



International Erasmus Mundus Master in
QUATERNARY AND PREHISTORY



**Future Prospect Study of New Potential Prehistoric
Sites by Applying U-Series Dating Method on
Carbonate Samples from West Gunung Sewu
Geopark, Indonesia**

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Abstract

This research aims on to expose and study the natural karst landform values of Gunung Sewu UNESCO Global Geopark (UGGp), especially the Western part and correlate it to the potential richness of the region to have prehistoric studies, conservation, and research being done for the present and future. With the numerous karst landform that withhold the natural characteristic features that supports the preservation of archaeological materials and human remains. Geochronological approach is being made by applying U-series dating method, the objective is to have an absolute date of these new potential prehistoric sites, coming from carbonate rock samples, that were collected from speleothems associated with archaeological age among these potential prehistoric sites. We have recorded in a total of 24 new potential prehistoric site which categorized into karstic cave landform, rock shelters among karstic conical hills, and 14 observations point along Kali Oyo karstic alluvial lowlands landform. Geological, geomorphological, physiographical, and archaeological surveys were done, and each location with scientific descriptions. The outcome of the survey and exploration fieldwork on these sites, were understanding the natural geomorphological landform use for habitation by ancient human, collecting carbonate samples eligible for applying U-series dating method, and discovery of surface findings artefact. In this research, it is now proven, that West part of Gunung Sewu UGGp holds and contains high potential also, viewing from the density, quality, and quantity of landforms that are suitable and highly prospective to become former human settlement in the past.

Keywords: geochronology, geomorphology, Gunung Sewu, U-series dating, prehistory

Résumé

Cette recherche vise à exposer et étudier les valeurs naturelles du relief karstique du Géoparc mondial de l'UNESCO de Gunung Sewu (UGGp), en particulier la partie occidentale, et de les mettre en corrélation avec la richesse potentielle de la région en termes d'études préhistoriques, de conservation et de recherche pour le présent et l'avenir. Les nombreuses formes de relief karstique qui retiennent les caractéristiques naturelles favorisent la préservation des matériaux archéologiques et des restes humains. L'approche géochronologique est réalisée en appliquant la méthode de datation de la série U, l'objectif étant d'obtenir une date absolue pour ces nouveaux sites préhistoriques potentiels, à partir d'échantillons de roches carbonatées prélevés dans des spéléothèmes associés à l'âge archéologique parmi ces sites préhistoriques potentiels. Nous avons enregistré un total de 24 nouveaux sites préhistoriques potentiels, classés en grottes karstiques, en abris sous roche sur des collines coniques karstiques et en 14 points d'observation le long des basses terres alluviales karstiques de Kali Oyo. Des études géologiques, géomorphologiques, physiographiques et archéologiques ont été réalisées et chaque site a fait l'objet d'une description scientifique. Les résultats de l'étude et de l'exploration sur le terrain de ces sites ont permis de comprendre l'utilisation du relief géomorphologique naturel pour l'habitat humain ancien, de collecter des échantillons de carbonate éligibles pour l'application de la méthode de datation de la série U et de découvrir des artefacts trouvés en surface. Cette recherche a prouvé que la partie ouest de Gunung Sewu UGGp recèle un fort potentiel, si l'on en juge par la densité, la qualité et la quantité des formes de relief qui sont adaptées et hautement susceptibles d'avoir servi d'habitat à l'homme dans le passé.

Mots-clés: géochronologie, géomorphologie, Gunung Sewu, la datation U-series, préhistoire

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I. INTRODUCTION

I.1 Theoretical Framework

I.1.1 Main Idea

The Quaternary period is the most recent and shortest era on the geological scale which started from 2.58 million years ago to the present (Lowe and Walker, 2014). This period has a particular importance, because of its relationship with prehistoric studies, especially the human evolution and also, the dispersal of Hominin across the continents. Which is a group consisting of modern humans, extinct human species and all our immediate ancestors (including members of the genera *Homo*, *Australopithecus*, etc). Apart from that, this period is also the period modern human are now living, what happen in the past has shaped what it is in the present, and what is happening in the present, will shape our future, as it is always planted in the mind of geologists, that "The present is the key to the past" first popularized by Scottish naturalist, James Hutton. The Quaternary period is also marked by the succession glacial and interglacial climatic phases strongly influencing the paleoenvironment of how ancient human started to have settlements and occupied a region all around the earth. Considering all of these events which mark the Quaternary period, the establishment of a chronological scale then it appears to be essential and very important to have well understanding and reconstruction of these past events.

One of the most significant research that is always related with Quaternary period is prehistory, as one of a field in science, it is based on the interdisciplinary study of continental fillings of sedimentary deposits which contain the paleontological and archaeological remains, that usually artefacts that are in form of bones (faunal remains) and lithic (stone) tool remains. From those material remains, we can try to understand and reconstruct on how them, ancient human (Hominin), in the prehistoric period, evolve in cultural, technology, and the way they live their life. Now, it is essential and crucial for us, to be able to give a precise age of this artefacts (archaeological – paleontological remains) bearing Quaternary sediment layers, on when these events happened and occurred in the past. We can obtain information on the duration of numerous phenomena or even determine the contemporaneity of specific events in various regions, to ultimately construct a chronological framework in a scale where it can be included together, such as climatic phenomena, evolutionary biological phenomena, and cultural – technological evolution phenomena.

I.1.2 Dating Method Applied to Quaternary and Prehistoric Studies

Dating methods applied to prehistory developed very quickly in during the 20th century. If relative dating methods such as biochronology were recognized even before (Guérin, 2002), this method of dating are often has a high relativity factor, that relies on the principle of superposition, which states that in undisturbed layers of sedimentary rock, the oldest layers are at the bottom and the youngest are at the top (Steno, 1669). These methods, nevertheless often remain insufficient to obtain a precise chronological framework scale to explain the detailed study of Paleolithic material cultures and the evolution of Hominin since the Pliocene. As we understood that Quaternary period is a very short period, and we need more precise dating result to prevent relativity result that often resulted in a wide range of age coming from the stratigraphic layer level or archaeological materials bearing layer. Therefore, since the discovery of natural radioactivity in the 19th century, a number of so-called “absolute” dating methods have been founded, developed, and applied to numerous fields of study.

Carbon 14 (^{14}C) radiometric dating method, is one of the best known and most common method by researchers and by public who are interested in the origins and evolution of human. However, even with the recent development of mass spectrometry, this method allows us to go back in time to events up to 50,000 years old. Other methods based on radioactive isotope decays, are uranium series (U-Th) method, which will be applied in this research on carbonate samples from Gunung Sewu karst area, potassium-argon (K/Ar), argon-argon (Ar/Ar) or based on the damage created in the minerals by natural radiation such as Electron Spin Resonance (ESR), Thermoluminescence (TL), Optically Stimulated Luminescence (OSL). These methods have made it possible to cover all prehistoric periods from the oldest ever recorded Hominin remains bearing site to the youngest human settlement in prehistoric chronological framework. These dating methods have made it feasible to establish the boundaries and benchmarks for geological phenomena that earth has been through. In the Quaternary period, the marine isotopic curve based on atmospheric variations of Oxygen 18 (^{18}O), and the variations of terrestrial paleomagnetism (Figure 1). The choice of the dating method that we will apply in a prehistoric site is function primarily by the nature of the sedimentary filling and deposition. Which therefore, resulted also a deposition of archaeological artefacts or human remains in the Quaternary sediment layers in each level of stratigraphy. Based on the geologic law of superposition (Steno, 1669), materials that were contained in the

lower stratigraphic layer will have an older age than the layer above, but that is not always applicable on every site, there might be some factors that could affect the mixing artefacts or remains between periods, usually it is often mentioned as reworked remains. In Quaternary paleontological and archaeological sites, materials data are varied. The skeletal and dental remains of mammals are often encountered and allow us to give an age to the archaeological layers in which they are found. The stalagmitic floors as well as volcanic ash layers are also often used as type of rock sample that are suitable to support absolute dating method by U-series and K/Ar. In recent years new developments methodological methods of the thermoluminescence (TL) and the Electron Spin Resonance (ESR) also made it possible to carry out dating on other materials such as heated flints and alluvial deposit quartz (Hameau, 2004).

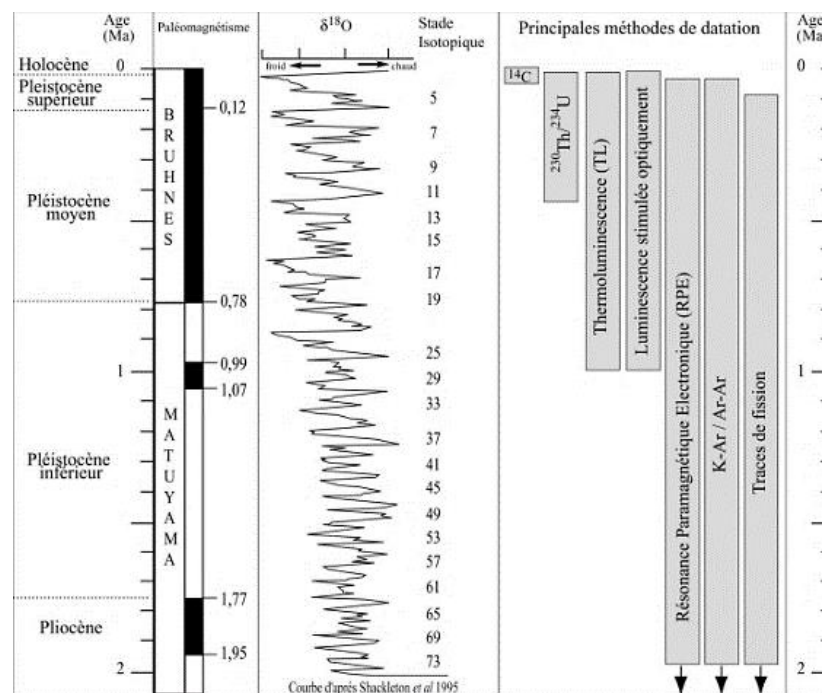


Figure 1 Dating methods and its ability to be applied in chronological framework (Hameau, 2004)

The history of radiometric dating methods applied to archaeological studies is relatively short, yet it has already witnessed significant breakthroughs that have broadened the scope of analysis. Until recently, most dating techniques emerged as incidental discoveries within the realm of geological research. Various experts are dedicated to studying archaeological sites and the materials found within them. Collaborating closely with other experts, such as geologists, chemists, physicists, and other scientists, they are actively pioneering new dating methods tailored specifically to the materials commonly encountered at archaeological sites.

Despite these advancements, there remains a noticeable level of scepticism among archaeologists when confronted with chronometric dates that challenge established beliefs. It is crucial to acknowledge and address these concerns, as overlooking them could have serious consequences. It is imperative to recognize that the archaeological record itself presents a chronological narrative, somewhat ambiguous, offering an independent yet interconnected perspective on the timing of Hominid evolution. This evolutionary sweep underscores the importance of refining dating methods and fostering interdisciplinary collaboration to enhance our understanding of the past, especially the prehistoric cultural – technological development changing, and ancient human dispersal evolution from time to time (Schwarcz, 2001).

I.2 Research Objectives

This research is aiming to expose and study the natural karst landform values of Gunung Sewu UNESCO Global Geopark (UGGp), especially the Western part, and correlate it to the potential richness of the region to have prehistoric studies, conservation, and research being conduct for the present and future. The main factor behind it, is because of the numerous karst landform that withhold the natural characteristic features that supports the preservation of archaeological materials and human remains. In that case, it would certainly increase the number of the materials and objects to be studied by experts, coming from different kind of specialities in the field of Quaternary geology, archaeology, prehistory, and human evolution studies. These unexplored landforms in West Gunung Sewu UGGp area that are going to be considered as potential prehistoric sites can be done by starting to differentiate and discriminate some typical karst landforms, such as karstic caves, lakes, sinkholes, underground rivers, and alluvial terraces/lowlands. Other than that, it required also to preserve archaeological material or ancient human remains. Thereby, materials that are deposited and stratified in a thick Quaternary sedimentary layer, can indicate the potential great understanding of a long and complete human technological – cultural evolution, chronology of human occupation and settlement in a sequential period in the area.

We also need to take into consideration and have well understood, the tectonic and volcanic activities that have implied in the region, by that, we could be aware of when did tectonic uplift and volcanic eruptions occurred. With that knowledge, we might potentially set an age limit (chronology) of when Gunung Sewu UGGp became fully

uplifted above the sea and appeared to transform into terrestrial environment, which can indicate the earliest possibility of how human started settling and occupying this region.

By applying U-series dating method, the objective is to have an absolute date of these new potential prehistoric sites, coming from carbonate rock samples that were collected from speleothems associated with archaeological age among these potential prehistoric sites. These absolute date results are aimed to know and understand precisely, when and which period did human in the past started and also stopped occupying these potential sites. Therefore, it could have a result of stretching to even more ancient or recent than previous researches have been done before, as well as adding up or complete the missing sequence of human occupation in the area. U-series dating is believed to be the best and most suitable dating method to be applied in this study case or research, as mentioned by Ivanovich and Harmond (1992). U-series dating by their radioactive half-life principle, could date between 10 – 500 ka, which is very compatible, as until this date, as stated by recent research, it is believed that in Gunung Sewu UGGp area, prehistoric (ancient) human at least started to colonize and settle in 180 ka (Simanjuntak, 2004) and occupied cave at least 120 ka (Sémah et al., 2007).

I.3 Research Questions and Problematics

1. What are the natural or geomorphological landform values of the West Gunung Sewu UNESCO Global Geopark (UGGp) karstic landscape that can be considered as potential prehistoric site?
2. What are the prehistoric sites that have been researched and established in Gunung Sewu UGGp before?
3. How to discover unexplored new potential prehistoric sites in the West part of Gunung Sewu UGGp area?
4. How is the potential to have a new age proposed by applying U-series dating, for the range of the earliest to the latest ancient human settlement and occupation in Gunung Sewu UGGp area compare to previous researches?

II. STATE OF ART

II.1 Physiography Regional and Geological Context of Gunung Sewu Region

The name Gunung Sewu which can be translated into Thousand Hills in Javanese, derives from the landscape which dominated with conical limestone hills which have a density of hills being estimated around ± 30 per km^2 , consisting around 40.000 hills with most of them containing caves that often rich in prehistoric remains (Bartstra, 1976). According to Haryono (2010), the estimated height of the hill is ranging from 80 m to 500 m above sea level. This area lays adjacent to the south coast of Central Java, situated between 6° and 9° South latitude and 105° and 114° East longitude, around 80 km from Pacitan gulf in the east to Oyo River in the West. Gunung Sewu karst area stretches 85 km west-east from Parangtritis Beach of Yogyakarta Special Province to Teleng Ria Beach of Pacitan, East Java. The area covers three provinces, namely Yogyakarta, Central Java, and East Java Province and 3 regencies, Gunung Kidul, Pacitan, and Wonogiri Regency. Its North-South width varies between 10 to 29 km with approximate area of 1300 km^2 . One of the notable features of Gunung Sewu Karst is the presence of a valley known as the ancient Bengawan Solo valley, which preserves the geological history of Java Island's uplift during the Quaternary period. This history reveals a significant shift in the river's course from a southward to a northward direction (Figure 2; Haryono, 2010).

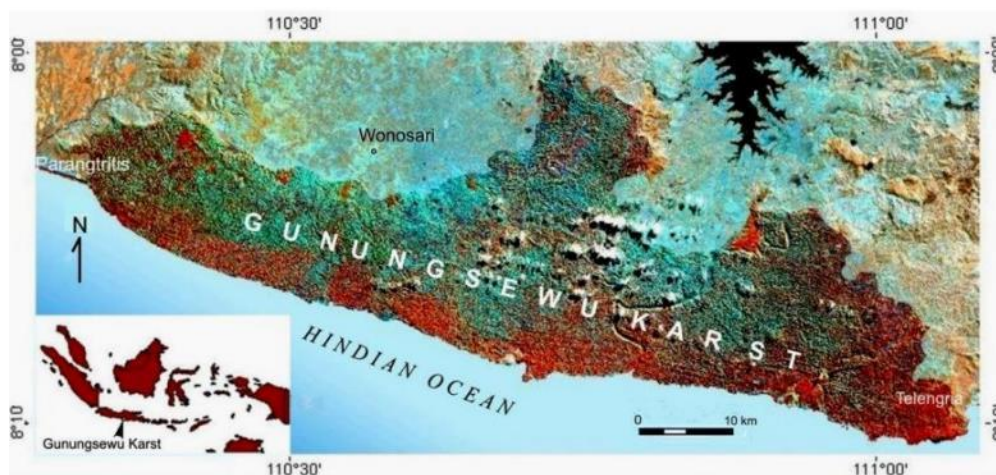


Figure 2 Landsat Enhanced Thematic Mapper Plus (ETM+) of Gunung Sewu Karst Area (Haryono, 2010)

The Gunung Sewu karst region is adjacent to the Indian Ocean on the south-central coast of Java (Figure 3; van Bemmelen, 1949). Elevation range is between zero and 512.5 m above mean sea level, and the highest portions centrally located about 25

km from the coast line (Haryono and Day, 2004). Regional physiography is characterized by distinct physical or natural features, including landforms, topography, climate, and geology, Gunung Sewu area is located in the Southern Mountains (van Bemmelen, 1949).

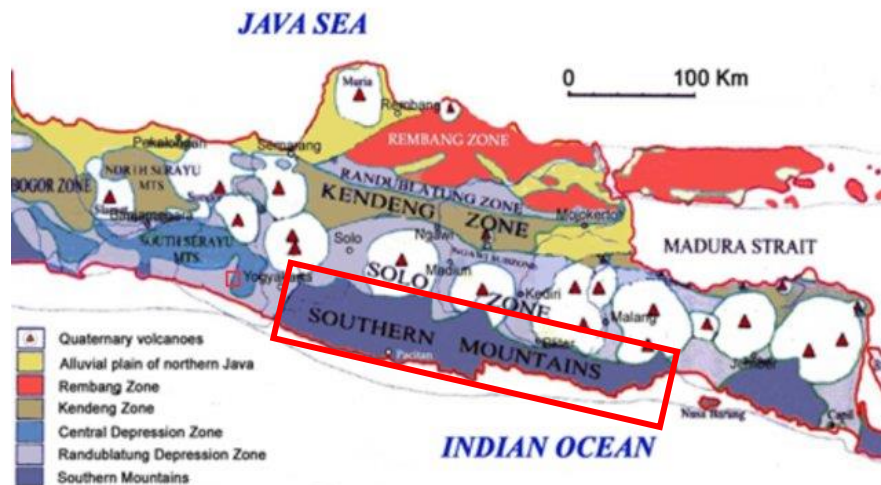


Figure 3 Regional Physiography of Java Island, (van Bemmelen, 1949)

The current climate in the Gunung Sewu karst region is significantly shaped by the Northwest and Southeast monsoons. This climatic pattern results in a well-defined wet season, occurring from October to April, and a dry season, which can be exceptionally parched, from May to September. The annual precipitation levels, documented from 14 local rain gauge stations over the period spanning 1960 to 1997, exhibit a range between 1500 mm and 2986 mm per year. The average annual temperature in this area hovers around 27°C (Haryono and Day, 2004).

The Gunung Sewu karst was made up of Neogene (Middle Miocene and Upper Pliocene) limestone, which referred to Wonosari-Punung Formation (Tmwp). The limestone consists of bedded chalky limestone in the north and massive coral limestone in the south (Figure 4; Balazs 1968; van Bemmelen 1970; Waltham et al. 1983; Surono et al. 1992; Rahadjo et al., 1995). The limestone in the area measures over 650 meters in total thickness. It is primarily composed of rudstones, packstones, and framestones, although there is significant lithological variation throughout. Also, biohermal structures, and volcanic ash deposits are scattered among the carbonate layers, as documented by Waltham et al., (1983). Moving towards the north and northeast, it is possible to notice that the bedded, chalky limestones become more prominent, eventually dominating the Wonosari Plateau. Underlying the limestone formations are mostly Miocene Epoch volcanic clastic sedimentary rocks, including the Wuni Formation, Sambipitu Formation,

A total of 30 geological heritage and 3 non-geological heritage sites are located in the Gunung Sewu Karst Area which is recognized as a geopark or national geological park by the Ministry's Geological Agency Mineral Resources Energy. These sites are targeted to be managed by the community based on community empowerment.

Based on the results of landsat image analysis, the Gunung Sewu Karst Area is grouped into 4 units, namely (Figure 5; Brahmantyo, 2006):

- Unit K1 Karst Plateau, this area is a karst area which has an elevation of 200-300 meters above sea level, the karst plateau on Gunung Sewu consists almost entirely Karst Plateau. This is due to the fact that there was uplift due to tectonics in the heights of the southern mountains, in this region many karst hills and caves are found.
- Unit K5 Karst Alluvial Plain, this area is a territory karst which has a low elevation, consisting of alluvium and beach. This area is located in Gunung Sewu beach, also many deposits were found the south coast of Java is in the form of sediment beach-rocks and sea-stacks.
- Unit K6 Doline, this area is a karst territory which has characteristics such as vertical system hole. This unit is often found in the Semanu, Gunungkidul region, which is a doline collapse area (Luweng Jomblang, Kalisuci, etc.), in the Pacitan area it is on the geosite Luweng Ombo, who is cave with a vertical system.
- K8 Dry Valley Unit, this area is a Karst area with a dry system valley or ancient valley. This unit covers up Bengawan Solo ancient river which is located in Gunungkidul and stretched up to Wonogiri.

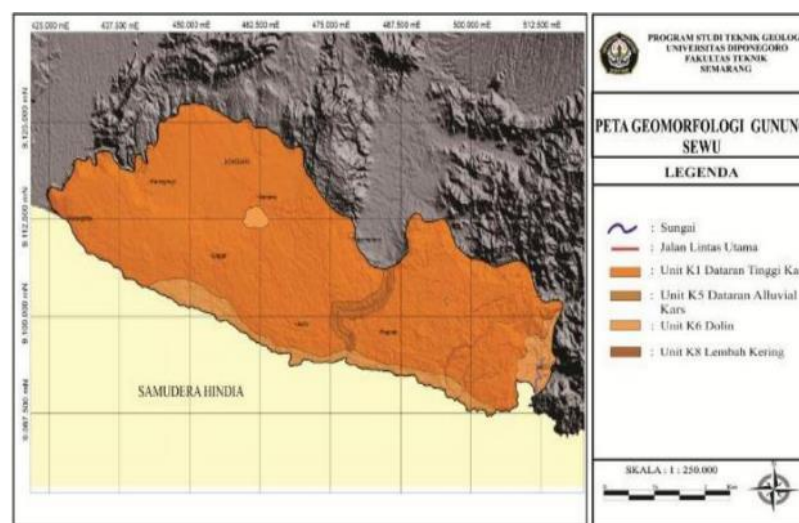


Figure 5 Geomorphology map of Gunung Sewu (Brahmantyo, 2006 in Hartawan, 2020)

From the results of the research conducted, there are 33 sites in the Gunung Sewu Area namely 30 Geological sites where: 11 sites are in the Gunungkidul Geoarea (Middle Miocene Marine Deposits, Sambipitu Formation), which consisted of Pindul Cave (Figure 6), Kalisuci, Luweng Jomblang, Siung Beach, Dry Valley Purba Sadeng, Bleberan Waterfall, Cave Jlamprong, Luweng Cokro, and Gua Ngingrong (Permadi, 2014).

