Hakone Volcanic Products dating from the Middle Pleistocene. Hon-komatsu Lavas are called Hon-komatsu-ishi as the name of the building stone, and Manazuru-misaki Lava is called Shin-komatsu-ishi.

4. Stone Heritage Structures of the Present

Of the very diverse use of stones in present Japan, one prominent example was presented to the public recently. Tokyo Central Station was completed in December 1914. It was a 330m long reinforced brick building with dome structures on northern and southern end. It was the symbol of modern Japan and the pride of the National Railway. It was roofed by 430 thousand pieces of slate from Ogatsu area, Ishinomaki City of Miyagi Prefecture. This slate comes from Upper Permian Toyome Series of the southern Kitakami Mountain Range. Slate from this series is well known for its use in roofing (Figure 39), its advantages over roof tiles include its lighter weight resulting in stronger seismic-withstanding properties.

However, the inside of the station, the railway men’s pride, was gutted by fire-bombing during World War II with only the outer wall left standing. Only 80 thousand pieces of the 430 thousand roofing slates were recovered. The station was temporarily repaired for practical use in the latter half of 1940s. The full restoration of
the station to its original state began in earnest more than half a century later in 2007 and was completed in 2012.

Figure 38. Summary of geology in the Atami area including Manazuru peninsula (Oikawa and Ishizuka, 2011).

The Ogatsu slate came to attention again, because Ishinomaki City of Miyagi Prefecture was devastated by the 9.0 magnitude earthquake and resulting tsunami in 2011 and was struggling to recover. As the roofing of the restored Tokyo Station would come at the last stage of the project, these slate pieces could again be quarried in time its completion. Now, many Japanese from all over the country come as tourists to visit the station (Figure 39, left).
Figure 39. The Ogatsu slate of the roof of Tokyo Station (left) and that of Shiogama Shrine (right) which was built in 1704 in Miyagi Prefecture (photos by H. Kato).

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Cover photo: Cheomseongdae (astronomical observatory tower) in Gyeongju.
Stone Heritage of the Republic of Korea

Chan Hee Lee and Young Hoon Jo

1. Introduction

The Republic of Korea, a peninsula country located in the east of the Asian continent (Figure 1a), has mountains covering approximately 70% of its entire territory and four distinct seasons. Traditional religions practiced here are Buddhism and Confucianism, which have had a considerable influence on cultural development, thought and behavior in the ancient Korean kingdoms and states. Later, particularly during and after the 19th Century, Christianity including Catholicism, was introduced into Korea from Europe and the West. The first state of the Korean peninsula was Gojoseon (BC 2333 to BC 108), followed by the Three Kingdoms Period (Goguryeo, Baekje and Silla; BC 57 to 675), Unified Silla (676 to 935) and Balhae (698 to 926). The Goryeo (918 to 1392) and Joseon (1392 to 1910) Dynasties followed in the middle and middle to modern periods, respectively. After the Japanese colonial period (from 1910 to 1945), the Korean peninsula was divided into North and South Korea based on the 38th parallel. In 1948 in the south, the Republic of Korea was formally established.

The geology of the peninsula is very diverse and its rocks are often well exposed in its mainly mountainous terrain. More than half of the Korean peninsula is composed of granite and granite gneiss. The former was mainly intruded during the Triassic, Jurassic and Cretaceous periods, whereas the latter was formed due to metamorphism and granitization of sedimentary rocks during the Pre-Cambrian eons (Figure 1b). These deep seated rocks were subsequently exposed at the surface of the earth due to diastrophism, uplift and denudation during several geological periods. Younger marine and non-marine sedimentary formations were deposited on the more ancient rocks in many places (Cheong et al., 2013). The geological character of the Korean peninsula is closely related to the selection of materials and construction techniques that shape the countries stone heritage.

The National Research Institute of Cultural Heritage in Korea; NRICH (2011a) stated that approximately 7,000 tangible cultural properties exist in Korea including national treasures, tangible cultural properties of cities and provinces, and cultural property materials. Of these, the number that can be assigned to its stone heritage is 1,882 (26.8%), ranging from petroglyphs and dolmens during the prehistoric ages to stone pagodas, stone Buddha statues, stone monuments, rock-carved Buddha statues, stone stupa, and flagpole supports during the historical period. In particular, stone pagodas
(25.8%), stone Buddha statues (23.5%) and stone monuments (18.1%) account for the highest portions of the existing stone heritage monuments (Figure 1c).

Figure 1. (a) Location of Korean peninsula. (b) Korean geological map. (c) Distribution map of representative Korean stone heritage sites (Lee and Chun, 2013). 1; Dinosaur footprint fossil sites in Uhang-ri, Haenam. 2; Dinosaur trackways in Daechi-ri, Haman. 3; Bangudae petroglyphs in Ulju. 4; Dolmen in Bugeun-ri, Ganghwa. 5; Silla Stele in Bongpyeong-ri, Uljin.
In this study, representative cultural properties related to Korea’s stone heritage were selected according to type dating from the prehistoric and historical periods up to the 19th Century. Based on the results of previous studies, each of the selected stone heritage monuments is briefly described in terms of historical value, lithological characteristics and provenance of the stone used, deterioration state, non-destructive diagnosis and conservation treatment. Furthermore, globally outstanding characteristics and values of the selected Korean stone heritage monuments are discussed as well as various attempts for preserving their original forms.

2. Stone Heritage Sites of Prehistoric Age

2.1 Dinosaur Footprint Fossils of Uhang-ri and Daechi-ri

Korea is globally renowned as an excavation site for dinosaur footprint fossils, which are observed more frequently than skeleton fossils and have been unearthed in more than 20 regions. The main dinosaur footprint fossil sites are shale-rich lacustrine sedimentary rocks of various sub-basins such as the Cretaceous Gyeongsang Basin (Huh et al., 2003). Dinosaur footprint fossils of ornithopods are found most frequently although those of theropods and sauropods are also observed. Representative dinosaur footprint fossils are described below.

Large (Figure 2a) and extra-large dinosaur footprint fossils (Figure 2b) in Uhang-ri, Haenam are mainly found in black shale (Figure 2c); only extra-large dinosaur footprint fossils in the open air are composed of tuffaceous sandstone that includes quartz and albite phenocrysts with rhyolite-rich matrix. Notable physical damage to these footprint fossils are cracks, delamination, fracture zone, and re-damage by repair materials; that of chemical damage is efflorescence (thenardite, Na₂SO₄) generated along the current routes of water flowing the fossil sites. Moreover, the results of physical characteristics analysis of the fossil sites using measurement of ultrasonic velocity indicate that the fossils in these sites are highly weathered (Yoo et al., 2012).

Dinosaur trackways in Daechi-ri, Haman, were found in shale with purple and grayish-green strata (Figure 2d) and consist of two ornithopod trackways with an average depth of 29 mm and one sauropod trackway with an average depth of 30 mm for manus and 35 mm for pes (Figure 2e). However, these fossils underwent severe physical damage by cracking due to relocation more than twice after the first excavation in 1993 in addition to inappropriate conservation treatment and secondary deterioration by plaster repair materials, thereby requiring comprehensive
improvement. Thus, in 2008, scientific conservation treatment was performed to remove previous repair materials, which included cleaning and desalination through an impregnation method, preliminary joining using a three-dimensional drawing, fabrication of a fiberglass-reinforced plastic (FRP) mold on the floor surface, joining and filling of cracks and missing parts, application of anti-swelling agents and consolidation (Figure 2f). Detailed investigation and scientific conservation treatment of dinosaur trackways greatly contributed to establishing a customized conservation system (Lee et al., 2012).

Figure 2. Photographs showing the large (a) and extra-large dinosaur (b) footprint fossils in Uhang-ri, Haenam. (c) Black shale composing the large dinosaur footprint fossils. The shale is laminated by accumulated clay and quartz (d), surface depth modeling (e), and conservation treatments (f) of the dinosaur trackways in Daechi-ri, Haman (Lee et al., 2012; Yoo et al., 2012).

2.2 Bangudae Petroglyphs

Petroglyphs are paintings or patterns carved on the rock surfaces by using sharp parts of hard stone or metal tools. These images serve as valuable information, concerning the contemporary aesthetic consciousness of our ancestors on topics such as life, religion and philosophy, before the invention of writing. Such artwork is a universal cultural phenomenon; approximately 400,000 petroglyphs are widely distributed across approximately 120 countries worldwide. Of these, 14 petroglyphs have been
designated as World Heritage Sites. At present, approximately 20 petroglyphs exist in Korea. In particular, petroglyphs in Cheonjeon-ri and Bangudae in Deagok-ri, Ulju, are included in the tentative lists of UNESCO World Heritage Sites in 2010.

Among them, Korea National Treasure No. 285, the Bangudae petroglyphs in Daegok-ri, Ulju, represents the first stone painting in Korea, regarded as the most sophisticated relic to reflect the life of prehistoric people. In these petroglyphs, diverse monuments of such as whales, tigers, deer, boar, turtles, ships, nets, harpoons, people and simply human faces are more explicitly carved than those in other sites (Figure 3a). In particular, eight types of whales and complex religious paintings related to whaling are major expressions representing the traditions of the whaling culture (Cultural Heritage Administration of Korea, 2012).

However, the Bangudae petroglyphs are repeatedly flooded and exposed for four to eight months of the year due to the presence of the Sayeon Dam constructed in 1965, six years before the discovery of these rock carvings. As a result, the dark green hornfelsed shale hosting the petroglyphs has a weathered layer with an average porosity of 25% at a certain depth from the surface, thereby showing differences in mineral and chemical compositions compared with the fresh surface which has an average porosity of 0.4% (Figure 3b). The result of a deterioration evaluation indicates that approximately 23.8% of the main rock surface areas have been damaged (Figure 3c) and the lower areas of the petroglyphs have weaker physical properties than those of the upper areas (Lee et al., 2012). As a consequence, Ulsan City and many researchers including those with the Cultural Heritage Administration of Korea are seeking a scheme to permanently conserve the Bangudae petroglyphs.

Figure 3. General view and occurrence (a), EPMA result of the weathered and unweathered parts (b), and deterioration map (c) of the Bangudae petroglyphs in Ulju (Cultural Heritage Administration of Korea, 2012; Lee et al., 2012).
2.3 Ganghwa Dolmens

A dolmen is a type of stone tomb constructed in the Bronze Age, and is considered a megalithic monument, as are the obelisks in Egypt and Stonehenge in the United Kingdom. Among the global distribution areas, the highest density of dolmens is observed in northeastern Asia, particularly in Korea, across which approximately 30,000 dolmens are distributed. Of these, the dolmens in Gochang, Hwasun and Ganghwa were designated as World Cultural Heritage Sites in 2000 after being evaluated as crucial remains by verification of the formation and development processes through their dense distribution and various forms.

Two forms of dolmens appear in Korea. The first is a burial chamber built underground in which there are small supporting stones and an upper stone is placed on the chamber; the other is a burial chamber on top of the ground that uses stone plates to block the four sides and includes upper stones on top. Because the former is mainly observed in the southern part of middle Korea and the latter appears in the northern part of middle Korea, dolmens of the former are referred to as southern-type dolmens, and those of the latter are known as northern-type dolmens. Dolmens in Gochang and Hwasun are southern-type dolmens. Most rocks used in these dolmens are tuffaceous volcanic rocks of various compositions that are distributed near the dolmens.

Of the approximately 40 dolmens in Ganghwa, that in Bugeun-ri (Historical Site No. 137) is the largest among the northern-type dolmens with a height of 2.6 m, length of 6.5 m, and width of 5.2 m (Figure 4a). This dolmen is in an excellent state of conservation. It has an upper stone of migmatitic gneiss, a left supporting stone of mica schist and a right supporting stone of granitic gneiss (Figure 4b, 4c). In this dolmen, fracture zones of various sizes are distributed throughout, and structural weakness are generated by the high inclinations and missing parts of the supporting stones (Moon et al., 2006).

Since most dolmens in Korea have been exposed to outside conditions for lengthy periods, physical damage due to blistering and scaling in addition to biological colonization by lichens, bryophytes, and algae is observed on their surfaces. Thus, all members including the cover stone require conservation treatment and regular cleaning and management. Furthermore, a method for reducing deterioration through long-term safety monitoring should be developed.

Figure 4. (a) Field occurrences of the dolmen in Bugeun-ri. (b) Right supporting stone composed of granitic gneiss with minor fold. (c) Plagioclase, quartz and mica observed in thin section of granitic gneiss (Moon et al., 2006).
3. Stone Heritage of the Historical Period

3.1 Silla Stele in Bongpyeong-ri, Uljin (6th century)

The Silla Stele in Bongpyeong-ri (National Treasure No. 242), with a height of 204 cm, was constructed in the 11th year of King Beopheung (524) in Silla Kingdom. It has an irregular quadrangular form and a front side on which an inscription is vertically engraved (Figure 5a). Overall, spaces between letters as well as the number of letters in each line are inconsistent; 399 letters are included in ten lines (Son and Shim, 2010). In particular, since this stele inscription contains rich content concerning the limitations of royal authority, decision-making processes, official ranking systems, and the structure of region-governing organizations and villages in the 6th century in the Silla Kingdom, it is regarded as important source of data that can be effectively used for identifying the social aspects of Silla (Figure 5b).

This stele is constructed of gneissose leucogranite (Figure 5c, 5d). Structural cracks and micro cracks are developed along the gneissose structure. Because the horizontal physical properties are weaker than the vertical physical properties, improvement and treatment of the cracked parts is required. However, given that the entire weathering grade, determined through ultrasonic measurement to represent a moderately weathered stage, consolidation is not urgently needed. Moreover, in terms of chemical degradation, 85.2% darkening by soil, iron oxide, and manual rubbing, together with 17.3% NaCl (salt) crystals deposited from the sea are identified as the main problems (Figure 5e, 5f). Hence, initial removal of surface contaminants and salt crystals from this stele is required by using pulp paper and pressure spraying with distilled water. Moreover, application of poultices should be considered through clinical tests (Jo et al., 2013).

Figure 5. (a) Occurrence of the Silla Stele in Bongpyeong-ri, Uljin. (b) Photographs and rubbing of detailed letters. (c) Polarizing microscope image of leucogranite. (d) X-ray diffraction pattern and magnetic susceptibility of leucogranite. (e) Elemental mapping results using P-XRF. (f) Scanning electron microphotograph of NaCl crystals (Jo et al., 2013).
3.2 Five-story Stone Pagoda in Jeongrimsaji Temple Site, Buyeo (estimated 6th to 7th century)

The Five-story Stone Pagoda in Jeongrimsaji Temple Site, Buyeo (National Treasure No. 9), a valuable pagoda constructed during the Baekje Kingdom, has distinct historical and artistic values in that its original form is well preserved, except for the upper part (Figure 6a). In particular, this stone pagoda effectively expresses the beauty of a simple and vibrant stone tower by eschewing the complexities of wooden structures. It is 8.92 m in height and consists of 149 members. With regard to style, its basement part is significantly lower than its body part.

The pagoda’s rock material is porphyritic biotite granodiorite and contains pegmatite veinlets, basic xenoliths, and porphyritic texture of plagioclase is consistently developed (Figure 6b, 6c). The results of a provenance interpretation confirmed that rocks from Ongnyeobong Peak, which is located 15 km to 20 km from Jeonggrimsa Temple, and Mt. Hwa have the same mineralogical and geochemical characteristics as those at this pagoda. In particular, ancient quarrying traces were observed at many outcrops in this region, thereby supporting the hypothesis that this region could have been used to supply the stone (Figure 6d), and is likely to have been supplied to Buyeo via the Geum River from Ganggyeong Port (Figure 6e, 6f) (Lee et al., 2007).

![Figure 6.](image-url)

(a) Field occurrence of the Five-story Stone Pagoda in the Jeongrimsaji Temple Site. (b) Porphyritic granodiorite containing pegmatite veinlets and basic xenoliths. (c) Mineral assemblage of plagioclase with albite twin and biotite altered partly into chlorite, quartz and sphene. (d) Photographs showing the ancient quarrying trace from an outcrop at Oknyeobong Peak. (e) Geum River nearby Oknyeobong Peak. (f) A map showing the distance of movement of rock between the stone pagoda, Oknyeobong Peak and Mt. Hwa (Lee et al., 2007).
3.3 Rock-carved Buddha Triad in Yonghyeon-ri, Seosan (estimated 6th to 7th century)

The Rock-carved Buddha Triad in Yonghyeon-ri, Seosan (National Treasure No. 84) is a representative Buddha statue of the Baekje Kingdom constructed in a rocky cliff within a gorge in Gaya Mountain; a Pensive Bodhisattva and Standing Bodhisattva are carved on each side of a Standing Buddha (Figure 7a). This Buddha triad statue has been considered as the greatest contemporary masterpiece because of its refined carving style and unique triad composition. It is a valuable cultural heritage monument in that it indicates contemporary Buddhist culture and interchanging relations such as the spread of Buddha style from China and India based on geopolitical location (Moon, 1999; Park, 2005).

Figure 7. (a) Field occurrence (1959) of the Rock-carved Buddha Triad. (b) Enclosed traditional wooden shelter of Buddha statue. (c) Semi-opened shelter with partly disassembled door and both walls. (d) The current state without the shelter (Lee et al., 2010).

The Buddha triad statue is carved on a rock face consisting of light gray medium-grained biotite granite which shows low slope stability due to the development of irregular discontinuities (Lee et al., 2010). In addition, since an enclosed traditional wooden shelter was installed to protect this Buddha triad statue from the atmospheric environment in 1965, internal leakage problems have occurred continually (Figure 7b). In particular, limitations in the shelter’s protective function owing to damage have resulted in deterioration to the statue by condensation, dust deposition, and efflorescence. Moreover, visitors have been inconvenienced due to a narrow observing space in the protective canopy and insufficient lighting. Consequently, to improve conservation and the viewing conditions, the walls of the shelter were partly disassembled in 2006 (Figure 7c), and the shelter was completely dismantled in 2007 (Figure 7d). After demolishing the shelter, conservation treatment and maintenance of the surrounding environment were performed in 2008; currently, the Buddha triad
statue is exposed to the external environment with no protecting structure (Lee et al., 2014).

3.4 Stone Pagoda in Mireuksaji Temple Site, Iksan (7th century)

Mireuksa Temple was the greatest Buddhist temple of the Baekje Kingdom established by King Mu (600 to 641), the 30th King of the Baekje. Three pagodas and three main buildings are divided by corridors to form respective areas (Figure 8a). The middle area is estimated to be a wooden pagoda site, and the eastern pagoda was restored to nine stories in 1992. The current Mireuksaji Stone Pagoda (National Treasure No. 11) is located in the western area; more than half has been destroyed except from the basement to part of the sixth story (Figure 8b). The stone embankment was reinforced up to the first story based on the west side, and the upper part was covered by concrete for repair in 1915 (Figure 8c). In January 2009, the Buddhist reliquary was excavated at the first-story center pillar stone of the stone pagoda. Inscription of the Gihae year (639) confirmed in the golden sarira enrichment record indicate the construction period of the west pagoda and identify the main founders and characteristics of the Mireuksa Temple (NRICH, 2013).

In 1998, a safety diagnosis reported that the structural stability of the stone pagoda was low and it was decided in 1999 to execute deconstruction and subsequent repair. Since October 2001, restoration and maintenance have been performed by NRICH. So far deconstruction of the pagoda has been completed except for the base. During this
process detailed data were collected through research in several fields such as conservation science (Figure 8d), construction (Figure 8e, 8f), archeology and art history and final restoration (Figure 8g) (NRICH, 2013). The stone of this pagoda is composed of biotite granite, the same rock type as occurs near Mt Mireuk and quarrying traces are scattered throughout the mountain area (Yang et al., 2000). The deterioration of the pagoda stones was evaluated and methods for selection of replacement stone were examined (Lee et al., 2009, Kim et al., 2011).

### 3.5 Cheomseongdae in Gyeongju (7th century)

Cheomseongdae in Gyeongju (National Treasure No. 31) is an astronomical observation structure constructed during the reign of Queen Sunduk (AD 647), the 27th ruler of the Silla Kingdom, and is the largest existing stone observatory tower in Asia (Figure 9a). For construction stone, alkali-feldspar granite (63%) was used for the base, the upper cylindrical body part, and a top part of Cheomseongdae (Figure 9b); micrographic granite (27%) was used for the lower cylindrical body part (Figure 9c). Since these two rock types have similar mineralogical and geochemical characteristics, they are considered to have been generated from the same granitic magma (Figure 9d). It has been verified that these rocks came from Mt. Nam to the south of Cheomseongdae where many ancient quarrying traces are found.

![Figure 9. (a) Field occurrence of Cheomseongdae. (b, c) Polarizing microscope images of alkali-feldspar granite and micrographic granite. (d) X-ray diffraction pattern and magnetic susceptibilities of component stones. (e) Infrared thermographic image of blistering (Jo et al., 2010).](image)

The result of a precise non-destructive diagnosis indicates that structural problems such as cracks and missing elements are found mainly in the lower part of Cheomseongdae, whereas the upper part has been damaged mostly by surface weathering such as blistering, scaling, and granular disintegration (Figure 9e). It was also determined that the surface was mainly contaminated by darkening (37.3%) and
biological colonization (58.0%). In particular, the darkening contaminants include microorganisms, clay minerals, dust and micro soil particles, which combined to form a thick layer that also led to discoloration after iron-oxidizing substances degraded from minerals and consecutive applications of plaster were added. Regarding the physical properties of the stone used in Cheomseongdae, it was determined through ultrasonic velocity measurement that they were at a moderately weathered stage on average (Jo et al., 2010).

