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GEOLOGY AND THE ROCK SOURCES OF SIRIH TEMPLE, SUKOHARJO REGENCY, CENTRAL JAVA PROVINCE

Geologi dan Sumber Bahan Batuan Situs Candi Sirih, Kabupaten Sukoharjo, Provinsi Jawa Tengah

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Abstrak

Candi Sirih merupakan tinggalan budaya dari masa Hindu-Buddha, yang masih cukup lengkap yang terbuat dari batuan tufa, sehingga dianggap sebagai candi yang tidak umum di Pulau Jawa karena menggunakan batuan yang bukan andesit. Hal inilah yang menjadi pokok permasalahan pada penelitian ini, yang mencakup bahan batuan candi dan kondisi geologi secara umum. Maksud dan tujuan penelitian ini adalah pemetaan geologi untuk mengetahui gambaran keadaan lingkungan alam yang mencakup morfologi, litologi, struktur geologi, dan menentukan lokasi pengambilan sumber bahan batuan untuk pembangunan candi. Metode penelitian diawali dengan kajian pustaka, survei, dan dilanjutkan dengan analisis petrologi, dan interpretasi data. Hasil pengamatan lingkungan memberikan informasi tentang bentang alam yang termasuk pada satuan morfologi dataran, dan satuan morfologi bergelombang lemah. Pola pengeringan permukaan dendritik, radial, dan rektangular, stadia sungai dewasa-tua, dan sungai periodik/permanen. Batuan penyusun adalah aluvial, dan satuan batuan tufa serta struktur geologi berupa sesar normal. Penentuan lokasi bahan batuan tufa (kasar. halus, berlapis) dan serpih untuk pembangungan Candi Sirih berasal dari lingkungan sekitarnya dalam radius 3.5-kilometer bujursangkar.

***Kata Kunci*: *Geologi, Sukoharjo, candi hindu, sumber batuan*.**

Abstract

Sirih Temple is a cultural heritage from the Hindu-Buddhist era, which is still quite complete, made of tufa rock, so it is considered an unusual temple in Java because it uses non-andesite rocks. This is the main problem in this study, which includes the material of the temple rock and geological conditions in general. The purpose and objective of this research is geological mapping to determine the description of the state of the natural environment which includes morphology, lithology, geological structure, and determining the location of the source of rock material for the construction of the temple. The research method begins with a literature review, survey, and is followed by petrological analysis and data interpretation. The results of environmental observations provide information about the landscape that is included in the morphological units of the plains, and the weak wavy morphological units. Drying patterns of dendritic, radial, and rectangular surfaces, mature-old river stage, and periodic/permanent river. The constituent rocks are alluvial, and the tuff rock units and the geological structure are normal faults. The location of the tuff (coarse, fine, layered) and shale materials for the Sirih Temple construction came from the surrounding environment in a radius of 3.5 square kilometers.

Keywords: Geology, Sukoharjo, Hindu temples, rock sources.

INTRODUCTION

Sukoharjo is a regency of Central Java in the southern part, bordered by Special Region of Yogyakarta; it is located at 7°32’17.00” – 7°49’32.00” S and

110°42’06.79” – 110°57’33.70” E. The regency borders by Surakarta Municipality and Karanganyar Regency to the north, Karanganyar Regency to the west, Gunung Kidul (DIY) and Wonogiri Regency to the south, and Boyolali Regency and Klaten Regency to the east.

The regency’s area is 46,666 Ha, consisting of 12 districts and 167 villages/town councils. Polokarto district takes up the most of the area, accounting to 6.218 Ha, while Kartasura occupies the smallest part, 1923 Ha.

Sukoharjo has been researched on geologically and archeologically. Much of the archeological studies have centered in Karangnyar Village, whereas geological surveys have been all around Weru (Figure 1).

Sirih Temple – the legacy of Hindu-Buddhist period made of tuff rocks still in relatively good state – is located in Dukuh Kersan, Karanganyar Village, Weru District, of Sukoharjo. Most of the rock ruins are near the object, some are let scattered while others are well-assembled at some point (Tjahyono & Istari, 2018, pp. 1–21).

The site is in a neighborhood of the locals, in the hillside of the properties managed by a foundation called Baitiy Makmur Sukoharjo. It is the only temple across Sukoharjo being in the best shape,