7 sites are located in Wonogiri Geoarea, which consisted of Girintontro Ancient Dry Valley, Sodong Cave, Tembus Cave, Luweng Sapen, Mrico/Mrica Cave, Potro-Bunder Cave, Beach Sembukan. 12 in Pacitan Geoarea, which consisted of Klayar Beach, Mbuyutan Beach, Beach Watukarung, Srau Beach, Pacitan Bay, Gong Cave, Tabuhan Cave (prehistoric site), Luweng Jaran, Gua Song Terus (prehistoric site), Luweng Ombo, River Baksoka, and Guyangwarak Lake (Permadi, 2014). 3 non-geological sites are Wanagama forests, Derived Forests and Ngrinjangan Archaeological Sites



Figure 6 Karst dome in Gunung Sewu UGGp (Kusumayudha, S. B., J. Setiawan, A. N. Ciptahening and P. D. Septianta, 2015) and Tourism in Pindul Cave Geoheritage site in Gunungkidul Geoarea (*Travel Kompas*, 2022)

II.3 Prehistory of Gunung Sewu Area Based on Previous Researchers

Gunung Sewu is an important region for the prehistoric research due to the richness in prehistoric artifacts. The discoveries of Paleolithic and Neolithic industries mark the long sequence of lithic traditions in this area (Sémah, et al. 2004). Studies had suggested that the beginning of cave occupation in Gunung Sewu began around 120 ka (Sémah, 2007; Fauzi, 2008). This region holds great importance in human history, as it is considered as a prehistoric capital of Southeast Asia. Human habitation in Gunung Sewu karst dates back to the Middle Pleistocene and has progressed through three distinct chronological phases. Initially, people settled in open areas along river courses. As caves

became accessible, human settlements shifted to these cave locations, extending into dry valleys and near doline ponds. The era of cave habitation came to an end when extensive agricultural land became available due to the drying out of major depressions (Haryono, 2010).

II.3.1 History of Prehistoric Research of Gunung Sewu in Chronological Order

Based on Simanjuntak, T. (2001), he compiled a brief research history of Gunung Sewu UGGp area, since the early 20th century from the oldest to the most recent studies:

- Discovery of the Sampung Bone Industry in Lawa Cave, Sampung, by Louis Jean Chrétien van Es (1926) and van Stein Callenfels (1928-1931)
- Van Stein Callenfels (1932) reported more than 100 open-site Neolithic workshops in the Punung area.
- Von Koenigswald and Tweedie (1935) discovered a Paleolithic site in Baksoka Valley with a lithic assemblage known as Pacitanian (Figure 8)
- Van Heekeren (1935, 1972) explored more caves in the limestone hill areas of East Java, discovering Sampung Bone Industry in Pugar area caves association with flexed burials, flake-blade tools and faunal remains.
- Von Koenigswald (1936) excavated a site located in the eastern slope of Gunung Cantelan near Punung, the shelter is now known as Song Agung, yielded flake tools, including arrowheads with convex bases, shell ornaments and loose human teeth.
- Soejono and Basuki (1953) excavated Song Terus and found stone tools, bones and shell tools and faunal remains (van Heekeren, 1972)
- Research conducted since the early 1990s in several limestone caves around Southern Mountains, revealed a chronology from early Holocene to 4500 BP. During 1990s, intensive research was carried out in the caves of Braholo and Song Keplek (Puslitarkenast – MNHN, Simanjuntak et al. 1994), and Song Agung
 - Braholo cave (west part)
 - Song Keplek cave (east part)
 - Song Gentong near Tulungagung
 - Song Agung
 - Some caves in Puger

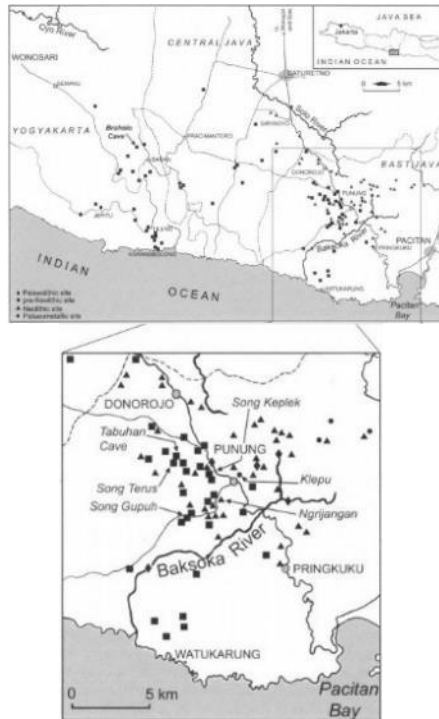


Figure 7 General and Detailed Map of Gunung Sewu Prehistoric Sites (Simanjuntak, 2004)



Figure 8 Baksoka River, Where Pacitanian Artefacts were scattered on the riverbed

Gunung Sewu is one of the most important areas for prehistory of the Indonesian archipelago or of the South East Asian islands in general, until now, there have been 130 prehistoric sites found in this area, both caves and open-air sites. Most of the sites were located in the eastern part of the area, in Punung, Donorejo, and Pringkuu districts (East Java Province), less abundant in the central and western part. These sites cover a long range of prehistoric culture and chronology, from Paleolithic, pre-Neolithic or Mesolithic, Neolithic, and Paleometallic periods (Simanjuntak et al., 1994).

Table 1 Chronology of Habitation with its General Characteristics in Gunung Sewu area (Simanjuntak, 2004)

date (years BP)	periodisation	culture	general characteristics
± 600	Klepu period	Palaeometallic	<ul style="list-style-type: none"> * main archaeological remains: pottery, iron objects, beads, stone flakes * habitation in open landscape * continued Neolithic tradition
2000 – 1000	Ngrijangan period	Neolithic in open landscape	<ul style="list-style-type: none"> * main archaeological remains: pottery, stone adzes and arrowheads * habitation in open landscape * the emergence of groups of <i>atelier</i>
2000 – 4000	'Gupuh' period	Neolithic in caves and rockshelters	<ul style="list-style-type: none"> * main archaeological remains: pottery, adzes, flakes * cave habitation (early Neolithic) * adze and pottery making * pre-Neolithic tradition still continued
4000 – 12,000	Keplek period	pre-Neolithic	<ul style="list-style-type: none"> * very dense archaeological remains: stone and bone tools, fauna * intensive exploitation of environmental resources (animal hunting) * exploitation of seeds in the later period * practice of primary and secondary burial * very intensive firing activities in caves * australo-melanesoid race and possibly Mongoloid race
12,000 – 60,000	Tabuhan period	Upper Palaeolithic ?	<ul style="list-style-type: none"> * main archaeological remains: flakes and atypical tools, fauna (Cervidae, Bovidae) * oldest cave habitation in Southeast Asia * subsistence: animal hunting
60,000 - 180,000	Terus period	Middle Palaeolithic ?	<ul style="list-style-type: none"> * main archaeological remains: flake tools, rounded and fresh, fauna (<i>Rhinoceros</i>, <i>Tapirus</i>, Cervidae) * habitation in open landscape along the river banks * subsistence: animal hunting
?- 180,000	Baksoka period	Lower to Middle Palaeolithic ?	<ul style="list-style-type: none"> * main archaeological remains: large flakes and core tools * habitation in open landscape along the river banks * subsistence: animal hunting

- The Baksoka period, the oldest among all, marks the initial colonization of Gunung Sewu. Unfortunately, precise absolute dates for this period remain elusive due to challenges in obtaining in situ samples. It is generally believed to predate the Song Terus period in the Middle Pleistocene. During the Baksoka period, people lived in open landscapes and along river courses, utilizing a Palaeolithic culture characterized by massive choppers, hand axes, and large flake tools, the famous Pacitanian culture belong to this period.
- The Terus period is defined by the presence of flake tools, most of which exhibit rounding, with only a few appearing slightly fresh. The artefacts resemble the Pacitanian in terms of patination but with smaller flakes and almost no pebble tools. These tools vary in size and some show signs of retouching to create various types, notably scrapers. Faunal remains are scarce, with occasional finds of *Rhinoceros*, *Tapirus*, and unspecified cervid remains. U-series dating of bones and teeth suggests an age ranging from 187,000 ± 21,000/-18,000 to 79,000 ± 3,000 BP. This phase is considered essentially continuous with the Baksoka period, with a strong emphasis on life in an open landscape. Another newer study done by Hameau and Falguères (2007), a coupled ESR/U-series dating provided consistent ages of 254.738 and 341.751 BP for two teeth associated with lithic artefacts coming from the Terus layer. It became an interesting discussion, nevertheless, by stratigraphic description of Terus layer, it showed that, once in a period, there was an active river flowing in this period layer from Song Terus. The objects that were dated on by coupled ESR/U-series could have been

transported from an unknown source and it became out stratigraphic context by the reworked that have been done.

- The Tabuhan period signifies the advent of true cave habitation, although findings are relatively sparse. The artifacts primarily consist of flakes and flake tools. The presence of cores and percutors indicates industrial activities within the caves. Faunal remains are mainly from the Cervidae and Bovidae families. Tabuhan Cave dating suggests this phase lasted from 60,000 to 12,000 years ago and marks the earliest known cave habitation in Southeast Asia.
- The Keplek period corresponds to the pre-Neolithic or Mesolithic era in general. It aligns with the Sampung Bone Industry of Van Heekeren (1972) in East Java and represents the peak of cave habitation, fostering a distinct regional culture with an intensive focus on natural resource exploitation, especially fauna. Key cultural elements during this period include lithic and bone tools. The Keplek period spans from 12,000 to 4,000 BP.
- The 'Gupuh' period is an early Neolithic stage dating from approximately 4,000 to 2,000 BP. It largely maintains pre-Neolithic traditions, such as cave habitation, flake tool production, and hunting. New elements emerge during this era, notably pottery and quadrangular adzes. While there isn't yet a definitive 'eponym' site for this period, Song Gupuh is tentatively suggested, pending further chronological evidence.
- The Ngrijangan period is a Neolithic stage dating to around 2,000-1,000 BP, characterized by habitation in open sites. The predominant cultural expression involves atelier sites where quadrangular adzes and arrowheads are intensively manufactured, along with pottery.
- The Klepu period represents a stage of Palaeometallic culture, marked by the introduction of tools, weapons, and beads made of metal. The Neolithic focus on open landscapes continues, as does the tradition of stone tool manufacture, although at a reduced intensity. This phase persists until around 600 BP and gives way to the historic period at an as-yet-undetermined date.

II.3.2 Baksoka Valley Open-air Site

The Baksoka valley near Pacitan (previously spelt Patjitan) in Java is home to lithic tool remain collections from the Palaeolithic period. These collections are thought to date mostly from the Late Pleistocene, and no radiometrically datable materials have yet been discovered in these areas (Keates, 2001). The specimens were initially

discovered on October 4, 1935, when W. M. F. Tweedie and G. H. R. von Koenigswald discovered Paleolithic stone tools in the arid area of the little River Baksoko, which flows towards Java's South shore (Bartsrta, 1976). In 1936 von Koeningswald's publication concerning the newly-found implements appeared in the Bulletin of the Raffles Museum. The assemblage is described by von Koeningswald under the name Patjitan culture or Patjitanian, this name being derived from a small town on the south coast of Java.

A number of artefacts collecting expeditions were undertaken by researchers in the Punung region in the post war period (e.g. see Bartstra 1976; van Heekeren 1972), and it is difficult to gain a reliable estimate of the total number of bifaces recovered (Simanjuntak 2004). However, von Koenigswald's remarks offer some insight into the sheer quantity of bifaces found in the region: 'Patjitan has in the space of a few years produced an enormous amount of material in the shape of handaxes. We ourselves had more than fifty full chests in Bandung, most of which, transported later to National Museum [Jakarta], have also unfortunately been lost. At times we found so many worked stone axes that every stone of larger proportions appeared to be an implement' (von Koenigswald 1956:122).

According to Brumm (2012), one researcher, after revisiting von Koenigswald's (1936) collection site in 1952, commented that 'the number and quality stone tools lying about in the Baksoka River surpassed my wildest imagination' (Marks, 1982:195). Few, if any, of the large bifaces from Southeast Asia have been discovered from stratigraphically secure contexts and so chronometric and absolute dates are not available (Simanjuntak 2004). The bifaces are typically ascribed in Indonesian chronological schemes to the pan-regional 'Pacitanian' industry (Jatmiko 2001; Simanjuntak 2004; Simanjuntak et al. 2010; Soejono 1961; van Heekeren 1955; von Koenigswald 1936). This industry is argued by scholars – usually those from outside the region – to be terminal Pleistocene or early Holocene in age based on Bartstra's geomorphological investigations in the Baksoka region, and thus assumed to represent a regional manifestation of the Hoabinhian (Bartstra 1984; Keates and Bartstra 2001).

Bartstra (1976, 1978, 1984) identified the remnants of a system of fluvial terraces at heights of up to 30 m above the streambed in the upper course of the Baksoka. Subsequent excavation of six of the terraces produced in situ artefacts but failed to recover fossils in the uppermost terraces or chronometrically datable materials (Bartstra

1976, 1984). Following a geomorphological analysis of the surrounding landscape, Bartstra argued that the present course of the river and its current depositional pattern are probably relatively recent phenomena, dating to no older than more or less 50 ka. Based on assumed rates of uplift and erosion he proposed that the elevated river terraces and the artefacts eroding from them are most likely terminal Pleistocene to early Holocene in age. Furthermore, following careful survey of the surrounding 300 km² region, he noted that ‘What is even more important is that so-called Palaeolithic types of artefacts occur in surface assemblages away from rivers’ (Bartstra 1982:319). In particular, the discovery of Pacitanian artefacts in association with Neolithic materials (e.g. axe/adzes, cf. Morwood et al. 2008) on surface sites underlined – in Bartstra’s estimation – the apparent young age of the tools (Simanjuntak 2004).

II.3.3 Song Terus (Cave) Site

Located near the village of Punung (Figure 9), this site was first being studied by Professor R.P. Soejono who undertook surface excavations in the Song Terus cave in the 1950s. The filling was not dated but the archaeological remains unearthed were long considered belong to Neolithic period. We also find a reference to Song Terus Cave in a book "The Stone Age of Indonesia" by van Heekeren in 1972.

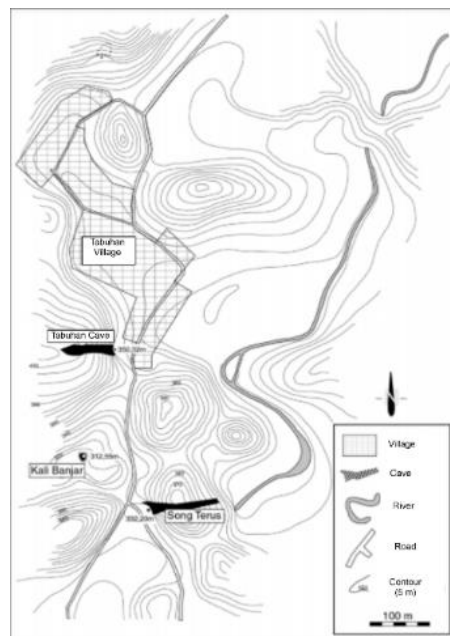


Figure 9 Topography map of the Song Terus and Tabuhan cave (Hameau, 2004)

Since 1994, the Franco-Indonesian team led by F. Sémah and H.T. Simanjuntak, has undertaken the establishment of systematic excavations of the sites of Song Terus and

Goa Tabuhan. This collaboration between the Indonesian Archaeological Research Center (*Pusat Penelitian Arkeologi Nasional*) and the Department of Prehistory of the National Museum of Natural History - Paris has enabled research into prehistoric cave sites to be developed in East Java. The excavation program developed in the Gunung Sewu region contributes to the advancement of our knowledge of Upper Pleistocene human settlements and their material cultures. Several caves or rock shelters are therefore the site of extensive excavations brought a large amount of precious data to be studied by numerous experts in each field.

The Song Terus cave was chosen for studying its sedimentary filling because of its advanced karst evolution: the main mouth of the cave is quite wide, the cavity has completely pierced the hill and thus possesses two substantial entries, the name *Terus* itself means 'continue'. Located very near Tabuhan cave (Figure 9), but at a lower altitude of 333 m above sea level, the general form of the cave is an elongated tunnel, 100 metres long and 20 metres wide (Sémah et al., 2004).

Two pits, named KI and KII (Figure 10), showed that the filling was thicker than 15 m were excavated in the inner part of the cave, to obtain an overview of the stratigraphy. The KII pit had to be stopped at c. 8 metres depth because of the thickness of encountered block fall, in the other hand, the KI pit reached more than 15 metres. The main entrance chamber of the cave has been used as a rock shelter during prehistoric times and is currently subject to extensive horizontal excavations, covering more than 45 m² (Sémah et al., 2004).

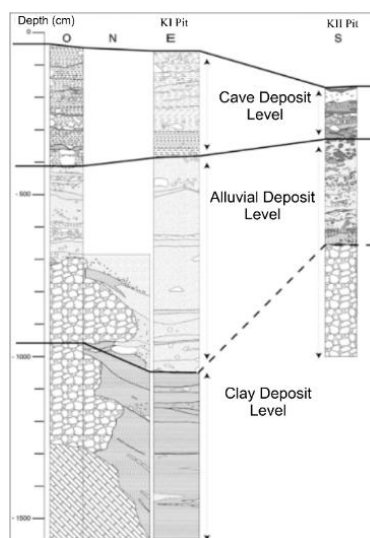


Figure 10 Stratigraphic profile of KI and KII pit (Hameau, 2004 and Sémah et al., 2004)

Based on Sémah et al., (2004), the stratigraphy of the KI pit can be roughly differentiated into two parts: a lower sequence deposited under stream influence; and an upper sequence representing a typical cave deposit (Figure 10) (Gallet, 2004, Sémah et al., 2004).

- Alluvial deposits

The base of the sequence consists of a thick, brown clayey sequence with several fluvial sand lenses and a few, thin, weathered volcanic ash layers. The deposits present a natural dip and wedging orientated from the wall to the centre of the cave, probably related to a 'sink' effect. At about 12 metres of depth, the clays give way to a coarse river deposit with interbedded reddish pebble, gravel and sandy layers, sometimes interrupted by weathered ashes. More or less rounded limestone blocks originating from the bedrock occur in places, pointing to the influence of the local environment on the sedimentation. All these fluvial layers have been subject to heavy weathering, which dissolved most of the limestone elements and formed thick ferruginous concretions. A large number of rolled and fresh artefacts occur within this unit, which continues over about 8 metres thickness. The artefacts are concentrated in certain layers, separated by sterile units. This deposit is identified as a fluvial terrace whose remnants have been trapped and preserved inside the cave.

- Cave deposits

The true cave deposits from the upper four metres of the sequence and are composed of three stages. The first stage is represented by more or less silty brown layers, with limestone blocks in places, often interrupted by fresh volcanic ashes. Some ash layers are of considerable thickness, up to 15 cm or more, and were presumably brought inside the cave by the wind. Evidence of human activity is present but was found rare in these layers. The second stage represents a strong recrudescence of karst activity, with indurated dark clayey layers alternating with white carbonate laminations or centimetric high density calcareous layers whose clayey content give a dark colour. These definitely undisturbed deposits do not contain any evidence of human presence. The upper part of the section, less than two metres thick, reflects a more active phase in the history of the cave. Several huge block falls occurred, best represented in the extensive horizontal excavation near the cave 'porch' than in the test pits. This is a normal situation, reflecting the more fragile character of the arched mouth of the cave compared to the inner vault. The block falls are separated from the underlying laminated layers, but their origin is

unlikely to be correlated with a climatic cause. More likely, they resulted from one or more severe earthquakes. The area near the entrance of the cave was most recently the focus of intensive use by prehistoric human groups. Natural and anthropic factors deposited a thick and somewhat loose sediment, part of which has been washed down into the inner part of the cave, following the overall dip of the floor. Fortunately, the many huge blocks in the cave entrance protected and retained a large part of these occupation floors.

A dating carried out on a shell taken from the top of the burial yielded an age of 9330 ± 90 BP. "Keplek" levels have been found in other sites in the region (Song Keplek, Gua Braholo) and are dated to the Holocene (Simanjuntak and Forestier, 1998; Forestier, 1998; Simanjuntak, 2002). At Song Terus, some ^{14}C datings have been carried out and give ages including Holocene period between 5770 ± 60 and 9330 ± 90 BP.

Based on a research from combined Electron Spinning Resonance (ESR) and U-series dating in the Song Terus cave by Hameau and Falguères in 2007, the study results provided us with new chronological markers which lacked in other Eastern Java sites. Coupled ESR/U-series dating provided consistent ages of 254.738 and 341.751 ka for two teeth associated with lithic artefacts. These results confirm the Middle Pleistocene age for the Terus archaeological assemblage. These ages also confirm that the caves in this area were formed at least since 300 ka and may have preserved geological, paleoclimatological, and archaeological records from the middle part of the Middle Pleistocene. Finally, the ages obtained in this study show that the Song Terus sedimentary filling cover the controversial period in Indonesia between the end of *H. erectus* and the first *H. sapiens*, and highlight the interest of the Gunung Sewu karst in South-East-Asian prehistorical research.

Table 2 U-series dating result from 2 teeth associated with lithic tools from Terus layer (Hameau et al., 2007)

	Z (cm)		^{238}U (ppm)	$^{234}\text{U}/^{238}\text{U}$	$^{230}\text{Th}/^{232}\text{Th}$	$^{230}\text{Th}/^{234}\text{U}$	U-series ages (ka)
ST3110	-448	Dentine	38.61 ± 0.89	1.10 ± 0.02	> 100	0.84 ± 0.03	$187 + 21/-18$
		Enamel	1.68 ± 0.11	1.12 ± 0.07	> 100	0.91 ± 0.06	$235 + 108/-49$
ST4698	-820	Dentine	65.58 ± 1.06	1.26 ± 0.01	> 100	0.91 ± 0.05	$215 + 41/-30$
		Enamel	4.17 ± 0.27	1.11 ± 0.07	> 100	0.99 ± 0.03	$307 + 97/-50$

II.3.4 Tabuhan Cave Site

The Gua Tabuhan site is located about a hundred meters from the Song Terus have at the exit from the village of Tabuhan. The cave is characterized by its large dimensions. The entrance to the cave is located 15 meters above that of the Song Terus cave with an altitude of 348 meters. The cave entrance is oriented towards the east and overlooks the valley where the river flows. The ceiling of the cave is remarkable for the number and size of its stalactites. The Tabuhan cave cavity opens into a hill limestone from the same Miocene coral massive as Song Terus.