3.6 Dabo Pagoda and Three-story Stone Pagoda of Bulguksa Temple (8th century)

Bulguksa Temple in Gyeongju was built in the 10th year (751) of the reign of King Gyeongdeok of the Silla Kingdom. The Dabo Pagoda (National Treasure No. 20), representative of special pagodas, is located at the east of the main Buddhist hall (Figure 10a), and the Three-story Stone Pagoda (National Treasure No. 21), representative of general pagodas, is at the west (Figure 10b). It is easily observed that the latter, with a height of 10.8 m, is a three-story pagoda established on a two-story basement, whereas the number of stories of the Dabo Pagoda, with a height of 10.3 m, is undetermined. Equigranular medium-grained alkali-feldspar granite in which small druse are developed was used in the two stone pagodas; rocks for other parts are mixed (Lee et al., 2005).

In 1925, the Dabo Pagoda was comprehensively deconstructed for repair, and the lower quadrangular banister of the second story and upper part were repaired in 1972. Nevertheless, due to inappropriate drainage at the second-story banister, the first-story support structure was damaged by weathering. Since repair was urgently needed, NRICH undertook conservation treatment in December 2008. Specifically, after preliminary investigation including the processes of three-dimensional scanning and making a deterioration map of the stone pagoda, eight elements in poor condition were replaced by partially disassembling the quadrangular banister of the second story, the octagonal banister, and the upper part.

Figure 10. Field occurrences and deterioration maps of the Dabo Pagoda (a) and the Three-story Pagoda (b) in Bulguksa Temple (Lee, 2007).

Furthermore, conservation treatment was undertaken on cracked and blistered parts, by removing concrete and cement mortar at joints and carrying out cleaning. The conservation process was completed in December 2009 (NRICH, 2011b). Parts of the
Three-story Stone Pagoda damaged during an attempted robbery in 1966 were partially repaired. In December 2010, a crack 1.32 m long and 5 mm in maximum width was confirmed in the cover stone on the northeastern upper basement through a regular safety inspection. As a result, deconstruction and repair measures were being performed and were due to be completed in 2014.

3.7 Five-story Stone Pagoda of the Seongjusaji Temple Site in Boryeong (9th to 10th century)

The Five-story Stone Pagoda of the Seongjusaji Temple Site (Treasure No. 19) has a form signifying the change from the Unified Silla to the Goryeo Period. It is 6.34 m in height and consists of 40 sections in total (Figure 11a). Because its original form, except for the upper part, was well-maintained, its value has been appreciated from the perspective of art history. Currently, its basement is exhibiting gaps between members, cracks, and differential settlement, resulting in tilting toward the east. The original members of this stone pagoda are composed of light gray medium-grained hornblende granite (Figure 11b), whereas black sandstone, a representative rock of this region, was used as replacement stone in part of the eastern basement.

Since hornblende granite that formed the original members of this stone pagoda does not exist at the Seongjusaji Temple Site, areas of Boryeong and Buyeo within 10 km of this temple site were investigated in detail for stone provenance interpretation. Results of visual examination and measurement of the whole-rock magnetic susceptibility confirmed that the rock type found at outcrops in Namgok-dong and Naehang-dong of Boryeong-si are identical to that used in the members of the stone pagoda of the Seongjusaji Temple Site. Moreover, by analyzing the petrological and mineralogical characteristics and geochemical evolution trend of the rock, it was verified that the two rock types are the same. Further, transportation routes of the stone were reviewed historically and geopolitically based on the above data, and it was determined that the rocks in the presumed area of origin would have been transported to the Seongjusaji Temple Site via Subu-ri of Ungcheon-myeon and the Ungcheon River through sea routes (Figure 11c) (Lee and Lee, 2009).
3.8 Rock-carved Buddha Statues of the Namharisaji Temple Site in Jeungpyeong (estimated 10th century)

The rock-carved Buddha Statues of the Namharisaji Temple Site in Jeungpyeong (Tangible Cultural Property of Cities and Provinces No. 197) are assumed to have been established during the period between the end of the Silla and the beginning of the Goryeo Dynasty. Based on the Buddha Triad, the Standing Buddha is located at the left, and Pensive Bodhisattva is at the right (Figure 12a). These Buddha statues were carved on light gray porphyritic biotite granite with microcline phenocrysts and pegmatite patches (Figure 12b), thus leading to severe surface irregularities and granular disintegration due to differential weathering (Figure 12c). In addition, nearly horizontal and vertical cracks have accelerated the mechanical weathering of the host rock (Figure 12d). Because nearly 100% of the entire surface is covered by microorganisms, the form of the carving is unclear (Figure 12e).

Figure 12. (a) Frontal view of the Rock-carved Buddha Statues of the Namharisaji Temple Site in Jeungpyeong (b) Microphotograph showing rock-forming minerals of quartz, microcline, biotite, and orthoclase in the host rock. (c) Cleavages of biotite opening widely by clay minerals. (d) Stereo-net plot of lineament systems affecting the host rock. (e) Biological colonization map. (f) Biocide spraying of the stone surface of the Buddha statues (Lee et al., 2011).

For stable conservation of the rock-carved Buddha statues in the long term, scientific conservation treatments were performed in 2006. First, a clinical test was conducted to determine the ranges and methods for conservation treatments. The test results confirmed that it was effective to combine primary dry and wet cleaning appropriately with secondary chemical cleaning (biocide). Based on this result, the Buddha statues were appropriately washed (Figure 12f), and based on stability threatening, conservation treatments were conducted in the order of joining, texturing and consolidating. Finally, the conservational environment was improved by relocating a
well in front of the Buddha statues, enhancing the ground, and removing trees (Lee et al., 2011).

3.9 Stone Standing Maitreya Statue of the Gwanchoksa Temple in Nonsan (estimated 10th to 11th century)

At a height of approximately 18 m, the Stone Standing Maitreya Statue of the Gwanchoksa Temple (Treasure No. 218) is the largest stone statue of Buddha in Korea (Figure 13a). It is located on a slightly inclined outcrop of granodiorite with a backdrop of Mt. Banya (Figure 13b). The Buddha’s feet are carved in the natural bedrock without a pedestal, whereas the upper and lower body and both arms are separately sculpted from large blocks to establish a complete statue. A cylindrical high crown appears on the head, expressing baldachin that has the square Gat shape of a traditional Korean hat. On the face, which is comparatively large in proportion to the body, the relative positions of eyes, nose, and mouth are adjusted to completely fill the entire face, thus enabling the face to overcome the impression of a flat image and to make a strong impression on the observer. The Buddha’s linear eyes appear very sharp; the pupils, composed of black shale, realistically express the strong image of the stone sculpture (Figure 13c).

Figure 13. (a) Frontal view of the stone standing Maitreya statue of Gwanchoksa Temple in Nonsan. (b) Granodiorite composed of quartz, plagioclase, microcline and biotite. (c) Slate consisting of pupil part. (d) Two-dimensional modeling using ultrasonic velocity.

This standing stone Maitreya statue had been physically weathered by blistering and scaling, and secondary contaminants and deposits are scattered around it (Figure 13d). Moreover, a risk of collapse of the host rock due to development of discontinuities is present. Also and a large quantity of crustose lichens covers the statue; fungi, algae, and bryophytes are also present (Yun et al., 2006). As such, to protect this statue from contamination by lichens, blistering, and cracks, conservation treatments were conducted in 2007 based on preliminary investigation with regard to appropriate
conservation methods. Overall, processes were performed in the order of dry and wet cleaning, joining of cracks, and reinforcement of missing parts using replacement rock. Maintenance of the surrounding environment was also conducted.

3.10 Five-story Stone Pagoda of the Magoksa Temple in Gongju (estimated 13th century)

The Five-story Stone Pagoda of the Magoksa Temple in Gongju (Treasure No. 799) is representative of the cultural heritage of the late Goryeo Dynasty and was constructed under the influence of Lamaism (Figure 14a). On the second-story body part of this pagoda, the mystic Buddhas of the Four Directions are embossed, whereas the upper part consists of a Lamaistic-style Pungmadong, which is unique in that it is found only at the existing White Pagoda of the Miaoying Temple in Beijing, China, and at the pagoda of the Magoksa Temple. This stone pagoda is composed mainly of dark gray fine-grained quartz diorite. The second-story body part and dew tray consist of granodiorite, and the basement, which was replaced during deconstruction and restoration work in 1970, is composed of biotite granite (Figure 14b). The texture and color of the biotite granite differs completely from that of the quartz diorite, which is the main rock used, thereby leading to a sense of substantial heterogeneity in appearance (Jo et al., 2012).

![Figure 14. (a) Current appearance of the Magoksa Temple stone pagoda. (b) Lithological map of the stone pagoda. (c) Contour two-dimensional map by projecting the ultrasonic velocity of the stone pagoda. (d) Digital photographs and thermographic images of representative blistering zones and blistering map of the stone pagoda (Jo et al., 2012; Jo and Lee, 2014).](image)

This stone pagoda is highly unstable due to the gradually low decreasing width of each story and because its northern part was substantially damaged when the Daegwangbojeon Hall was set on fire in 1782. Thus, it has lost most of its original form. In addition, constant deformation occurred even after deconstruction and restoration of this pagoda in the 1970s, thus resulting in missing parts, cracking,
blistering, and scaling of original rock and repair materials, all of which could be easily observed by the naked eye (Jo and Lee, 2014). Hence, a precise safety diagnosis including ground exploration and behavioral monitoring was performed in 2006 and deterioration degree evaluation, three-dimensional scanning and monitoring were undertaken in 2008 (Figure 14c) with infrared thermographic analysis and investigation using an endoscope being conducted in 2012 (Figure 14d). Based on all these results, scientific conservation treatments have been performed to maintain the original form of this pagoda.

3.11 Seoul City Wall (after the 14th century)

The Seoul City Wall (Historic Site No. 10), approximately 18.1 km long, was constructed to protect Hanyang (now Seoul), the capital in the Joseon Dynasty (Figure 15a). Since the beginning of its construction in the fifth year of King Taejo (1396) (Figure 15b), its original form has been well maintained through extensive restoration measures performed during the reigns of King Sejong (1397–1450) and King Sukjong (1661–1720) (Figure 15c). However, when trams were introduced to the city as a new transportation mode during the Japanese colonial era, the city walls were heavily damaged. Even after Korean independence, rapid industrialization led to frequent damage to the walls. Fortunately, after the 1970s, the Seoul City Wall was gradually restored to its original form with repairing of the walls to promote national pride. The Seoul city walls have been listed recently in the tentative UNESCO World Heritage List (2012).

![Figure 15.](image)

Figure 15. (a) General map of Seoul City Wall published by Seoul Metropolitan Government (2014). (b) Photograph of Sungnyemun Gate and its vicinity in early 1904 (Photographer: George Rose; Collection of Cha Sang-sun, head of Stereoscope). (c) Different techniques used to construct the wall during the reigns of King Sejong and King Sukjong. (d) Pinkish granite used as the main rock material for Seoul City Wall. (e) Ancient quarrying trace found in places during provenance investigation (Lee et al., 2013).
Based on the results of previous studies, it is estimated that pinkish granite (approximately 80%), leucocratic granite (approximately 5%), gneiss (approximately 3%), and dark red granite (approximately 2%) were mainly used for constructing the Seoul City Wall (Figure 15d), though small amounts of fine-grained granite and aplite were also added (Lee et al., 2013). The various rocks used reflect the availability of the rock types adjacent to the City Wall rather than to other rocks intended for use by the technician in charge of its construction. This occurred because the political situation for the City Wall, built at a time when a large amount of stone was required for many projects just after the national foundation, dictated that local resources be used, unlike other famous heritage sites such as the Angkor of Cambodia, where stone was supplied from a long distance (Uchida and Shimoda, 2013).

In particular, the rock for the early Joseon period of the city wall was mainly supplied from the inner four mountains adjacent to the City Wall, though a large amount of construction stone was subsequently supplied from a fixed quarry outside the City Wall after the middle Joseon period (Figure 15e). Thus, the material authenticity of Seoul City Wall can be identified by examining the diversity of material distribution and changes in provenance according to period and location. These criteria are also expected to be applied for selecting the same rock for future restoration (Lee et al., 2013).

3.12 The Tombstone of Chungmugong Yi at the Chungryeolsa Shrine in Namhae (17th century)

The Chungryeolsa Shrine (Historic Site No. 233) of Namhae, or the Noryang Chungryeolsa Shrine, was established to commemorate the loyalty and soul of Chungmugong Yi Sun-sin, who sacrificed his life for his country during the naval battle at Noryang, in the year of the Imjin War when the Japanese invasion of Korea ended. Its history traces back to the year of 1633, 34 years after the death of Chungmugong Yi, when a straw-roofed house was constructed for performing ancestral rites. An epitaph was composed by Song Si-yeol under the penname of U-am and engraved by Song Jun-gil in the second year (1661) of King Hyeonjong. The monument was erected by Naval Commanders of the Three Provinces, Park Kyeong-ji, and Kim Si-seong, in 1663 (Figure 16a). Currently, the north, east, and west sides of the Chungryeolsa Shrine are surrounded by the sea; letters carved on the sandstone tombstone show artificial discoloration due to a red pigment and rubbing. In addition, lamination is clear at the front and rear sides of the tombstone (Figures 16b and 16c).

Moreover, in terms of inorganic contaminants at the boundaries of the surface layer, granular disintegration layer, and scaling layer of the tombstone, Ca, S and Cl were detected on the surface layer (Figure 16d, 16e) though their concentrations decrease closer to the granular disintegration layer. Surface contaminants were not found in the scaling layer, whereas Fe and K elements forming the rock were detected (Figure 16f). Thus, to reduce granular disintegration, blistering, and scaling of the tombstone of Chungmugong Yi, desalting and surface consolidating were conducted in 2010 (Cho et al., 2012). The value of the tombstone has been well preserved as an important monumental inscription through active management.
Figure 16. (a) Field occurrence and wooden shelter of the tombstone of Chungmugong Yi at the Chungryeolsa Shrine in Namhae. (b) Rear side of the tombstone appearing the lamination. (c) Sandstone with excellent sorting and rounding. (d) Two-dimensional mapping of the element concentration using P-XRF. (e) Salt crystals observed in composition minerals. (f) Comparative diagram of relative concentrations according to the elements on surface, granular disintegration, and scaling layers (Cho et al., 2012).

3.13 Seokbinggo (Stone Ice Storage) (18th century)

Seokbinggo is a Stone Ice Storage in which ice collected in the winter was preserved to be used in summer. At present, a total of six Seokbinggo structures, Treasures Nos. 66, 305, 310, 673, and 323 and Historical Site No. 169, are located in Gyeongju, Andong, Changnyeong, Hyeonpung, Cheongdo, and Yeongsan of South Korea, respectively (Figure 17a). All of these structures were built in the late Joseon Dynasty and remain to the present day. Seokbinggo can keep ice collected in winter until summer because the selected locations utilize the natural environment, and the insulation design is effective. Thus, they are regarded as part of Korea’s heritage of early integrated scientific technology.

For effective ice-storage, the Seokbinggo has an arch structure in a semi-basement. Scientific design and construction were applied by establishing appropriate location environments, underground space, installing vents, drains, and narrow entrances. In particular, the arch structure transfers loads of the upper part to the lower part to maintain durability and maximize the internal capacity (Figure 17b). For efficiency of these structures, granite was selected as the construction material (Figure 17c). Thus, the Seokbinggo are valuable cultural heritage structures in that the applied scientific and technological principles reflect the knowledge and creativity of the Korean ancestors (Figure 17d). Furthermore, it is anticipated that these techniques can be
applied in low-energy industries and can be used to establish an eco-friendly conservational environment system for certain cultural sites (Kim and Lee, 2013).

Figure 17. (a) Locations of Seokbinggo in the Korean peninsula. (b) Arched interior structure of the Gyeongju Seokbinggo. (c) Polarizing microscopic image of alkali feldspar granite. (d) Schematic diagram of natural cooling effect of the Hyeonpung Seokbinggo (Kim and Lee, 2013).

4. Summary and Conclusion

In this study, dinosaur footprint fossils (geoheritage monuments) distributed in the Cretaceous sedimentary rocks of the Mesozoic era in Korea were introduced along with a brief description of Korean stone heritage monuments such as petroglyphs, and dolmens of the prehistoric age of Korea’s stone heritage. Concerning stone heritage of the historic period, the Silla Stele in Bongpyeong-ri and Cheomseongdae in Gyeongju of during the period of the Three Kingdoms (BC 57 to 676) and the Five-story Stone Pagoda of the Jeongnimsaji Temple Site, Rock-carved Triad Buddha in Yonghyeon-ri, and Stone Pagoda in Mireuksaji Temple Site of Baekje Kingdom (BC 18 to 666) were discussed.

For the period of the Unified Silla Kingdom (676 to 935), the Dabo Pagoda and Three-story Stone Pagoda of the Bulguk Temple and the Five-Story Stone Pagoda of the Seongjusaji Temple site were presented. From the stone heritage of the Goryeo Dynasty (918 to 1392), the Rock-carved Buddha Statues of the Namharisaji Temple Site, Stone Standing Maitreya Statue of the Gwanchoksa Temple, and Five-Story Stone Pagoda of the Magoksa Temple were investigated. Finally, from the Joseon Dynasty (1392 to 1910), the Seoul City Wall, Tombstone of Chungmugong Yi at the Chungryeolsa Shrine and Seokbinggo were described.

Igneous rock accounts for the highest portion of the stone used for establishing the monuments chosen here to represent Korea’s stone heritage, and is involved in approximately 84% of state-designated cultural properties. Categorization according
to rock types indicates that granite was used most often, 68.2% in 397 cases, followed by diorite, 8.2% in 48 cases, and sandstone, granite gneiss, tuff, slate, marble, and limestone in less than 4% each.

Examination of the stone heritage monuments introduced in this study indicates that clastic mud sedimentary rock is the host rock for dinosaur footprint fossils and petroglyphs but that tuff, granite, and gneiss were mainly used in dolmens. In addition, for the Tombstone of Chungmugong Yi at the Chungryeolsa Shrine, sandstone found near the area of its placement was used.

In contrast, despite different periods and styles of construction, granite was used in the Silla monument in Bongpyeong, Cheomsongdae in Gyeongju, Five-story Stone Pagoda of Jeongnimsaji Temple site, Rock-carved Triad Buddha in Yonghyeon-ri, Stone Pagoda in Mireusaji Temple Site, Dabo Pagoda and Three-story Stone Pagoda of the Bulguk Temple, Five-story Stone Pagoda of the Seongjusaji Temple site, Rock-carved Buddha Statues of the Namharisaji Temple Site, Stone Standing Maitreya Statue of the Gwanghoksa Temple, Five-Story Stone Pagoda of the Magoksa Temple, the Seoul City Wall and Seokbinggo. With regard to stone supply, rock distributed within the region of each site was used, and the petrological characteristics and types of granite vary accordingly. In addition, in the case of Seoul City Wall and of Seokbinggo, each requiring a large amount of rock, some small amounts of metamorphic and sedimentary rock were also used.

It is generally known that the weathering and damage degrees of stone is strongly influenced by climatic factors such as temperature and precipitation. Although the average Korean temperature is 14 °C it may increase to more than 35 °C in summer and decrease below -10 °C in winter. The annual average precipitation in Korea is nearly 1,300 mm, although it greatly differs according to region and season; rain events are generally concentrated in summer. Lee and Chun (2013) reported the distribution of stone heritage sites according to the topography, annual average temperature and precipitation of Korea, indicating that most Korean stone heritage sites are in areas prone to middle to high rates of weathering. Therefore, examination of environmental control methods for conservation is required considering the importance of stone heritage monuments exposed to outside conditions, and monitoring and management systems should be established for stable conservation in the long term.

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STONE HERITAGE
OF
MALAYSIA
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Cover photo: Terengganu Inscription Stone.
1. Introduction

Malaysia, a country in Southeast Asia, is bounded by latitudes 1° 00’N and 7° 30’N and longitudes 99° 30’E and 119° 30’E. It is bordered by Thailand, Indonesia, Singapore and Brunei. Other neighboring countries which share maritime borders with Malaysia are Vietnam and The Philippines. Malaysia comprises the Malay Peninsula in the west, and Sarawak and Sabah which are part of Borneo Island in the east. The total landmass of Malaysia covers an area of 329,847 km². Peninsular Malaysia makes up 132,090 km² or 39.7% of the total area, whilst Sabah and Sarawak, known as East Malaysia, make up 198,847 km² or 60.3% of the total land area. The capital of Malaysia is Kuala Lumpur. Malaysia has a total of 2,669 km of land borders including 506 km with Thailand, 1,782 km with Indonesia and 281 km with Brunei (Figure 1).
2. Stone Heritage of Pre-historic Times

2.1 Stone tools

A Paleolithic site with hundreds of stone tools was discovered at Bukit Bunuh (Figure 2) by a group of archeologists from the Centre for Global Archeological Research, Universiti Sains Malaysia (USM). The site has been dated as originating at least 1.83 million years ago with further dates of 40,000 years ago and 30,000 years ago. This has made Bukit Bunuh the oldest site in the world outside Africa which has been chronometrically dated.

Significantly, meteorite impact rocks were discovered at Bukit Bunuh area in 2001. The meteorite impact rocks comprise ‘suevite’ that occurs in the form of boulders scattered in the oil palm plantation at Bukit Bunuh, Kota Tampan, Lenggong Valley, Perak (Figure 2). Suevite is a rock type that formed under the very high pressures and temperatures that resulted from the impact when a meteorite plunged to earth. It is comprised of partly melted material, typically forming a breccia containing glass and crystals or lithic fragments. Suevite was formed in and around the meteorite impact craters by the sintering of molten fragments together with unmelted clasts of the country rock. The existing parent rock was crushed and brecciated due to the extreme force during the meteorite impact on the study area. The breccias were then cemented by the matrix formed by the crystallization of the partially melted rock (Figure 3). Suevite resembles tuff breccia or pumice tuff, however this rock is not of volcanic origin.