Figure 11 Entrance of Tabuhan cave
(<https://pacitankab.go.id/>)

The sedimentary filling of Tabuhan cave is composed over almost its entire height thick layers of clay between which stalagmitic floors are interspersed. These floors are generally thin (a few centimetres). It is noticeable also that in this filling several episodes of collapse of the wall of the cave resulting in clusters of blocks in the stratigraphy. Furthermore, the sedimentary cave filling of Goa Tabuhan does not present sandy alluvial levels as at Song Terus, certainly because of its higher position in altitude. Finally, the last two meters of the sedimentary filling are marked by a succession of clay-silty levels of cave deposits (clays, silts) in which appear layers of very fresh volcanic ash. These layers correspond to one of the last phases of sedimentary deposition in the Tabuhan cave. The presence of stalagmitic floors corresponds to a climatic period relatively humid.

Proposed by Hameau (2004), the deepest stalagmitic floor dated at Goa Tabuhan (GT931) has an age of 326 ± 10 ka. At Song Terus, the first fillings formed of clays were deposited at least 200 ka ago. The results obtained by dating various speleothems in the two caves seem to highlight successive phases of sedimentation. The most marked is the one that would have contributed to the formation of the very numerous stalactites

covering the entrance porch at Goa Tabuhan between 40 and 55 ka. A broken and fallen stalactite in the recent levels at Song Terus also gives a result belonging to the same time interval on the ceiling of the cave, numerous stalactites could correspond to a wet episode that would be more recent than the major collapse occupying the entrance to the cave. Two ages (43.2 ± 1.5 ka and 51.8 ± 2.8 ka) were obtained on a large stalactite corresponding to this wet episode, then fallen to the ground during a more recent event (samples GT9901 & 02). The stalagmitic floor GT9904 giving an age of 53.8 ± 12 ka is also more recent than the collapse since this floor developed on a block from the ceiling. We can therefore estimate that the collapse of the entrance porch of Tabuhan Cave is older than 50 ka.

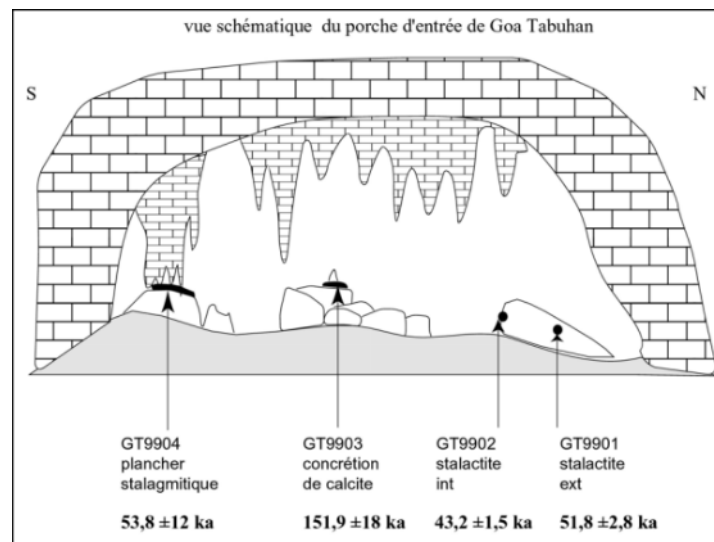


Figure 12 Age results from Gua Tabuhan (cave) entrance (Hameau, 2004)

II.3.4 Song Keplek (Cave) Site

According to the research that have been done by Noerwidi (2017), the main feature of Song Keplek Cave which still located around eastern part of Gunung Sewu (Figure 13), that had preserved one of the critical and important burials to explain modern human arrival in Island Southeast Asia is Song Keplek 5. This site located at the bottom of a hill, and it is situated at altitude of 333 meters above actual sea level. Initially it was dated back to 7020 ± 180 BP on charcoal from the grave fill, but the features of the skull pointed to a Mongoloid affinity (Déroit, 2002; Widiyanto, 2006).

In front of the cave there is a long and narrow slope flanked by two hills, which descends to the Pasang Rivers at about 200 meters on the southeast direction. Most of the back part of the cave space is filled by huge boulders of limestone, which have fallen

from the roof. In the front part with a 20 m wide is the entrance, with the main chamber is oriented northwest – southeast (Simanjuntak et al, 2002).

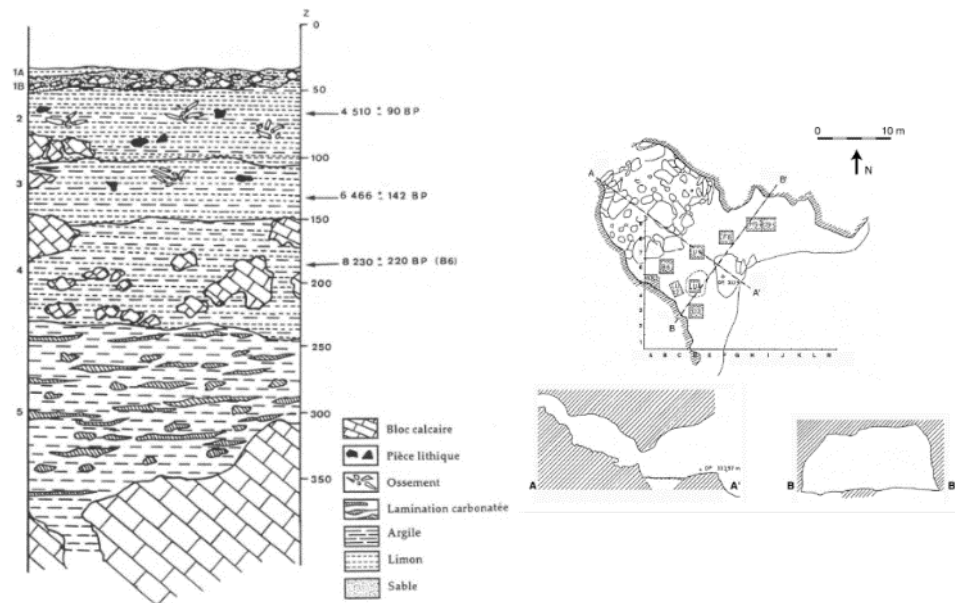


Figure 13 Stratigraphic profile section of Song Keplek cave site with ^{14}C dating results (Forestier, 1998) and Map of Song Keplek cave site (Simanjuntak et al., 2002; Detroit, 2002)

In Song Keplek cave site, totally twelve squares have been excavated; six squares are 2 x 2 meters and another six with various measurements (Figure 13). The deepest squares excavated are B6 and A5, which reached around six meters depth. Other squares were excavated only for the upper part of the sedimentary filling, because of the presence of big limestone blocks. Vertically, the cultural sequences in Song Keplek could be divided into Preneolithic (or Mesolithic, in the older terminology) in layer 4 – 2, and Neolithic in layer 1 (Figure 13; Simanjuntak et al, 2002). The upper part of archaeological layers of Song Keplek site is composed of layers 1a, 1b and 1c, which contained fragments of pottery and polished adzes, yielded an age between 700 and 3000 BP, and correspond to the Neolithic period. Archaeological layers exposed below the Neolithic phase are layers of 2, 3, and 4. They are rich in flakes and bones tools, spanning an age in between 4500 to 8000 BP, and they are locally quoted as corresponding to the “Keplek level”. Layer 5 is the deepest human occupation layer. It yielded flakes and faunal remains which suggest a correspondence with the so called “Tabuhan level” (locally known from Tabuhan and Song Terus cave sites). By applying ^{14}C dating method, it has yielded age results which can be seen completely in Table 3. The dates for the Tabuhan

period, which the oldest known period, yielded an extend age between 15.880 to 24.420 BP (Simanjuntak et al, 2002).

Table 3 ¹⁴C dating results from Song Keplek burial site (Simanjuntak, 2002)

Square	Depth (cm)	Date	Laboratory	Sample	Context
B5	3 – 7	790 ± 100	P3G 1998	Charcoal	Pottery, Adzes & Flakes
B5	5 – 16	1940 ± 120	P3G 1998	Charcoal	Pottery, Adzes & Flakes
F8	10 – 18	4510 ± 90	Beta 69689	Charcoal	Flakes & Bones Tools
B5	18 – 30	3260 ± 110	P3G 1998	Charcoal	Pottery, Adzes & Flakes
LU2	80 – 92	5900 ± 180	P3G 1996	Charcoal	Human Burial (SK4)
F8	85	6466 ± 142	Batan 1996	Charcoal	Flakes & Faunal Remains
I9	105 – 120	3053 ± 65	AA96775	Human Bones	Human Burial (SK5)
H9	106 – 115	7020 ± 180	P3G 1999	Charcoal	Human Burial (SK5)
B6	113 – 114	7580 ± 210	P3G 1996	Charcoal	Flakes & Faunal Remains
B6	160 – 164	8230 ± 220	P3G 1996	Charcoal	Flakes & Faunal Remains
B6	188	8870 ± 210	P3G 1998	Charcoal	Pebbles Accumulation
B6	260 – 270	15880 ± 540	P3G 1998	Bone	Flakes & Faunal Remains
B6	489	21380 ± 360	P3G 1999	Charcoal	Concentration of Bones
B6	590 – 600	24420 ± 1000	P2G 2000	Bone	Flakes & Faunal Remains

II.3.5 Braholo Cave Site

Braholo and Song Terus cave are located approximately 40 km apart from each other and still in Gunung Sewu region (Amano, 2022). Braholo Cave is located on the edge of Central Java’s Wonosari plateau, around 13 km away from the present-day southern Javanese coast, close to the village of Semugih. It is on the slope of ± 45 m high limestone hill and has 15 m high northwest entrance, a domed ceiling reaching c. 12 m and a floor area of ± 600 m². Mentioned by Amano et al., (2022), the cave is orientated along a northeast–southwest axis and the eastern and the southern areas of the cave floor are covered with huge boulders and debris from roof falls as well as some stalagmites. Braholo Cave was excavated between 1997 and 2001 by the Indonesian Center for Archaeological Research. A total of 16 excavation squares of 2-2 m were excavated, with the deepest squares reaching a maximum depth of 7.3 m. The basal occupation layers were presumed to have not been reached since excavations in most squares were halted due to the presence of huge limestone boulders. A stalagmitic floor located in the mouth of the cave was sampled for U/Th dating and produced an age of 245 ± 69/-40 ka BP (Sémah et al., 2004). The cave has well stratified archaeological deposits dated between 33,100 ± 1,260 and 3,050 ± 100 BP (Figure 14; personal photograph, 2024). Excavations yielded numerous archaeological materials including those usually associated with the Neolithic of Southeast Asia such as pottery, shell ornaments, and polished stone adzes (Bellwood, 1997; 2013), as well as numerous artifacts typical of the pre-Neolithic of Java.

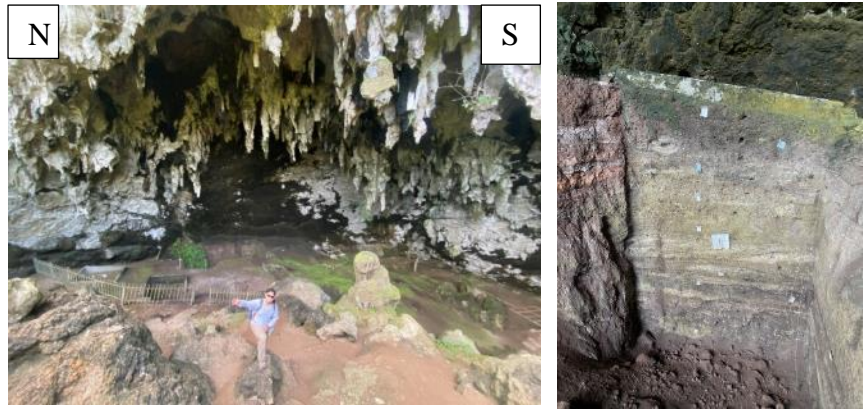


Figure 14 Gua Braholo (cave) entrance (left), stratigraphic profile ± 2.75 m (right), personal photography (2024)

Excavations in Braholo cave site revealed evidence for human occupation from $25,798 \pm 536$ to 3050 ± 100 cal BP (Simanjuntak, 2002). Braholo Cave yielded numerous archaeological materials, including those usually associated with the Neolithic of Southeast Asia, such as pottery, shell ornaments, and polished stone adzes (e.g., Bellwood 1997, 2013), as well as numerous artifacts typical of the pre-Neolithic of Java, including stone and bone implements and other modified animal bones and teeth. The early Holocene stone tool assemblage included mortars, anvils, pestles, and grinding stones. Remains of red hematite were found in several mortars and pestles, suggesting that they were used to process hematite powder. The cave's Holocene layers, dated between 8500 ± 230 and 3050 ± 100 cal BP, are characterized by concentrations of burnt animal bone fragments and hearths (after Simanjuntak, 2002 in Amano et al., 2015).

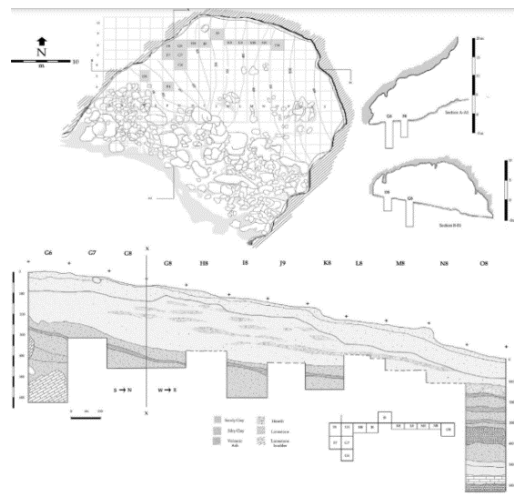


Figure 15 Map and Stratigraphic profile section of Braholo cave site (Simanjuntak, 2002 in Amano et al., 2015)

II.3.6 Song Gupuh (Cave) Site

According to studies conducted by Morwood et al. (2007), Song Gupuh is a partially collapsed cave located in the Gunung Sewu of East Java, Indonesia. It has deposits spanning over 16 m and a faunal sequence that dates back approximately 70 ka. Significant shifts in the animal ranges depicted highlight the effects of both human activity and climate change. Maximum biodiversity occurred during the Terminal Pleistocene and Early Holocene. With the first indications of resource importation from the coast, a renewed emphasis on the exploitation of small-bodied species (macaque monkeys and molluscs), and the use of bone and shell tools, human occupation of Song Gupuh and other cave sites in the area increased dramatically starting around 12 ka. Human activity, especially after the onset of the Neolithic around 2.6 ka, subsequently contributed to a progressive loss of many species from the area, including tapir, elephant, Malayan bear, rhino and tiger, and this extinction process is continuing.

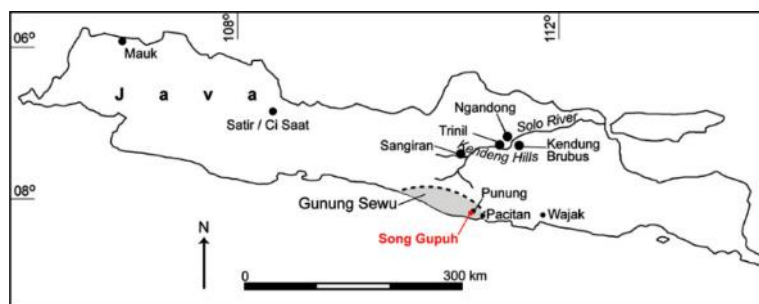


Figure 16 Location map of Java Island, Gunung Sewu region, and Song Gupuh Cave Site (Morwood et al., 2007)

The 70-ka void between the end of the last glacial period and the present is filled in part by the faunal sequence at Song Gupuh in East Java. Song Gupuh, which is locally spoken Javanese for "Flee Cave". At an elevation of 339 meters above sea level, it is situated at the foot of a limestone hill 2 km north of the Baksoko/Kladen River and 10 km from the south coast (Figure 16; Morwood et al., 2007). This karst region's limestones seem to weather rather quickly, creating a landscape that is full of rounded hills that are covered in dolines, sinkholes, and caverns.

Song Gupuh faces north and is located on the south side of a karst cone. Its dimensions at the entrance are 50 m by 13 m by 13 m and 13 m high. It began as a dissolution-formed underground cavern that was eventually made visible by collapse processes along a central east-west axis. The modern shelters at the foot of the scarps that flank two sizable cone-shaped karst features on either side of the Punung road indicate

the boundaries of the original cave. Song Gupuh would have made up the former cave's southern boundary. At a later stage of the cave's evolution, Song Gupuh Kidul, Song Gunung, and Song Citril, three nearby interconnected source caves, would have acted as a sink, receiving sediment-rich slopewash. On the other hand, there has been recent disturbance at the location. The deposits at the east end were at least 60 centimeters higher before the above hill slope was cleared for cultivation. Thereafter, the deposits at the top started to erode. Professor R.P. Soejono (Indonesian Centre of Archaeology) and Associate Professor Harry Allen (University of Auckland) excavated five 2 -2 m sectors (I2, K3, K5, N4, P6) at Song Gupuh in 1995, 1997, 1999 and 2000 (Sutikna, 2001). They reached a maximum depth of 3.7 m and obtained an associated radiocarbon date of 7570 ± 170 BP. The excavations yielded artefacts of stone, bone, teeth, wood, shell and a single item of metal (a gold ring); pottery (fragments and completed pots); burials containing grave goods, such as pots, beads and stone adzes; hearths; faunal remains; and plant remains, including charcoal and seeds. The morphology of the shelter and its surrounds, however, indicated that the deposits were likely to be much deeper, with older occupation levels, artefacts and faunal evidence.

Thermoluminescence (TL), optically stimulated luminescence (OSL), thermal ionization mass spectrometry (TIMS), uranium series, and radiocarbon dating techniques were used to determine the ages of the Song Gupuh deposits. In situ flowstone deposits that formed on collapse material on the cave floor were dated using the U-series method. Using analytical techniques previously mentioned, the results of these samples will yield maximum and minimum age constraints for the timing of sediment deposition above and below the collapse material (Zhao et al., 2001). To determine the amount of time that had passed since the sand-sized quartz grains in the sediments were last exposed to sunlight, we employed the same dual aliquot (DAP) red TL dating technique that was thoroughly explained in Westaway and Roberts (2006). The red TL result should be conservatively viewed as a maximum age, to allow for the possibility that not all of the grains had been sufficiently bleached at deposition (Figure 17; Morwood et al., 2007).

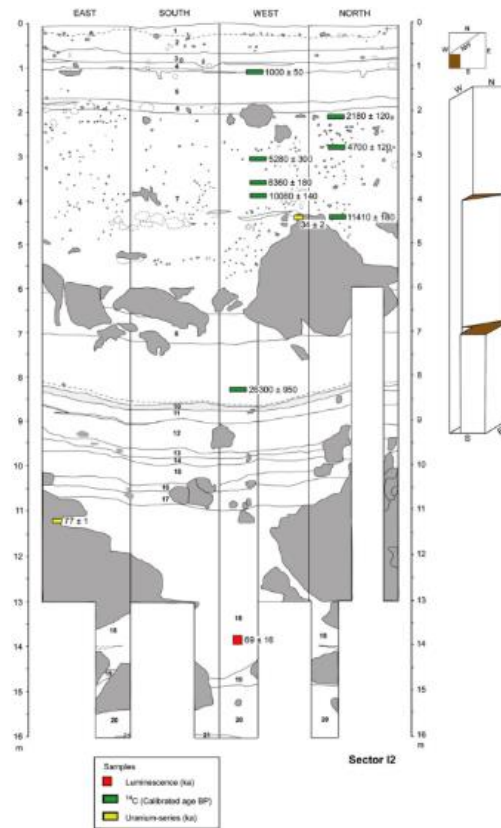


Figure 17 Absolute Dating Results within the stratigraphic profile of the site (Morwood et al., 2007)

Morwood et al., (2007) excavated 7284 stone artefacts from Sector I2, the oldest were discovered 12.5 m below the current shelter floor, and their age was estimated to be 50,000 BP based on available luminescence and radiocarbon data. The pre-Neolithic deposits at the site exhibit a single technological tradition, despite variations in artefact densities. This tradition is marked by a focus on the utilization of chert, silcrete, and other siliceous materials with varying quality and colour to create flakes with different dimensions and thickness, typically derived from multiplatform cores. The majority of stone tools were quickly made on flakes, as evidenced by use wear and retouch, and their corresponding cores were typically big and not greatly reduced.

II.3.7 Gua Mandung (Cave) Site

According to a research conducted by Kaharudin (2023), Gua Mandung (cave) is an inland prehistoric site in Gunung Sewu karst area of central Java, Indonesia, this area is rich in valleys and corridors which make up Gunung Sewu's distinct labyrinth-like landscape. He reported evidence of occupation at the site of Gua Mandung since at least 11,073 cal BP. Numerous bone tools with varying functions and an abundance of terrestrial fauna indicate that these early cave dwellers used sophisticated subsistence

techniques to make the most of the resources available. The ongoing exploitation of small to large terrestrial fauna, such as monkeys, porcupines, deer, pigs, cattle, rats, snakes, and monitor lizards, is documented in Gua Mandung. In addition to primary aquatic resources like fish, freshwater and marine shells, barnacles, crab, and sea urchins, Gua Mandung's early occupants benefited from the site's proximity to neighboring lakes and its approximately 5-kilometer walk to the coast. The research from the Gua Mandung excavation (Kaharudin, 2023) suggests that, although it was a smaller subsistence strategy, the exploitation of coastal resources appears to have been widespread when compared to other archaeological sites in the area by the early inland human population of the Gunung Sewu karst area.



Figure 18 Left: Gua Mandung has a chamber on the west (right) and a rockshelter that extends eastward (left). Right: 1 × 1 m test pit on the rockshelter of Gua Mandung. Figure by Prasetya in Kaharudin (2023)

Gua Mandung is a limestone cave located in Tanjungsari village, Gunungkidul, Daerah Istimewa Yogyakarta, Java. On Java's south coast, Gua Mandung is situated roughly 4.5 km north of Baron Beach and 175 meters above sea level. Situated on the upper, north-facing slope of the hill, the cave is part of Gunung Sewu Karst's labyrinthine cone landscape (Figure 41). Archaeological research at Gua Mandung has the potential to greatly advance our knowledge of prehistoric communities in the Gunung Sewu karst region, to ascertain the archaeological potential of Gua Mandung, a team from the Research Institute of Jogjakarta for Archaeology, Anthropology, and Geology (RIJANG) conducted a preliminary test excavation there in 2020. According to the results of our initial research, humans have been occupying Gua Mandung since the early Holocene and most likely into the Terminal Pleistocene. Gua Mandung can be classified as an inland site based on the archaeological materials found during the excavation, which included a range of tools and faunal remains that showed the site was primarily used for

terrestrial resources. However, a sizable amount of coastal and freshwater resources found at Gua Mandung suggest that marine resources might have also been important to the early occupants of the site's subsistence economies. Among the many locations in the Gunung Sewu region with potential for archaeology is Gua Mandung.

Three charcoal samples from spits 6, 26, and 40 were sent to the Australian National University Radiocarbon Laboratory for dating. In order to reconstruct the period of occupation recovered by our Gua Mandung assemblage, the three radiocarbon dates were placed within a depositional model in OxCal v4.4 (Bronk Ramsey, 2009a), to interpolate age-depth associations across our stratigraphic record. This depositional model assumes a Poisson (or random) accumulation of sediment (Bronk Ramsey, 2008), calculated from the available age data by averaging the model over many values of k (Bronk Ramsey and Lee, 2013).

Table 4 Radiocarbon samples obtained from Gua Mandung (Kaharudin, 2023)

ID	Spit	Layer	Sample type	14C Date \pm error	Calibrated date BP (cal BP)	Modelled date BP (mod BP)
S-ANU-69033	6	2	Charcoal	212 \pm 23	300-0	317-1
S-ANU-68125	26	4	Charcoal	8364 \pm 36	9471-9285	9484-9147
S-ANU-69035	40	5	Charcoal	9526 \pm 34	11,073-10,681	11,075-10,662

II.3.8 Lake Guyang Warak – Paleoenvironment Reconstruction

According to a research conducted by Purnomo (2008), this lake is situated on a karst area in the Gunung Sewu region, which is a region consist of numerous Paleolithic and Iron Age prehistoric sites (Heekeren 1955, Heekeren 1972, Sémah 2002, Simanjuntak 2004). This lake is located roughly two kilometers from Song Terus, a prehistoric cave that has been dated between 300 and 5 ka (Hameau, 2005). A sedimentological study conducted on a series of sediments from Song Terus Cave (Gallet, 2004) demonstrated that the cave's sedimentation environment varied from Pleistocene times until 5000 years ago, depending on factors such as volcanic activity, fluvial activity, and human activity. It has been fascinating to examine earlier research on the sedimentation of Song Terus Cave, which is near Lake Guyang Warak. There is still a dearth of knowledge regarding the environment during the upper Holocene period, which is younger than 5000 BP, when this lake sediment was formed. The third step involves identifying the environment background reflected in the sediment's deposit based on its characteristics and searching for potential correlations and continuity with the sedimentation found on Song Terus Cave's uppermost layer, known as the "Keplek Layer," which is dated back to 5000 BP (Hameau, 2005).

In reference to Purnomo (2008), he suggested that the sediments that were deposited in this lake allow us to know that Guyang Warak lake is more characterized by a mix clay of smectite and kaolinite based on infrared spectroscopy analyses. The middle section, where the lamination occurred more frequently, varies according to the quantification result of their proportion. Since there are variations in the number of frequencies along the core, counting the laminations has enabled us to determine the various variations in the environment. The sedimentation of Lake Guyang Warak was impacted by the volcanic activity, especially in the lower regions.

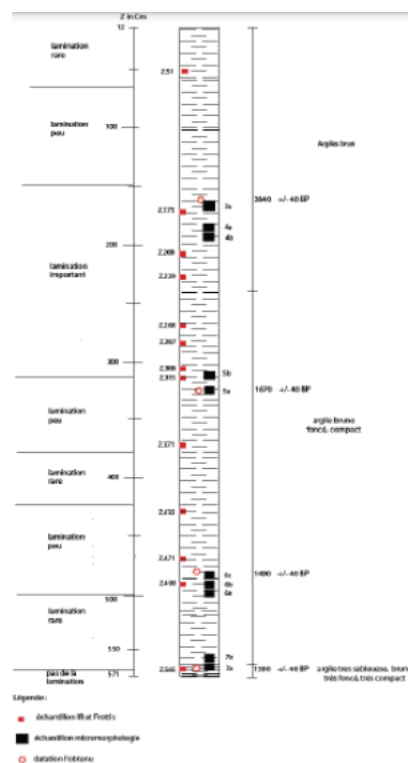


Figure 19 Stratigraphic log from GW/05 core (Purnomo, 2008)

From an archaeological perspective, the dating result only permits a correlation with the recent 1500 years of human occupation in the area, not with older Holocene prehistoric sites close to the lake. The result's interpretation is generally quite complicated. The inversion of the ^{14}C dating result indicates that the influence of human activity appears to have begun around 1200 BP, as evidenced by the different sedimentation rhythm, variations in clay mineral content, and the presence of older organic materials in the sediment. He (Purnomo, 2008) tried to make a hypothesis that these evidences he had could be connected to an anthropization activity near the environment of the lake, which allowed the erosion of older organic soil probably during in humid period.

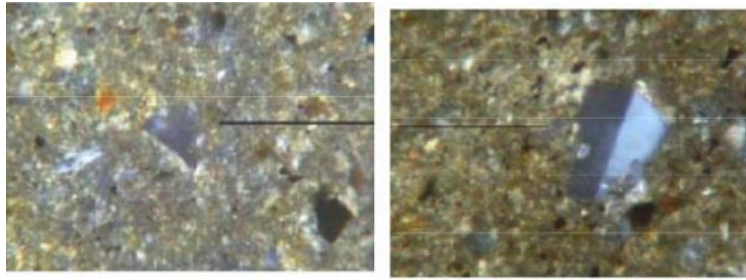


Figure 20 Petrographic thin section of Volcanic minerals from Lake Guyang Warak Sediments (Purnomo, 2008)

II.3.9 Gua Wuru (Cave) Site, West Gunung Sewu UGGp

Wuru cave is located in Jetis, Saptosari Gunung Kidul, is one of the horizontal caves that contain archaeological data (Alifah, 2015). This cave has a relatively small room, elongated and curved (Figure 21), but in this cave has many ecofacts, some of which indicate the presence of human treatments (burned and trimmed). Most of the bone specimens have begun to experience the process of fossilization. To add more, there is also found shells, pottery, hazelnut and coal. Several archaeological studies that have been carried out show significant data on cave dwelling sites in this area. Cave sites have distinctive forms of land use and types of artefacts and ecofacts. Apart from being used as a residence, the cave was also used as a work space (making equipment such as stone tools and bone tools), and also functioned as a grave (Nurani, 2006). Research conducted by the Yogyakarta Archaeological Agency in 2013, in Saptosari District, Gunung Kidul, found a cave that had ecofacts and artefacts in fragmentary condition, namely Wuru Cave. Morphologically, Wuru Cave has narrow, long and winding room conditions (3m wide, 15 meters long and 7 meters height) and natural lighting conditions that are not very good. Several samples of findings brought show that there are different types of ecofacts and some of them show indications of pruning of the bone.



Figure 21 Cave entrance (Yogyakarta Archaeological Agency, 2013)

This cave is located on the middle slope of a hill with a moderate slope. In front of Wuru Cave stretches a fairly wide valley stretching in an east-west direction. Currently around Wuru Cave is teak forest land and the valley in front of Wuru Cave is a field planted with cassava. The current condition of the cave is that it is an abandoned land mining location for fertilizer materials because it was abandoned by the miners. The excavated soil layer is approximately 2 meters thick from the original ground surface (measured from the soil on the cave walls). This condition resulted in the disclosure of archaeological findings in the form of ecofacts and artifacts scattered in piles of excavated excavations and some of them were on the floor of the cave chamber.

Geologically, Wuru Cave is composed of a type of karst coral reef which has high porosity because it has many holes in the cave walls. This condition makes the layers of the cave walls easily weathered which are then deposited downwards to form the layers of the cave floor. Geomorphologically, Wuru Cave is located in a karst area with a labyrinth type. The labyrinth karst type is a type of karst that is characterized by valley corridors that are controlled by the presence of faults or joints. Karst morphology is composed of limestone blocks separated by valleys or canyons that extend as a result the process is formed by an intensive dissolution process in fault lines or joints (Haryono, 2001). The environment around Wuru Cave provides many water sources including Tlogo Ndongong, Tlogo Tritis, Tlogo Sumber, Tlogo Mandung and periodic river flows around a radius of 5 km.

II.3.10 Kali Oyo Open-air Site

Based on research that was conducted by Nurani et al., entitled “*Pola keruangan okupasi manusia pada kala Pleistosen hingga awal Holosen di DAS Kali Oyo Gunungkidul dan DAS Kali Baksoko Pacitan*” in 2020 was carried out in two stages. The first stage is carried out in in 2016 in Gunungkidul Regency and the second stage was carried out in the Pacitan Regency in 2019. The first stage of research included a survey on 7 (seven) the main sub-districts are in the Oyo River watershed area and occupied caves are in Gunungkidul Regency. The seven districts are: Playen, Wonosari, Karangmojo, Nglipar, Ngawen, Semin, and Ponjong. The survey succeeded in reaching 24 observation points of the Oyo River meanders and 3 points were hills and caves. Based on searches, especially at meander rivers, it is known that not all of them contains lithic cultural remains. Several locations have been identified and divided into three types, namely location points with the potential for lithic artefacts, especially technological ones

belonged to Paleolithic, location point with many finds of lithic artifacts with raw materials, and location point which is the location of the main source of rock raw materials for making lithic tools (Nurani, 2017; Nurani & Hascaryo, 2016). The hypothesis that will be tested is if there is a pattern of relationship between the form of activity and the form of the physical environment in the Gunung Sewu area, then cultural remains (the results of human activity) will reflect certain spatial patterns in the dimensions of space (horizontal) and time (vertical).”

The results of the research carried out showed that the lithic findings were made being the most dominant. Two types of analysis of lithic finds were carried out during the research, namely macroscopic and microscopic analysis. Macroscopic analysis is carried out for determining the rock materials in plain view as well as the technological aspects applied to stone artefacts. The microscopic analysis was carried out at the laboratory includes petrographic analysis of lithic remain findings to determine the materials more detail, and to also possibly know the sources of origin of lithic raw materials. Most of the lithic tools that were found during the field research were made out of chert material.



Figure 22 Flakes from Kali Oyo, GNK 11 Karangmojo (left) dan GNK 13 Nglipar (right) (Nurani et al., 2020)

II.4 Uranium Series Dating Method

According to Ivanovich (1982), uranium-series dating is a radiometric dating method used to determine the age of materials, primarily geological samples such as rocks, minerals, and fossils. The principal aim of geochronology is to classify the earth's history in terms of a sequence of events of known duration (for an excellent review see Fitch et al. 1974). The main available matrix of evidence is contained within the

terrestrial rocks. Precise physical measurements, however, capable of providing an estimate of the absolute age of specific rocks and minerals became possible only with the discovery of radioactive decay. Virtually all quantitative determinations of geological age are based on the phenomenon of radioactivity. Thus, determination of absolute age is based on the fact that a given radionuclide decays at a known rate, and forms a geological clock. In principle, any radionuclide can be used as a radioactive clock provided its half-life, which determines its decay rate, is of chronologically useful duration (see Holmes and Holmes 1978). The methods listed may be subdivided into three basic groups. The first group involves decrease in concentration of a radionuclide from an initial level, or a build-up of a stable daughter product (U/Pb, Th/Pb, K/Ar, Rb/Sr, I/Xe, Re/Os, $^4\text{He}/\text{U}$, ^{14}C , ^{10}Be , ^{26}Al , ^{32}Si , ^{36}Cl , and ^{41}Ca dating methods). The second group is based on the measurement of the degree of restoration of radioactive equilibrium in a radioactive decay series following an initial external perturbation (uranium-series disequilibrium dating methods). The third group involves the integration of a local radioactive process in a sample due to the presence of ambient radioactivities which remain approximately constant with time (thermo-luminescence, for example). Clearly, age determination made using methods of the first and second groups depends on accurate measurements of concentration of parent nuclides and their daughter products, while those based upon the third category depend on exploitation of a reliable integrating process. In all cases, certain assumptions must be made about initial conditions, whether the system remains closed, and some other aspects of the subsequent geological history.

II.4.1 Uranium Series Dating Method Principles

The U-Th dating method was first applied to corals by Potratz et al. (1955) and Barnes et al. (1956). This work has highlighted the connection that exists between the $^{230}\text{Th}/^{234}\text{U}$ activity ratio and the age of the corals. Uranium series dating method relies on the radioactive decay of isotopes of uranium present in the sample. A radioactive nucleus is one which at any instant may change spontaneously into a different nuclear type. This process, called radioactive decay, is a statistical process in which the decay rate is proportional to the number of radioactive nuclei of a particular type present at any time t . The constant of proportionality, λ , termed the decay constant, is the probability of decay per unit time interval. It is related to the half-life, $t^{1/2}$, of a radionuclide (radioactive

nuclide) by $A - 0.693/t^{1/2}$. The half-life of a radionuclide is the time required for the decay of exactly one-half of the original number of its nuclei.

Radioactive decay is affected by two alternative types of particle emission: either the moderately heavy alpha particle or the light beta particle. The particles are released with great energy and are often accompanied by gamma rays, penetrating electromagnetic radiation similar in nature to X-rays. Alpha particles, nuclei of helium atoms, are tightly bound assemblies of two protons and two neutrons, have a positive charge of 2 units, and a mass of 4 units. By emitting an alpha particle, a nucleus of atomic number Z loses two protons and is thus transmuted into an element of atomic number $Z - 2$; for example, $^{238}\text{U}_{92}$, decays by alpha-particle emission to become $^{234}\text{Th}_{90}$. Beta particles are electrons, having negligible mass in comparison with a nucleon, and a negative charge of 1 unit. Therefore, a nucleus of atomic number Z which emits a beta particle loses a unit of negative charge. This is equivalent to gaining one positive charge with no change in mass, and so becoming another element of atomic number $Z + 1$ see (Table 5; Ivanovich, 1982) with each radioelement's half-life.

The most common uranium-series dating method is based on the decay series of uranium (^{238}U), which ultimately decays into stable lead (^{206}Pb) through a series of intermediate isotopes. The decay of uranium occurs through a sequence of alpha and beta decays, with each decay step having a specific half-life. By measuring the ratios of parent isotopes (e.g., ^{238}U) to their daughter isotopes (e.g., ^{206}Pb) in a sample, we can determine the amount of time that has elapsed since the material was last heated or exposed to the environment.

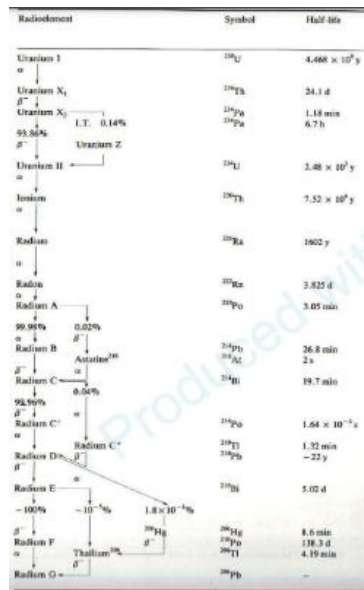
Uranium-series dating has been extensively used in fields such as geology, archaeology, and paleoanthropology to establish chronological sequences, estimate ages of rock formations, and determine the timing of various events in Earth's history. For dating carbonates, the principle lies on the solubility difference between uranium and thorium. Uranium is soluble and present when the CaCO_3 precipitates while thorium is absent because it's not soluble. This method is particularly useful for dating materials that range between 10,000 and 500,000 years (Ivanovich and Harmond, 1992).

Uranium series dating method could be applied to samples from different nature that we can find in earth and useful for applying to prehistoric studies, allowing in particular to date the continental sedimentary fillings:

- Bones (Cherdyntsev, 1956; Rae and Ivanovich, 1986)

- Calcite (Rosholt and Antal, 1962; Schwarcz, 1981; Shen, 1985; Falguères et al., 1992)
- Teeth (Mc Kinney, 1977; Bahain et al., 1992; Michel, 1995)

Table 5 The Uranium ($4n + 2$) decay series (Ivanovich 1982)



II.4.2 Radioactive Disequilibrium in Uranium and Thorium Family

The Uranium-Thorium (U-Th) dating method is based on the fractionation between different radioelements within a decay chain. There are three natural radioactive chains. Each of them begins with an actinide (^{238}U , ^{235}U and ^{232}Th) having a long half-life ($T_{1/2} > 0.7 \text{ Ga}$) and ends with a stable isotope of lead. During their decay, isotopes emit alpha, beta particles and gamma radiation. See (Figure 23; Ivanovich and Harmond, 1992 in Hameau, 2004) to understand decay chain in the Uranium and Thorium families.

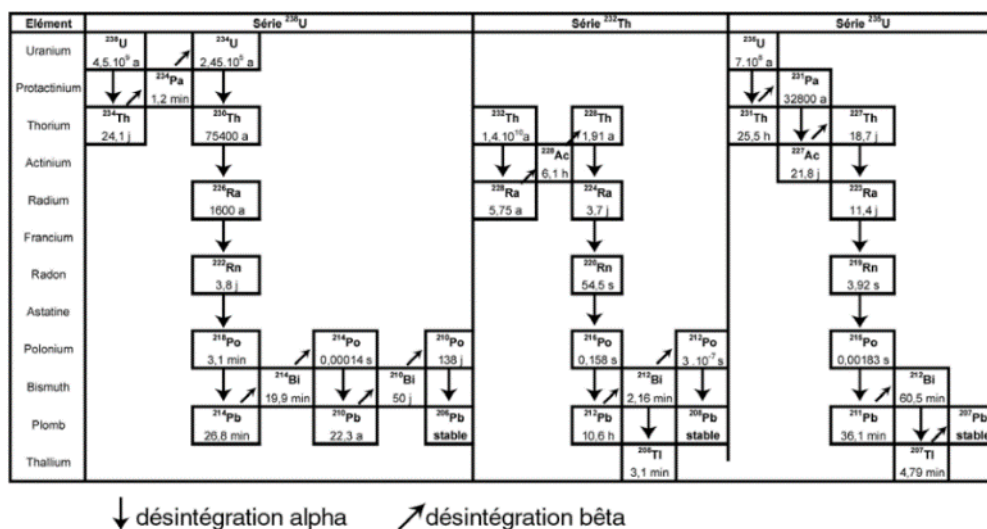


Figure 23 Decay chain in the Uranium and Thorium families (Ivanovich and Harmond, 1992 in Hameau, 2004)

In a closed system, all radioactive decay chains tend towards a state of equilibrium secular. A geochemical disturbance creates imbalance in the radioactive chain. So intense and in a high amount, that the system has not returned to secular equilibrium, it is possible to calculate the age of the disturbance by measuring isotopic ratios. In the case of the U-Th method, the disturbance is a chemical fractionation between uranium and thorium. In the natural environment, U and Th have geochemical different behaviour. Thorium is always in the Th^{4+} form, while uranium is either in the U^{4+} form, or in the U^{6+} form, depending on the oxidoreductive conditions. In the middle reducing agent, U and Th have the same behaviour, on the other hand, in an oxidizing environment, uranium can form compounds such as uranyl ions UO^{2+} which are very soluble in an aqueous medium. According to Langmuir (1978), the distribution of these uranyl complexes varies with pH.

The uranium in solution in the seepage water is integrated directly into the speleothems at the time of their formation. In the teeth and bones during the fossilization, organic matter, by decomposing, creates a reducing environment which causes the fixation of uranium in tissues. It is therefore often considered that all the uranium contained in the sample entered at the time landfill and therefore all the ^{230}Th present today comes only from the disintegration of this uranium over time. Taking into account this model early incorporation of uranium, measuring the $^{230}\text{Th}/^{234}\text{U}$ isotopic ratio makes it possible to calculate the age of the sample.

II.4.3 Age Equations in Uranium Series Dating

Based on Hameau (2004), the growth of the $^{230}\text{Th}/^{234}\text{U}$ ratio is exponential (Figure 23), the age is then calculated from an equation (1) of type:

$$\frac{^{230}\text{Th}}{^{234}\text{U}} = 1 - e^{-\lambda \cdot 230t} \quad (1)$$

t = time

$^{230}\text{Th} / ^{234}\text{U}$ = activity report

$\lambda \cdot 230$ = disintegration constanta of ^{230}Th ($9,22 \cdot 10^{-6} \text{ ans}^{-1}$)

It should be noted that beyond 350,000 years, the $^{230}\text{Th}/^{234}\text{U}$ ratio tends towards 1 and the age can no longer be determined precisely by alpha spectrometry. An excess of

^{234}U is generally observed in groundwater and seawater compared to ^{238}U , due to a greater geochemical mobility of ^{234}U .

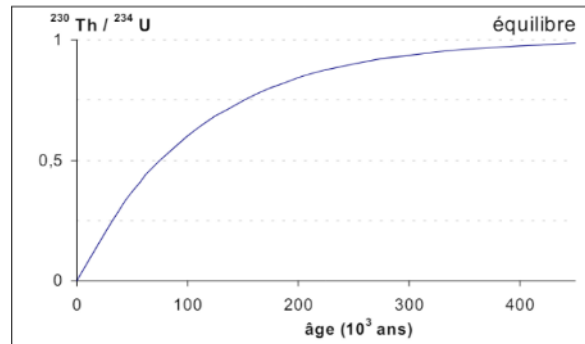


Figure 24 $^{230}\text{Th}/^{234}\text{U}$ graphic activity ratio over time.

The centuries-old balance between ^{238}U and ^{234}U do not exist. To take this imbalance into account; we then use the following equation (2) (Ivanovich and Harmon, 1992):

t = time

$^{234}\text{U}/^{238}\text{U}$ and $^{230}\text{Th}/^{234}\text{U}$ measured activity reports

λ_{230} = disintegration constanta of ^{230}Th

λ_{234} = disintegration constanta of ^{234}U ($2,80 \cdot 10^{-6}$ ans $^{-1}$)

$$\frac{^{230}\text{Th}}{^{234}\text{U}} = \frac{^{238}\text{U}}{^{234}\text{U}} (1 - e^{-\lambda_{230}t}) + (1 - \frac{^{238}\text{U}}{^{234}\text{U}}) \left(\frac{\lambda_{230}}{\lambda_{230} - \lambda_{234}} \right) (1 - e^{-(\lambda_{230} - \lambda_{234})t}) \quad (2)$$

A simple solution to the age equation can also be done graphically (Figure 25; Schwarcz, 1979).

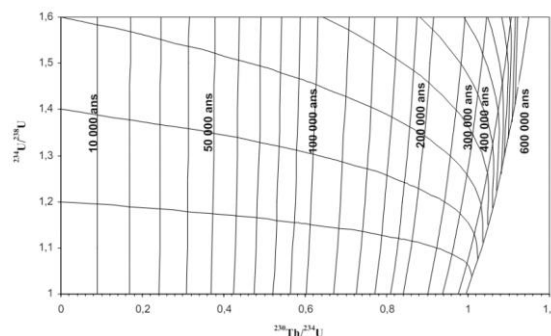


Figure 25 Variations of $^{230}\text{Th}/^{234}\text{U}$ and $^{234}\text{U}/^{238}\text{U}$ activity ratios over time (Schwarcz, 1979 in Hameau, 2004).

III. MATERIALS AND METHODOLOGY

III.1 Materials

Primary Data Materials

- Location or coordinate database of landforms in West Gunung Sewu UGGp: karstic caves, sinkholes (dolines), lakes, underground rivers, and alluvial lowlands which are considered potential to be new potential prehistoric sites, that were discovered while exploring the region.
- Carbonate rock samples, mostly broken speleothems that were collected from fieldwork in exploring potential prehistoric caves. Intended for applying U-series dating method.