![Figure 2. Location map of Bukit Bunuh, Lenggong, Perak.](image)

The suevite found in this area has was jointly declared a new Quaternary Stratigraphic Unit by the Minerals and Geoscience Department and Universiti Sains Malaysia in May 2011. It is the only suevite site of Quaternary Age discovered in Asia.
chronometric dating, the suevite rock was dated as 1.83 million years old (Late Quaternary age). In Lenggong area, the Bukit Bunuh Complex is overlying unconformably the metamorphic rocks of the Kinta Limestone that is made up predominantly of crystalline limestone or marble and hornfels that were metamorphosed by a granitic intrusion during the Late Triassic period. A stratigraphic column of the Lenggong area to show the stratigraphic position of the Bukit Bunuh Complex is shown in Figure 4.

**Figure 3.** Suevite, the meteorite impact rock at Bukit Bunuh.

<table>
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<tr>
<th>Era</th>
<th>Period</th>
<th>Epoch</th>
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<td>Cenozoic</td>
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<td>Pleistocene</td>
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<td>Unconformity</td>
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<td>Palaeozoic</td>
<td>Devonian to Permian</td>
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<td>Kinta Limestone</td>
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**Igneous rock**

<table>
<thead>
<tr>
<th>Era</th>
<th>Period</th>
<th>Units</th>
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<tr>
<td>Mesozoic</td>
<td>Triassic</td>
<td>Bintang Granite</td>
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**Figure 4.** Stratigraphy of Lenggong area to show the stratigraphic position of Bukit Bunuh Complex (modified from Kamal Roslan Mohamed et al. (2012)).
The heritage significance of the suevite rock and its accurate dating is that the archeological researchers discovered a stone tool (hand axe) embedded in the suevite (Figure 5) proving that this tool dated from at least 1.83 million years ago. The discovery of some of the oldest hand axes in the world and other tools embedded in the suevite suggests the earliest hominid presence in Southeast Asia at 1.83 million years ago (Mokhtar Saidin, 2012). The discoveries of many similar stone tools in Bukit Bunuh area during the excavation for the archeological studies support the interpretation that Bukit Bunuh was once occupied by a pre-historic community. The occurrence of suevite indicates that this area had been struck by a meteorite that resulted in the destruction of the local Paleolithic culture some 1.83 million years ago. The later generations of the paleolithic inhabitants used the suevite itself as a source of material for making stone tools. Lenggong Valley where Bukit Bunuh is located was proclaimed as a world heritage site by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) on 30th June 2012.

Figure 5. Hand axe embedded in suevite that was dated as 1.83 Ma by the fission track dating method. This indicates that the hand axe is older than 1.83 Ma (Mokhtar Saidin, 2012).

3. Stone Heritage in Historical Times

3.1 Gravestones at the Bukit Kaledang Royal Graveyard

The granite and limestone gravestones at the Royal graveyard located at Bukit Keledang provide information for the interpretation of the history of the Sultanate of Terengganu that was established since 1708 (Askury Abd. Kadir et al., 2001). Bukit Keledang is situated at 5° 19.829’N, 103° 8.108’E.

Sultan Zainal Abidin I, the founder of the Sultanate of Terengganu, established the administrative capital of Terengganu in Kuala Berang located in the upstream area of Sungai Terengan before it was shifted to Kuala Terengganu, located in the
downstream reaches of the same river. Sultan Zainal Abidin I passed away in 1722 or 1723 at the age of 57 years old and was buried at Bukit Keledang Royal Graveyard. The gravestone of the grave of Sultan Zainal Abidin I was made from the granite that was carved in the shape of a Malay traditional boat. The other grave at the Royal Graveyard is the grave of Cik Puan Besar Zainab binti Bendahara Bongsu, wife of Sultan Zainal Abidin II, located next to the grave of Sultan Zainal Abidin I. The gravestone of the grave of the Cik Puan Besar Zainab binti Bendahara Bongsu is made from massive limestone and granite (Figure 6).

3.1.1 Granite gravestone

The granite used as the gravestone at the Bukit Keledang Royal Graveyard is light grey, medium- to coarse-grained with isolated quartz grains (Askury Abd. Kadir et al., 2001). Lithologically, the granite is similar with that of the Bukit Chetai granite which is part of Kapal Granodiorite (Cobbing et al., 1992) or also known as Kapal Batholiths. The granite comprises 40% quartz of about 5 mm in size, 50% feldspar of various sizes and 10% mafic minerals such as hornblende associated with the biotite. The granite exhibits uniform texture and colour and fulfils every stage of physical tests for suitability as a dimension stone (Mohd Zukeri Abd. Ghani, 1995). The granite in Terengganu especially at Kuala Berang is well known for these properties and is now exploited commercially. The light grey granite is known as Sekayu granite. A pink variety is known as Rosa Tenggol, and dolerite is known as Terengganu Green.

Figure 6. The gravestone at the Royal graveyard at Bukit Keledang that is made up of massive limestone and granite.

3.1.2 Limestone gravestone

Based on lithology and fossil content, the limestone of the gravestone at Bukit Keledang Royal Graveyard is very similar with the natural occurrence of limestone at Bukit Biwah. The limestone is grey to dark grey in colour with the occurrence of
foraminifera, gastropods, corals and algae (Figure 7). Secondary calcite veins and folded stylolitic structures can be observed. Since limestone is not common in Terengganu, the limestone of the gravestone most probably originated from the fossiliferous limestone mogote at Bukit Biwah or Bukit Taat. Bukit Biwah (605 m) which exhibits prominent karst topographic features is located in Sungai Terengan Valley (Askury Abd. Kadir et al., 2001). Fossils discovered in the northwestern part of Bukit Biwah consist of foraminifera, corals and gastropods: *Globivalvulia cf. graeca* Reichel, *Endothyra* sp., *Glomospira* sp., *Tuberitina* sp., *Parafusulina* sp. and *Calcisphaera* sp. (Fontaine and Khoo, 1988; Fontaines et al., 1988). Algae, foraminifera and corals occurred abundantly in the southern part. These indicate that the Bukit Biwah limestone is Middle Permian in age (285-275 million years ago). The geological map of part of Terengganu and the distribution of the granite and limestone is shown in Figure 8.

Figure 7. (a) Hand specimen of the grey limestone at Bukit Biwah, (b) Corals within the dark grey limestone, (c) Microphotograph of the limestone with fossil gastropods.

Figure 8. Geological map of part of Terengganu state (left) and location of Bukit Keledang and Bukit Biwah.
3.2 Inscription and Commemorative Stones

3.2.1 Terengganu Inscription Stone

Terengganu Inscription Stone is the oldest artifact bearing a *Jawi* (Malay language written using arabic alphabets) inscription (Figure 9). The inscription is believed to have been composed on 22 February 1303. Among the inscriptions on the stone are the ten Islamic laws and their punishments. The discovery of the inscribed stone proves that Islam reached Terengganu in or before the 14th century. The stone is not only the oldest Malay text in Arabic script that still exists, but is also the earliest record of the introduction of Islam into the Malay Peninsula. The inscription is also significant in terms of the development of writing and the Malay language in Malaysia.

The Terengganu Inscription Stone was accidentally discovered near Sungai Tersat at Kuala Berang, Terengganu, in 1899 after the area was hit by a flash flood. The inscription on the stone proclaims Islam as the state religion of Terengganu. The inscribed stone also proved that a government existed in Terengganu long before Melaka was founded. Even after Melaka was founded, Kuala Terengganu still remained as an important port. On 13 July 2009, the 700-year-old Terengganu Inscription Stone was listed as an item eligible for world heritage recognition during the UNESCO International Advisory Committee meeting in Barbados.

The inscription stone is about 215 kilograms in weight, 84 centimeters in height, 53 centimeters wide at the top and 27 centimeters wide at the bottom. The thickness of the stone is 24 cm and it is made up of dolerite which is a dark greenish grey, fine-grained, homogenous igneous rock, commonly occurring as small intrusions or dykes found in Hulu Terengganu District. Study of the rock composition using nuclear technology known as Neutron-Induced Prompt Gamma-Ray Techniques (NIPGAT) undertaken by Jaafar Abdullah et al. (2012) confirmed that the Terengganu Inscription Stone was made from dolerite. Dolerite also can be found in many other parts of Peninsular Malaya (Schwartz, 1995).

3.2.2 Pangkor Inscription Stone

The inscription stone of Pangkor (known as Tiger Rock) is a huge granite boulder that is located at Teluk Gedung, not far from the Dutch Fort in the southeastern part of Pangkor Island. The rock measures about 10.7 m long and 4.6 m wide and stands at 4.3 m tall. Today, it is sheltered by a pavilion. The stone carries a carved image of a tiger carrying away a child, two round-shaped leaves, and the letters, "If Carlo 1743" and "VOC" which probably refers to the Dutch East India Company (Vereenigde Oostindische Compagnie) (Figure 10).

There are several theories as to who did the inscription. According to one, it was done by the Dutch soldiers in memory of a Dutch dignitary’s son who was snatched by a tiger in 1743. Another sinister version of the tale claimed that the Malays and Bugis kidnapped and murdered the boy in revenge of the ill treatment of the locals by the Dutch. The sketch of a tiger may have referred to the Malays who hated the Dutch who conquered their beloved island and was intended to scare the Dutch away.
According to some local people, the tiger referred to the Portuguese who kidnapped the Dutch boy as they were rival colonials to the Dutch. For the Malays who are Muslims, it is against the Muslim faith to kidnap babies even if they are the babies of our enemies. According to them, the Malays were accused of the crime in order to turn them into the villains.

Figure 9. Four sides of the Terengganu Inscription Stone (photographs courtesy of Terengganu State Museum).
Figure 10. The inscribed stone of Pangkor or the Tiger Rock: (top) the inscribed stone with the sketch of a tiger, (bottom left) coarse-grained porphyritic biotite granite, and (bottom right) the possible scenario when the inscribed stone was carved by the Dutch soldiers in 1743. The Dutch Fort can be seen at a distance (reproduced from Cheah, 2009).

The inscribed stone is a huge in-situ granite boulder as the entire Pangkor Island is underlain by the light grey, coarse-grained porphyritic biotite granite (Figure 11). The granite contains subhedral megacrysts of K-Feldspar set in xenomorphic to hypidiomorphic granular groundmass of quartz, feldspar and mica. The mineralogy of the granite mainly comprises K-feldspar, quartz, plagioclase, and biotite with tourmaline, muscovite and hornblende. Magnetite, zircon, ilmenite, rutile, topaz, apatite, fluorite, monazite and allanite occur as accessory minerals. The granite is possibly connected at depth with the Main Range Granite, the main granite mass in Peninsular Malaysia (Wong, 1991). Age dating on an in-situ porphyritic biotite granite boulder on the west coast of Pulau Pangkor indicated an age of \(209\pm8\) million years ago or Middle to Late Triassic (Bignell, 1972).
3.2.3 Keningau Oath Stone, Sabah

Sabah is one of the two states in East Malaysia, located on Borneo Island which is the third largest island in the world. The Keningau Oath Stone was erected to commemorate the terms in which the former British Crown Colony of North Borneo joined the former colony of Sarawak and the other states of the Federation of Malaya to form Malaysia. It was officially installed on August 31, 1964 at the compound of the old Keningau District Office in Sabah.

The oath stone which is more than 2 tons in weight is actually a sandstone boulder taken from the middle of Sungai Pegalan at Kampung Senagang, a small village at the Keningau-Tenom road (Figure 12). Geologically, the Keningau area is underlain by Pleistocene to Recent alluvium and flysch deposits of the Eocene to Early Miocene Crocker Formation. Lithologically, the Crocker Formation comprises sandstone and interbedded mudstone/shale (Muhammad Akmal Abd Sail, 2007). The Keningau Oath Stone most probably originated from the thick to massive sandstone beds of the Crocker Formation. A simplified geological map of the Keningau area is shown in Figure 13.
Figure 12. Sandstone boulder of the Keningau Oath Stone.

Figure 13. Geological map of Keningau and surrounding areas (left) and location map of Keningau area (right).
3.2.4 Batu Ritong Dolmen, Bario, Sarawak

Batu Ritong or Ritong Rocks is one of the few dolmen structures which still stands in an upright position and is located in the Kelabit Highlands, Bario, Sarawak. It consists of four standing slabs with average dimensions of 2 m long, 2.3 m wide and 0.5 m thick. The sealing cap measures 4.6 m long, 3 m wide and 0.76 m thick (Figure 14). According to local legend, this commemorative structure was erected for a Kelabit aristocrat called Ritong during a big feast where many people were invited to help. The structure has been listed as a historical monument in accordance with Part V of the Sarawak Cultural Heritage Ordinance 1993.

Geologically, Batu Ritong is made up of sandstone of the Miocene Meligan Formation (Figure 15). The Meligan Formation, named after Meligan Range, is composed mainly of massive sandstones and forms prominent mountains in the interior of northeast Sarawak including Batu Lawi (2,027 m) and the Tama Abu Range (1,200 m – 1,600 m) (Haile, 1961). Haile (1962) reported that the Meligan Formation comprises grey, greenish, or yellowish grey, medium- to coarse-grained sandstone which is generally quartzose. In parts, the sandstone is interbedded with light brownish grey mudstone.

3.3 Stone Heritage Buildings

Malaysia has a tropical climate characterized by high rainfall and humidity, consequently areas of thick jungle and trees are common. Woods from tropical jungle have been commonly used by the local people as construction materials. Therefore not many buildings, fortresses or monuments made from stone can be seen in Malaysia today. Only a few ancient man-made structures made from ironstone and from clay bricks have been preserved until the present day.
3.3.1 A-Farmosa fortress, Melaka (stone wall)

Melaka is a small state located about 140 km to the south of Kuala Lumpur. It is a historical state where many buildings and structures were built during about 400 years of colonializations by the Portuguese, the Dutch and the British. One of the historical structures that still stands until today is A Formosa fortress. A Famosa which means "The Famous" in Portuguese is a Portuguese fortress located in Melaka Historical City, Melaka State, Malaysia. It is one of the oldest surviving European architectural remains in Asia. The fortress was built by the Portuguese led by Alfonso de Albuquerque in 1512, one year after they defeated the armies of Melaka Sultanate and invaded Melaka in 1511. Extensions were added to the original fort around 1586 as the Melaka’s population expanded. The plan view of the fort as it was in 1630 is shown in Figure 16. However the only remaining part of the fortress that is still
standing today is a small gate house which is known as *Porta de Santiago* (Figure 17). The other parts of the fortress were demolished by the British in 1630.

![Figure 16. Old Portuguese map of Fortress of Melaka in 1630.](image)

A-Formosa was built using ironstone or laterite that were available in the nearby areas during its construction. The laterite was cut into brick-like shape to form big blocks used in the construction of the fortress. Laterite is commonly formed in hot and wet tropical areas and is rich in iron and aluminium. Laterite is commonly rusty-red in colour because of the iron oxides content. Laterites develop by intensive and long-lasting chemical weathering of the underlying parent rocks (Figure 18) and usually form in areas of low topographical relief and gentle crests and plateaus with little erosion of the surface cover. An essential feature for the formation of laterite is the repetition of wet and dry seasons. The rocks are leached by percolating rain water during the wet season and the resulting solution containing leached ions is brought toward the surface by capillary action during the dry season. The reaction zone, where the laterites normally form, is in the zone that is always in contact with water, i.e. the zone between the lowest and the highest levels of the ground water table. Laterization is a prolonged process of chemical weathering which produces a wide variation in the thickness, grade, chemistry and ore mineralogy of the resulting product.

Geologically, Melaka and surrounding areas is underlain by sedimentary and metasedimentary rocks (Figure 19). The sedimentary rocks consist mainly of shale, mudstone and sandstone. The metasedimentary rocks comprise predominantly dark to very dark grey graphitic quartz-mica schist, light greenish grey, buff quartz-mica schist and tourmaline-mica schist (Zainol Abidin Sulaiman, 2016, pers. comm.).

The schists are strongly foliated and contain fine-grained quartz and micas that consist of biotite and/or muscovite. The quartz crystals are fine-grained, elongated in shape and lie with their long axes parallel with the foliation plane. The micas generally constitute more than 25% of the rocks. Tourmaline also occurs in some of the schists (Zainol Abidin Sulaiman, 2016, pers. comm.).
Biotite, muscovite and tourmaline are silicate minerals. Biotite and tourmaline contain Fe and Al elements, whilst muscovite contains Al. Chemical weathering or laterisation processes acting on the schists in Melaka and surrounding areas produced the laterites that were used to construct the historical fortress of Melaka.

**Figure 17.** A-Formosa: (left) *Porta de Santiago* a small gate house, the only remaining part of A-Formosa that is still standing today in Melaka Historical City and (right) the ruins of A-Formosa.

**Figure 18.** The formation of laterites from the chemical weathering on the underlying bedrock.
3.3.2 The Hindu-Buddhist Temple at Bujang Valley, Merbok, Kedah (stone structure)

Bujang Valley, a historical complex yielding many archaeological remains, is located in Kedah State northern Peninsular Malaysia. Bujang Valley is situated near Merbok, between Gunung Jerai in the north and the Muda River in the south. It is the richest archaeological area in Malaysia stretching to approximately 224 km².

In the Bujang Valley the ruins of a Hindu-Buddhist temple that may date from more than 2,000 years ago can be observed. More than fifty ancient tomb temples, called candi (pronounce "chandi"), have also been unearthed. These ancient structures were constructed with blocks of laterite as well as clay bricks (Figure 20). At Sungai Batu, remains of a jetty, iron-smelting sites, and a clay brick monument dating back to 110 AD have been discovered. Together these make up the oldest man-made structures to be recorded in Southeast Asia.

Other items also found during the archeological study of this area include inscribed stone caskets and tablets, metal tools and ornaments, ceramics, pottery, and Hindu icons. The artefacts found in the Bujang Valleys indicates the influence of Hindu-Budhist culture amongst the local people since about 2,000 years ago, before Islam came to the Malay Archipelago.
Figure 20. Ruins of the ancient Hindu-Buddhist Temple at Bujang Valley: (left) the temple built from laterite blocks and (right) the temple built from clay bricks.

Geologically, the Bujang Valley is underlain by alluvium overlying metasedimentary rocks (Figure 21). The metasedimentary rocks comprise an argillaceous facies of the Mahang Formation that is made up predominantly of dark grey mudstone, shale, metamorphic shale and siltstone. Pyrite is abundant locally (Burton, 1968). Since the Mahang Formation was formed in a partially enclosed basin, a high concentration of iron that formed the laterites was possible. The laterites on the Mahang Formation is sometimes a few metres thick and may contain up to 45% Fe (Burton, 1968). The laterites used for the construction of the ancient temples most probably originated from the weathering process operating on the underlying rocks of the Mahang Formation.

Figure 21. Geological map of part of Kedah state (left) and location map of Bujang Valley (right).
3.3.3 Dutch Fort, Pangkor Island, Perak (stone wall)

Pangkor Island is an island located in the west of Perak state. The Dutch Fort at Pangkor Island was constructed in 1670 for the storage and protection of tin supplies. The Dutch called it ‘Fort Dinding’ after Sungai Dinding, a major river at Lumut, Perak. It is located at Teluk Gedung, not far from the site of the Pangkor Inscription Stone. The fort was destroyed in 1690 by the Malays who objected to the methods used by the Dutch in obtaining the tin. It was rebuilt by the Dutch in 1743 but due to continuous attack by the Malays it was finally abandoned in 1748. The Dutch Fort was the location of the Pangkor Treaty, a historic treaty between the British Government and the Perak throne in 1874 which began British colonial domination in the Malay Peninsula.

The fort was eventually reconstructed by Malaysia’s museum department in 1973 and was gazetted as an ancient monument and historical site under the Antiquities Act 1976 No. 242 Perak Gazette dated March 21, 1978. It was built using clay bricks. However, no information is available concerning the source of the clay used to make the bricks. The foundations and the floor of the fort are made from porphyritic biotite granite. The Dutch Fort, as reconstructed, is shown in Figure 22.

Figure 22. The Dutch Fort at Pangkor Island: (upper left) the fort after reconstruction, (upper right) the bricks, (lower left) the foundations of the fort made up from porphyritic biotite granite, and (lower right) the floor of the fort.
3.4 Heritage Chiselled Stone

Historically, the name of Batu Pahat District, in Johor, located in the southwestern Peninsular Malaysia was originated from a well chiselled on the grey medium- to coarse-grained biotite granite (Figure 23). Geological map of the Batu Pahat area is shown in Figure 24.

Figure 23. A well chiselled on the grey medium- to coarse-grained biotite granite along the joint and sheared planes.

Figure 24. Geological map of Batu Pahat area.
The well was said to have been dug using chisel by the fleeing Siamese troops for water supply after a failed attack on Melaka during the reign of Sultan Mansur Shah, the third Sultan of Melaka who ruled from 1446 to 1459. The chiselled well is located near Kampung Minyak Beku, 11 km to the south of the mouth of Batu Pahat River. The 0.5 m x 1.0 m well was dug by chiselling the granite along the joint and sheared planes (Figure 25). Even though the chiselled well is situated only a few metres above the sea level, it yields fresh water and not affected by the sea water (Figure 26). The chiselled well is artesian in nature where the source of water comes from the nearby granitic terrain. The historic chiselled well still exists until today even after abandoned for about six centuries.

Figure 25. The well was dug by chiselling the granite along the joint and sheared planes.

Figure 26. The well is situated only a few metres above the sea level and yields fresh water.

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STONE HERITAGE
OF
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Cover photo: Stone vessel, stone axe and stone axe head.
Stone Heritage of Papua New Guinea

Arnold Lakamanga

1. Introduction

The independent State of Papua New Guinea comprises the mainland (eastern part of the large island of New Guinea) and adjacent islands of the eastern part of the mainland, whilst the western New Guinea mainland and surrounding islands, known as Papua Province, are part of the Republic of Indonesia (Figure 1).

The geological framework of Papua New Guinea consists of a series of geological terranes from four major geological tectonic settings; the Australian Craton that underlies the Fly Platform, the New Guinea Orogen represented by the mountainous spine of mainland Papua New Guinea and which formed as a result of tectonic collisions, the Melanesian Arc consisting of the islands in the current Bismark Sea, and, finally, the Pacific and Caroline Plates which are being subducted into the Manus and Kilinailau trenches and lie beneath current sea level (Williamson et al., 2005; Sheppard and Cranfield, 2012). The first three units however have been a source of stone used for stone structures and implements featured in this chapter,

In Papua New Guinea every society or community either has now or had in the past, stone objects of some unique cultural and heritage value which may influence members of the community in various ways, as we will see in some stone objects featured in this chapter. The uses of stones and stone structures includes use in sacrificial ceremonies connected with war or for achieving an abundance of food and for magical influence on almost everything in life, They may also be significant in matters of idolatry and worship, and of stating land ownership or marking land boundaries.

The stone objects featured in this chapter are described according to their province of origin rather than in order of their relative significance or size. Their locations are shown in Figure 1.

2. Stone Heritage Sites by Province.

2.1 Siwai, Bougainville Island

Several stone structures and implements are found in the Siwai area, South Bougainville Island (Figure 2). The stones found here are significant objects for domestic usage and land ownership.
2.1.1 Regional Geology

The rock lithologies found in the Siwai area consist of agglomerate, andesitic rocks (Figure 3) and fan deposits all derived from the volcanic activity that took place during the Cainozoic Period. The soils around the Siwai area consist of eroded volcanic rocks of the Crown Prince Range and other volcanos such as Takuan, Taroka and Loloru.
2.1.2 Pig Stone

The half-buried pig stone, Sinawo Kuru, is traditionally considered to be a pig that was turned to stone. Legend has told that a local ancestral person called Masiparu, of the Kurowa tribe in Siwai, had a neighbour (un-named) who owed Masiparu debts he couldn’t repay. Masiparu getting angry, took his spear and split a rock with it. The neighbour fled the area taking with him a pig, one of his treasured processions. Along the way, the fleeing neighbour left his pig to rest, but since Masiparu had placed a curse on the pig it turned into a stone.

The pig stone is currently the proof that the land belongs to the Kurowa tribe of Siwai. Figure 4 shows the pig stone with its legs and snout apparently buried in the soil.

2.1.3 The Sacrificial Stone Tablet

The sacrificial tablet is where the ancestral Masiparu gave sacrifice to the gods for an abundant harvest of okari nuts in the next season (Figure 5). Sacrificial items such as okari nuts and small possums were killed and burnt on this stone.
The stones mentioned in this section are fine to coarse-grained, mafic to feldspar phyric andesite. The phenocrysts are of plagioclase feldspars. Other minerals seen in the rocks are augite, hornblende and some olivine. The matrix of specimens collected will most likely also contain some biotite, hypersthene, magnetite and quartz.

![Figure 5. Sacrificial Stone Table.](image)

### 2.1.4 Stone Vessels and Implements

The vessels shown in Figure 6 were used for various purposes, including storage and crushing of seeds and nuts. They are currently kept in houses as ancestral implements. The stone vessels were made from medium grained volcanic sandstone.

The origins of the stone axes (Figure 7a, 7b) and tool (Figure 8) are not known by the current custodians of these implements, however the common occurrence of these implements implies that they were locally produced from the rocks present in Siwai. The stone axes/tools are formed from fine-grained andesite.

The implement with wings (Figure 8) must have been a hand tool, with the wings providing a strong grip on the tool for cutting.

The above stone implements appear to be formed of the same rock types as the Siwai ‘stones’ but of a comparatively fine-grained variety or more likely are formed from volcanioclastic fine-grained sandstones/siltstones. The latter material was easily worked by the craftsmen that created them. The Siwai stones are harder and would not be easily worked without modern equipment. Due to the various ages and uses for the implements it is hard, without further examination, to make a positive identification of the source of stone of the axes and cutting tools but most of the tools were probably formed from stones or boulders collected from streams and rivers and were then shaped for their different uses. The shapes formed may be based partly on tradition and be partly a by-product of the way they were manufactured. The creation of these
stone axes and other implements took a long time and involved chipping away until the desired shape was achieved.

Figure 6. Stone vessels.
2.1.5 Prophetic Footprint

The stone footprint (Figure 9) is said to be that of a prophet or someone of a prophetic nature that passed through Siwai during ancestral times. The print is 36 cm in length and its width in the central region is 13 cm, and almost 2-3 mm in depth.
This is one of the two footprints in the area, almost 5 kilometres apart. Prior to the supposed coming of this person, the Siwai people were nomadic and lived by hunting and gathering; eating mainly ants from the trees, and gathering whatever is edible from the plants. This ‘prophet’ is reputed to have brought what in current terms is classed as cultivated food, mostly grown in gardens.

The footprint stone is formed from the same material as the other Siwai Stones, felsic to mafic coarse-grained feldspar phyric andesite.

2.2 East Sepik Province

Some stone heritage sites, including stone structures significant for land ownership and clan identity, are situated in the Dagua area, East Sepik Province.

2.2.1 Regional Geology

The rocks found in the surrounding area of the province are mostly sedimentary units of Miocene age, locally termed the Senu Beds and the Puwani Limestone units. The Senu Beds are found in moderately dissected terrain in the foothills of the mountain ranges and consist of indurated poorly sorted conglomerate and sandy conglomerate, lithic sandstone, sandy siltstone, planktonic foraminiferal siltstone, pebbly siltstone and minor limestones. The Puwani Limestone forms ridges and plateaux with karst topography and comprise massive to nodular bedded white, buff or bluish coralgal reef limestone, sandy and pebbly limestone, biosparite, some biopelsparite, limestone grit and minor sandstone and siltstone units. These sedimentary units were deposited in a variety of marine environments, including deep water turbidity regime and shallow water carbonate shelf.

2.2.2 Bebemik’s Cave

Legend tells of a spirit or man, Koiyaken who came from Madang along the west coast to Kubren village in the Dagua area in the East Sepik Province. He came with his children (cave bats) and was looking for a place to stay. Bebemik, an old woman lived alone in a cave up in the mountains of Kubren village, the cave was small but well kept at that time (Figure 10). Koiyaken could not find any other place suitable for staying so when he came across Bebemik’s home, the cave, he instantly fell in love with the place and so decided to settle there as well.
The only problem was that the cave Bebemik was too small for living, so Koiyaken called together all the other ‘masalais’ (spirits) from nearby villages to come and help him open up the cave. They dug open a larger chamber with compartments measuring up to about 30 meters in height and 20 meters in length. The cave became the home for Koiyaken and his children, the cave bats (Figure 11). This cave was skilfully made with compartments or chambers, stairways and a cooking place (Figure 12).

The host rock in which the cave formed is pure limestone, a sedimentary rock composed largely of the minerals calcite and aragonite which are different crystal forms of calcium carbonate (CaCO₃) (Figure 13). This limestone is part of the Puwani Limestone, which is a basal sedimentary unit of Early to Middle Eocene age (12.5 to 22.5 Ma). This unit is lensoid varying between 50 to 100 m in thickness and is composed of massive to nodular bedded buff to pinkish coralgal limestone with a thin pebble conglomerate with fossil crinoid stems near the base. The Puwani Limestone is tightly folded into a series of northerly trending synclines and anticlines, with some fold limbs faulted along the same trend.

Figure 10. Bebemik’s cave entrance.
Figure 11. Bebemik’s room.

Figure 12. One of the cave chambers.
2.3 Stone Heritage in the Northern Province

2.3.1 Regional Geology

The regional geology of Northern Province within which Isivita is located can be divided into two main lithological variants. The central and western end of the province is occupied by the Owen Stanley Range end-members which comprise; i) the Papuan Ultramafic Belt Ophiolite (gabbro and volcanic) rocks, and ii) the Owen Stanley Metamorphic units such as the Kagi and Emorocks. Towards the south and south east of Kokoda, there are a series of diorite and porphyritic microdioritic intrusions which are part of the Mount Davidson Volcanic complex. The eastern portion of the Northern Province, where Popondetta township is located, and in the Isivita area, all is overlain by the volcanic products of the Mount Lamington eruption. The plains of Popondetta and towards the coasts the rocks are mostly andesitic agglomerate and tuff and water laid deposits of the Mount Lamington cone volcanic apron. The foot hills of Mount Lamington, at Isivita, encompass the andesitic agglomerate, tuff and lava forming the cone of Mount Lamington.

2.3.2 The Isivita Legend (human butchering) Stone

The legend stone in Isivita is, in geologic terms, andesitic agglomerate which had its source from the Mount Lamington volcanic eruption and was subsequently transported down slope where it is now exposed at the Isivita area (Figure 14). According to the ancestral belief, the stone existed long before the 1951 Mount Lamington eruption which, geologically, would indicate an earlier volcanic event prior to 1951 which was responsible for the formation and transportation of the stone to its present location. This interpretation would concur with the known tectonic regime of Papua New Guinea where there is likely to have been a series of reactivated episodes of volcanism in areas of high tectonic activity.
Figure 14. Isivita (human butchering) stone site in Kiorota area, Oro Province.

The legend stone which is grey in colour is prophyritic in texture and its mineralogy consists of feldspar, quartz, muscovite, biotite and magnetite with minor amounts of hornblende and pyroxene and with partial pyrite mineralisation.

The dimensions of the stone are; 151 cm length, 44 cm height, and 53 cm width at the base and 49 cm at the top. The top was originally flat but subsequently it weathered to its current shape and size (Figure 15).

Figure 15. Human butchering stone table of the time of warring and cannibalism.
### 2.3.3 Heritage Value of the site of the Isivita Stone

As late as the early 1900s, traditional Papua New Guinea communities were still practicing cannibalism. The Isivita stone marks the transition from cannibalism to Christianity by the people of Kiorota village and its surrounding neighbours.

The current location of the stone (Figure 16) was the site a large legendary tree known as Isivi that is aid to have brought an abundance of birds and animals to the area. For some unknown reasons Isivi was chopped down, and exposed the stone which the plant Isivi had preserved. To this date, the place the stone stood is called Isivita, interpreted in the Kiorota language as the place where Isivi (the tree) stood.

![Figure 16. The human butchering stone area is now a Christiany prayer area.](image)

During the cannibalism era in the current Kiorota area, warriors went out to kill people to eat. This story features four males, Horombe, Hauriri, Useri and Sorari, all sons of a man called Pehara, from the Beikis clan. These men would bring back their kill and cut up the meat on the stone now called the Isivita stone. The stone, in Figure 15, was originally flat and naturally provided the surface for this purpose but the stone has since lost its shape and texture due to natural processes such as weathering.

At the time this was going on, between 1920-1930, Christianity was approaching Isivita, with Missionaries already landing along the coastal areas of the Northern Province. One missionary, Reverend Henry Holland heard of this cannibalism in the Isivita area and wanted to conquer this area with Christian values. Upon reaching Isivita, he saw this lovely flat stone and decided to rest, and eventually fell into a deep sleep. With him, he had three items, the bible, a seed of a German taro (now called taro kongkong throughout PNG) and a seed of a choko plant.

While the Reverend was sleeping, the warriors returned with their kills, and seeing a white man sleeping on their butcher stone the warriors became fearful and curious as to where this “Parara (Taupa) Embo” white human being had come from. Reverend Holland woke up to face these fearsome warriors who had spears at the ready to attack if he made any wrong move. Being a man of God he was able to communicate with...
warriors and these cannibals became the Reverend's first followers that helped him to build a church.

The people of Kiorota now use this site for religious activities including praying and fasting.

2.4 Stone Heritage Sites in Jiwaka Province

The traditional stone quarries for manufacture of axes are located in the Kunjin and Tun area, Anglimp, South Waghi Electorate, Jiwaka Province (Figure 17). The stone axes are significant symbols for clan identity and land ownership. The quarries were abandoned in the late 1960s and reopened for anthropological studies by the Australian National University in the early 1990s. The quarry sites are now covered by montane forest and the clan landowners have reserved the sites as consecrated areas and have many myths associated with accessing the quarry sites (Figure 18).
2.4.1 Brief background history/legend of the Kunjin stone area

There were four quarries originally dug by ancestors for the mining rock material to be used to make the Kunjin stone axes (Figure 19). Two quarries, Kunjin Mountain Quarry and Yesemb Quarry, experienced significantly intensive traditional mining while the other two were less significant.

Kunjin Mountain Quarry
This is the main quarry where most of the rocks used for making the Kunjin stone axe were mined.

According to the legend, there was a couple who went out on a hunting expedition in the jungle. After the tiring walk uphill, the husband and wife sat down to rest. As they were in a more private environment away from the main village, they decided to have sexual intercourse to relieve themselves. In the process of intercourse, the wife felt something sharp pinching her back from the ground. She immediately told her husband to stop so that they could check what it was. They found the sharp piece of rock sticking out of the ground and the husband seeing how glassy and sharp it was, decided to take it to be used as a cutting tool.

According to the legend two “masalai meri” female spirits keep guard over the quarry. There are three boom gates or check points which men have to pass through before reaching the quarry. No females are allowed to go through.

Yesemb Quarry
Notable mining activities have taken place at this quarry but not as intensive as the main quarry at Kunjin.

Kumbaming Quarry
This quarry was not as popular as the two previous quarries. People at Kunjin and Yesemb heard that ten people tragically died in the pit/tunnel due to the collapse of the quarry.
Perr Quarry
This is a sacred pit which was not popular and no significant mining took place at this location.

Figure 19. Locality map of quarry sites within the black rectangle. Local tracks are shown in yellow.

2.4.2 Regional Geology
This region falls within the Minj Topographic Map Sheet 7886 encompassing Jiwaka and the Western Highlands, Simbu and Madang Provinces in part. Jiwaka Province hosts the Kunjin and Tun stone axe quarries which are situated within the basement Omung Metamorphic rocks. The main lithological variants can be subdivided into a weakly metamorphosed sequence of siltstone and slate with intercalations of partly pillowed lava, volcanic breccia and tuff, lapillistone, sandstone and minor felspathic sandstone and conglomerate with small lenses of biomicritic limestone originally deposited on a deep continental shelf and surrounded by the volcano sedimentary sequence of the Kana, Maril and Kondaku Units. The quarry sites are located on the northern limbs of the prominent Kubor Anticline.

2.4.3 Rock used for making Stone Axes (Obsidian)
The local stone axes were primarily made from Obsidian. The name was originally derived from a similar stone found in Ethiopia by Obsius (obsianus lapis). Obsidian is formed when felsic lava is extruded from a volcano and cools down very rapidly. Obsidians are commonly found on the margins of rhyolitic lava flows. The extremely
high silica content of such lava induces high viscosity and polymerisation of the lava. The increased viscosity impedes crystallization, and the lava solidifies as a glass.

Obsidian is a natural occurring glass with smooth amorphous texture. It is hard and brittle and fractures with a conchoidal shape. Its hard edges were used in primitive cutting and piercing implements, weapons and ornaments for ceremonial purposes.

Obsidian is metastable at earth’s surface and Obsidian older than a few million years rarely preserves its glassy texture because the glassy rock is rapidly destroyed or altered by weathering, heat or other processes. The breakdown is accelerated by presence of water. Pure obsidian is dark in colour but its magnesium and iron content gives a dark brown to black or green colour.

2.4.4 Formation Hosting the Volcanic Glass

The volcanic glass from which the stone axes of the region are derived probably originates from the Tsenga Volcanic sequence or within the basement rocks. As noted above, such volcanic glass is often unstable when exposed at low temperatures for a long period of time when they undergo a readjustment of atomic arrangement to a more stable crystalline structure as seen in the Kunjin Tun Quarry.

Figure 20 shows devitrified volcanic glass with obvious crystal growth on the periphery. However, the classic conchoidal fractures on the top of the image retain the property of the volcanic glass or obsidian.

The quarry sites and old workings indicate highly weathered, brown to yellowish brown, variegated, black, oxidised and friable to earthy material (Figures 21 and 22). The devitrified glass unit is intercalated with the Omung unit and is highly deformed in some areas. The regional structural regime might indicate that the volcanic glass unit here was structurally emplaced (Figure 23).

Figure 20. Devitrified glass formerly obsidian.
Figure 21. One of Kunjin/Tun tunnels in the background.

Figure 22. Kunjin/Tun Tunnel with highly weathered Omung metamorphic rocks and an intercalated lava flow.
The stone axes are made from a devitrified volcanic glass (formerly obsidian) which occurs as a thin layer within a lava flow within the massive Omung Unit. The devitrified lava is possibly derived from the regionally extensive Tsenga Unit commonly occurring in the Minj area. The lava is fine grained, greenish grey to black, laminated and striated in part with occasional quartz-carbonate veining. The beds generally trend 120° and dips 30-35° and with a dip direction of 230° southwest due to its position on the Kubor Domal Anticlinal structure.

2.4.5 Heritage Value Tools & Implements

Stone tools and implements found in this area are shown in Figure 24.

Uses of the mined rocks (obsidian)

The primary use of the mined competent rocks was used to make traditional stone axes. The Kunjin stone was used widely in the upper highlands region of Papua New Guinea and stone axes were traded with people from the Simbu, Jiwaka, Western Highlands, Enga and Southern Highlands provinces. A stone axe is one of the traditional artefacts that is currently seen at the back of Papua New Guinea’s legal tender two kina note. The main use of the axe was felling trees, building houses, making gardens, hunting, and as a weapon during tribal warfare. Smaller pieces of rock were sharpened and used as cooking knives. They were also used for performing surgery on injured warrior in orders to remove pieces of broken arrow. Sharpened stone is also used for bride price payment.
Figure 24. Examples of stone implements and ornaments, (a) milling tools, (b) stone axe and cutting implements, and (c) ornamental tools for ceremonial purposes.

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Cover photo: Pediment of San Joaquin Church (upper half) and a close-up view of its central part (lower half).
Stone Heritage of the Philippines

Conrado R. Miranda

1. Introduction

Warm tropical seas surround the seven thousand islands of the Philippine archipelago and are perfect for coral growth. The archipelago extends from about latitude 5° North to 20° North and from longitude 115° East to 125° East (Figure 1). The Philippine Institute of Volcanology and Seismology (PHIVOLCS) lists more than twenty active volcanoes, and many more inactive ones (Figure 2). The volcanoes are distributed over the whole area of the Philippines, from north to south and east to west: from the Babuyan Islands in the north to the island of Jolo in the south. The coral, over time, has provided an abundance of coral stone whilst emanations from the volcanoes have provided an abundance of volcanic tuff. In addition the common sedimentary rocks, sandstone and limestone (in various forms) are significantly represented as building stones and there are occasional sites with zeolite (Figure 3).

The stone heritage of the Philippines is the result of natural and human (religio-socio-political) forces. There are a number of dramatic natural features, the most famous probably being the almost perfect cone of Mayon volcano. In addition there are limestone caves in Sagada, Banaue, where ancient wooden coffins still hang from the nearby limestone cliffs (Figure 4), and others in which there is an underground river in the Puerto Princesa Subterranean River National Park, Palawan (Figure 5). This river is 24 km long and runs through limestone caves. There is also evidence of indigenous activity involving rocks in the Philippines, see below on the inscribed stones of Ticao.

Mayon volcano in Albay has erupted 49 times, the most recent being in 2009 (Figure 6; Mines and Geosciences Bureau (MGB), 2010, p. 37). Mayon is a composite cone (stratovolcano) formed from lava flows, pyroclastic flows, airborne ash deposits and debris flows. It stands nearly 2500 m above sea level and has a base circumference of 62.8 km (PHIVOLCS, 1995). Taal volcano is famous for being a volcano on an island in a lake in an island (Luzon) but it is only just over 300 m above sea level (Figure 7; MGB, 2010, p. 162). It has erupted 33 times in historic times, the last being in 1977. Mount Pinatubo has only erupted four times in historic times: 6,000 BCE, 350 BCE, 1342 CE and 1991. The other most active volcanoes are Bulusan in Sorsorgon, Canlaon in Negros Oriental and Hibok-Hibok on Camiguin Island.
Figure 1. Philippine provinces (courtesy of Philippine GIS Data Clearinghouse).
Figure 2. Distribution of Volcanoes in the Philippines (courtesy of PHIVOLCS-DOST; PHIVOLCS, 2008).
Figure 3. Geological map of the Philippines (Philippines Bureau of Mines, 1963). Sedimentary and metamorphic rocks are colored yellow and lighter colors but including the purple in the Legend. Igneous rocks are represented by pink to mauve colors plus the strong green colors.
Figure 4. Sagada coffins in Banaue, Ifugao, northern Luzon (photo courtesy of John N. Crossley).