Secondary Data Materials

- Regional physiography map of Gunung Sewu UGGp.
- Geological map of Gunung Sewu UGGp (Bemmelen, 1970; Surono et al., 1992; and Rahardjo et al., 1995 in Haryono, 2010).
- Geomorphological map of Gunung Sewu UGGp (Brahmantyo, 2006 in Hartawan, 2020).
- Coordinate locations of previously researched prehistoric sites in West Gunung Sewu UGGp from Alifah (2015, and in press).
- Literature review and reference studies of prehistory of Gunung Sewu UGGp from previous researchers.

III.2 Methodology

III.2.1 Data Collection Fieldwork and Laboratory Methodology

- a) Literature study of the geological and geomorphological condition of Gunung Sewu UNESCO Global Geopark (UGGp), also about the values that it has, starting from the history, geoheritage, bioheritage, and cultural heritage sites.
- b) Literature study and review of prehistoric sites in Gunung Sewu UGGp that have been studied and established before.
- c) Fieldwork of exploration in finding potential new prehistoric sites in Gunung Sewu UGGp, from creating a database of karst features or landforms in Gunung Sewu UGGp: karstic caves, sinkholes, lakes, underground rivers, and alluvial lowlands are some landforms in a typical karstic landscape, that could be potential for prehistoric settlement and occupation sites. In which the realization in field were only by

exploring caves, sinkholes, and alluvial lowlands landform, resulted by limited time available for having more intense fieldwork.

- Karstic caves, based on recent database, the total karst cave in Gunung Sewu UGGp is no less than 119 caves (Haryono, 2010), by this amount, it has a high potential of prehistoric human settlement between these caves. Caves served as valuable shelters and provided protection for ancient humans in a variety of ways (Clottes, 2003), such as: natural protection, climate control, shelter from the elements, protection from wildlife, storage, defensible positions, cultural and spiritual significance, and community living. After each cave prospection, furthermore, selecting which carbonate samples are the best that can represent the site's age well enough, and to determine the start and the end period of human occupation in the area, which could propose a new age than previous researchers. For instance, a long sequence of quaternary cave sediments that can be correlated with speleothems (stalactite, stalagmite, and flowstone) that are associated with it, by speleothems that are covering the sediments means the minimum age and or if the speleothems were broken and deposited in the quaternary sediment layer, it could be horizontally correlated, showing the exact age of when did that exact layer was formed or deposited.
- Sinkhole and karstic lakes, are type of landform that has a great potential to be a suitable settlement and occupation location for ancient humans. There are a lot of benefits of having a settlement near a lake, namely, access to water (source of life), food resources, protection from predators, tool and material resources, cultural and social factors. Also, lake deposits are often excellent for preserving pollen data, which could be very useful for archaeobotanist, geologists, and prehistoric researchers, in order to reconstruct paleoenvironment and paleoclimate of the area
- Underground rivers, the concept of prehistoric settlements situated near underground rivers is quite rare. Although, there is evidence of ancient human utilizing cave systems, which may include underground river passages, as part of their settlement areas. These cave systems provided

shelter, access to water, and protection from the elements and predators. One example of a prehistoric settlement that may have been closely associated with an underground river system is the Caves of the Aggtelek and Slovak Karst, which is a UNESCO World Heritage site (<https://whc.unesco.org/en/list/725/>) located on the border of Hungary and Slovakia. The extensive cave systems in this region, such as the Baradla-Domica cave system, include underground rivers and have evidence of ancient human habitation, as well as numerous archaeological finds associated and dated back to Upper Paleolithic (Wei Chu, 2018).

- Karstic alluvial lowlands, may also be potential for prehistoric settlements because of some reasons, such as; water resources, resource availability, and protection from external threats. Based on Simanjuntak (2004) in Baksoka River, where Pacitanian artefacts were scattered on the riverbed can be a great example on how this landform and environment could be potential for new potential prehistoric site.
- d) Collecting and retrieving artefacts, faunal remains, and sample from surface findings in potentials caves and alluvial deposits on Kali Oyo (karst alluvial lowlands). Through systematic collection, classification, analysis, and database creation of these surface findings, will help further prehistoric archaeology studies in the region, for instance, lithic technology, archaeozoology, and furthermore.
- e) Carbonate samples collection which are mostly consist of broken and unactive speleothems (stalactite and stalagmite). Retrieved from the cave floor or surface of new potential prehistoric cave sites.
- f) Selection of new potential prehistoric sites that have been explored, by eliminating and selecting based on their level of potential and also type of carbonate samples that are eligible for Uranium-series dating method or not. The procedure will be performed initially in Laboratory of Sedimentology, Archaeometry and Dating, Laboratory of Chemistry and Dating and Laboratory of Mass Spectrometry in *Musée de l'Homme, Histoire Naturelle de l'Homme Préhistorique (UMR 7194)*. Nevertheless, caused by several technical reasons in the initial laboratory in Paris, we could not perform the analyses. Therefore, mechanical, chemical, and mass spectrometry procedure will be performed in

Laboratorium Mineral – BRIN (Badan Riset dan Inovasi Nasional) South Lampung Regency, Indonesia. Afterwards, the isotopic ratio of ICPMS results revealed, then process of U-series age calculation analyses will be done in *Institut de Paléontologie Humaine (IPH), Muséum national d'histoire naturelle (MNHN)* Paris. This U-series dating method's objective is to have an absolute date of when and which period did human start and also stop occupying these potential sites, which it could resulted stretching to even more ancient or recent than previous researches that have been done before. Radiometric dating of U-Series on carbonate samples that are going to be collected from fieldwork.

U-series dating basically composed of:

- Mechanical sample preparation (cleaning, cutting and grinding),
- Chemical preparation (U-Th separation and purification),
- Measurement of the isotope ratios using mass spectrometry, and
- Age calculation

g) Nevertheless, unfortunately caused by technical problems in *Laboratorium Mineral – BRIN (Badan Riset dan Inovasi Nasional)* South Lampung Regency, Indonesia, the initial plan mentioned above could not be performed on time before the submission of this master thesis draft. Therefore, in Chapter IV.3 U-series Dating Results Reference in Gua Tabuhan and Song Terus (cave) site, we will take that as an ideal reference example of a successful geochronological approach on a well-studied prehistoric site. Such as giving recommendation on which samples to be select, for the best suited and reliable in applying U-series dating method. Furthermore, by having a similar region, which is East part of Gunung Sewu, gives a great example, to be approach and apply on the West part also.

III.2.2 U-series Dating Methodology Reference

Taking into reference based on Master 1 (M1) internship work that author have done successfully, under the supervision of Christophe Falguères (*DR CNRS*), in Laboratory of Sedimentology, Archaeometry and Dating, Laboratory of Chemistry and Dating and Laboratory of Mass Spectrometry in *Musée de l'Homme, Histoire Naturelle de l'Homme Préhistorique (UMR 7194)*. Eight samples constituted by pure calcite (CaCO_3) were prepared mechanically, 6 of them are targeted to become “internal standards”, that have already been analysed before and 2 are new unknown samples

(Table 6). The samples to be used as internal standard and for intercalibration are chosen for their known characteristics such as uranium content, exogenous thorium and activity ratios, covering the applicability domain of U-series dating method. The purpose of preparing such samples called “standards” is to check the reliability and reproducibility of the analyses. This dating method requires some international analytical standard and internal standard to be well calibrated using mass spectrometry and then validate the ages of unknown samples. Thus, each chemistry can provide a robust result for dating unknown samples.

The main steps for U-Series dating are: i) mechanical sample preparation (cleaning, cutting and grinding), ii) chemical preparation (U-Th separation and purification), and iii) measurement of the isotope ratios using mass spectrometry. This whole internship took one week for each step in 3 different laboratories of *Musée de l'Homme* that have been mentioned above.

Table 6 Summary of Information and Mechanical Preparations for U-series Dating Samples Used in M1 Internship

No.	Sample Name	Sample category	Sample Type (nature)	Site Location	Petrology Description	Breaking	Cleaning (foucaue)	Weight before Grinding (gram)	Ultrasonic	Oven	Grinding	Manual Grinding	Weight after Grinding (Powder-gram)	Granulometry (200 um)	Photos Availability	Operator	Date of Preparation
1	ST-06	Internal standard for intercalibration	Calcite (Carbonate rock)	Song Terus Cave, Indonesia		Yes	Yes	20.248	Yes	Yes	Yes	Yes	19.000	Yes	Yes	Yves B. SUSILO	13-17/02/2023
2	ST-05	Internal standard for intercalibration	Calcite (Carbonate rock)	Song Terus Cave, Indonesia		Yes	Yes	27.908	Yes	Yes	Yes	Yes	27.231	Yes	Yes	Yves B. SUSILO	13-17/02/2023
3	OBS-CA-01	Internal standard for intercalibration	Calcite (Carbonate rock)	Observatoire, France		Yes	Yes	45.243	Yes	Yes	Yes	Yes	44.800	Yes	Yes	Yves B. SUSILO	13-17/02/2023
4	OBS-CA-04	Internal standard for intercalibration	Calcite (Carbonate rock)	Observatoire, France		Yes	Yes	54.166	Yes	Yes	Yes	Yes	53.999	Yes	Yes	Yves B. SUSILO	13-17/02/2023
5	Chateau Sommet	Internal standard for SEM detector calibration	Calcite (Carbonate rock)	Chateau Sommet, France		Yes	Yes	42.567	Yes	Yes	Yes	Yes	39.843	Yes	Yes	Yves B. SUSILO	13-17/02/2023
6	Grotta Grande (GG)	Internal standard for SEM detector calibration	Calcite (Carbonate rock)	Grotta Grande Italy		Yes	Yes	68.485	Yes	Yes	Yes	Yes	67.100	Yes	Yes	Yves B. SUSILO	13-17/02/2023
7	CV Stalactite	unknown sample	Calcite (Carbonate rock)	Couvent Visitation, France		Yes	Yes	45.119	Yes	Yes	Yes	Yes	5.39	Yes	Yes	Yves B. SUSILO	13-17/02/2023
8	CV Stalagmite	unknown sample	Calcite (Carbonate rock)	Couvent Visitation, France		Yes	Yes	24.311	Yes	Yes	Yes	Yes	2.37	Yes	Yes	Yves B. SUSILO	13-17/02/2023

What we can conclude from this internship work and report of U-series dating, are that from 11 samples, 8 of them were standard carbonate that have been analysed before and 3 of them were unknown carbonate samples that have not been analysed yet. Two interlaboratory standard were analysed (Coral and Salam) and provided results in agreement with the known and expected values. One internal standard ST-05 represents the base of our work. The results are homogeneous and demonstrate the ability of this sample to be considered as a reliable standard, one thing needs to be considered is that, which position of the sample were being retrieved, was it the lower (older) layer or upper (younger) layer, will obtain either an older or younger result as well. The sampling and mechanical preparation protocol which was applied for the carbonates seems to be efficient according to the obtained results. The carbonates coming from different caves as Observatoire, Chateau, Grotta Grande were compared with previous results obtained in our laboratory are coherent. They need to be analysed more in order to be taken as

internal standards and will be sent to other labs for intercomparisons. The U-series analyses performed on Visitation have given reliable ages in agreement with what have been expected by archaeologists and other field of expertise.

IV. RESULT AND DISCUSSION

IV.1 Potential Karstic Cave Sites of West Gunung Sewu (Gunungkidul)

Totally, after fieldwork of exploration have been done, there are 24 locations or observation points that were considered as new potential prehistoric cave sites in West Gunung Sewu UGGp region (Figure 26), which can be categorized into methods of finding the exact location reference or coordinate. Finding and exploring these new potential sites were done by personal exploration of the region with the help of local inhabitants, local tourist attraction, and based on previous researcher (Alifah, 2015 and in press). Locations of these karstic caves and rock shelters among the karstic conical hills, were spread and concentrated in the South and East-Northeast part of the region in this research area, which covered up into 15 villages and 6 districts (Ponjong, Rongkop, Saptosari, Paliyan, Panggang, and Purwosari) in Gunungkidul Regency (Figure 26 and Table 9).

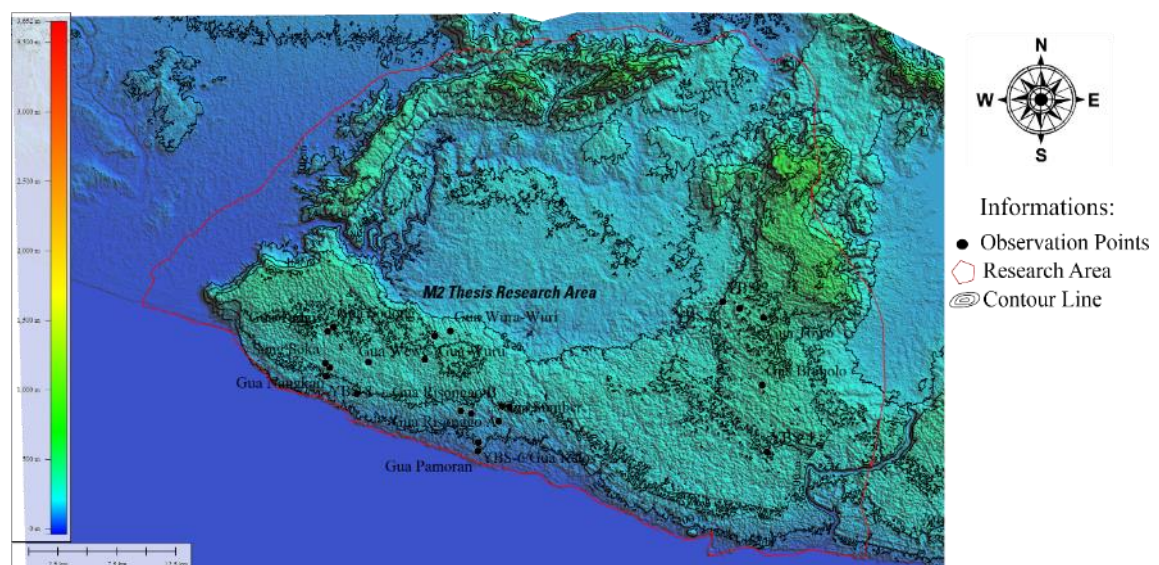


Figure 26 Map of New Potential Prehistoric Cave Sites

In reference to Gunung Sewu geomorphological map by Brahmantyo (2006), the research area covers up and could be classified into Unit K1 Karst Plateau and Unit K5 Karst Alluvial Plain (Lowland). As being observed in field (Figure 27), Unit K1 Karst Plateau could be represented by conical hill landform, in a karst landscape are dominant in the region and Unit K5 Karst Alluvial Plain could be represented by the meandering

river (Figure 28) of Kali Oyo. In the other hand, geologically, the research area could be categorized into Wonosari-Punung Formation (Tmwp), observed by Miocene aged limestone consists of bedded chalky limestone in the north and massive coral limestone in the south. The limestone in the area measures over 650 meters in total thickness. It is primarily composed of rudstones, packstones, and framestones, although there is significant lithological variation throughout (Balazs 1968; van Bemmelen 1970; Waltham et al. 1983; Surono et al. 1992; Rahadjo et al., 1995).



Figure 27 Conical hills landform in Unit K1 Karst Plateau, observed by human's view (-8.004323859450382, 110.71562201556718 and -8.147520472267479, 110.62498945541282)



Figure 28 Conical hills landform in Unit K1 Karst Plateau observed by bird's view (-8.139724135533365, 110.61395251327318)



Figure 29 Karstic alluvial plain shown in Kali Oyo meandering river (-7.957490372359788, 110.46441857590969)

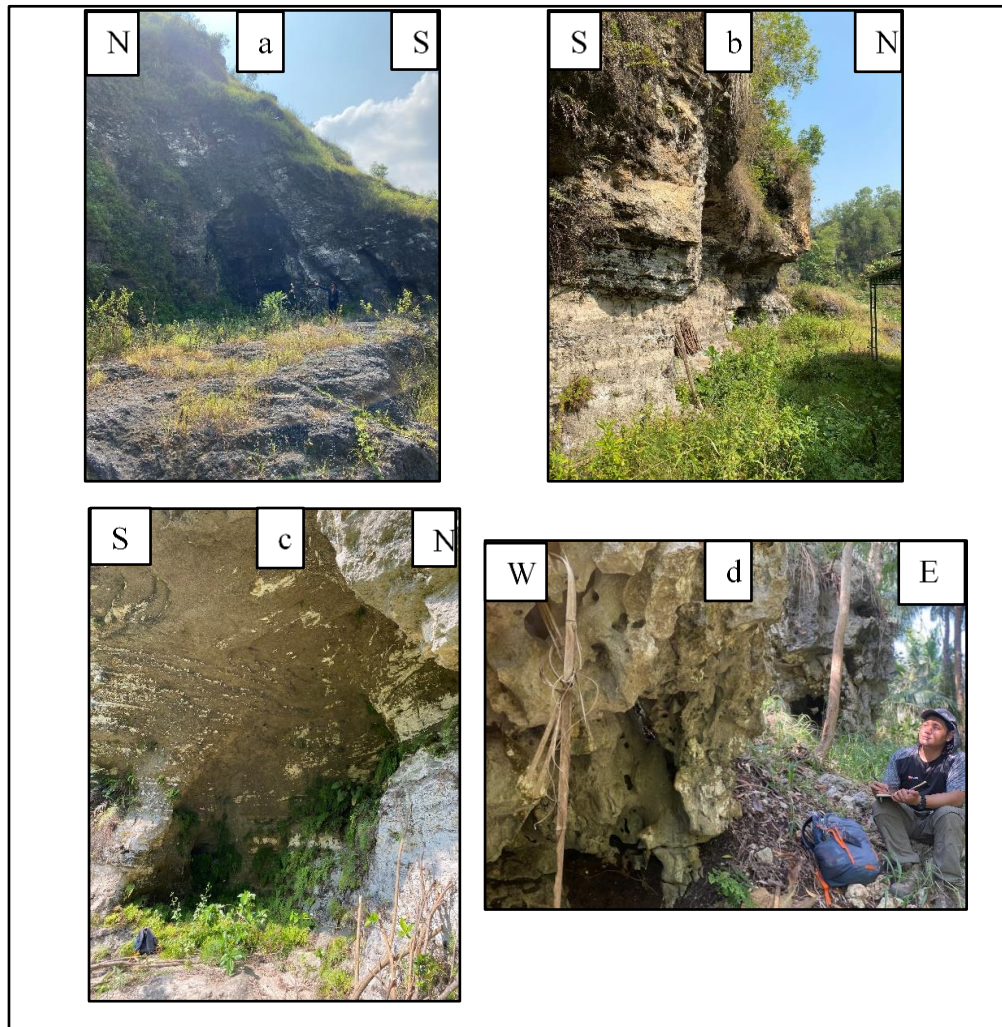


Figure 30 Chalky limestone bedding in YBS-2 and 3 (a,b, and c) and coral limestone in Gua Wewe rock outcrop observed (d)

Table 7 Database of New Potential Prehistoric Sites in West Gunung Sewu

No.	Name	Type	Coordinate	Location Reference	Village, District	Surface Findings	Carbonate Samples	Excavated Before	Potential
1	YBS-1	Rock shelter	-8.01087411266304, 110.7317	Personal Exploration	Sidorejo, Ponjong	No	No	No	Low - Medium
2	YBS-2	Rock shelter	-8.006129527223345, 110.718	Personal Exploration	Sidorejo, Ponjong	No	No	No	Low - Medium
3	YBS-3	Rock shelter	-8.00568397191011, 110.7186	Personal Exploration	Sidorejo, Ponjong	No	No	No	Low - Medium
4	Gua Towo	Cave	-8.0177448748603, 110.74988	Local Tourist Attraction	Karangasem, Ponjong	No	No	No	Low - Medium
5	YBS-4	Rock shelter	-8.120792484998706, 110.752	Personal Exploration	Bohol, Rongkop	No	No	No	Low - Medium
6	Gua Sumber	Cave	-8.097251370046216, 110.546	Alifah (2015)	Planjan, Saptosari	Yes	Yes	No	Medium - High
7	Gua Wura-Wuri	Cave	-8.02793291180097, 110.5089	Alifah (2015)	Karangduwet, Paliyan	Yes	Yes	No	Medium - High
8	Gua Wewe	Cave	-8.03183951677453, 110.4965	Alifah (in press)	Jetis, Saptosari	No	No	No	Low - Medium
9	Gua Risonggo A	Cave	-8.08584406142638, 110.5486	Alifah (in press)	Planjan, Saptosari	No	No	No	Low - Medium
10	Gua Risonggo B	Cave	-8.085834049724241, 110.548	Alifah (in press)	Planjan, Saptosari	Yes	Yes	No	Medium-High
11	YBS-5	Cave	-8.086123170661434, 110.554	Alifah (in press)	Giring, Paliyan	No	No	No	Low - Medium
12	Gua Pamoran	Cave	-8.119878330015453, 110.529	Alifah (in press)	Kanigoro, Saptosari	Yes	Yes	No	Medium-High
13	YBS-6/Gua Ketos	Cave	-8.113230203961583, 110.530	Personal Exploration	Kanigoro, Saptosari	No	Yes	No	Low - Medium
14	YBS-7	Rock shelter	-8.091243415200507, 110.524	Personal Exploration	Kanigoro, Saptosari	No	No	No	Low - Medium
15	Gua Gabul	Cave	-8.088971096497096, 110.516	Alifah (in press)	Kanigoro, Saptosari	Yes	Yes	No	Medium-High
16	Gua Nangkan	Cave	-8.055913048357043, 110.416	Alifah (in press)	Giriwungu, Panggang	Yes	Yes	No	Medium-High
17	YBS-8	Rock shelter	-8.062478322144552, 110.412	Personal Exploration	Giriwungu, Panggang	No	No	No	Low - Medium
18	Song Soka	Cave	-8.05253562008932, 110.4124	Personal Exploration	Giriwungu, Panggang	Yes	Yes	No	Medium-High
19	YBS-9	Rock shelter	-8.051876354958193, 110.445	Personal Exploration	Girimulyo, Panggang	No	No	No	Low - Medium
20	Song Pedang	Cave	-8.075947386745625, 110.436	Alifah (in press)	Girikarto, Panggang	Yes	Yes	Yes (Alifah, in press)	High
21	Gua Tritis Ngloro	Cave	-8.049751983400794, 110.489	Alifah (in press)	Ngloro, Saptosari	Yes	Yes	No	Medium-High
22	Gua Ngerong Jero	Cave	-8.058439007931126, 110.418	Personal Exploration	Giriwungu, Panggang	No	No	No	Low - Medium
23	Gua Tangis	Cave	-8.028023442044434, 110.414	Personal Exploration	Giripurwo, Purwosari	No	No	No	Low - Medium
24	Gua Wuru	Cave	-8.031612722654552, 110.496	Alifah (2015)	Jetis, Saptosari	Yes	Yes	Yes (Alifah, 2015)	High

IV.1.1 YBS 1,2, and 3 Rock Shelters and Cave

YBS is an abbreviation of author's personal name in naming these potential sites while exploring the region, owing to the fact that they got no names yet, even not known up to now by the local inhabitants. These 3 potential sites are really strategic in terms of the localization, because it is located in side of the National Road 3, Sidorejo Village, Ponjong District. Located in -8.01087411266304 & 110.73170935400864 (YBS-1), -8.006129527223345 & 110.71826211991738 (YBS-2), and -8.00568397191011 & 110.71869127335222 (YBS-3) by coordinate. YBS-1 is a limestone rock shelter (outcrop) composed out of chalky limestone bedding as its host rock facing South, with an entrance height ± 1.7 m and width ± 3 m (Figure 31). YBS-2 is a bedded clastic limestone cave but without extended chamber facing East, with an entrance height ± 5 m and width ± 3 m (Figure 31). YBS-3 bedded clastic limestone rock shelter facing West and just located across YBS-2, with a height ± 6 m and width ± 4 m, but it is quite hard to access because there is a trench in front of the shelter's entrance (Figure 31). These rock shelters and cave has deposited Quaternary sediments under the rock shelter (ground) or cave floor, which highly doubtful for having a thick sedimentary filling deposit. A good air circulation and natural lighting, but no surface findings found at all and located quite far from water source, so we concluded that these potential sites have low-medium potential to be inhabited by ancient humans, but it may be potential to become a temporary habitation shelter to protect them from bad climate, weather, and wild animals.