Figure 5. Entrance to the underground river, Palawan (photo courtesy of Mike Gonzalez).
Tectonics and Philippine Geology

The Philippines is a location of intense tectonic activity, which is the result of the interaction of three major tectonic plates in the Western Pacific Domain: namely, the Pacific, Eurasian and Indo-Australian Plates. The Pacific Plate slides under the other two plates. At the south-western portion of the Western Pacific Domain is the Southeast Asian Tectonic Region. It is composed of the Philippine Sea Plate and the south-eastern edge of the Eurasian Plate. The complex tectonic zone created by their interaction is the Philippine Archipelago. The Philippine Mobile Belt of the Philippine Archipelago is the group of landmasses that apparently originated from the sub-equatorial regions moving to their position with the rotation and spreading of the Philippine Sea Plate during Eocene to Miocene times. The different lithologic units
have been classified into (1) metamorphic rocks, (2) ophiolites and ophilitic rocks, (3) magmatic rocks and active volcanic arcs, and (4) sedimentary basins.

Nine individual sedimentary basins are distinguished within the Philippine Mobile Belt (MGB, 2010, p. 39). The sedimentary sequences within the basins are of both terrestrial and marine origins and these may be up to 8000 m deep. These contain limestone and frequently sandstone, though the relative distributions of these differ.

Rocks

The principal rocks used for constructions in the Philippines are coral stone, sandstone, limestone and volcanic tuff, with one notable mention of zeolite and the occasional use of granite (a crystalline igneous rock) and marble. Coral stone is also known as coral limestone, shell limestone, coral shell stone, South Seas Taveuni shell stone, fossil stone, and Pacific Pearl coral stone. It is found in abundance at or near the seashore and many churches and also watchtowers used this material in their construction. The sandstone varies in colour from almost white to red. Limestone varies significantly around the country and is sometimes hard to distinguish visually from coral stone, which is not surprising since they are both basically calcium carbonate. MGB (2005) reported “The only known deposit of zeolite, which has been put into production over the Philippines archipelago, is the one situated in Mangatarem, Pangasinan” (Figure 8). Zeolite was used for construction of Mangatarem Church, Pangasinan.

Granite was used in a number of lighthouses. Marble is found in a number of places, notably the island of Mindoro, near Puerto Galera, also Bataan, Dingle, Iloilo, and even in Tondo, Manila (MGB, 2010: Bowring, 1859). Marble, together with limestone, is still mined in the mountainous northeast of Bulacan. Bowring (1959) wrote: “Finely variegated marbles exist in the province of Bataan, and some have been used for ornamenting the churches; but their existence has excited little attention…” There is also a marble quarry at Gabaldon, Nueva Ecija.

In the Philippines volcanic tuff is referred to, confusingly, as “adobe.” It is not the same as the adobe clay used to make bricks in places such as Mexico and California. The word comes from the Spanish adobar: to plaster. Because of the large number of volcanoes adobe is found throughout the archipelago. Moreover ophiolites and ophiolitic rocks are widespread in the whole archipelago (MGB, 2010).

The adobe (tuff) found in the Philippines varies in quality; that in Angono being quite soft. However the adobe from Meycauayan, Bulacan, 20 km from Manila up the River Polo, is much harder and of very good quality. In the nineteenth century, Zúñiga (1893) described the adobe from there as being the most famous and the hardest known around Manila, and reported that the king used it for the royal buildings. He also says that the quarry there is the best in the country. The adobe from Meycauayan was said in the eighteenth century to have been the source of the hardest variety, called “bulik” (Jose, 2003). The present day highly urbanized city of Meycauayan sits on adobe and adobe was used in buildings there until the late 1960s.
2. Timeline

The prehistory of the Philippines is sketchy. There has been limited exploration but the National Museum is vigorously pursuing aspects of national archaeology.

Before the Spaniards began their settlement of the Philippines in 1565 there was an age of contact with the great traditions of Asia. Further, Muslims had converted much of the south including Tawi-Tawi, Jolo and Mindanao and had established mosques in those areas. The Philippines was first settled by Spanish in Cebu but they quickly moved to Panay, then six years later Manila became the capital. The Spaniards quickly constructed churches, but also forts and other fortifications such as watchtowers. In the nineteenth century they also built lighthouses.

The indigenous peoples seem not to have used stones for constructing buildings, but they sometimes used them in their rice terraces, which are now believed to date from no later than the beginning of Spanish occupation (Acabado, 2015). There is also one odd stone construction by Ifugao during the American occupation. The local people built one of their ceremonial benches, hagabi, which were usually constructed from wood, in stone for the American Lieutenant Governor Owen A. Tomlinson for the inauguration of the new stone Presidencia in Kiangan, Ifugao, in 1913 (Figure 9; Jenista, 1987). According to Jenista (1987), the local Ifugao were pleased about the stone hagabi because Tomlinson, who spent five years in Ifugao, learnt the local language and respected the local customs. The hagabi is still to be found in front of the Kiangan Museum in Ifugao. There had previously been a stone building there as it is known that stones from the old Presidencia were reused for stone walls and pavement in the Ifugao Central School in Kiangan.
2.1 Prehistory

Stone tools that are dated to the Pleistocene, about 750,000 years ago, provide the earliest evidence of the presence of people in the Philippines. Such evidence has been found in Palawan and in Tuguegerao in the Cagayan Valley, northern Luzon, where stone tools, hammer stones and chert flake tools have been discovered. The stone tools and large flakes were created by striking river pebbles with a hammer stone. This early evidence of human activity using stone tools is similar to that found in other parts of the world. Tabon Cave in Palawan appears to be a kind of Stone Age factory, with both finished stone flake tools and waste core flakes having been found at four separate levels in the main chamber. Charcoal left from three assemblages of cooking fires there has been Carbon-14 dated to roughly 7,000, 20,000, and 22,000 BCE (Scott, 1984). The complex is managed by the Philippine National Museum, which declared it a National Cultural Treasure in February 2011. Otley Beyer and von Koenigswald also found what they called “hand-axes” of flint, quartz and chalcedony in Rizal-Bulacan (Hoover, 1976).

Beyer (1947) also explored the areas within the vicinity of Taal Lake and mentioned discovering a Pleistocene outcrop containing palaeolithic choppers or hand-axes from Barrio Sampa in Taal, Luzon.

In 1965 in Leta-Leta cave, northern Palawan, a little jar was found that is associated with the Late Neolithic period (approximately 1000 to 1500 BCE). It was excavated in a burial site where a stone adze was also found (Ramirez and Szabo, 2009).

The Manunggul jar was one of several stunning artefacts discovered in Manunggul Cave, Lipuun Point, Palawan, by a group of archaeologists who investigated the site from 1962 to 1965 (Monbrison and Alvina, 2013). In addition to burial jars, they also recovered human remains covered in red paint and adorned with bracelets made of jade, shells, and stone beads (Fox, 1966).
The Angono Petroglyphs in Binangonan, Rizal province date back to around the late Neolithic, about 3000 BCE, but were only discovered in 1965 (Figure 10). They are among the oldest surviving examples of rock engravings in Asia and are believed to be the oldest in the Philippines. The glyphs are located in a cave in a rock formation belonging to the Pleistocene Guadalupe Formation. There are 127 figures engraved into volcanic tuff. This particular tuff was soft enough to be worked using a denser piece of stone. The images comprise people, animals and geometric shapes. Many of the human carvings appear to be in a squatting position, which perhaps suggests this was a place of worship. Unlike examples of prehistoric art elsewhere, there is no indication that colours were ever incorporated in the drawings. The World Monuments Fund placed the Angono Petroglyphs on its list of endangered monuments in 1996. There is another, younger, set of such carvings, which are considered to be the second oldest known artworks in the Philippines and comprise a series of geometric shapes. These are at Alab, Bontoc, in the mountainous northern Philippines and are believed to date to 1500 BCE.

Figure 10. Angono petroglyphs in Binangonan, Rizal (photo courtesy of Francis San Buenaventura).

A village at least a thousand years old has recently been discovered in 2012 on Mount Maclayao, in Sitio Kamhantik, Mulanay town, Quezon (latitude 13° 34’ N, longitude 122° 27’ E). Fifteen tombs carved out of limestone were found in the Buenavista Protected Landscape. The National Museum reported that remains of habitation and burials from approximately the tenth to the fourteenth century had been found and that this was the first time carved limestone tombs had been found in the Philippines (report in the British newspaper, The Telegraph, 20 September 2012). The limestone was mapped by the Bureau of Mines and Geosciences (now the Mines and Geosciences Bureau, MGB) as the Malumbang Formation (MG, B, 1983). The limestone tombs are presumed to be located within the outlier of the Malumbang
Formation that outcrops at the peak of Mount Maclayao. The Malumbang Formation is essentially fossiliferous and sandy limestone of a cream buff or dirty white color.

Surrounding the village of Batad, Banaue, there are rice terraces that differ from many of the rice terraces of the area in that they are constructed using stones, rather than just mud (Figure 11). Although there is a long-standing belief that these were constructed a thousand years ago or so, according to recent research by Acabado it is now contested that rice terraces were only constructed after the Spanish arrival, though by the eighteenth century at the latest (Acabado, 2015).

Figure 11. Stone rice terraces, Batad, Banaue (photos courtesy of John N. Crossley).
In 2011, two stones were found at Ticao, Masbate, which bear inscriptions in Baybáyín, the ancient script of the Philippines. One is round and the other trapezoidal. The former is thought to be a stone sinker that was usually bound with a piece of rope in a crosswise manner across the center to weigh down a fishnet. “Face 1 of the Ticao Trapezoidal Stone seemed to have originally functioned as a platform for ritual offerings in a native simbahan [church] or place of worship” (Borrinaga, 2011). At first some people felt these were fakes but Borrinaga’s investigations and the nature of the texts now confirm that these inscriptions came from about the sixteenth century, though one face of the trapezoidal stone was inscribed much later, perhaps even more than a century.

There seems to be no evidence that indigenous peoples of the Philippines constructed any stone buildings but, as noted above, on occasion they did use stone for the rice terraces, for example in Batad, Banaue. However, most settlements in the Philippines before the Spaniards arrived were mainly to be found close to water. Very many were on the seacoast, while others were beside rivers. Of course there were other settlements in some of the mountains, notably the Cordillera in northern Luzon.

2.2 Historic times

It seems highly probable that some stone was used in mosques in the southern Philippines after the ingress of Islam in the fourteenth century CE. “The true mosque … is a large permanent structure built on a stone foundation and located near water” (Rodell, 2002). The earliest physical evidence of Islam in the Philippines is a tombstone on the island of Jolo, which has been provisionally dated to 1320 (Petersen, 2002). The Sheik Karimal Makdum Mosque was the first mosque established in the Philippines in Simunul, Tawi-Tawi, around 1380 in the 14th century CE (760 AH). Remnants of the original very hard wooden pillars remain and it is probable they were embedded in stone. King Faisal Mosque, Marawi City, Lanao del Sur, incorporates stone, probably coral stone, but the other notable mosques are covered in stucco and it is not clear what their construction materials are and no further information seems currently available.

The arrival of Muslim scholars from nearby Indonesia brought with it the concept of the kota or fort. The Muslim inhabitants of the southern Philippines built such fortresses, which were usually occupied by entire families rather than just warriors. It is said that at the height of the Maguindanao sultanate’s power, there were many such forts around Western Mindanao to block the Spanish advance into the region. These kotas were usually made of stone and bamboo or other light materials and surrounded by networks of trenches. Bamboo kotas were easily burnt or destroyed. Eventually the Sultanate was subdued by the Spaniards and the majority of kotas dismantled or destroyed. Many of those remaining were destroyed by much later American expeditions and, as a result, very few kotas still stand. However, there are some notable ones: Kota Bato: literally translated as “stone fort” the first known stone fortification in the country, its ruins exist as the Kutawato Cave Complex and Kota Jolo: the capital and seat of the Sultanate of Sulu. When the Spaniards occupied it in the 1870s they converted the kota into the world’s smallest walled city. Kota Selurong,
which had been an outpost of the Bruneian Empire in Luzon, later became the City of Manila in 1571.

2.3 Spanish times

When the Spaniards began to settle the Philippines, commencing with Legazpi’s expedition in 1565, their main aim was the conversion of the indigenous peoples to Christianity, rather than military conquest, though of course they came with many soldiers and did not hesitate to use them if they felt threatened. They first established themselves in the Visayas, initially Cebu but they soon moved to Panay where they had better food supplies. Even Legazpi’s expedition had six Catholic priests and they set about converting the local people to Christianity and baptizing them. In 1570 they moved north to Luzon and made Manila the capital from 1571. The conversions were largely the work of the religious orders of monks (otherwise known as friars). Discalced (or shoeless) Franciscans came in 1578, Jesuits, who had only been founded in 1534 and whose Mexican mission only started in 1572, arrived in 1581, Dominicans in 1587, and finally the Recollects (Discalced Augustinians) in 1606. On the other hand, secular priests, i.e. those not belonging to a religious order, although they had been in the Philippines since 1565, were few and scattered. The Spaniards assigned different geographical areas to these different religious orders.

The colonizers policy of “reducing” indigenous communities so that they lived “within the sound of the mass bell” meant that local communities were aggregated together, usually enlarging an existing settlement. The colonizers were remarkably successful and the country became the only Catholic country in Asia, with the vast majority of its people becoming Christians—and attending mass.

There needed to be places to say the mass and naturally the Spaniards immediately set about constructing churches. Though the churches built by the Spaniards were originally of wood roofed in nipa (Nypa fruticans) like indigenous constructions, they soon began building using stone. Over the succeeding four and a half centuries Christianity has maintained its hold on the country, though now there are also a number of non-Catholic Christian sects. Attendance at religious services on Sundays is very high compared with that in most countries of the world. Moreover the rites of passage contribute to religious congregation and weddings and funerals, in particular, attract huge numbers of people to their local churches.

Politically the church and state have worked closely together—as they did in Spain before the Spanish Civil War of the 1930s. Thus the Catholic Church has had a significant impact on political decisions and conversely the state has strongly supported the Catholic Church. The overall effect has been that church institutions, and specifically buildings, have been maintained and supported both by the local people and also by state subventions. Everyday life is infused with religious items: for example, most public motor vehicles will have crucifixes or statues at the front near the driver, and people will often be seen making the sign of the cross when they pass a church.
The range of forms of building that have remained from Spanish times, that is to say from 1565–1898, as well as churches, includes cemeteries, forts and other fortifications, walls (including circumvallations), watchtowers, bridges, lighthouses and houses, which were built from about 1600 CE on. Stone was also used for houses (in Vigan, Ilocos Sur, and Manila). Unfortunately, civic buildings are less common since the capital, Manila was damaged extensively during World War II and the buildings of the old walled city, Intramuros, were largely replaced by modern commercial ones.

3. Heritage Stone Constructions

3.1 Churches

Spanish settlements, again like the indigenous ones, were originally close to the water and the Spaniards soon began using coral stone excavated from the seacoast to build their churches. These, or their successors, provide a large proportion of the stone heritage of the Philippines. The buildings constructed, even those of stone, were susceptible not only to earthquakes, but also to the many typhoons that annually cross the Philippines, usually in the Visayas and north of there, in particular Luzon. Besides the powerful winds, the rain that typhoons brought caused significant damage. Nevertheless, in very many cases but apparently not all, churches were rebuilt on the same site. In addition, and even more devastating, were the earthquakes. The most significant recent earthquake was the 1948 Lady Caycay (or Kaykay) one that occurred with a magnitude of 8.2 at 1:46 in the morning of 25 January 1948. The epicentre was between the Antique municipalities of Anini-y and Dao (present-day Tobias Fornier) in the west of Panay Island (Bautista et al., 2011). In 2013 an earthquake of magnitude 7.2 struck Bohol on 15 October at 8:12 am, destroying a number of historic churches. It is not clear when, or if, these churches will be reconstructed.

One other major source of destruction was due to the American policy of conducting heavy bombing before sending in ground troops during the Second World War. The most obvious casualty was the old walled city of Intramuros, though many parts of the Philippines were significantly affected.

One exception to churches being rebuilt on the same site was recently found in Club Balai Isabel Resort, Talisay, Batangas, where the ruins of an old church have recently been discovered. Ming dynasty pottery indicated a date of about the fifteenth-sixteenth centuries CE. Carved stone and coral effigies called likha had been found there earlier (Cuevas and Vitales, 2010; Vitales et al., 2011). The original town of Tanauan was founded in 1754 after an earlier eruption of Taal volcano and Talisay was originally one of its barrios (Galende, 1996). The church that has been found was built when the town of Tanauan was located on the northern shore of Taal Lake. Tanauan is now farther east along the Lake Taal shore, in what was then one of its barrios. The structure exposed in the excavations was made of greyish adobe (tuff) blocks like those commonly used in the walls of churches in Batangas as well as in Manila, covered in the interior with a thin layer of stucco. The thin- to medium-bedded, fine-
grained vitric tuff, welded volcanic breccia with tuffaceous sandstone and shale that has been mapped as the Taal Tuff is believed to be the rock used for the former Tanauan Church, as well as other churches around Taal Lake (MG, B, 1991). Taal Tuff is spread around Taal Lake, which is a volcano-tectonic depression (MGB, 2010).

Despite all the depredations from typhoons, earthquakes and war, there are numerous stone churches dating from the late sixteenth century to the nineteenth century that survive and are of historic significance and contribute to the stone heritage of the Philippines, in particular there are four listed as World heritage sites: San Agustin Church in Paoay, Ilocos Norte (1604), Nuestra Senora de La Asunciòn Church, Santa Maria, Ilocos Sur (1765; Figure 12), St Thomas of Villanova Church, Miag-ao, Iloilo (1797), San Agustin Church, Intramuros (1604), the last of which has withstood seven earthquakes. The nearby Manila cathedral on the other hand has been destroyed several times, by earthquakes and then by Allied bombing in the Second World War.

Soon after the Spaniards settled in Manila they began exploring what are now Ilocos Norte and Sur. The conquest was remarkably peaceful with hardly any battles occurring. The Augustinians were the first religious order to come to the Philippines (in 1565) and they rapidly established themselves. Soon after they had been given the Ilocos area for religious conversion, they started to build churches. Over the years the numerous churches have been rebuilt or enlarged. The result is a large number of distinguished churches in a relatively small area.

San Agustin Church in Paoay, Ilocos Norte, was originally built in 1604, but the present church was only started in 1699. This was built in the Earthquake Baroque style, because of its massive structure with coral-stone walls 1.67 m thick, and was
designed to withstand earthquakes. In addition it has fourteen 2.5 m thick buttresses (Galende, 1996). Next to the church is a separate three-storey bell tower that was enhanced in 1753–56, using coral stone reinforced with molave wood (Layug, 2007). The coral stone is believed to have been sourced from the uplifted coral reefs that occur in the coastal areas of Ilocos Norte (MG, B, 1985). These reefs, believed to be of Late Quaternary Age, comprise consolidated coral fragments and other calcareous debris.

Nuestra Senora de la Asunción Church, Santa Maria, Ilocos Sur, with its monumental façade and thick sidewalls, is unique because it sits atop a hill and is encircled by a stone retaining wall that gives it an appropriate citadel appearance: it was indeed designed as a fortress (Galende, 1996).

While not a World Heritage site, Narvacan church, also in Ilocos Sur, is noteworthy. It was probably first built about 1701 and was constructed from lahar (Layug, 2007; Galende, 1996), the usually mudflow from a volcano. In the case of the 1991 eruption of Mount Pinatubo, the lahar was usually extremely destructive, setting hard where it went. Despite being burnt in 1722 and severely damaged in World War II the church was soon restored.

Miag-ao church, Iloilo, will be dealt with below, along with other churches in Iloilo.

San Agustin Church, Intramuros, was first built in stone beginning in 1586 and was finished in 1604 (Figure 13; Jose, 2003). Considered to be one of the best examples of an urban church and monastery, this church also serves as a repository of some of the most important works of Philippine religious art and literature from the period, though much was taken by the British when they invaded in 1762–63. It has survived numerous earthquakes and even, to a significant extent, the Allied bombing, though adjoining buildings were destroyed or severely damaged. It was built from adobe (tuff) from the quarries of Guadalupe, Makati, Meycauayan, Bulacan, and San Mateo (Galende and Jose, 2000).

Based on observations on several churches in Intramuros, most of the stones used are volcanic tuff (adobe). Jose (2003) relates that an eighteenth century manual by the Augustinians points out the areas of Guadalupe, along the Pasig River, or from San Juan del Monte on the opposite bank as sources of the volcanic tuff. The other major source mentioned is Meycauayan, Bulacan. Other quarry areas noted were in the Laguna Province, south of Manila. There were observations made in the eighteenth century that the durability of the tuff positively correlated with the whiteness of the rock (Figure 14; Jose, 2003).

The Diliman Tuff member of the Guadalupe Formation that blankets Diliman, Quezon City, and large portions of Makati, Pasig, Paranaque and adjoining areas such as Rizal and Laguna is presumed to have been the rock sequence from which stone was quarried for most of the churches and houses in the Metro-Manila area (MGB, 2010). It also underlies areas of Bulacan. Diliman Tuff consists of thin- to medium-bedded, fine-grained, vitric tuff and welded volcanic breccias with subordinate amounts of tuffaceous, fine- to medium-grained tuffaceous sandstone (cf. Taal Tuff above). Dark
mafic minerals and bits of pumaceous and scoriaceous materials are dispersed in the glassy tuff matrix. The thickness of the Diliman Tuff is 1,300 to 2,000 m.

Figure 13. San Agustin Church, Intramuros (photo courtesy of John N. Crossley).

Figure 14. Manila Cathedral adobe, one showing black scoriaceous/pumaceous fragments.