Figure 31 YBS-1 (left), YBS-2 cave (middle) and YBS-3 (right) rock shelter potential site

IV.1.2 Gua Towo (Cave)

Gua Towo (-8.0177448748603, 110.74988422781892) is a limestone cave located in Gunung Tuwu, Karangasem Village, Ponjong District. Location reference from local tourist attraction. Cave entrance facing North, extended from East to West, having a

height ± 9 m and width ± 15 m. The whole cave body or host rock were formed under a karstic conical hill, named Tuwu Hill (*Bukit Tuwu*). Cave network and chamber are not quite widely developed. Observation on Gua Towo, showed a great air circulation, natural lighting, and also it is located near water source which is Telaga Sunut and a small stream. However, it seemed to be highly exploited for tourism purposes, as observed by concrete construction covering the original sediments from several meters before entering the cave until it covered up almost the whole cave floor. Therefore, it is quite hard to discover surface findings, and to interpret the cave filling sediment's thickness, as could be seen in the photo, there were no geological characteristics that indicates sedimentary cave fillings are thick. Therefore, we consider Gua Towo as having low to medium potential to be occupied by humans in prehistoric times.

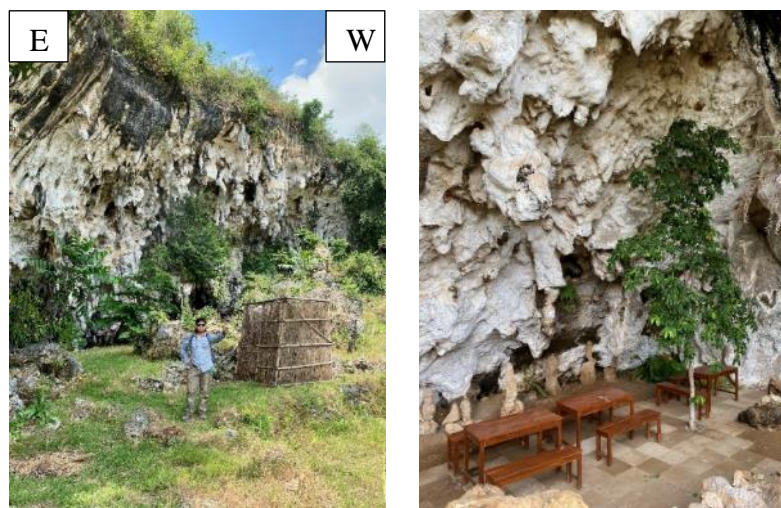


Figure 32 Gua Towo potential site, exploited for tourism for opening a restaurant (right)

IV.1.3 YBS-4 Rock Shelter

YBS-4 is a rock shelter composed out of coral limestone outcrop as its host rock, located in Bohol Village, Rongkop District, finding this potential site was helped by local villager. The shelter entrance is a hill slope $\pm 20^\circ$ facing North with an entrance height ± 2 m and width ± 3 m (Figure 33). This rock shelter has deposited Quaternary sediments beneath, that could be potential to contain and deposit artefacts or any other archaeological remains. Having a great air circulation and natural lighting, but no surface findings found at all and located quite far from water source, so we concluded that these potential sites have low-medium potential to be inhabited by ancient humans, but it is probable to become a potential temporary habitation shelter functioned as a natural protection.



Figure 33 YBS-4 Rock shelter

IV.1.4 Gua Sumber (Cave)

Gua Sumber is a coral limestone cave (-8.097251370046216, 110.54604553669677) located in Planjan Village, Saptosari District, location reference from Alifah (2015) without results and analyses. This cave has an entrance with height: ± 7 m, width: ± 5 m, facing North extended from West-East (Figure 34), despite that, cave entrance covered by dam made by local inhabitants and used as garbage disposal or disposing the belongings of their dead (local Javanese beliefs). Cave chamber network is elongated continuously to the rear. It is also believed by locals to be more extended and connected to the other end of the cave will appear to the neighboring village, where local inhabitant received information from professional cave explorers. Gua Sumber has great natural lighting and air circulation, despite that, it became worse as we enter more to the network chamber of the cave (Figure 34). Deposits of thick cave filling sediment is quite doubtful, as seen that the cave floor was mainly covered by big limestone blocks, with a size between boulder to pebble, therefore it is hard to interpret about it and also, no sign of lower parts of vertical speleothems being covered by cave filling sediments. Some surface findings that were discovered on the cave floor are faunal remains which were fossilized fragmented bones. Carbonate samples were taken from broken non active stalagmite that was discovered on the cave floor, several meters from the cave entrance (Figure 35), showed a wavy lamination structure. Gua Sumber could be categorized into having medium-high potential to be excavated, also to do more comprehensive research in the future.

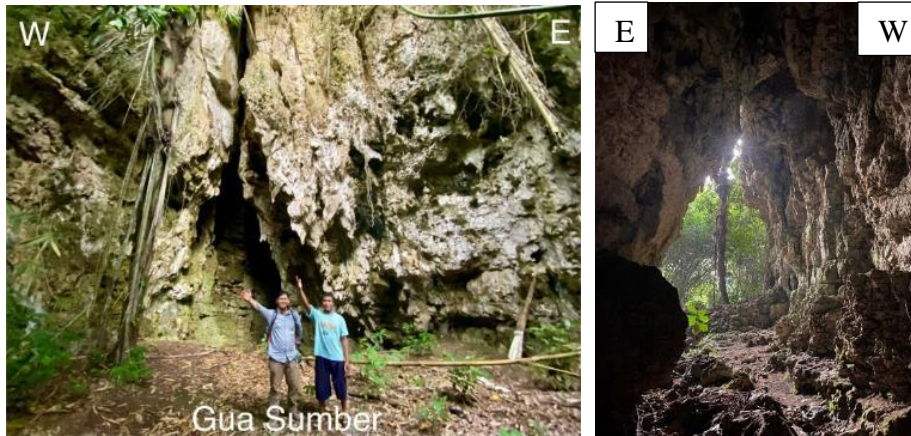


Figure 34 Gua Sumber potential cave, with local inhabitants who helped allocate/find the cave (left) and view from inside (right)



Figure 35 Carbonate samples, broken stalagmite was discovered and retrieved

IV.1.5 Gua Wura-wuri (Cave)

Gua Wura-wuri is a limestone cave (-8.02793291180097, 110.50896318861264) located in Karangduwet Village, Paliyan District, location reference from Alifah (2015) without results and analyses. This cave has an entrance with height: ± 8 m, width: ± 15 m, facing South extended from West-East (Figure 36), access to the cave is quite hard because it is covered by thick vegetations in front of the cave entrance, far from village main road and located in the valley between conical hill landform. Cave chamber network is wide but not elongated. Gua Wura-wuri has great natural lighting and air circulation. The cave is quite doubtful to have deposited thick cave filling sediment, as seen that the cave floor was mainly covered by big limestone blocks, with a size between boulder to pebble, therefore, it is hard to interpret about it. Some surface findings that were discovered on the cave floor is probable lithic remain (Figure 37), considered having different rock material with the surroundings, more compact (dense), and weird shape, might have been knapped by human. Carbonate samples were taken from broken

stalactite that was discovered on the cave floor several meters from the cave entrance (Figure 37). According to the description above, Gua Wura-wuri could be categorized into having medium-high potential to be excavated, also to do more comprehensive research in the future.



Figure 36 Gua Wura-wuri potential site



Figure 37 Probable lithic tool (left) and Carbonate sample from broken stalactite (right)

IV.1.6 Gua Wewe (Rock Shelter)

Gua Wewe is a coral limestone rock outcrop shelter (-8.03183951677453, 110.49653284003622) located in Jetis Village, Saptosari District, location reference from Alifah (2015) without results and analyses. This cave has an entrance with height: ± 3 m, width: ± 5 m, facing West and extended from North-South (Figure 38). Observed from the morphology and size, Gua Wewe is not extensive enough to be considered as a cave, even though it was named by Alifah (2015) Gua which means cave in Indonesian language. Gua Wewe has sediments deposited underneath the rock shelter, but probably thin deposits, great natural lighting and air circulation. There are no surface findings that were discovered at all. Gua Wewe located quite far from water source, so we concluded

that this potential site has low-medium potential to be inhabited by ancient humans, but it could be potential to become a temporary shelter for natural protection.



Figure 38 Gua Wewe potential site

IV.1.7 Gua Risonggo A-B (Cave)

Gua Risonggo A and B (-8.08584406142638, 110.5486911604278) are coral limestone caves located across each other in Planjan Village, Saptosari District, location reference from Alifah (in press) with yet to be known results and analyses. One facing West, and the other facing East. For Gua Risonggo A, sediments were massive and widely disturbed by local plantation, and dam construction, then no surface finding was found (Figure 39). Gua Risonggo B has a really wide cave entrance with height: ± 10 m, width: ± 30 m (Figure 40), at first, it seemed to not have a developed network or chamber, which probably covered by thick sediments. By interpreting and observing the cave floor furthermore, there is one spot of location in the South part, that showed a morphology of an access to a deeper extended cave chamber, which is a gap between coral limestone host rock and cave floor sediments, this indication shows that Gua Risonggo has extended cave chamber more to the South and deposited thick cave filling sediments, also discovered a potential lithic flake as surface finding. Gua Risonggo B has great natural lighting and air circulation. According to the description above, Gua Risonggo A-B could be categorized into having medium-high potential to be excavated especially Gua Risonggo B with an extended cave chamber, also to do more comprehensive research in the future.



Figure 39 Gua Risonggo A, sediments were massively disturbed by dam construction



Figure 40 Gua Risonggo B potential site (left), view from inside (right)

IV.1.8 YBS-5 Cave

YBS-5 is a coral limestone cave (-8.086123170661434, 110.55434651031953) located on the roadside which is very strategic location, in Giring Village, Paliyan District, location reference from personal exploration. Cave facing West, extended from North to South. YBS-5 cave has height: ± 10 m, width: ± 7 m (Figure 41), in spite of that, YBS-5 cave entrance is covered by concrete construction made for irrigation by local authorities (Figure 41), therefore it is very difficult to access the cave, although cave network chamber seemed to be extended as we see from outside. YBS-5 could not be observed if it has thick sediments deposited or not, as we could not access the cave, poor natural lighting and air circulation with no surface findings at all. We consider YBS-5 cave as having low to medium potential to be occupied by humans in prehistoric times, because of the limitation of data acquisition that have been mentioned above.

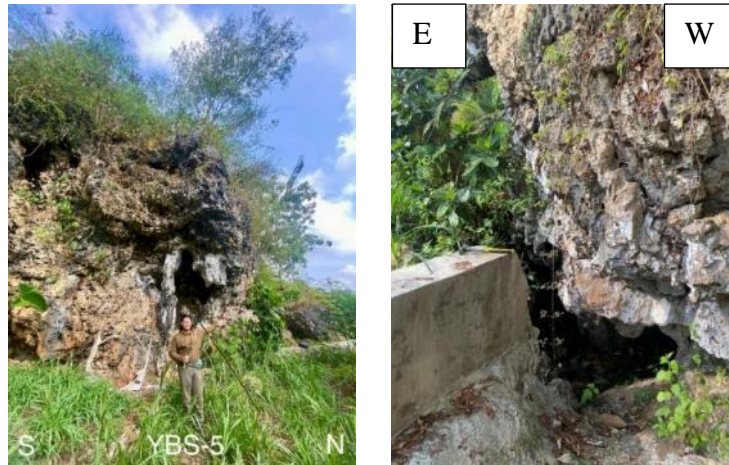


Figure 41 YBS-5 potential site (left), with concrete construction for irrigation blocking the entrance of the cave (right)

IV.1.9 Gua Pamoran (Cave)

Gua Pamoran is a clastic chalky limestone cave (-8.119878330015453, 110.52990674946594) located in Kanigoro Village, Saptosari District, location reference from Alifah (in press) with yet to be known results and analyses. This cave has an entrance with a height: ± 10 m, width: ± 7 m, cave entrance is facing West extended from North-South (Figure 42), it is located in one side of a hill, so it is required to have a small hike with a slope $\pm 20^\circ$ to access the cave. Cave chamber network is wide but not elongated, it has, great natural lighting and air circulation. Gua Pamoran has thick cave filling sediments deposited as observed on cave floor, as sediments buried lower part of a continuous stalagmite. Carbonate samples were taken from broken limestone block that was discovered on the cave floor several meters from the cave entrance, despite that, we consider that it is not eligible for U-series dating, because, that kind of limestone rock sample, might have been eroded, broke, and transported or moved out of its context. Which implies, this block could belonged to Miocene aged limestone (Wonosari-Punung Formation, Tmwp), that will not qualify to be dated by U-series dating method, and it will not show any archaeological age, data or information to reconstruct the chronology of human past life in the region, which is the main objective of this research. Some surface findings that were discovered on the cave floor are faunal remains (fossilized bones), some are identified as Cervidae's antler (Figure 43a), Artiodactyl's astragalus (Figure 43b), and other not yet identified fragmented bones (Figure 43c and d). According to the description above, Gua Pamoran could be categorized into having

medium-high potential to be excavated, also to do more comprehensive research in the future.



Figure 42 Gua Pamoran potential site

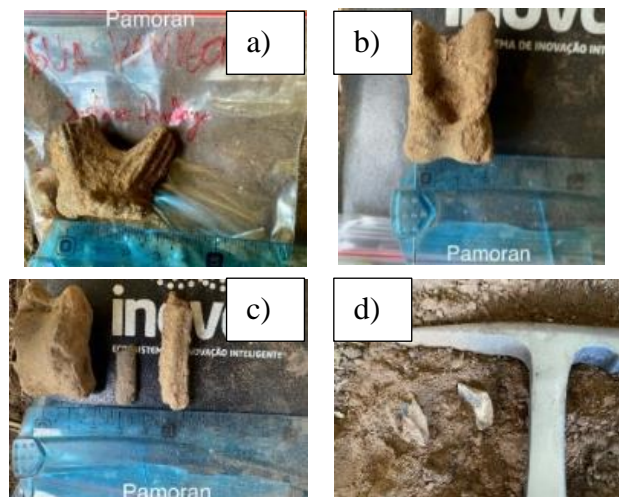


Figure 43 Surface findings of faunal remains: a.) Cervidae's antler, b.) Artiodactyl's astragalus, c) and d) Not yet identified fragmented bones

IV.1.10 YBS-6/Gua Ketos (Cave)

YBS-6/Gua Ketos is a clastic limestone cave (-8.113230203961583, 110.53020384487841) located in Kanigoro Village, Saptosari District, location reference found by personal exploration and help from local inhabitants who named it also. This cave has an entrance with a height: ± 8 m, width: ± 5 m, a cave entrance is facing South and extended from West-East, it is located in a valley side of a karstic conical hill, so it is required to have a small hike with a slope $\pm 20^\circ$ to access the cave (Figure 44). Cave chamber network is divided into 2 chambers, the East entrance especially, is extended-elongated widely and deeply as we move more to the inside, it has thick cave filling sediments deposited as observed on some limestone blocks' continuous lower part were

buried by sediments, also by its location in the lower altitude and in valley between karstic conical hills, it might be a suitable location for massive sediments supply in the depositional process. Cave floor is mostly covered with massive vegetations that caused surface findings are hard to be found (Figure 45). This cave has great natural lighting and air circulation. Carbonate samples were taken from broken stalactite and limestone block rich in calcite crystals (Figure 45) that were discovered on the cave floor several meters from the cave entrance, despite that, we consider that the limestone block is not eligible for U-series dating, because having the same case as mentioned before (see IV.1.9, page 63), which was out of archaeological contextualization. Instead, a broken non-active stalactite that was retrieved, is eligible and might show an age result which is in context on when cave floor or minimum age of the youngest layer beneath was formed (Figure 45). According to the description above, YBS-6/Gua Ketos could be categorized into having low-medium potential to be excavated, also to do more comprehensive research in the future, it just lacked of surface findings.



Figure 45 YBS-6/Gua Ketos potential site, left and right chamber



Figure 44 YBS-6/Gua Ketos view from inside with thick vegetation (left), extended cave network at the rear part(middle) and carbonate samples: broken stalactite and not eligible calcite (right)

IV.1.11 YBS-7 Rock Shelter

YBS-7 is a rock shelter composed out of bedded clastic limestone outcrop as its host rock, located in Kanigoro Village, Saptosari District, finding this potential site by personal exploration. The entrance is facing South with an entrance height ± 2 m and width ± 3 m (Figure 46). This rock shelter has deposited an unknown thickness of Quaternary sediments beneath, a great air circulation and natural lighting, but no surface findings found at all and located quite far from water source, so we concluded that this potential site have low-medium potential to be inhabited by ancient humans, but it is probable to become a potential temporary habitation shelter, functioned as natural protection.



Figure 46 YBS-7 Rock shelter site

IV.1.12 Gua Gabul (Cave)

Gua Gabul is a limestone cave (-8.088971096497096, 110.5166458282732) located in Kanigoro Village, Saptosari District, location reference from Alifah (in press) with yet to be known results and analyses. This cave has an entrance with a height: ± 10 m, width: ± 6 m, cave entrance is facing North extended from East-West, it is located in one side of a hill, so it is required to have a small hike with a slope $\pm 20^\circ$ to access the cave (Figure 47). Cave chamber network is divided into two parts, each one on the East and West part, which are both wide and also elongated, especially the West part. Gua Gabul has thick cave filling sediments deposited, as being observed on speleothem, where lower part of continuous draperies was buried by cave filling sediments. Speleothems such as stalactite, stalagmite, and draperies are well developed (Figure 49). This cave has great natural lighting around the entrance and good air circulation. Some surface findings that were discovered on the cave floor are some fragmented pottery remains. By observing furthermore, it seemed that previous researcher had done a test pit in the rear end part of East chamber (Figure 48), even though we have not found the

published research about it. Carbonate samples were retrieved from non-active stalagmite, probably a stalagmitic floor, that was discovered and retrieved on the test pit hole after, which is located at the rear end of East chamber (Figure 49). It is considered eligible for U-series dating, as this type of carbonate sample might show a result of minimum age for the archaeological layer deposited underneath, as it may contain archaeological remains or usually known as an artefact bearing layer. According to the description above, Gua Gabul could be categorized into having medium-high potential to be excavated, also to do more comprehensive research in the future.

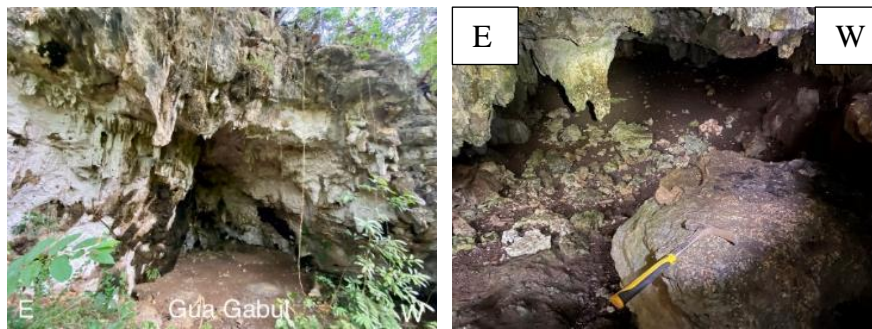


Figure 47 Gua Gabul, East (left) and West (right) chamber

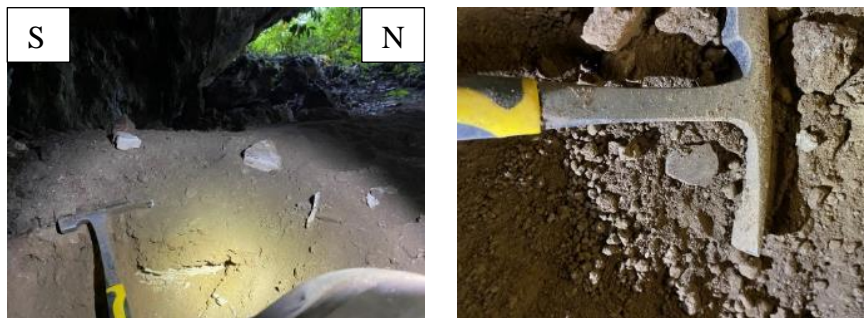


Figure 48 Test pit hole with nonactive stalagmitic floor (left), surface finding of pottery remains (right)

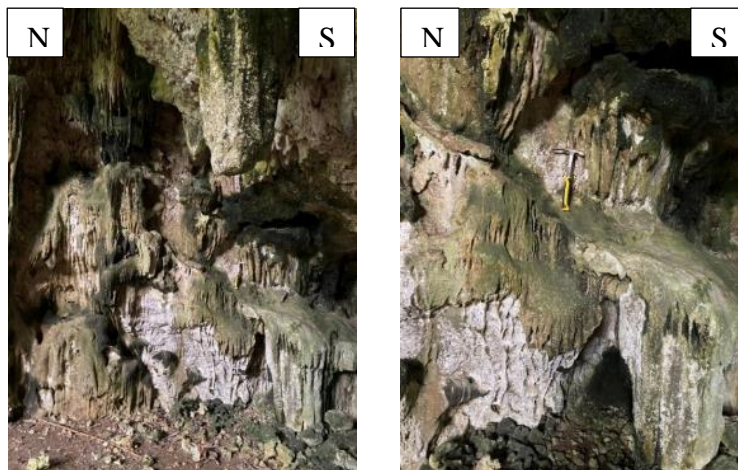


Figure 49 Well developed speleothems, draperies in Gua Gabul

IV.1.13 Gua Nangkan (Cave)

Gua Nangkan is a coral limestone cave (-8.055913048357043, 110.41600938772058) located in Giriwungu Village, Panggang District, location reference from Alifah (in press) with yet to be known results and analyses. This cave has an entrance with a height: ± 8 m, width ± 10 m, cave entrance is facing South extended from West- East (Figure 50), it is located in one side of a hill, so it is required to have a small hike with a slope $\pm 25^\circ$ to access the cave (Figure 50). Cave chamber network is which are wide and also elongated. Gua Nangkan has thick cave filling sediments deposited which could be seen by some limestone blocks with boulder size, seemed to have a continuous part underneath the cave floor, judging by its size. Cave entrance covered by massive vegetation, speleothems such as stalactite, stalagmite, and cave pop corns are well developed (Figure 51). This cave has great natural lighting around the entrance and good air circulation. Some surface findings were hardly discovered on the cave floor, except there are some charcoal. No carbonate samples were taken from this cave, because there are no eligible carbonate samples for U-series dating. Gua Nangkan could be categorized into having low-medium potential to be excavated, also to do more comprehensive research in the future.