Iloilo: a special case of church buildings

After arriving in Cebu in 1565, Legazpi soon moved his headquarters to the Island of Panay, which now comprises the provinces of Iloilo, Antique, Aklan and Capiz. The settlements flourished and as a result the province of Iloilo is replete with historic churches made of stone. In the case of Leon, which was the local summer capital up in the cooler mountains, the stones were quarried from the surrounding hills. This is not
surprising as Leon is approximately 20 km from the sea. The church, begun in 1871, is still unfinished with work is continuing to this day. The principal stone is reddish sandstone (Figure 15).

The World Heritage church in Miag-aø, Iloilo, which is dedicated to Saint Thomas of Villanueva was originally built between 1787 and 1797 (Figure 16). The massive sandstone blocks used in the construction were quarried in Sitio Tubog, San Joaquin and the mountains of Igbaras (about 10 km away into the interior), and some stones were taken from Camando, a barangay of Leon (considerably further away). In the restoration a simple sandstone ashlar has sometimes been placed over concrete and rubble fill (Figure 17). The bas-relief on the west front has mixed influences from Spanish, Chinese, Muslim and local. In the centre of the pediment is a coconut tree depicted as the tree of life with St Christopher dressed in local, traditional clothing carrying the Child Jesus on his back. Other elements feature the daily life of the people of Miag-aø of its time including native flora (papaya, coconut and palm trees) and fauna (cf. the western front of San Joaquin, constructed a century later, discussed below.).

In the case of Santa Barbara church in Santa Barbara, Iloilo, adobe (tuff) and coral stone were brought from Alimodian, whence the materials were transported by carabao drawn carts (sleds) (Layug, 2007). It is interesting to note that carabao (water buffalo) were not used as draught animals until the Spaniards had arrived. The church has recently been carefully restored, but stone buttresses have been introduced as a retrofit measure to strengthen the church against earthquakes.
The church of Santa Monica in Dingle, about 40 km northeast of Iloilo City, was started in 1829 and is built of yellow sandstone (Layug, 2007). Stone from this area was also used elsewhere. In Guimbal, the church of St Nicholas of Tolentino was started in 1742 using yellow sandstone and coral stone, the latter locally being called igang. Although it has been damaged by earthquake and burnt, it has always been quickly restored. Not far away is a stone watchtower (see below).

Figure 16. Miag-ao church, Iloilo, (a) west front and (b) detail of the pediment (photos courtesy of John N. Crossley).
In Iloilo City itself the present church of St Joseph, which was started in 1873, is made of stone and brick, but in the restoration in the 1980s marble from the island of Romblon, just to the north of Panay, has been used on interior walls and floor (Galende, 1996). In the suburb of Molo in the same city the church of St Anne was built using coral stone in 1831. It was damaged, losing its belfries, during the Second World War.

In the case of the church of St John the Baptist, Igbaras, Iloilo, the same stone was used as in the church at Miag-ao; they were quarried from mountains in the area.

The church of San Julian in Janiuay was built from materials from as far away as Guimaras (a distance of 40 km), which also supplied stone for Fort San Pedro in Iloilo (Galende, 1996). Since all three places are close to water, transportation would have been at its simplest—though still difficult. Unfortunately guerrillas, expecting a Japanese attack, burnt the church in 1942 and only ruined walls remain.

The church in San Joaquin in the town of the same name is built of white coral stone quarried from the shores of Punta Malagting, Barangay Igcadlum in Igbaras though some may also be from Punta Talisayan, Punta Malagting Tubus, Talus and Sinagbuhan (Figure 18). It was built in 1869 and its west front carries a dramatic bas-relief sculpture celebrating the Spanish victory at Tetuan, Morocco, in the Spanish-Moroccan war beginning in 1859.
For the church of St Nicholas of Tolentino, Lambunao, Iloilo, stones were quarried in Dingle, the same source as for the cemetery of Janiuay, which is not far from there. Marble was also recorded at Dingle (Bowring, 1859).

In Tigbauan, the church of St John of Sahagun was built from reddish coral stone and limestone, beginning in 1867 (Figure 19; Layug, 2007). On the other hand the church of St Anthony the Abbot in Tubungan is made of adobe (tuff). Although the original church was partially destroyed by American forces in 1942 and totally wrecked by an earthquake in 1948 it has been faithfully restored, retaining the Aztec appearance of the side entrances (Galende, 1996).

The southern part of Panay inland consists of a belt of geological units that trend in a southwest to northeast direction turning south to north in the higher latitudes. The formations that are the most probable source of the sandstone, limestone, coral stone (and other minor rocks) are the Singit Formation, Tarao Formation and Iday Formation (MGB, 2010). It was Corby (1951) who gave the name “Singit Formation” to the massive sandstone with conglomerate layers that crops out as a continuous belt in the southwest margin of the Iloilo Basin (Japan International Cooperation Agency, 1985). Four members have been delineated, the uppermost and of interest in relation to the churches is Barasan Sandstone, named after Barrio Barasan, in Igbaras. Thick-bedded, coarse-grained conglomeratic sandstone with thin intercalations of shale comprise this member that is prominent in the western flank of the Panay Central Basin as hogbacks and cuestas.

In Guimaras Island, the Buenavista Limestone was the source of the limestone said to have been taken from Guimaras.
Some other notable Philippine stone churches

Many other churches around the Philippines also used coral stone: for example, Our Lady of Peace and Good Voyage in La Carlota City and Our Lady of Guadalupe in Valladolid, both in Negros Oriental (Lugay, 2007).

At around 1590, Plaridel, Bulacan, is one of the earliest settlements to be established as an encomienda. An encomienda was a grant by the Spanish Crown to a colonist, the encomendero, conferring the right to tribute and forced labor from the native inhabitants in return for which the encomendero was to provide protection against the enemies of the natives and education in the Catholic faith. As Phelan (1959) has pointed out, the encomienda was never a land grant. The Parish Church of Santiago Apostol in Plaridel has a unique Moorish architectural style among the Augustinian Churches in the province. The present church was originally built in 1602 and established as the town church of the newly created Pueblo de Quingua, the former name of Plaridel. It was here that the money and jewels of San Agustin in Intramuros, Manila, were kept during the British Occupation in 1762-63 (Galende, 1997). Fr Tómas Quijano built a new church there of “strong material” but the church was burnt
down the year he was named prior there, though it was immediately rebuilt. It is notable for its Moorish architectural features, especially the west front, which is of typical Islamic shape. Adobe (tuff) stones used in the church were from the town of Meycauayan, while the bricks used were made at Sitio Nabugtos at Barangay Santa Ines.

On the island of Cebu, the church of St Thomas of Villanueva (Villanova) is unusual in that it was built using rocks from the sea in 1755 (Lugay, 2007; Javellana, 2010). This church burnt down during the war in 1942 but was reconstructed in 1946 being renovated again in the 1980s. The present structure uses coral stone.

Lugay (2007) records nearly fifty other historic churches that use stone in their construction. Most of these feature coral stone (almost two thirds), some adobe (tuff, almost a third) and a few, limestone.

3.2 Fortifications

The use of stone in kotas by Muslim inhabitants of the southern Philippines has already been noted. From a little before 1600 the Spaniards constructed various forms of fortification against the Muslims from the southwest, pirates from China and Japan and then the English and the Dutch who began taking an increasing interest in the region, its produce and the Spanish gold. It has been claimed that, during the Spanish colonial era, which began in 1565, many artefacts were destroyed or re-used in such buildings and, in particular, that the Spanish walled city of Intramuros in Manila used “stone bricks” taken from the original city wall of pre-Hispanic Maynila. However this seems unlikely, since the original Spanish fortifications of Manila comprised simple wooden palisades. Thomas (2014) says, “There were already fortifications of earthworks and the trunks of coconut palms.” Sharpened bamboo was used elsewhere.

The Spaniards took Manila in 1571 and started what became their major settlement. After a major fire in 1583, Bishop Salazar reportedly discovered the volcanic tuff, locally called adobe, in the quarries of San Pedro, Makati, and this has become a standard building material in the Philippines. Stone had first been used for construction of the cathedral and the bishop’s house at the suggestion of the very practical Jesuit, Antonio Sedeño, who drew the plans for the first fortress in the city, built the first lime kiln and also taught the Filipinos to manufacture and lay bricks and tiles, persuading Salazar to use adobe to rebuild his residence after the fire of 1583, and this was the first construction by the Spaniards using this material (Leonard, 1964; de la Costa, 1961). When Governor Gómez Pérez Damariñas arrived in 1590 he came with instructions to fortify the city. This he proceeded to do, ordering the fortifications of Manila to be replaced by stone walls made of adobe (tuff) that totally encircle the city. In 1899 the American commander, General Wheeler, said the walls were “the finest specimen of medieval defensive architecture within the limits of our [American] influence” (Wheeler and Olivares, 1899). The stone was quarried from Guadalupe, Makati, and Meycauayan, Bulacan. The walls still stand, having been substantially restored after the Allied bombing under Imelda Marcos and the Intramuros Administration. Guadalupe is about 10 km up the River Pasig from Intramuros. Only 4
km from Intramuros, along Roxas Boulevard is Fort San Antonio Abad, which was originally constructed in 1584. It was captured by the British and used as a foothold in their invasion of 1762. Damaged in the Second World War it was not restored until the 1970s.

In Zamboanga, in the far southwest of the Philippines, in 1635, upon the requests of the Jesuit missionaries and Bishop Fray Pedro of Cebu, the Spanish governor of the Philippines, Juan Cerezo de Salamanca (1633–1635), approved the building of a stone fort for defence against pirates and raiders of the sultans of Mindanao and Jolo. This fort was originally called Fuerza de San José but in 1759 Fort Pilar -Fuerza de Nuestra Señora del Pilar- was constructed to replace the older one (Javellana, 1997). It formed the southernmost bastion of the Spanish Philippines and it is made of coral stone.

Taytay Fort, otherwise known as Fuerza de Santa Isabel, Palawan, was rebuilt under Governor Fernando Manuel de Bustillo Bustamente y Rueda (assassinated in 1719) in the early eighteenth century and completed by 1738. Previously it had been made of wood; the new one was made of coral stone. It was built as a defence against Muslim warrior-raiders who regularly attacked parts of the Philippines (Figure 20).

![Figure 20. Taytay Fort, Palawan (photo courtesy of John N. Crossley).](image)
Fort San Pedro, Iloilo, where a stone fort was first constructed in 1610 is made of coral stone from the island of Guimaras, which is just opposite the city of Iloilo. It was built by Tómas de Castro y Andrade, who also built the Taytay fort (Javellana, 1997).

3.3 Cemeteries

The Spaniards built walled cemeteries. Some of these remain from the nineteenth century and are still in use, for example, at Campo Santo at San Joaquin where coral stone was used in the construction (Figure 21).

The stone for the cemetery of Janiuay, Iloilo, was quarried from mountains in Dingle, a town in central Iloilo 27 km away. In the case of Cabatuan cemetery, Iloilo, stone was quarried from the mountains in Leon about 20 km away.

![Figure 21. Campo Santo; cemetery of San Joaquin, Iloilo (photo courtesy of John N. Crossley).](image)

3.4 Watchtowers

In Guimbal, Iloilo, there is a sixteenth century watchtower constructed extremely close to the sea and made out of coral stone, probably mined from the adjoining beach (Figure 22). The church at Guimbal is about half a kilometre inland from the watchtower. There are ten surviving examples of watchtowers in the Philippines. Other examples are at Panglao, and Balilihan, Bohol, but the latter was severely damaged by an earthquake in 2014 though Panglao escaped undamaged.
3.5 Bridges

The old Spanish bridge of Taytay Boni at Guibongan, in Barangay Igtuba, Miag-ao, Iloilo, was constructed of blocks (apparently limestone) in 1854 (Figure 23). It is named after “Father” Boni Neular, the construction foreman. It connected Guimbal and Miag-ao and was still in use after the Second World War. However it was damaged in the Lady Caycay earthquake of 1948, which created tidal waves and landslides in the area. The creek was ultimately covered and the land dried up. Consequently the bridge is no longer in use.

Figure 22. Watchtower at Guimbal, Iloilo (photo courtesy of John N. Crossley).
Malagonlong Bridge is a five-span 136 m long stone bridge with five arches and a carriageway with an average width of 6 m (Figure 24). It was built between 1840 and 1850 during the Spanish colonial period in Tayabas, Quezon. It lies on the Tayabas-Pagbilao Rd at latitude 14°N, longitude 121°37’E, 12 km due north of Lucena City. Although a new bridge has been built a short distance to the east, the old bridge is still passable to the present day. It is considered a testament to the craftsmanship of the time and provides a glimpse of the use of natural materials. The 100,000 adobe blocks, patiently laid out by the residents of Tayabas, were cemented together using molasses, eggs and blood to build a structure that has lasted through the ages (Gonzales, 2006). Considered an engineering feat at that time, the bridge over the deep ravine through which the Dumaca River flows, has “pockets” or balconies on its sides to allow passers by to enjoy the scenic view. This bridge, some 150 km southeast of Manila, is a major link to the rest of the towns and provinces in southern Luzon. It was used until 2004 when the government completed the construction of a wider concrete bridge, The Malagonlong bridge is being preserved to enrich cultural heritage as well as to provide an alternate bridge.

There is also the Sombria Bridge in Tagbilaran City, Bohol, which has the highest elevation among colonial bridges in the province. Unfortunately the old Spanish bridge, the Puente de Piedra, which was parallel to the Jones Bridge in Manila, was not only damaged in the war but completely removed.
3.6 Lighthouses

In the case of lighthouses, which only began to be constructed in the nineteenth century, Noche (2005) has compiled a significant list. Brick and steel were commonly used but some lighthouses and sometimes the accommodation for the Spaniards maintaining the lighthouse was built of stone; for example, the Faro de Punta Luzaran, Dolores, Nueva Valencia, on the island of Guimaras (also known as Gusi lighthouse), which is the second oldest lighthouse in the Philippines, has accommodation made of stone but the lighthouse itself of brick. However the spiral staircase and the remaining parts of the base of the Luz del Rio de Pasig in Binondo (Metro Manila) use adobe (tuff) as does the lower portion of that of the Puerto de Manila. The latter adobe is from Meycauayan Granite was used in the lighthouses of Gintotolo, Islote de San Bernardino (Leyte), Cabo Engaño, Isla Palaui (Cagayan), and Cabo Melville, Balabac (Palawan).

3.7 Houses

Writing to King Philip II on 26 June 1587, Governor Santiago de Vera wrote:

“I have informed your Majesty of the deep affliction and pressing need in which I found this city, because all the houses and property had been destroyed by fire [in 1583], not even the fortifications escaping. On account of the constant danger from fire, because the buildings were being constructed of wood and bamboo, thatched with straw, and because many quarries and much limestone had been discovered, which is brought down the river, I forbade that any houses should be built of other material than stone, since this could be done at a very slight expense. … I trust, God helping, that, in ten years, the city will be built entirely of stone, for from two stone houses here the number has increased to twenty large houses, besides a monastery; and a considerable number of buildings, very substantial and well planned, are at present in
Six years later thirty-two stone houses were recorded in Manila by Geronimo de Salazar y Salcedo, the Spanish fiscal in Manila but, in 1603, even the stone houses suffered in a subsequent fire:

“On the twenty-ninth of April of this year it was God’s will that there should be so great a fire in this city that, within two hours, there were burned one hundred and fifty houses, among them the best of the city, and the thirty-two built of masonry, one of which was mine.” (BR XII, pp. 85-86).

Nevertheless stone continued to be used and de la Concepción (1788) wrote in the following century that there was damage amounting to a million pesos – “a loss that shows how opulent was then the city of Manila” (de la Concepción, 1788, vol. IV). Zúñiga (1893) continually mentions stone being used in constructions around Manila. Under the Marcos Presidency, Imelda Marcos used the Intramuros Administration to restore a typical bahay na bató (Filipino for “stone house”) opposite San Agustin in Intramuros. Such ancestral houses usually have solid stone foundations or brick lower walls, and overhanging, wooden upper storey with balustrades and capiz (kapis) shell sliding windows, and a tiled roof. The materials used were those found locally; the Hornado house in Camalig, Albay in the shadow of Mayon volcano used adobe (tuff) (Zialcita and Tinio, 1980).

In Vigan there are two prevalent types of old house: the bahay na bató and the cantería y teja, which is built entirely of stone of which Villa Angela is an example (Figure 25; Florendo, 2012).

4. Conclusion

This chapter has only touched the surface of the study of the stone heritage of the Philippines. Much more research is needed in many areas, notably archaeology, as well as on specific geological characteristics such as a comparison of the petrographic and mineralogy of the rocks used and the formations that may have been the source of the materials used for buildings. The documentation of the Spanish era churches is good, but little has been done on other buildings. One notable exception is Diaz-Trechuelo’s work on architecture (Diaz-Trechuelo, 1959). As this chapter has shown, the Philippines has an extremely rich stone heritage, but more research needs to be done to document it fully. Recently a whole book (Fadriquela, 2013) has been devoted to heritage wood in the Philippines; there is more than enough to produce a whole book on the magnificent stone heritage of the Philippines.
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Cover photo: Statues along Nagaraj Bridge in Phimai Temple.
1. Introduction

Thailand is located in the center of Southeast Asia covering an area of approximately 514,000 square kilometers. The notable features of Thailand's terrain are high mountains, a central plain, and an upland plateau. Mountains cover much of northern Thailand extending southwards along the border with Myanmar in the west and down through the Malay Peninsula. The central plain is a lowland area drained by the Chao Phraya River and its tributaries which empty into the Gulf of Thailand. The Khorat Plateau extends eastwards from the central plain to occupy northeastern Thailand, a region of gently rolling low hills with a long stretch of the Mekong River separating Thailand from Lao PDR and the Phanom Dong Rak Mountain Range separating Thailand from Cambodia (Figure 1).

Thailand is rich in natural rock and mineral resources; it is underlain by rock formations ranging from Precambrian in age (>540 million years old) up to sedimentary formations of recent age (less than one million years old). Early humans learned to use natural resources including stone (rock), wood and bone for building shelters and creating tools. However, for the construction of buildings, stone proved much more resistant than other materials so that even today, modern man still takes advantage of its resistance and aesthetic value in the construction of various important structures. Therefore, rock or stone is not only the recorder of the Earth’s history but also a recorder of humankind’s cultural development. In the following sections, examples of Thailand’s stone heritage are arranged in temporal order.

2. Stone Heritage of the Prehistoric Period

2.1 Phuphrabat Historical Park

Situated on Phuphrabat hill, Ban Phue district, 67 kilometres from Udon Thani province, the Phuphrabat archaeological site covers an area of about 5.5 square kilometres and features a large number of ancient stone structures and objects from both prehistoric and historic times, mostly of Dhvaravadi, Lop Buri and Lanchang styles (Thai World Heritage Information Centre, 2014). Many objects such as prehistoric paintings and sculptures are significant evidence proving that this area was occupied continuously from prehistoric to recent times (Figures 2 to 4). Furthermore,
the site is not just about archaeology, also its geological importance has resulted in the site being designated as a national geoheritage site.

Phuphrabat Historical Park contains many ancient stone structures defining a megalithic culture (i.e. structures made of large stones, utilizing an interlocking system without the use of mortar or cement, as well as representing periods of prehistory characterised by such constructions) from around 3,000 years ago (Wongthes, 2014). The megalithic culture is one of the important cultures in Southeast Asia and many archaeologists believe that most megaliths in the world, including megaliths in Phuphrabat Historical Park, are related to religious worship and funeral ceremonies (Historical Archives Archdiocese of Bangkok, 2010).

Megaliths in Phuphrabat were created by adapting natural sandstone ‘caps and pillars’ as religious places; Nang Eusa’s hall for example is a naturally occurring sandstone cap and pillar formed by differential weathering and erosion of early Cretaceous sandstone beds deposited about 120 million years ago (Kuttikul, 2008). The softer beds were eroded and weathered away quickly leaving a shape similar to a mushroom stem while the harder beds were much more resistant and remained to form the mushroom cap (Figures 5 and 6). The whole landscape of Phuphrabat hill, including
the forest park and the historical park, is nominated for inclusion in the UNESCO World Heritage List. The geological map of this area is shown in Figure 7.

Figure 2. Nang Eusa’s monument with bai-sema; leaf-shaped stones marking the boundaries of a Buddhist temple.

Figure 3. Paintings that depict the livelihood of prehistoric community which can be traced back to approximately 2,500-3,000 years ago.

Figure 4. Ancient Buddha carvings around 800 years old.
Figure 5. Nang Eusa’s hall; the natural megalith modified by early human.

Figure 6. Nang Eusa’s hall forming processes.

Figure 7. The geological map of Phuphrabat area.
3. Stone Heritage in the Historical Period

3.1 Phanomrung Historical Park

Phanomrung Park is a site of spectacular Khmer architecture dating from around 1,000 years ago. It is located on top of an extinct volcano at 383 metres above mean sea level in Chaloem Phra Kiat district, Buri Ram province, northeastern Thailand. Originally, it was built as a Hindu religious temple (Figure 8) using sandstone and laterite but later became a Buddhist temple. Several construction stages were undertaken during the 10th-13th centuries (Tourism Authority of Thailand, 2014a).

![Figure 8. The Hindu god ‘Shiva Nataraja’ in dancing posture. Photo courtesy of Rath Jitrattana.](image)

The monumental staircase of Phanomrung (Figure 9) is stunning with its strong mouldings on the sides giving a feeling of power and mass, typical of great classical Khmer temples (Siribhadra et al., 1992). A plan of the whole area was designed on the basis of the axis leading from the staircase (east) to the principal tower (west) (Figure 10). As the temple location is on top of the mountain, the architect took advantage of this geographical location by designing the straight throughway from the entrance door on the east leading to the farthest 15th door on the western end of the temple. The design allowed the majestic aura of the rising sun to shine from the entrance door straight through all the fifteen doors to the western end of the doorway (Figure 11). Visitors can view this impressive phenomenon only twice a year. Phanomrung is now in a tentative list of UNESCO World Heritage Sites.

In terms of geology, sandstone of the Phu Phan Formation (Figure 12), around 120 million years old, was a major material used for building Phanomrung. It displays many colors from reddish brown to white, is fine to coarse grained and is typically cross bedded (Meesook, 2011). Considering the lithology of the sandstone and distance from Phanomrung, the Ban Kruat stone quarry is presumed to be one of the quarry sites associated with Phanomrung’s construction. The quarry covers an area of...
about 4.8 square kilometres and is around 30 kilometres southeast from Phanomrung. Sandstone was extracted from both the surface and underground.

Apart from sandstone, volcanic rock (basalt) also plays an important part in Phanomrung’s construction. As mentioned above, Phanomrung is located on top of an extinct volcano and basalt resulting from an ancient eruption of the volcano forms the basement rock of the temple. There occur both vesicular and massive basalt in this area and considering the basaltic lithology, even though vesicles may lower rock strength, the basalt here is still a strong and resistant rock as confirmed by the temple base which has remained intact for over 1,000 years. A simplified geological map of the Phanomrung area is shown in Figure 13.

**Figure 9.** The monumental staircase and walkway at Phanomrung Historical Park. Photos courtesy of Rath Jitrattana.
Figure 10. A plan of Phanom Rung Historical Park (Buri Ram Province, 2015).

Figure 11. The western end of the doorway. Photo courtesy of Rath Jitrattana.
3.2 Phimai Historical Park

Phimai Historical Park plays an important role in being one of the most remarkable Khmer temples in Thailand. It is located in the town centre of Phimai district, Nakhon Ratchasima province, northeastern Thailand, about 260 kilometres northwest of Angkor Wat, Cambodia. Phimai Historical Park covers an area of 1,020 x 580 metres (Figures 14 to 15) and if its size is compared with that of Angkor Wat, Phimai must have been an important city in the Khmer empire. It was originally constructed in the 11th to 12th centuries after a large part of the Buddhist Kingdom of Dhvaravadi was conquered and became the domain of the Khmer Empire (Quaritch Wales, 1969). Much evidence indicates that Phimai was built as a Mahayana Buddhist sanctuary; for example the inscriptions inside the principal tower signify the Buddhist origin of
Phimai, praising Lord Buddha and mentioning the name of King Suriyavaraman I as a Mahayana Buddhist, as well as specifying the years related to the Buddhist Era of 1579 and 1589 (i.e., 1036 and 1046 AD).

It is important to note that other Khmer temples at that time, such as Angkor Wat and Phanomrung, were all built as Hindu temples while the Buddhist sanctuary of Phimai is unique in being the exception. Due to their historical and aesthetic value, the Thai government has proposed Phimai together with the two ancient Khmer temples of Phanomrung and Muangtam to be included in the tentative list of UNESCO World Heritage Sites under the name ‘Phimai, its Cultural Route and the Associated Temples of Phanomrung and Muangtam’ (UNESCO, 2014a).

Geologically, northeastern Thailand is well known as a good source of dimension stone, especially sandstone. This area is dominated by the Khorat Plateau, an undulating plain about 400 kilometres across formed of gently folded upper Mesozoic non-marine sediments including notable red sandstone beds. Therefore, sandstone was mainly used for building Phimai Temple (Figure 16) and other Khmer temples, particularly sandstone of the Phu Phan Formation as mentioned in Figures 12 to 13. The formation generally consists of greyish-white medium to coarse grained sandstone and cross-bedding indicates a depositional environment of a braided and meandering stream system in a hot and humid climate (Department of Mineral Resources, 2007).

Figure 15. Chala Passage Way (left) and the principal tower (right) of the Phimai temple.

Figure 16. Sandstone was used as the construction material for Phimai temple and its statues. (a) Rabieng Khot (Photo courtesy of Namphon Khampilang), (b) Principal Tower (left) and Prang Bhramathat (right) (Photo courtesy of Rath Jitrattana), and (c) Statues along Nagaraj Bridge (Photo courtesy of Namphon Khampilang).

The sandstone was extracted from many quarries in the high mountains and brought to the construction site on land routes by beasts of burden such as elephants, horses and cattle or by water routes on rafts. There are four important quarries related to Phimai, i.e., 1) Sikiew district sandstone quarry site, Nakhon Ratchasima province (Figure 17), 2) Sung Noen district sandstone quarry site, Nakhon Ratchasima province, 3) Huai
Thalaeng district laterite quarry site, Nakhon Ratchasima province, and 4) Ban Kruat district sandstone quarry site, Buri Ram province.

Figure 17. Sikiew stone quarry site.

3.3 Muang Sing Historical Park

Muang Sing Historical Park (Tower of the City of Lions) is believed to be the westernmost outpost of the Angkor-centered Khmer Empire and is located in Sai Yok district, Kanchanaburi province, western Thailand. It was constructed as a temple in Bayon style in the 12\textsuperscript{th} century (Figure 18), a period when the Khmer Kingdom was still flourishing. The temple was related to the Khmer kingdom in the reign of King Jayavarman VII (1180 to 1219 AD). A stone inscription of Prince Vira Kumara, King Jayavarman VII’s son, mentioned 23 cities and one of these cities, named Srichaiya Singhapura, was later identified by archaeologists as Muang Sing. After the Khmer Period, Muang Sing was abandoned until the reign of King Rama I when it was rebuilt as a Kanchanaburi border town (Tourism Authority of Thailand, 2014b).

The historical park comprises an area of about 1 square kilometer enclosed by laterite walls (Figure 19), located on a steep bank of the Khwae Noi River where the waterway is narrow and meandering. The southern wall winds along the Khwae Noi river course, while the other three sides are quadratic. There are four monuments in the park, the first one is in the centre of the area and northwest of this are the foundations of the second temple. The other two monuments are quite small (Figure 20).

One feature that makes Muang Sing special is that it was built mostly in laterite while other Khmer buildings were built in sandstone. Archaeologists still cannot find the reason why the temple was built in laterite even though the surrounding area contains
abundant sandstone which is more beautiful and easier to carve (Figure 21). Laterite
was cut in rectangular blocks and transported along the Khwae Noi River by raft from
a quarry ‘Thong Nakarat’ around 10 kilometres away. The laterite quarry was found
not far from an outcrop of the Carboniferous-Permian shale and sandstone that
presumably was a primary source rock of the laterite. When shale and sandstone are
chemically decomposed, they form a by-product containing high iron and aluminum
contents, major elements of laterite formation (McFarlane, 1976). Moreover, the ratio
of iron and aluminum also affect the density of laterite. That is, if the unconsolidated
material is rich in iron, it will produce laterite with a high density (Figure 22), on the
other hand, if the unconsolidated material is rich in aluminum, the laterite will have a
low density (Schellmann, 2014).

Figure 18. Muang Sing Historical Park built in Bayon style. Photo courtesy of Rath Jitrattana.

Figure 19. Laterite wall of Muang Sing. Photo courtesy of Rath Jitrattana.
There are both laterites of high and low density found at Muang Sing Historical Park, in addition, the laterite texture here is another feature that makes this historical park attractive. This texture was formed by concretion processes with quartz grains as a nucleus to concretions which were then cemented together by clay minerals to finally form a texture with the appearance of beans or popcorn (Figure 23). Considering various physical forms of laterite related to chemical composition and the lateritization processes, it seems likely that the source of the laterite utilised at Muang Sing was not just from a single quarry but came from several different quarries though laterite quarries in the area close to the park other than that at Thong Nakarat have not yet been found.
3.4 The King Ram Khamhaeng Inscription

The King Ram Khamhaeng Inscription of 1292 AD is perhaps the oldest surviving Thai language inscription. The text describes Ram Khamhaeng’s invention of the prototype Thai alphabet that is the foundation for the modern alphabet used in Thailand (UNESCO, 2014b). Furthermore, the inscription’s rare detailed description of the Sukhothai Kingdom also reflects universal values shared by many countries in the world today. Those values include the systems of law and government, economic freedom, and religious morality, in this case Buddhism, one of the world's major religions. The inscription's value as a historical document has already been evident as it was used to support Thailand's successful proposal to inscribe the ‘Historic Town of Sukhothai and Associated Historic Towns’ into the World Heritage List in 1991. After that, the inscription itself was accepted into the Memory of the World List by UNESCO in 2003 (Adireksarn, 2003). The inscription is now exhibited at the National Museum in Bangkok (Figures 24 to 26).
The first transliteration of the inscription was undertaken by King Rama IV and his colleagues, but it was not published until 1897, when it appeared in the journal ‘Vajirayan’. An English translation was completed by A. Bastian in 1864. Afterwards, the inscription was transliterated and translated many times and into many languages, the most recent Thai transliteration and translation being undertaken by Dr. W. Pongsripian in 2009 (Hutangkura, 2014).

Considering its physical characteristics, the inscription was made on a resistant calcareous siltstone which is why it could survive for over 700 years with only a little erosion. It is 114.50 centimetres high with four sides and topped by a quadrilateral pyramid. There are 35 lines on each of the first and second sides and 27 lines on the third and fourth sides with each side being 35.50 centimetres wide. Generally, the inscription is in good physical condition, except for some minor surface cracks. The writing is nearly all legible, with only about six small places where a few letters have either disappeared or are too difficult to decipher.
3.5 Wat Phu Tok

Wat Phu Tok or Phu Tok temple comprises the whole area of a single mesa-type mountain known as Phu Tok Noi situated in Bueng Khan province, northeastern Thailand. With their faithfulness to Buddhism, the monks and villagers spent five years building a network of thrilling wooden staircases and walkways to the top of Phu Tok Noi Mountain, a good example of folk engineering knowledge. There are several meditation sites, both man-made huts and natural sites such as caves and rock beds. The staircases and walkways are also known as ‘the stairway to heaven’ (Figure 27). There are six successive stages of steps, plus a seventh-stage comprising a scramble up roots and rocks to the shady forest at the summit, together representing the seven factors of enlightenment in Buddhist psychology (Tourism Authority of Thailand, 2014c). At the summit, fresh air and panoramic views over the surrounding countryside can be experienced. In addition, because of the cool and quiet atmosphere, Wat Phu Tok attracts many people to come and meditate.
Figure 27. The walkway climbing up to the summit of Phu Tok Noi. Photo courtesy of Rath Jitrattana.

In terms of geology, Phu Tok Noi is a type section of Phu Tok Formation which is the only formation recording earth history in Thailand during the period of about 75 million years ago (Department of Mineral Resources, 2013). The section is about 140 metres thick, containing interbedded very fine grained, rippled sandstones and fine – coarse grained sandstones (Figure 28). Walking from the foot to the top of the mountain reveals the depositional environment and geomorphological evolution of the rocks that eventually became Phu Tok Noi Mountain as seen today (Figures 29 and 30). The geological map of part of Bueng Khan province and distribution of the Phu Tok Formation is shown in Figure 31.

Figure 28. Ripple marks found in very fine grained sandstone of the Phu Tok Formation.

Figure 29. Differential erosion of sandstones has created concave cliffs around Pho Tok Noi Mountain. Photo courtesy of Rath Jitrattana.
Figure 30. Geomorphological evolution of Phu Tok Noi Mountain. Graphic models by Tassana Jadeanan.

Figure 31. Simplified geological map of part of Bueng Khan province and Wat Phu Tok area.

3.6 Khao Chee Chan Sculptural Image

This image was carved into the rock face of Chee Chan Mountain, Chonburi province on the auspicious occasion of the ‘Fiftieth Anniversary (golden jubilee) Celebrations of His Majesty King Bhumibol Adulyadei’s Accession to the throne’ in 1996. The seated image of Buddha Subduing Mara was carved in imitation of a Buddha image in
Sukhothai and Lanna style arts. It is 130 metres high and 70 metres wide (Figure 32). It is world’s biggest sculpted image of Buddha. A beautiful park is set surrounding the area of the image under the administration of the Royal Thai Marine Corps. Chee Chan Mountain itself is a remnant of Thailand’s once wartime mining effort; during the Vietnam War when the Thai navy undertook stone mining to use at a nearby American base. After the war, mining continued to provide stone for local roads and construction projects (Nakanat, 1998).

Figure 32. Khao Chee Chan Sculptural Image. Photo courtesy of Rath Jitrattana.

Geologically, the major rock constituting Chee Chan Mountain (Figure 33) is massive, medium-grey streaked with pale grey and brown, finely crystalline pyritic limestone. Ridd (2011) indicates that minor folding and complex large-scale folding can be observed and a pronounced cleavage is picked out by segregated laminae of non-calcareous material (Figure 34). There are 3 fault planes and at least 2 joint sets founded in the cliff face. These faults and joints caused a stability problem but a rock bolting technique was used to solve this problem.

The carving of the Buddha image started from projecting the outline of the image by laser at night-time (Figure 35) and drawing along the laser lines by water color and in the daytime the lines were adjusted to guide the carving process. Finally, the carved lines of 30-40 centimetres width and 10 centimetres depth were created and tiled with a golden mosaic. Due to its size and the glitter of the mosaic filled carved outline, the impressive image can be seen from a considerable distance.
Figure 33. Geological map of Khao Chee Chan area.

Figure 34. Banded limestone at Chee Chan Mountain with mineral segregation picking out the cleavage.

Figure 35. Using laser technology to draw the Buddha image outline. Photo courtesy of Dacha Luangpitakchumpol.
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Cover photo: Stone statues at Khai Dinh Tomb in the Complex of Huế Monuments (photo by Nguyen Thi Minh Ngoc).
Stone Heritage of Vietnam

Tran Tan Van, Nguyen Thi Minh Ngoc and Do Ngoc Huyen

1. Introduction

The geology of Vietnam, comprising fragments of different tectonic plates including ancient continental crust, records a long history of geological evolution resulting in complex geological features with various rock types and minerals. The rocks, ranging from very ancient (2,500 million years old) to recent, were variously derived from either magmatic, metamorphic or sedimentary origins. Broadly speaking, though northern Vietnam displays a rich diversity of rock types, limestone predominates there and constitutes some 35–40 percent of the mainland. Central Vietnam is characterized by paleo-metamorphic rocks of the Kontum uplifted massif, a part of the ancient supercontinent Gondwana, bordered around with polymictic Paleozoic rock formations. To the south is a territory of intrusive igneous rocks dating from Mesozoic times up to the present. At Vietnam’s southern tip lies the Mekong Delta that is composed mainly of modern riverine - marine sediments with a few scattered exposures of late Paleozoic - Mesozoic igneous and sedimentary rocks. Figure 1 shows the geological map of Vietnam, which is compiled from geological maps of different parts of Vietnam at scale of 1:200,000 (General Department of Geology and Mineral Resources), with magmatic rocks edited according to Bui Minh Tam et al. (2010), Quaternary geology edited according to Nguyen Duc Tam et al. (1995, 2010), and stratigraphy edited according to Tong Duy Thanh and Vu Khuc (2006).

Archaeological evidence suggests that human culture in Vietnam appeared earliest in northern Vietnam at least 33,000 years ago and resulted in the first manifestations of Vietnam’s ‘stone heritage’. Since such an ancient time, prehistoric and later people have traditionally used stone, especially limestone, for many different purposes.

This chapter on Vietnam’s Stone Heritage, therefore, refers mainly to limestone. Sections 2 and 3 below give an overview of limestone and some of its applications in Vietnam’s cultural history up to the present day. Section 4 similarly reviews the use of other types of stone.
Figure 1. Geological map of Vietnam at scale of 1:1,000,000 (mainland part).
2. Overview of Limestone

2.1 Definition of Limestone and Karst

Most people in northern Vietnam are familiar with limestone which forms either jagged peaks of mountain ranges with steep rugged cliffs, the lower hills of residual mountains and clusters of offshore islands. In such limestone topography, people often encounter caves and may even see streams flowing out from such caves or disappearing into their depths.

The main components of limestone (CaCO$_3$) are elemental calcium (Ca) and carbon dioxide (CO$_2$). The dominant attribute of limestone is that it is soluble in water, resulting in the formation of caves and holes. The processes involved are called “karstification” and the geology of such areas is usually described as “karst geology” of “karst landscape”. The conservation and sustainable development of karst regions is generally considered to have important economic consequences for agriculture, ecosystems, and nowadays, for tourism (Tran Tan Van et al., 2005).

2.2 Distribution of Limestone in Vietnam

Limestone makes up about 10% of the Earth’s surface and up to nearly 20% of the mainland territory of Vietnam, which is approximately 60,000 km$^2$. In particular, limestone is distributed mostly in the north of the country (see Figure 2), covering large areas in Hoa Binh province (53.4%), Cao Bang province (49.47%), Tuyen Quang province (49.92%) and Ha Giang province (38.01%). Many cities are enclosed by limestone terrain, namely Mai Chau (Hoa Binh province), Moc Chau, Son La (Son La province), Tua Chua, Tam Duong (Lai Chau province), Dong Van, Meo Vac (Ha Giang province).

2.3 Limestone Formation Process

Vietnam’s limestones formed during several different geological periods with a predominance of outcrops of Devonian to Permian age (280-350 Ma) as found scattered through Northeast, Northwest, Central and even southernmost Vietnam. Limestone of Middle Triassic age (about 235 Ma) is mainly distributed in Northwest Vietnam (Figure 2).

Limestones in Vietnam originated through various processes; some mainly chemical (i.e. precipitation from CaCO$_3$ rich seawater or biological (i.e. accumulation of shells, bones and remains of marine species) or biochemical. They formed in various paleo-environmental conditions such as shallow sea, deep sea or carbonate shelf marine environments. Some limestone types are quite pure, occurring in massive or stratified outcrops but some other types are intercalated with other sedimentary lithologies such as mudstone, coaly shale, silica rich clastic sediments or bauxite forming thin to very thinly stratified structures. Due to geological movements, limestone layers may be gradually uplifted, compressed, bent and also fractured (Figure 3), thus facilitating deep percolation of rainwater and promoting solution and karstification processes.
Figure 2. Distribution map of main limestone exposures in Vietnam.
2.4 Karstification

Karstification is the result of interactions between limestone, water and carbon dioxide together with other biological factors, taking place over a long time in order to form karst landforms and landscape types. Vietnam has favorable conditions for intensive karstification as listed below:

- Abundance of limestone in geological formations of young to old ages with a total thickness of up to 10,000 m.

- Active tectonic regimes which have facilitated limestone to be fractured, creating a favorable environment for water and air circulation within limestone outcrops.

- High rainfall, up to 1,800-2,500 mm/year, which is favorable for karstification.

- Well-developed biota in warm, humid conditions, generating the high level of carbon dioxide gas that is needed for karstification.

2.5 Types of Karst Landforms and Landscapes

In Vietnam, karst systems are relatively well developed, forming several types of topographies typical for humid tropical karst and also some unique karst landforms. These include:

- **Karren**, a popular karst landform, featured by solution pits, grooves and runnels in jagged, sharp, peculiar shapes with sizes ranging from very small (1-2 mm) to quite large (5 -10 m).

- **Karst funnel (sinkhole)**, a funnel-shaped landform in sizes ranging from tens to hundreds of meters. Funnels formed due to dome collapse often have vertical walls and a cavity bottom which absorbs surface water and may be partly covered by clay, humus and limestone boulders.

- **Karst valley**, a group of karst funnels several kilometers long, thousands of meters wide, probably with subterranean springs and surface water flows on the bottom. Blind valley is a blocked valley section with the presence of some shallow holes at the
lower part. During heavy rains, water runoffs pour into such areas, filling and blocking the caves and flooding may occur in the case of inefficient draining.

- **Karst polje (karst field)**, a flat plain found in limestone regions, probably seen with surface run-off or outcrops of residual karst towers.

- **Soaring karst landform**, including peaks, ranges, blocks, cones, towers, etc. of various sizes and diverse shapes, soaring from lower surroundings.

There are three typical karst landscape types in Vietnam:

- **Karst peak cluster-valley landscape**, including small depressions, valleys in between the peaks, ranges and high soaring peak clusters.

- **Residual karst landscape at the plain margin**, including residual limestone blocks rising from the surrounding plain.

- **Mixed karst landscape**. Ha Long karst landscape, is an example of this type, originating on-land followed by invasion by the sea, it features countless islands where karst structures soar above the sea surface.

### 2.6 Karst Caves

Caves are unique products of the karstification process. The formation of karst caves usually undergoes three stages: (1) corrosion (dissolution), (2) mechanical erosion, and (3) collapse. Some dry caves, formed since ancient times, have been uplifted without any further development due to the lack of further water impact. Some other caves, formed at the water level of the surrounding streams and rivers, continue to develop and are known as "wet" or "active" caves. There may be water circulation between inner and outer portions of the caves where water outflow joins streams exiting the cave complex or vice versa when a stream or even a river disappears into the cave.

Cave formations may include:

- **Caves**, in simple or complex structures reaching tens to hundreds of meters in depth and a few tens of meters to tens of kilometers in length. Some large limestone areas possess intensive underground water circulation, creating spectacular subterranean rivers.

- **Precipitated calcite within caves** forming as stalagmites and stalactites, sometimes displaying peculiar and charming shapes such as stone bells, stone curtains, stone pillars, etc.