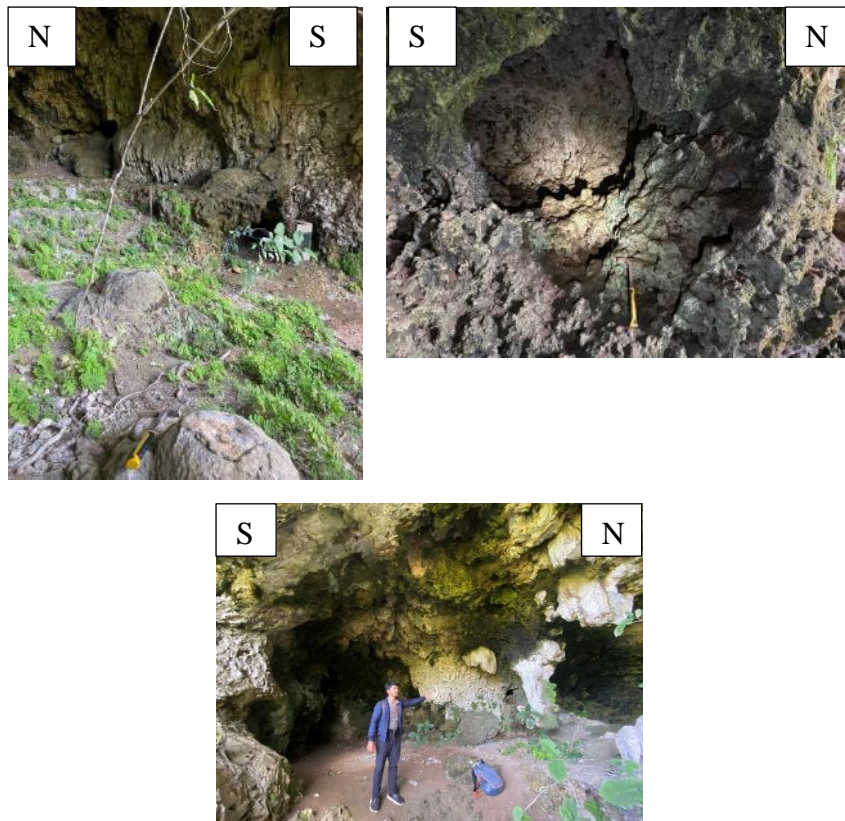


Figure 50 Gua Nangkan potential site, thick vegetation on the cave floor, pop corns (speleothem) are well developed

IV.1.14 YBS-8 Rock Shelter

YBS-8 is a rock shelter composed out of bedded clastic limestone as its host rock, located in Giriwungu Village, Panggang District, finding this potential site by personal exploration. The shelter is facing East, extended from South-North, with an entrance height ± 3 m and width 2 m (Figure 51). This rock shelter has deposited Quaternary sediments beneath, which might potentially contain archaeological remains, a great air circulation and natural lighting, but no surface findings found at all and located quite far from water source. We concluded that this potential site has low-medium potential to be inhabited by ancient humans, but it is probable to become a potential temporary habitation shelter functioned for protection.



Figure 51 YBS-8 rock shelter potential site

IV.1.15 Song Soka (Cave)

Song Soka is a coral limestone cave (-8.05253562008932, 110.41248991229945) located in Giriwungu Village, Panggang District, location reference from personal exploration. This cave has an entrance with a height: ± 30 m, width: ± 10 m, cave entrance is facing West extended from North-South, cave's host rock is the whole limestone karstic conical hill (Figure 52). Cave floor covered by massive vegetation in the entrance part, cave chamber network is wide but not elongated, there are two parts, one on the South part and other in the North part. Song Soka has thick cave filling sediments deposited, which could be observed by judging its size of some limestone blocks seemed to have a continuous lower part underneath the cave floor. Aside from that, Song Soka geographically located in low altitude, and along lowland valley among karstic conical hills, these factors, also might support that sediments supply could be in high quantity when the process of cave filling deposition occurs sourcing from cave's interior (host rock weathering) or exterior. Speleothems such as stalactite are well developed (Figure 52). This cave has great natural lighting in the whole part and good air circulation. Some

surface findings were discovered on the cave floor, which are some faunal remains, especially located on the slope in front of the cave entrance. The one that is identified is Macaque's canine (Figure 53), and the others are fragmented bones that are not identified yet. There were some carbonate samples from broken limestone block that were taken from this cave, but not eligible carbonate samples for U-series dating. Song Soka could be categorized into having low-medium potential to be excavated, also to do more comprehensive research in the future.



Figure 52 Song Soka, North part (left) and South part (right)



Figure 53 Surface findings: faunal remains, unidentified fragmented bone (left) and Macaque's canine

IV.1.16 YBS-9 Rock Shelter

YBS-9 is a rock shelter composed out of bedded clastic limestone as its host rock rich in calcite crystals, located in Girimulyo Village, Panggang District, finding this potential site by personal exploration. The entrance is facing East, extended from South-North, with an entrance height ± 2 m and width 2 m (Figure 54). This rock shelter has deposited Quaternary sediments beneath which could potentially contain some archaeological remains, a great air circulation and natural lighting, but no surface findings found at all and located quite far from water source which can be lakes, rivers, etc, so we concluded that this potential site have low-medium potential to be inhabited

by ancient humans, but it is probable to become a potential temporary habitation shelter to protect them from bad climate, weather, and wild animal threat.



Figure 54 YBS-9 rock shelter potential site

IV.1.17 Song Pedang (Cave)

Song Pedang is a coral limestone cave (-8.075947386745625, 110.43678028265154) located in Girikarto Village, Panggang District, location reference from Alifah (in press). This cave has an entrance with a height: ± 10 m, width: ± 15 m, cave entrance is facing South extended from West- East, cave's host rock is the whole limestone karst hill (Figure 55). The cave body or host rock consist of a whole karstic conical hill, cave chamber network is wide but not elongated. This potential site had been excavated previously (Alifah, in press) with yet to known results and analyses, also excavation pits were all closed already by the time we visited the site. Speleothems such as stalactite are well developed (Figure 55), this cave has great natural lighting in the whole part and good air circulation. Song Pedang has thick cave filling sediments deposited which could be seen by judging the size of some limestone blocks, it seemed that they have a continuous lower part buried underneath the cave floor. To add on, the factor of Song Pedang geographically located in a lower altitude and along lowland valley among karstic conical hills, these factors will give a high chance to deposit a high quantity of cave filling sediments when the formation occurs sourcing from interior (host rock weathering) or exterior of the cave. Some surface findings were discovered on the cave floor, which are some faunal remains, especially located on the slope in front of the cave entrance. The one that has been identified is Bovidae's molar, some fragmented mandibles, and the others are fragmented bones that are not identified yet, totally there are plenty of faunal remain findings, ± 20 unidentified pieces were found distributed and scattered along the cave floor. Despite that, we discovered a lithic remain, that is possibly

a jasper flake (Figure 56). There were some carbonate samples from calcite minerals in broken limestone block that were taken from this cave, but not eligible carbonate samples for U-series dating. Song Pedang could be categorized into having high potential to have more comprehensive research in the future.



Figure 55 Song Pedang potential site



Figure 56 All surface findings discovered in Song Pedang (left), potential jasper lithic flake (right)

IV.1.18 Gua Tritis Ngloro (Cave)

Gua Tritis Ngloro is a coral limestone cave (-8.049751983400794, 110.48902965579579) located in Ngloro Village, Saptosari District, location reference from Alifah (in press) and was helped to locate by local farmer. This cave has an entrance with a height: ± 10 m, width: ± 20 m, cave entrance is facing South extended from West-East (Figure 57), but covered by thick vegetation. Cave chamber network is wide and a bit elongated with a low ceiling ± 1.6 m, speleothems such as stalactites are well developed. This cave has great natural lighting in the entrance part and good air circulation. No surface findings were discovered at all and by interpretation, there are no arguments that can defend that this cave has thick cave filling sediments, except try to open a test pit and advance archaeological excavation. Gua Tritis Ngloro could be categorized into having low-medium potential to be excavated, also to do more comprehensive research in the future.



Figure 57 Gua Tritis Ngloro potential site

IV.1.19 Gua Ngerong Jero (Cave)

Gua Ngerong Jero is a coral limestone cave (-8.049751983400794, 110.48902965579579) located in Giriwungu Village, Panggang District, location reference from local tourist attraction. This cave has an entrance with a height: ± 30 m, width: ± 20 m, cave entrance is facing South extended from West-East (Figure 58). By observing the morphology, this cave showed a characteristic of a karstic sinkhole landform, where some part of the ground showed that subsidence process had occurred. Huge limestone blocks sizing from boulder to pebble are scattered all over the ground or cave floor, this indicates that these limestone blocks were former body of the whole limestone karst hill that got collapsed, result of underground void, caused by acidic water erosion process for consist and persist time. That by time as the voids were getting bigger, and limestone ceiling could not resist the heavy weight above, collapse or subsidence occurred and formed a karstic sinkhole (doline) landform. We need to use stairs to access the cave which is also, covered by thick vegetations. Cave chamber network is wide and elongated at the rear, speleothems such as stalactites are well developed. As it is a karstic sinkhole landform, no supporting characteristics and indications, it is quite hard to determine the thickness of cave filling deposit. This cave has great natural lighting in the entrance part and good air circulation. Surface findings are difficult to find because sediments around the cave entrance are really thin with steeply sloping down into cave entrance or covered by large limestone boulders, caused by a typical subsidence process of sinkhole formation in a karst landscape. Gua Ngerong Jero could be categorized into having low-medium potential to be excavated, also to do more comprehensive research in the future. This site is most likely to be a develop as a tourism spot.

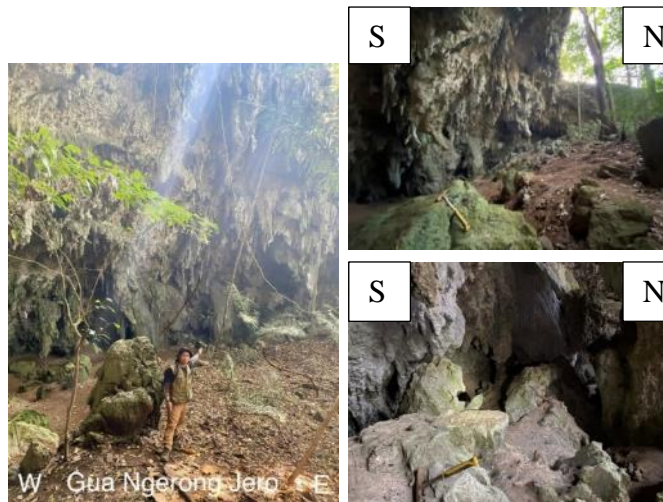


Figure 58 Gua Ngerong Jero (left), sinkhole landform morphology, and cave extended chamber network (right)

IV.1.20 Gua Tangis (Cave)

Gua Tangis is a coral limestone cave (-8.049751983400794, 110.48902965579579) located in Giripurwo Village, Purwosari District, location reference from personal exploration. This cave has an entrance with height ± 25 m, width: ± 15 m, cave entrance is facing East extended from North-South, and the whole limestone cave (host rock) is part of a karstic conical hill (Figure 59). Cave chamber network is wide but not elongated at the rear, speleothems such as stalactites are well developed, cave filling sediments might probably be thick because huge limestone boulders' lower part were continuously embedded into the cave floor. This cave has great natural lighting in the entrance part and good air circulation. Surface findings are difficult to find. Gua Tangis could be categorized into having low-medium potential to be excavated, also to do more comprehensive research in the future.



Figure 59 Gua Tangis potential site

IV.1.21 Gua Wuru (Cave)

Gua Wuru is a coral limestone cave (-8.049751983400794, 110.48902965579579) located in Jetis Village, Saptosari District, location reference from Alifah (2015). She has conducted a research in this cave with her team (Yogyakarta Archaeological Agency), check on sub chapter II.3.10 (page 39) for her complete result, analyses, and conclusion. Where she stated that the current cave condition resulted in the disclosure of archaeological findings in the form of ecofacts and artefacts scattered in piles of excavated excavations and some of them were on the floor of the cave chamber. This cave has an entrance with a height: ± 7 m, width: ± 5 m, cave entrance is facing South extended from West-East, and accessing the cave with a little hike ± 150 m (Figure 60). There are two cave entrances (left and right) separated by a column (speleothem), cave network extended widely as we enter inside to the Southwest part of the cave's chamber, speleothems such as stalactites and column are well developed. This cave has great natural lighting part and good air circulation especially on the area around cave entrance, with having huge chamber and extended network shows how potential this cave is for human settlement. Inside the Southeast part of the cave's chamber, cave floor had been excavated until the depth of ± 2.5 m (Figure 61) by Alifah (2015), also written on the same article, miners were responsible for exploiting this cave also. Carbonate samples were taken from in the cave floor which is a broken stalactite (Figure 63) and the oldest layer was exposed because of excavation pit that was done by Alifah (2015) (Figure 61), which is from a broken limestone of the cave deposit, but unfortunately it was ineligible for U-series dating, because the uncertain origin of the limestone block could be out of archaeological context. Surface findings are really rich to be easily found, there are total of 15 faunal remain pieces were found, the identified ones are, Bovidae's molar and phalange bone (Figure 63), and yet to be identified are fragmented bones (Figure 63). Gua Wuru is a potential site that is really suitable to do more comprehensive research in the future, since it has a lot of potentials to be studied on.



Figure 60 Gua Wuru divided cave entrance by a column (left) and first chamber (right)

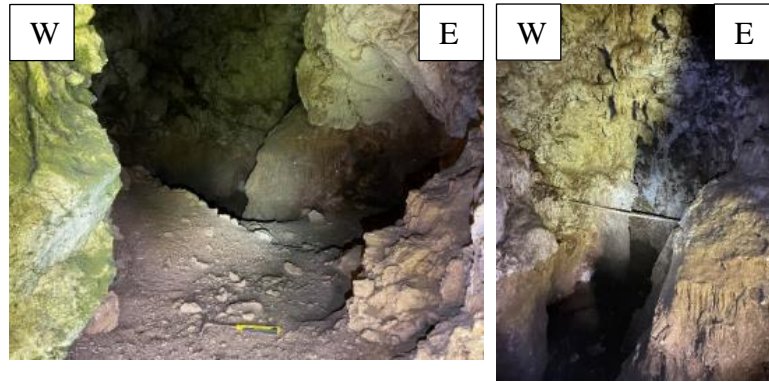


Figure 61 The excavated cave floor of Southeast part of the cave's second chamber

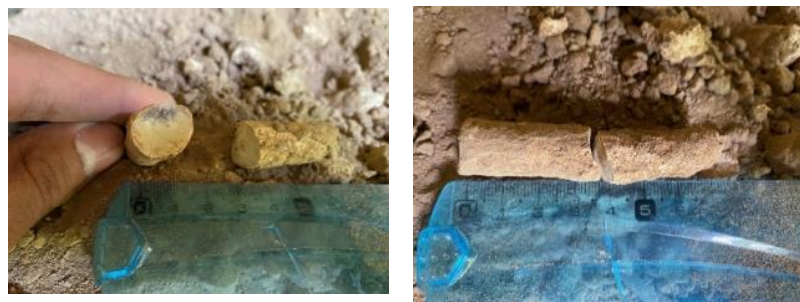


Figure 62 Carbonate samples from broken stalactite found on cave floor



Figure 63 Surface findings of faunal remains: Bovidae's molar and phalange bone

IV.2 Potential Karstic Cave Sites Eligible for U-Series Dating

In a total of 24 caves and rock shelters of new potential prehistoric sites have been recorded in this fieldwork, we have selected every each of them to be assigned as categories of the sites' potential level. Which are low-medium, medium-high, and high potential, based on whether the supporting natural geomorphological landform of the site, geological condition, surface findings discovery (lithic or faunal remains), and also the site had been excavated and scientifically published by previous researchers or not. According to (Table 7) Database of New Potential Prehistoric Sites in West Gunung Sewu, from total 24, there were only 5 potential caves sites (Table 8), that will proceed

into U-series dating process, by taking into consideration the type of carbonate samples that were taken from these potential sites.

Most of those sites that are not eligible for U-series dating, are the carbonate samples in a form of calcite crystals or limestone blocks that were found and retrieved on cave floors. These samples, which was mentioned in previous sub chapter, the reason why it is considered not eligible for U-series dating, is because these broken limestone block sizing from boulder to pebble, might have been eroded, broke, and transported or moved out of its contextualization, which implies, this block could belonged into Miocene aged limestone (Wonosari-Punung Formation, Tmwp) that will not qualify or over the limit of U-series dating and the result will not show any archaeological age, data or information to reconstruct the chronology of human past life in the region, which is the exact objective of this research. These are the potential sites, that were selected and considered eligible for U-series dating with each photo of carbonate samples taken in laboratorium of *BRIN (Badan Riset dan Inovasi Nasional) Kawasan Sains RP Soejono, Pasar Minggu, Jakarta* (photos were taken before being sent to *Laboratorium Mineral – BRIN South Lampung*):

Table 8 Selected new potential prehistoric sites eligible for U-series dating

No.	Name	Type	Coordinate	Location Reference	Speleothem Type
1	Gua Sumber	Cave	-8.097251370046216, 110.5	Alifah (2015)	Broken Stalagmite
2	Gua Wura-Wuri	Cave	-8.02793291180097, 110.50	Alifah (2015)	Broken Stalactite
3	Gua Gabul	Cave	-8.088971096497096, 110.5	Alifah (in press)	Broken Stalagmite
4	YBS-6/Gua Ketos	Cave	-8.113230203961583, 110.5	Personal Exploration	Broken Stalactite
5	Gua Wuru	Cave	-8.031612722654552, 110.4	Alifah (2015)	Broken Stalactite

IV.2.1 Gua Sumber (GS)

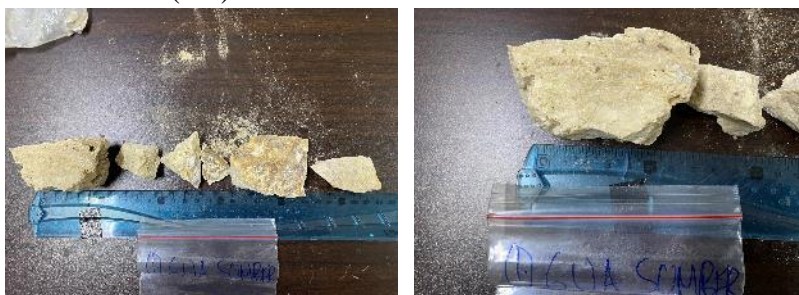


Figure 64 Carbonate samples: broken stalagmite from Gua Sumber potential site

Gua Sumber (GS) carbonate sample which is in a form of broken stalagmite was collected on the cave floor, then we break it by hammering it into smaller pieces $\pm 2-5$ cm size (Figure 64). By observing the texture, this limestone specimen has white to greyish color, clay to medium sand grain size, well sorted round grain shape, mud supported,

carbonate type cement, compose of calcite minerals. Structure observation shows a cross lamination sedimentary structure. Possible detrital pollution which is clay – sand sized clastic impurities, that will require cleaning sample process with driller for removing it.

IV.2.2 Gua Wura-wuri (GWW)



Figure 65 Carbonate samples: broken stalactite from Gua Wura-wuri potential site

Gua Wura-wuri (GWW) carbonate sample which is in a form of broken stalactite was collected on the cave floor, with the condition as seen in (Figure 65). By observing the texture, this specimen has white to greyish color, clay to fine sand grain size, well sorted round grain shape, mud supported, carbonate type cement, compose of calcite minerals. Structure observation shows a stalactite structure. Some clastic impurities from clay to sand size were shown in some part of the sample, which were not dominant, but still required to be cleaned by a driller.

IV.2.3 Gua Gabul (GG)



Figure 66 Carbonate samples: broken stalagmite from Gua Wura-wuri potential site

Gua Gabul (GG) carbonate sample which is in a form of broken stalagmite or a probable stalagmitic floor, was collected on a layer below the cave floor, as this pit was opened by previous researcher. Then we break it by hammering it into smaller pieces ± 5 -8 cm size (Figure 66). By observing the texture, this limestone specimen has white to greyish color, clay to medium sand grain size, well sorted round grain shape, mud supported, carbonate type cement, and compose of calcite minerals. Structure observation shows a wavy lamination sedimentary structure (Figure 68). The condition

of the sample is quite fresh, showed by just minor clastic impurities along the laminated side of the sample, it still need impurity cleaning by a driller, even though, not a massive one.

IV.2.4 Gua Ketos/YBS-6 (GK)

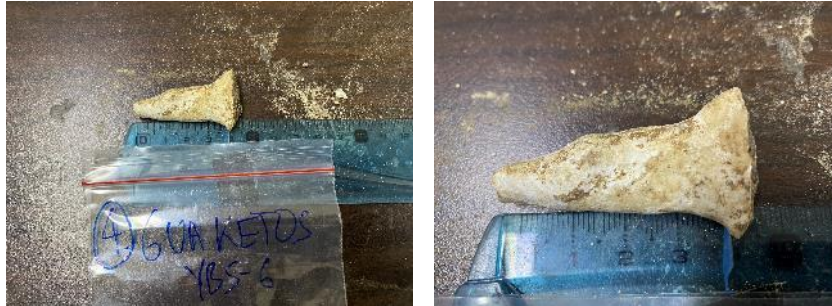


Figure 67 Carbonate samples: broken stalagmite from Gua Ketos/YBS-6 potential site

Gua Ketos/YBS-6 (GK) carbonate sample which is in a form of broken stalactite was collected on the cave floor, with the condition as seen in (Figure 67). By observing the texture, this specimen has white to greyish color, clay to fine sand grain size, well sorted round grain shape, mud supported, carbonate type cement, compose of calcite minerals. Structure observation shows a stalactite structure. Clastic impurities are seen all over the side of this sample, it surely need an impurity cleaning by a driller before being transformed into powder form for chemical and ICPMS process.