- **Precipitated calcite** at karst water outcrops above the ground surface or outside the cave entrance (so-called travertine), usually porous and hollow, sometimes creating flat terraces. Formation of travertine involves the role of microorganisms.
2.7 Natural Preservation Zones, Scenic Landscapes and Cultural-Historical Relics

Most natural preservation zones, scenic landscapes and cultural-historical relics, particularly in northern Vietnam, are distributed in limestone areas. Some examples are Ha Long Bay (the World Natural Heritage site in Quang Ninh province which was declared by UNESCO in 1994 and 2000 and lies in of Phong Nha-Ke Bang National Park (Figure 4a), a World Natural Heritage Site in Quang Binh province, declared by UNESCO in 2003, and Trang An Scenic Landscape Complex, the World Cultural and Natural Heritage site in Ninh Binh province, declared most recently by UNESCO in 2014 (Figure 4b). The above sites include a number of other internationally acknowledged items, namely Cat Ba island - the World Biosphere Reserve zone in Hai Phong city (declared by UNESCO in 2004), Kien Giang island - Coastal Biosphere Reserve, Kien Giang province (declared by UNESCO in 2006), the Dong Van karst plateau global geopark (Figure 4c), Ha Giang province (declared by UNESCO in 2010), Ba Be lake Ramsar site (Figure 4d), Bac Kan province (declared by UNESCO in 2011) (Tran Tan Van et al., 2010).

Figure 4. (a) Limestone islands in Ha Long Bay - the World Natural Heritage site (Quang Ninh province), (b) Residual karst towers in Trang An Scenic Landscape Complex - the World Cultural and Natural Heritage site (Ninh Binh province), (c) Quan Ba valley at Dong Van karst plateau global geopark (Ha Giang province), and (d) Ba Be Lake Ramsar site (Bac Kan province).
2.8 Archaeological Sites

Most archaeological sites in Vietnam have been found at caves in limestone areas. Post Paleolithic Age societies have been discovered to include the Nguom Culture (Thai Nguyen province, 23,000 BC) and the Son Vi Culture (Phu Tho province, 20,000-12,000 BC). Societies during the post-Paleolithic - pre-Neolithic period include Soi Nhu Culture (Quang Ninh province, 18,000-7,000 BC). Neolithic age societies include the Hoa Binh culture (Hoa Binh province, 12,000-10,000 BC), the Bac Son Culture (Lang Son province, 10,000-8,000 BC), the Quynh Van Culture (Nghe An province, 8,000-6,000 BC), the Cai Beo Culture (Hai Phong city, 7,000-5,000 BC) and the Da But Culture (Thanh Hoa province, 6,000-5,000 BC). Bronze Age societies include the Ha Long culture (Quang Ninh province, 3,500-1,500 BC and Phung Nguyen Culture (Phu Tho province, 2,000-1,500 BC).

3. Traditional Use of Limestone in Vietnam

3.1 Prehistoric Period

Recently, scientists from Vietnam, the United Kingdom and Japan have discovered at the Trang An Scenic Landscape Complex (Ninh Binh province) dozens of caves containing archaeological relics of prehistoric humans from all the above-mentioned (Section 2.8) cultures going back as far as 33,000 years BC. Results of the studies on geology, caves formation, archaeology and environment in this area show that prehistoric humans had continuous residence, constantly facing and adapting to the evolution of their geologic surrounds and changes in climatic conditions, especially the most extreme environment after the last glacial maximum. They took advantage of the limestone in these places in all aspects of life; making tools, establishing fireplaces for cooking and heating, as shelters for residence and eventually for constructing kingdom walls, as seen in the later ruins of the capital of Vietnam’s first independent feudal state. In the Trang An scenic landscape complex, the first tools were made mostly of limestone, unlike many other cave dwelling archaeological cultures where the tools were mainly made from riverine gravels or pebbles of other rock types. More specifically, the prehistoric inhabitants of Trang An limestone caves knew how to select dolomite, the hardest type of limestone in Trang An, to make their tools (Figure 5).

3.2 Period of Countries’ Foundation at Hoa Lu Ancient Capital

Hoa Lu ancient capital, a part of the Trang An Scenic Landscape Complex, was the capital of the first centralized feudal state of Vietnam. In 968, Dinh Bo Linh who ascended the throne and took the name of King Dinh Tien Hoang reunified the country under the name of Dai Co Viet and built its capital at Hoa Lu, Truong Yen commune, Hoa Lu district, Ninh Binh province. The capital of Hoa Lu existed for 42 years (968-1010). It was under the government of the Dinh dynasty for 13 years (968-980), followed by 29 years (980-1009) under the rule of the Le dynasty. After taking the throne in November 1009, in July (lunar calendar) of Canh Tuat year (1010), Ly Cong Uan moved the capital from Hoa Lu to Thang Long. Since then, Hoa Lu became the
‘ancient capital’ but in the traditions of the ancient societies, the Vietnamese people continued to use limestone widely as in royal life and rural life, in art, culture and spiritual life (Figures 6-10).

Figure 5. Labor tools made from limestone in some caves in Trang An scenic landscape complex. The crushed limestone fragments (lower-right) are believed to have helped in cooking.

Despite the time and vicissitudes of history, the Hoa Lu ancient capital still preserves many historical remains (Figures 8-10). These include natural and man-made kingdom walls and the two majestic temples of King Dinh Tien Hoang and King Le Dai Hanh (Figure 8).
Figure 6. Hoa Lu Capital, covering about 300 hectares, was a strong military base surrounded by interconnected limestone mountains and artificial walls.

Figure 7. Present entrance gate to Hoa Lu ancient capital.
Chapter 9. Stone Heritage of Vietnam

Figure 8. Royal beds in King Dinh Tien Hoang Temple (left) and King Le Dai Hanh Temple (right) made of limestone.

Figure 9. Caves used as places of worship.

Figure 10. One Pillar pagoda in Hoa Lu (left) and Sutra Pillar (right) made of limestone 973 year ago.
3.3 Later Periods

3.3.1 Stone Stelaes of Doctor Laureates

The traditional usages of limestone were extended after King Ly Cong Uan moved the capital to Thang Long (nowadays Hanoi) in 1010, for example as seen with the stone stelaes of doctor laureates in the Temple of Literature - Imperial Academy which was Vietnam’s first ‘university’ built in 1074.

Stone stelaes of doctor laureates were to honor those who passed the royal exams held by the Le and Mac dynasties. Inscriptions on each stela record the history of examinations held during the period from 1442 to 1779. There are 82 stelaes, corresponding to 82 examinations held, installing 1304 doctor laureates. The first one was erected in 1484 to record the history of the examination held in 1442. The last stela was erected in 1780 to record the history of the examination held in 1779. Decorations on the stelaes in this temple of literature are various, reflecting historical art development of Vietnam from the 15th century to the 18th century (Figure 11).

Figure 11. Stone stelaes of doctor laureates are not just an informative document source reflecting an over-300-year historical period under Le-Mac dynasties, but also a lively picture of the unique recruitment and training of talents in Vietnam, referring to the ideology of talent-based national governance.
3.3.2 Mausoleum

The feudal dynasties of Vietnam left a valuable architectural heritage in the form of rock tombs. Currently in Hiep Hoa district, Bac Giang province, there still remain 26 tombs in this category. The ancient rock tombs in Hiep Hoa, particularly Dinh Huong mausoleum and Ngo family mausoleum, are typical representatives of architectural and sculptural art in the Lee-Mac dynasties which have been recognized for many years as cultural monuments at the national level.

The mausoleum of Ngo family was built in the 18th Chinh Hoa year (1697) in Thai Tho village, Thai Son commune, Hiep Hoa district. This is the place where the body of the Duke named Ngo Cong Que - a famous martial general in the reign of King Le Hy Tong (1676-1705) was entombed. The total area of this mausoleum is approximately 400 m², surrounded by laterite walls. Inside are located two rows of human statues and many animal statues carved from salt stone (Figure 12) from the Y Son salt mountain, Hoa Son commune which is about 1.5 km away.

The Dinh Huong mausoleum in Dinh Huong village, Duc Thang town, located about 1.5 km from the Ngo family mausoleum, was built in 1729 under the reign of King Le Trung Hung (1733-1788). This mausoleum is the resting place of the navy martial Admiral La Doan Truc (1688-1749). The total area of this mausoleum is about 300m², surrounded by laterite walls where a series of human and animal statues carved from green stone are located (Figures 13-14).

![Figure 12. Statues of human and horse at the in the Ngo family mausoleum.](image-url)
Figure 13. Front lobby of the navy martial Admiral La Doan Truc’s tomb at Dinh Huong mausoleum.

Figure 14. An elephant on its knees in front of the grave of Admiral La Doan Truc.

As time passes by, the stone statues in these tombs remain beautiful and relatively intact, reminding one of a “golden age” of the Viets’ rock sculpture art.

3.3.3 The Phat Diem Stone Church

The Phat Diem stone church, 117m in width and 243m in length, stands in a campus 22 ha in area in Phat Diem townlet, Kim Son district, Ninh Binh province, ca.120 km
to the south of Hanoi. The Phat Diem stone church consists of a lake, a grand Cathedral with five separate side chapels, three artificial grottoes, and a majestic bell tower named Phuong Dinh. It is regarded as one of the most beautiful and unique churches in Vietnam (Figures 15-19).

Figure 15. The façade of the Phat Diem stone church showing features of the traditional temple architecture.

Figure 16. Statue of imperial carriage on lotus resembling Buddha on lotus, considered a unique architectural style in the world.

The church was built using limestone and wood by Priest Phero Tran Luc and his followers, starting in 1875 and ending in 1898. Although it was a Catholic church, its
The uniqueness lies in the fact that it was modeled after traditional Vietnamese temple architecture, indicating the interaction between Catholic and Buddhism and between Eastern and Western cultures.

At present, a nomination dossier is being prepared for UNESCO’s inclusion of the Phat Diem stone church on the World Cultural Heritage List.

**Figure 17.** Entrance to the Phat Diem stone church built completely in stone.

**Figure 18.** Phuong Dinh dome with sophisticated stone arrangement, Phat Diem stone church.
4. Traditional Use of Other Stones in Vietnam

4.1 Laterite

Laterite is a typical product of laterization in wet damp tropical weather conditions like those in Vietnam. Laterite was formed in many different kinds of host rock, but the most common host rocks are young and old basalt formations occurring commonly in northern and central provinces and the Central Highland. Due to the permeated weathering process, various elements are either brought to or carried away from laterite, so it becomes porous and the remaining skeleton consists mostly of SiO$_2$, Al$_2$O$_3$ and Fe$_2$O$_3$.

Laterite is comparatively soft near the water table, but it becomes harder and harder after being excavated because of water loss. So in the rural highlands, especially in the north, the local people use laterite widely in their daily life. People only need to remove the hard surface layer that is 0.5 - 1m thick to reach the softer laterite. Spades and shovels only are needed to dig up the laterite in pieces that are ready to build houses, fences or wells. In modern times when new construction materials are widely available, laterite is still in use for certain purposes, including for decoration (Figure 20).
4.2 Table Slate

The most well-known area for table slate in Vietnam is Lai Chau. Geologists have even established a formation exclusively for it: the Lai Chau formation (T₂l-c lc), which comprises mostly black clay shale with interbeds of siltstone and roofing slate, and locally coaly shale.

The properties of table slate in Lai Chau are advantageous for making roofs and floors because it is black, homogenous and does not fade with the passage of time. Moreover its temperature, electrical and corrosion resistance are high and it is very durable. Since long ago, the local people have used table slate to cover the floors of their houses. When the French built the Hanoi Opera House in 1901-1911, they also used this slate. To date, table slate of Lai Chau is used widely in high-ranking construction projects and is also exploited commercially (Figure 21).
4.3 Other Stones

While North Vietnam has a tradition of using limestones, laterite and some other soft rocks such as pyrophyllite in construction and sculpture, nevertheless, in Central and South Vietnam, magmatic rocks, sandstone and quartz have been just as popular. The most spectacular examples are the sculptures of the Yin Yang praying symbol Linga-Yoni and musical instruments such as stone horns and lithophones.

4.3.1 Linga-Yoni

Linga is a symbol of a male’s private part, and Yoni is that of a female. They represent the Yin and Yang in the universe, and express the proliferation, creation and existence of humankind.

Cat Tien holy land, located in Cat Tien district, Lam Dong province, is the name of an archeological site discovered in 1985. The holy land extends over 15km along the Dong Nai river, from Quang Ngai commune to Duc Pho commune of Cat Tien district. During the excavation, scientists discovered numerous sets of Linga-Yoni which are varied in styles, shapes, sizes. They are dated from the 8th to 10th centuries and were made with different materials such as sandstone and quartz (Figure 22).
The sandstone Linga-Yoni is composed of the 2.1m-high Linga and the 2.26m-high Yoni. The quartzite Linga is 25 cm in height and 3.5 kg in weight. It is exceptionally valuable and rare being sophisticatedly and uniquely carved. Both sets are considered the greatest Linga-Yoni in Southeast Asia.

### 4.3.2 Stone Musical Instruments

#### Early findings of lithophones in Vietnam

In 1949 in Ndut Lieng Krak, Dak Lak, Central Highland, road builders discovered a set of 11 bars of grey stone that appeared to show evidence of having been carved. The sizes of the bars vary, with the longest one being 101.7 cm in length and weighing 11.21 kg and the shortest one being 65.5 cm in length and weighing 5.82 kg. This discovery was announced to Georges Condominas, a French archeologist working at the Ecole Française d’Extrême Orient. In June 1950, Professor Condominas brought the bars to Paris to be examined by music professor André Schaeffner. Afterwards, these researchers released their results (Schaeffner, 1951; Condominas, 1952), affirming that the lithophone in Ndut Lieng Krak “resembled no other known lithophones”. Currently, this lithophone is being exhibited in the Musée du Quai Branly, Paris.

In 1956, during the Vietnam War, a second lithophone was discovered and an American lieutenant took it to New York for exhibition.

On the 2nd September 1979, Mr. Bo Bo Ren, an ethnic Raglai man in Khanh Son proclaimed an instrument that he had unearthed and had subsequently hidden in a cave for tens of years. This latter set consists of 12 stone bars with different dimensions and lengths for different sounds. Mr. Bo Bo Ren himself arranged the 12 bars into 2 sets of 6 bars each. In set A, the heaviest bar is 9 kg, and the lightest one is 5 kg. In set B, the
heaviest bar is 28.1 kg and the lightest one is 10.5 kg. The total weight of set A is 50.5 kg and that of set B reaches 110.8 kg.

In 1979, at Binh Da archaeological site, located in An Binh district, Bien Hoa city, Dong Nai province, 42 bars of lithophones were collected. The discovery of lithophones in Binh Da is an important landmark in research on the cultural story ofprehistoric people and history of stone musical instruments because it is at this place that the instrument was dated as 3,000 years old.

In 1980, Georges Condominas discovered another lithophone comprising 6 bars at Bu Do village, Loc Bac commune, Bao Loc district, Lam Dong province. This was an instrument kept by the Kgien family (Ma people) through 7 generations.

When Vietnamese researchers entered the field the study and collection of stone musical instruments surged forwards. By 1990, 200 bars of stone instruments had been found in scattered sites such as Dak Lak, Khanh Hoa, Dong Nai, Ninh Thuan, Lam Dong, Song Be and Phu Yen.

During the excavation on Doc Gao mountain in To Hap commune, Trung Hap district, Khanh Son, the researchers found numerous signs of the crafting of lithophones with various stone blocks and pieces of porphyric rhyolite that are abundant in this area. Signs of the local manufacture of lithophones confirm that the prehistoric residents of this place, the Raglai people, are the real owners of these instruments.

**Lithophone and stone horn of Tuy An, Phu Yen**

The Tuy An lithophone was discovered in June 1990 at Mot mountain, Trung Luong commune, An Nghiep district, Phu Yen province. The instrument consists of 8 bars with different dimensions and shapes. Specialists have assessed this instrument to be the most complete lithophone in setting and sounds among the instruments ever found in Vietnam, including the above-mentioned Ndut Lieng Krak (Dak Lak) instrument. This instrument is dated as 2,500 years old.

In 1994, archaeologists were astonished when a pair of frog-shaped stone horns was discovered in Phu Can village, An Tho commune, Tuy An district. These horns were found beneath a ruin of Cham Pa, and had been preserved and used through seven generations of nuns in Hau Son pagoda, a period lasting for approximately 150 years (Figure 23). The pair of frog-shaped stone horns consists of a larger horn which represents the female and a smaller one which represents the male. The “female” horn is 75 kg in weight and 35 cm in height; the bottom is 40 cm wide; the convexity of the back is 55 cm; the blowing hole is 2.5 cm wide; the distance from the blowing hole to the loop hole is 29.6 cm. The “male” horn is 34.5 kg in weight and 35 cm in height; the bottom is 29 cm wide; the convexity of the back is 52 cm; the distance from the blowing hole to the loop hole is 29.5 cm. According to the National Scientific Committee this ancient wind instrument is unique, made from basalt, possibly by the Cham people prior to the 6th century.

Currently, Phu Yen province is making an application to UNESCO for the recognition of the stone instrument of Tuy An for inclusion in the World Cultural Heritage list.
Ms. Katherine Muller-Marin, Head of Office of UNESCO Hanoi, attempting to blow the stone horn and play the Tuy An lithophone. Mrs. Muller highly appreciates these two unique heritages, especially the flexible linkage and combination between them.

Discoveries of lithophones after Tuy An instrument

In June 2003, Mr. K’Branh in Bo Nom village, Lam Dong province discovered a 20-bar instrument. The two longest bars are 22cm wide and 151cm and 127cm long respectively. The shortest bar is 10cm wide and 43 cm long. The remaining bars have lengths of 71 to 75cm and width of approximately 15 cm. This is the instrument with the most bars so far discovered.

In July 2006, another lithophone was found in Ham My commune, Ham Thuan Nam district, Binh Thuan. The instrument consists of 8 bars, of which the longest one is 95 cm in length, 17 cm in width and 12.5 kg in weight. The other bars are smaller, gradually decreasing to 52.5cm in length and 4.5kg in weight of the last one. All of the 8 bars show sophisticated carving and resemble each other with two thick ends that are larger than the body, which becomes smaller in the middle. This discovery surprised the archaeologists because the site, influenced by Sa Huynh culture, was located near the beach whereas all the previous lithophones had been discovered in mountainous areas.

On 17th November 2010, the Binh Thuan Museum received an ancient lithophone discovered by a local person at a village, Da Kai commune, Duc Linh district. This instrument was made from dark blue rock and consisted of 5 bars. It is notable that earlier the Binh Thuan Museum had worked with the Japanese experts to unearth another lithophone which was only 3 km away from the above-mentioned site.

In June 2013, the local residents of Trung Luong village, An Nghiep commune, Tuy An district, Phu Yen province, which was about 15km away from the place where the Tuy An lithophone was discovered in 1990, found 14 stone bars of various colours and shapes. These bars generate the same sound as Tuy An (Figure 24).
Figure 24. Fourteen stone bars discovered by local residents of Tuy An in 2013.

The bars are ivory-white with black green cores. They display various shapes (rectangle, trapezium, bow-shaped) and non-uniform dimensions. The biggest and longest bar is 38 cm in length, 13 cm in width and 4.5 kg in weight. The smallest and shortest one is 18 cm in length, 4.5 cm in width and 0.6 kg in weight.

On the 29\textsuperscript{th} May 2014, a local farmer discovered two sets of lithophone while he was farming at Long Son commune, Dak Mil district, Dak Nong province. These sets have an age of 3,000 years (Figure 25).

Figure 25. The two sets of stone bars discovered at Long Son commune, Dak Mil district, Dak Nong province in 2014.
It is preliminarily identified that the first set has 10 bars and the second one has 7 bars. Comparison with other lithophones in Dak Nong, Lam Dong and some other provinces shows that these two sets have some similarities in shape as well as in their cultural and historical value.

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Back cover photographs (anti-clockwise from top left):

1. Bas relief of Bayon Temple, Angkor Thom, Cambodia
2. Lemo Stone Cemetery, Makale, Toraja, Indonesia
3. Stone walls of Osaka Castle, Japan
4. Ogatsu slate of the roof of Tokyo Station, Japan
5. Dabo Pagoda in Bulguksa Temple, the Republic of Korea
6. A-Formosa fortress in Melaka Historical City, Malaysia
7. Human butchering stone table, Papua New Guinea
8. Malagonlong Bridge, Tayabas, the Philippines
9. Phanomrung Historical Park, Thailand (photo by Rath Jitrattana)
10. Phat Diem Stone Church, Vietnam
Stone is a durable and naturally occurring material used by humans throughout the world from the birth of humankind up to the present day. In prehistoric times stone was used to make simple tools, jewellery and even musical instruments, later to construct buildings for dwellings, tombs or for ceremonial/religious purposes and fortifications leading to modern uses of stone in today’s infrastructures. Carefully preserved stone objects may therefore provide a historic record of the cultural and social development of human societies in each country of the world and representative examples of such objects are all elements of a 'stone heritage' which varies from country to country. In this book, each chapter describes various examples of objects which contribute to the stone heritage of a specific country in East and Southeast Asia (i.e., chapters on Cambodia, Indonesia, Japan, Korea, Malaysia, Papua New Guinea, Philippines, Thailand and Vietnam).

Many of the stone heritage objects and sites described in this book attract international and domestic tourism and so can make an important contribution to the local economy. In turn, the tourist’s visit may be enriched by learning more about the origin and source of the stone used in the object’s construction. In these ways CCOP hopes that this book will help to improve the quality of life in the region as well as encouraging public interest in geology and its significance in the region’s cultural and economic development.

This book was prepared with strong support from the Japanese government through the Geological Survey of Japan (GSJ), National Institute of Advanced Industrial Science and Technology (AIST), from the initiation of the project to the publication. We are more than happy to see this book assist people to learn how geology contributes to our daily life.