IV.2.5 Gua Wuru (GW)



Figure 68 Carbonate samples: broken stalactite from Gua Wuru potential site

Gua Wuru (GW) carbonate sample which is in a form of broken stalactite was collected on the cave floor, with the condition as seen in (Figure 68). By observing the texture, this specimen has white to greyish color, clay to fine sand grain size, well sorted round grain shape, mud supported, carbonate type cement, compose of calcite minerals. Structure observation shows a stalactite structure. This sample needs a cleaning by a drill,

as shown by clastic impurities were shown mostly along the cylindrical side of the stalactite

IV.3 U-series Dating Results Reference

As seen on Chapter III.2.2 U-series Dating Methodology Reference, page 50, after M1 internship experience working on U-series applied on carbonate samples to become internal standards of the laboratory, the results are homogeneous and could demonstrate the ability to be considered as a reliable standard. So, we consider the analyses work that have been done before, could really be a guidance and ideal example for applying U-series dating on carbonate samples in this research, where unfortunately could not perform its own U-series analyses for 5 selected potential sites (see Chapter III.2.1 Data Collection Fieldwork and Laboratory Methodology, page 51). To add on, the sampling and mechanical preparation protocol which were applied, also seemed to be efficient according to the obtained results. These analyses result reference is under the supervision of Christophe Falguères (*DR CNRS*) of the same laboratory. The result comes from 2 most studied and well establish sites located in East part of Gunung Sewu UGGp, still belong the same region with our research, except this is the other part. These samples are retrieved from Song Terus and Gua Tabuhan (cave) with each designated code name ST and GT, also mentioned as prehistoric site references in chapter II. As seen on Table 9, there are 11 samples from Gua Tabuhan and 2 samples from Song Terus. In Gua Tabuhan, each of this sample were coming from carbonate rock samples retrieved or collected from surveying process (n=3), on the cave entrance (n=2), scree entrance (n=1), stalagmite (n=3), and calcite (n=2), each with its depth (z) in the stratigraphic section when being taken. In the other hand, Song Terus, have 2 carbonate samples, both coming from excavation of M9 square pit.

Table 9 Carbonate samples origin source from Song Terus and Gua Tabuhan

Gua Tabuhan		
GT1000	<i>sondage</i>	z=1000
GT1170	<i>sondage</i>	z=1170
GT9901	<i>entrée de la grotte</i>	
GT9902	<i>entrée de la grotte</i>	
GT9903	<i>entrée de l'éboulis</i>	
GT9907	<i>sondage</i>	z=931
GTB1	stalagmite	B1 z=350
GTB2	stalagmite	B2 z=350
GTB3	stalagmite	B3 z=350
GTC3	calcite	C3 z=400
GT	calcite	z=370
Song Terus		
ST9821	<i>fouille M9</i>	
ST9821 brû	<i>fouille M9</i>	

IV.3.1 Gua Tabuhan (cave) Reference

As observed on Table 10, from all 11 samples that were analysed, on each, they showed mass spectrometry isotopic ratio result, that consist of ^{238}U ppb, ^{232}Th ppb, $^{234}\text{U}/^{238}\text{U}$, $^{230}\text{Th}/^{234}\text{U}$, $^{230}\text{Th}/^{238}\text{U}$, $^{230}\text{Th}/^{232}\text{Th}$, each with \pm (k=2) Calculated Age (ka), each with Positive Error and Negative Error and corrected age. For Gua Tabuhan (Table 10), the age result after correction, carbonate sample collected from survey, GT1000 yielded an age of 341 ± 41 ka and GT9907 yielded an age of 331 ± 38 ka. We can take some important remarks, that, a new understanding of Gua Tabuhan, at least, the cave had been formed more or less 341.000 years ago and this result could also extend, the first human occupation of caves on the area. For carbonate samples coming from cave entrance and scree entrance, age results without correction yet, which are GT9901, GT9902, and GT9903, yielded an age of 47 ± 1 ka, 46 ± 1 ka, and 155 ± 6 ka. which indicates, the current cave entrance had been shaped and formed the way it is today at least for 47.000 years ago. Other samples coming from stalagmites of Gua Tabuhan, sample GT B1, GT B2, GT B3132, yielded an age of 132 ± 4 , 129 ± 4 ka, and 138 ± 4 ka. This indicates stalagmites that covered or deposited on the layer with each depth (z), showed a minimum age $129 - 138 \pm 4$ ka of the archaeological layer underneath. For samples originated from calcite, GT 2012 C3 resulted without correction, yielded an age of 127 ± 3 ka and GT z=-370 with correction, yielded an age of 129 ± 4 ka. This indicates that the calcite bearing layer associated with artefacts deposited, at maximum, could be dated back to 129 ± 4 ka.

IV.3.2 Song Terus (Cave) Reference

In the other hand, Song Terus which only has 2 samples (Table 10), derived from excavation of M9 square pit, ST9821 and ST9821 *brûlée* without correction, yielded an age of 101 ± 2 ka and 92 ± 2 ka. Which indicate the chronology of human occupation age where carbonate samples were collected from artefact bearing layer in M9 square pit.

Table 10 U-series dating results on Gua Tabuhan (GT) and Song Terus (ST)

Sample name	^{238}U ppb	\pm (k=2)	^{232}Th ppb	\pm (k=2)	$^{234}\text{U}/^{238}\text{U}$	\pm (k=2)	$^{230}\text{Th}/^{234}\text{U}$	\pm (k=2)	$^{230}\text{Th}/^{238}\text{U}$	\pm (k=2)	$^{230}\text{Th}/^{232}\text{Th}$	\pm (k=2)	Calculated Age (ka)	Pos. Err.	Neg. Err.	Corrected age	pos er	neg er
GT1000	341,071	3,688	96,346	1,267	1,156	0,012	1,003	0,013	1,160	0,015	12,547	0,093	346	41	38	341	41	38
GT1170	276,295	2,909	36,296	0,412	1,058	0,011	0,971	0,013	1,027	0,013	23,886	0,159	343	41	29			
GT9901	203,820	2,210	1,124	0,013	1,136	0,013	0,352	0,005	0,400	0,005	221,664	1,580	47	1	1			
GT9902	498,163	5,672	0,685	0,008	1,112	0,012	0,345	0,004	0,384	0,005	854,026	5,180	46	1	1			
GT9903	62,675	0,691	0,098	0,001	1,104	0,014	0,771	0,013	0,851	0,013	1662,039	12,835	155	6	6			
GT9907	297,549	3,188	7,585	0,085	1,027	0,011	0,960	0,011	0,986	0,011	118,205	0,693	331	38	27			
GT B1	197,752	2,159	27,997	0,306	1,082	0,012	0,724	0,010	0,784	0,010	16,926	0,111	137	4	4	132	4	4
GT B2	212,118	2,275	30,960	0,362	1,095	0,012	0,719	0,010	0,787	0,010	16,481	0,115	135	4	4	129	4	4
GT B3	177,903	1,950	26,000	0,300	1,093	0,012	0,741	0,010	0,810	0,011	16,946	0,118	143	4	4	138	4	4
GT 2012 C3	133,302	1,368	6,677	0,071	1,071	0,011	0,696	0,008	0,745	0,009	45,480	0,281	127	3	3			
GT z=-370	212,731	2,359	35,705	0,417	1,131	0,012	0,723	0,009	0,818	0,010	14,891	0,099	135	4	4	129	4	4
ST9821	204,927	2,135	1,859	0,019	1,117	0,011	0,614	0,007	0,686	0,008	230,992	1,326	101	2	2			
ST9821 brûlée	220,377	2,292	3,033	0,032	1,121	0,012	0,578	0,007	0,648	0,007	143,866	0,821	92	2	2			

IV.4 Potential Prehistoric Open-Air Sites from Karstic Alluvial Lowlands of Kali Oyo, Gunung Kidul and Bantul

The fieldwork of exploration and expedition along river terraces of Kali Oyo alluvial deposits, in a search of human trace remains of occupation and settlement that might have occurred around the old stadia meandering river of Kali Oyo. Afterwards, we will mention Oyo River as Kali Oyo, as *kali* in Indonesian language means river. The latest research was done Nurani et al., (2020) which have discovered dominantly lithic artefacts from the upstream part of Kali Oyo, but in this research, we tried to explore from the downstream part from Imogiri, Bantul area until Semin, Gunungkidul area, which is the upstream part of Kali Oyo (Figure 70).

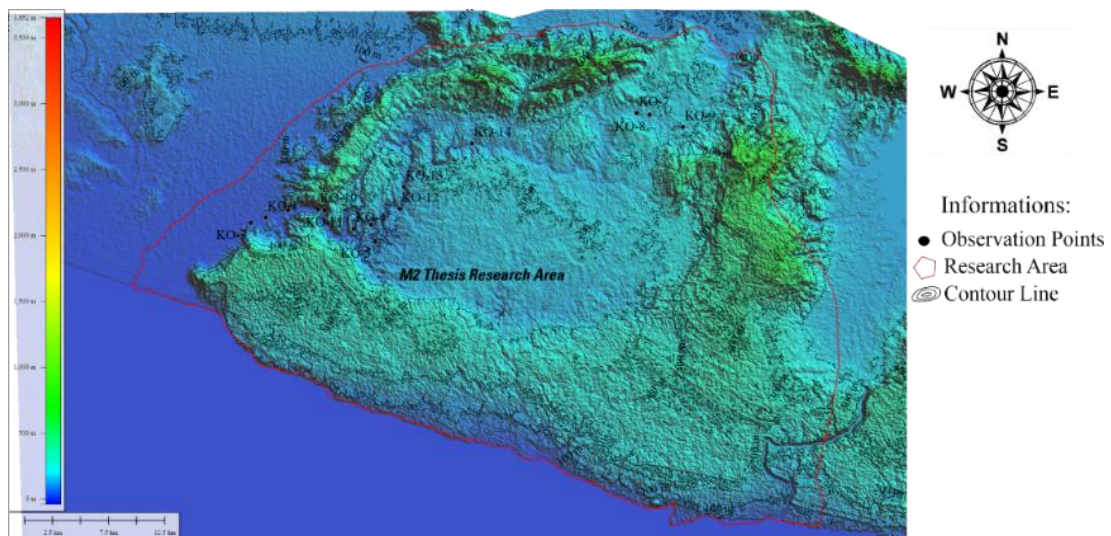


Figure 69 Map of Potential Prehistoric Open-Air Sites from Karstic Alluvial Lowlands of Kali Oyo, Gunung Kidul and Bantul

Until the end, we have pinned, observed, and analysed 14 observation points or locations along the river, each of this location, we discovered and found lithic remains scattered above or sometimes a bit deposited or buried but still outcropped in the alluvial deposits, designated code name for each observation points is KO and followed by the number of order time it was (Table 10). Unfortunately, we did not discover any rock outcrop or Quaternary sediment deposits that could show stratigraphic section (artefact bearing layers) of these findings in all 14 observation points, because almost all points are located in the downstream, where in geological perspective, the water river erosional rate is high. Also, these artefacts have been transported from source that is hardly to be traced. As the result of this, all artefacts mainly lithic remains, were all considered out of depositional, stratigraphic, and geochronological contextualization, which where we

could not apply any absolute radiometric dating at all. Except, applying relative dating methods, for instance, as technological and cultural approach on artefacts' characteristics occurred on the lithic remains are belonged to which period, which could result in a large or small range of age. Each of every observation point (location), have their own detailed table database of surface findings information, with designated code name for each artefact that were classified, thanks to Mr. Sigit E. Prasetyo (*BRIN*), who advised, guided and helped a lot in lithic tools classification and analyses.

These surface findings consist of lithic remains, which we can determine lithic potential raw materials, tool typology (named based on classifying, analysing, and observing the physical - morphological characteristics), and also differentiate it with geofacts. Apart from that, some faunal remains were also collected, but these type surface findings that were collected, are highly doubt if they are considered to be categorized as fossilized form of bones or not. Therefore, there is a high probability that these faunal remains and does not belong to prehistoric period. All detailed information on each observation point form KO-1 to KO-14, such as geomorphological, geological, local physiography, and field report are located in appendix. Here, we presented some important remarks of lithic remains surface findings discovered while exploring Kali Oyo that needs to take into considerations of advance lithic tool analyses. They consist of geomorphological field photos (Figure 70), lithic artefacts on field and in lab, and database of artefact findings of each observation points:

Table 11 Potential Prehistoric Open-Air Sites from Karstic Alluvial Lowlands of Kali Oyo, Gunung Kidul and Bantul

No.	Name	Coordinate	Village, District, Regency	Surface Findings on Alluvial Deposits	
				Lithic Remains	Faunal Remains
1	KO-1	-7.951625240879616, 110.3	Selopamioro, Imogiri, Bantul	Yes	Yes
2	KO-2	-7.945880390078603, 110.3	Sriharjo, Imogiri, Bantul	Yes	Yes
3	KO-3	-7.956023901363638, 110.3	Sriharjo, Imogiri, Bantul	Yes	Yes
4	KO-4	-7.961283927153939, 110.4	Banyusoco, Playen, Gunung Kidul	Yes	Yes
5	KO-5	-7.9711999485155225, 110.4	Banyusoco, Playen, Gunung Kidul	Yes	Yes
6	KO-6	-7.957697239951622, 110.4	Banyusoco, Playen, Gunung Kidul	Yes	Yes
7	KO-7	-7.86768030621488, 110.68	Watusigar, Ngawen, Gunung Kidul	Yes	Yes
8	KO-8	-7.86920187881109, 110.69	Watusigar, Ngawen, Gunung Kidul	No	No
9	KO-9	-7.879219335402592, 110.7	Kemejing, Semin, Gunung Kidul	No	No
10	KO-10	-7.94533453483004, 110.42	Sriharjo, Imogiri, Bantul	Yes	No
11	KO-11	-7.9462271825186175, 110.	Selopamioro, Imogiri, Bantul	Yes	No
12	KO-12	-7.944845711478008, 110.4	Jatimulyo, Dlingo, Bantul	Yes	Yes
13	KO-13	-7.9273760623414375, 110.	Jatimulyo, Dlingo, Bantul	Yes	No
14	KO-14	-7.892223246524772, 110.5	Gading, Playen, Gunung Kidul	Yes	No

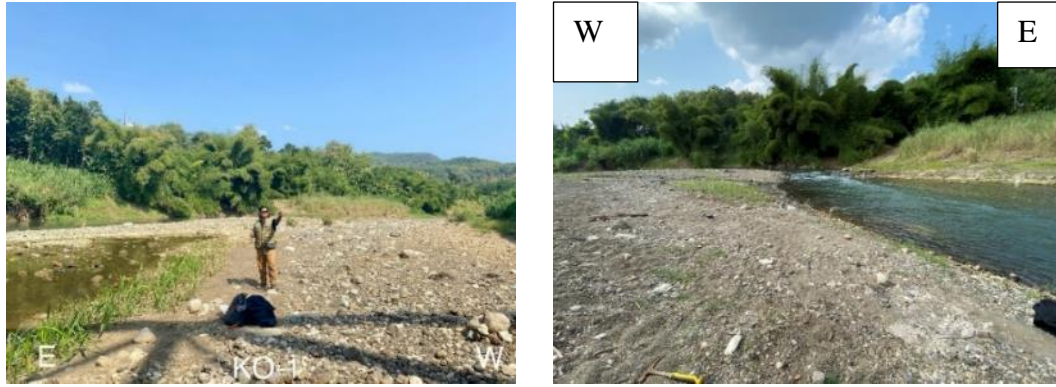


Table 12 KO-1 Detailed Lithic Remains from Surface Finding

Figure 70 Kali Oyo-1 (KO-1) observation point, view to the South (left) and to the North (right)

Location	Surface Findings on Alluvial Deposits (n)	Lithic Remains		Speciment Code
		Raw Material	Typology	
KO-1	Artefacts (6)	Chert	Side Scraper	KO/1/A1/24
			Flake	KO/1/A2/24
		Jasper	Denticulated Flake	KO/1/A3/24
		Chert	Flake	KO/1/A4/24
			Core	KO/1/A5/24
		Crystalline Limestone	Flake	KO/1/A6/24
	Geofacts (9)	Crystalline Limestone		KO/1/G1/24
		Jasper		KO/1/G2/24
		Andesite		KO/1/G3/24
		Chert	KO/1/G4/24	
			KO/1/G5/24	
			KO/1/G6/24	
		Jasper	KO/1/G7/24	
		Chert	KO/1/G8/24	
		Chert	KO/1/G9/24	
Jasper	KO/1/G10/24			
Total		15		



Figure 71 Denticulated flake (jasper) - KO/1/A3/24, in field (left) and in lab (right)



Figure 72 Side scraper (chert) - KO/1/A1/24, in field (left) and in lab (right)



Figure 73 End scraper (quartzite) - KO/2/A2/24, in field (left) and in lab (right)



Figure 74 Core (chert) - KO/2/A1/24, in field (left) and in lab (right)

Table 13 KO-4 Detailed Lithic Remains from Surface Finding

Location	Surface Findings on Alluvial Deposits (n)	Lithic Remains		Speciment Code
		Raw Material	Typology	
KO-4	Artefacts (7)	Chert	Side Scraper	KO/4/A1/24
			Core	KO/4/A2/24
			Flake	KO/4/A3/24
			Core	KO/4/A4/24
		Calcedony	Flake	KO/4/A5/24
			Flake	KO/4/A6/24
		Geofact (2)	Chert	
Quartzite			KO/4/G2/24	
Total		9		



Figure 75 Side scraper (chert) - KO/4/A1/24, in field (left) and in lab (right)



Figure 76 Cortical flake (chert) - KO/5/A1/24, in field (left) and in lab (right)

Table 14 KO-6 Detailed Lithic Remains from Surface Finding

Location	Surface Findings on Alluvial Deposits (n)	Lithic Remains		Speciment Code
		Raw Material	Typology	
KO-6	Artefacts (7)	Chalcedony	Side Scraper	KO/6/A1/24
		Jasper	Burin	KO/6/A2/24
		Chert	Flake	KO/6/A3/24
		Crystalline Limestone		KO/6/A4/24
				KO/6/A5/24
				KO/6/A6/24
		Chalcedony	KO/6/A7/24	
	Geofacts (4)	Chert		KO/6/G1/24
		Quartz		KO/6/G2/24
				KO/6/G3/24
		KO/6/G4/24		
Total		11		

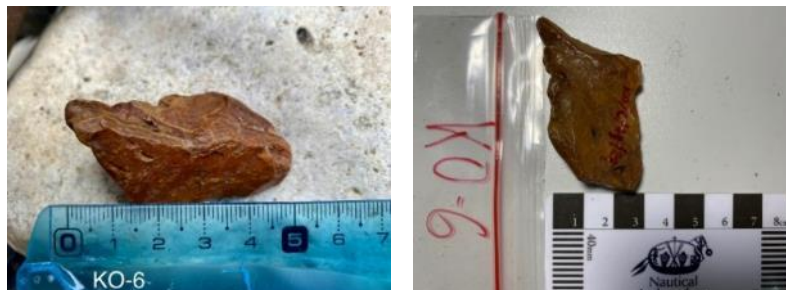


Figure 77 Side scraper (chalcedony) - KO/6/A1/24, in field (left) and in



Figure 78 Flake (chalcedony) - KO/6/A7/24, in field (left) and in lab (right)



Figure 79 Flake (chert) - KO/6/A6/24, in field (left) and in lab (right)

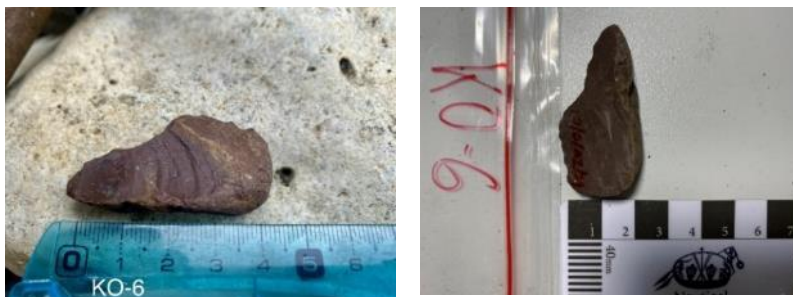


Figure 80 Burin (jasper) - KO/6/A2/24, in field (left) and in lab (right)

Table 15 KO-10 Detailed Lithic Remains from Surface Finding

Location	Surface Findings on Alluvial Deposits (n)	Lithic Remains		Speciment Code
		Raw Material	Typology	
KO-10	Artefacts (14)	Crystalline Limestone	Core	KO/10/A1/24
			Flake	KO/10/A2/24
			Flake	KO/10/A3/24
			Burin	KO/10/A4/24
			Scraper	KO/10/A5/24
			Side Scraper	KO/10/A6/24
			Core	KO/10/A7/24
			Core	KO/10/A8/24
			Flake	KO/10/A9/24
			Flake	KO/10/A10/24
			Flake	KO/10/A11/24
			Flake	KO/10/A12/24
			Flake	KO/10/A13/24
			Flake	KO/10/A14/24
Geofact (6)	Crystalline Limestone		KO/10/G1/24	
	Chert		KO/10/G2/24	
	Basalt		KO/10/G3/24	
	Crystalline Limestone		KO/10/G4/24	
	Chalcedony		KO/10/G5/24	
	Crystalline Limestone		KO/10/G6/24	
Total		20		



Figure 81 Side scraper (chert)- KO/10/A1/24, in field (left) and in lab (right)



Figure 82 Flake (crystalline limestone) - KO/13/A4/24, in field (left) and in lab (right)



Figure 83 Side scraper (chert) - KO/14/A1/24, in field (left) and in lab (right)



Figure 84 Flake (chert)- KO/14/A2/24, ventral view (left) and dorsal view (right)

V. CONCLUSION

Natural landform values of the karstic geomorphological landscape of West Gunung Sewu UNESCO Global Geopark (UGGp) that can be considered as potential prehistoric site are caves in a form of dissolution or sinkhole process. Especially, Gua Gabul (cave), which observed to have the best carbonate sample originally collected from stalagmitic floor, for this type of sample, application of U-series dating method could show the minimum age of the archaeological layer underneath (artefact bearing layer). Also, rock shelters located among karstic conical hills, that were formed by Wonosari-Punung Formation (Tmwp)'s limestone outcrop could also be considered to be studied on. Totally, there are 24 new potential prehistoric cave sites recorded in this research. Despite that, karstic alluvial lowland landform holds plenty of lithic remains or tool artefacts scattered on alluvial deposit in a total of 14 observation points were pinned, located, and analysed along Kali Oyo, despite that, they were all considered out of depositional, stratigraphic, and geochronological contextualization, which where we could not apply any absolute radiometric dating at all, to get the age when were these tools produced, used, and being left out. There are plenty well researched and established prehistoric sites in Gunung Sewu UGGp area, as mentioned in Chapter II, but mostly are situated and centralized in the East part, in this research, it is now proven that West part of Gunung Sewu UGGp holds and contains high potential also, viewing from the density, quality, and quantity of landforms that are suitable and highly prospective become former human settlement in the past.

In order to discover unexplored new potential prehistoric sites in the West part of Gunung Sewu UGGp area, the need of exploration and deeply comprehensive research of this area is crucially required. The potential to have a new age proposed by applying U-series dating, has a high chance. As observed on U-series dating results referencing to survey on Gua Tabuhan and Song Terus (East Gunung Sewu UGGp), earliest human occupation could stretch up to is 341 ± 41 ka (sample GT1000). As long as massive researches are being conduct, methods of dating and technology keeps on evolving and updating, determining an age for reconstructing the chronology of ancient human past life become more interesting with each new finding. Especially in this area, Gunung Sewu UGGp, which is famous to be known as the capital of prehistory in Southeast Asia.

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