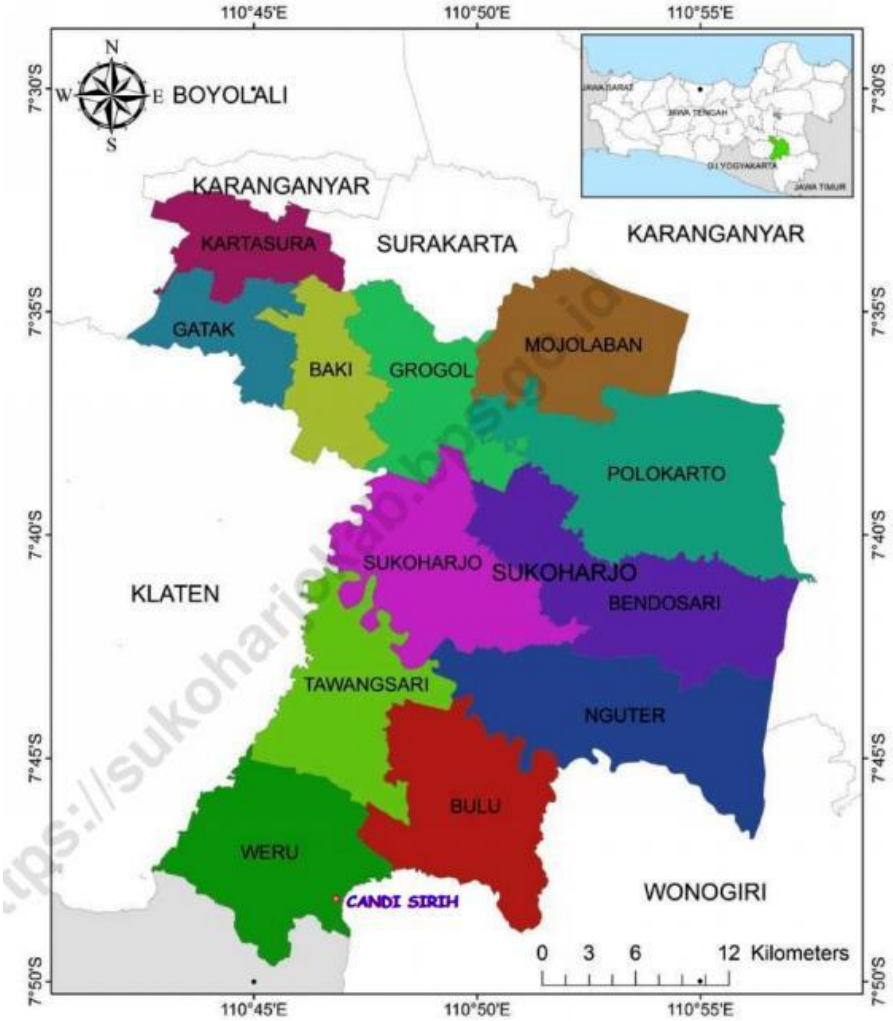

Figure 1: Location of Sirih Temple in the administrative area of Weru District, Sukoharjo, Central Java (**Source**: BPS Kabupaten Sukaharjo, 2020)

despite most of the rocks slipping off from the initial structures (Tjahyono & Istari, 2018, pp. 1–21).

Sirih is well kept, even in the absence of an officially appointed entity to care for it, courtesy of the local people's kind hearts. With most temples across Java constructed from andesite rocks or bricks, Sirih stands strikingly different: it was of tuff rocks. At the most, other temples simply had tuff rocks installed on their securing fence. The tendency to tuff rock over andesite rocks or bricks is of interest (Tjahyono & Istari, 2018, pp. 1–21).

A collaborative study was held by Education and Culture Agency of Sukoharjo and Archeological Center of Special Region of Yogyakarta in 2018, indicating that it was not a sole temple, but part of a larger compound or complex: a main temple facing three perwara temples securing by safety fence. It is in line with the mainstream practice of eighth – ninth century Hindu-Central Java: where a complex was divided into three sections, with the most sacred part being in the middle. The joint endeavor indicated the west orientation of the temple. One thing to remember is that further steps need taking concerning validating the observation results; parts of the temple are still buried deep in the ground (Tjahyono & Istari, 2018, pp. 1–21).

The research questions this study seeks to answers are: a) How is the landscape of the researched location? b) What is the stratigraphy of the location like? and c) How is the geological structure of the location.

Sukoharjo is indicated in such maps as Peta Rupa Bumi Indonesia Lembar Manyaran (1408-323/Edisi-I/2001), with a scale of 1:25,000, Peta Geologi Lembar Surakarta (1408-3) and Giritontro (1407-6), with a scale of 1:100,000. It can be accessed by two-wheel or four-wheel vehicles. The data presented here were from 2019's study by the writer, in collaboration with Archeological Center of Special Region of Yogyakarta (Balai Arkeologi Daerah Istimewa Yogyakarta).

METHOD

The literature reviews on this study covered gathering information through related previous studies, books, journals and internet links; and surveys were conducted to observe geomorphology, lithology, geological structures as well as detecting the rock sources. The following are detailed phases of the study.

1. Geomorphology, a study of the landforms of the earth using a system developed by Desaunettes (Desaunettes, 1977, p. 111; Todd, 1980, p. 560), based on the slope and high relief of a place. It is also relative to surface drainage pattern covering water quantity, river flow, and river transformation stadiums.
2. Lithology or description of the physical characteristics of a rock of an area generally identified through petrological analysis. The analysis concerns with rock types, rock colors, mineral composition, rock textures, rock structures, form and size of fragments, matrix and cement.
3. Geological structure, a field examination on the form of the earth following deformation, including fault, fold, and joint.
4. Determining the rock sources through petrological analysis.

The literature review results were coupled with field search, resulting in the discussion presented here.

RESULT AND DISCUSSION

1. Geology of Sirih Temple Region

Sirih Temple was discussed geologically in details in the following.

a. Geomorphology

North Serayu Mountain and South Serayu Mountain are two main components of the mountains of Central Java, where Bogor Zone and Kendengan Mountain are

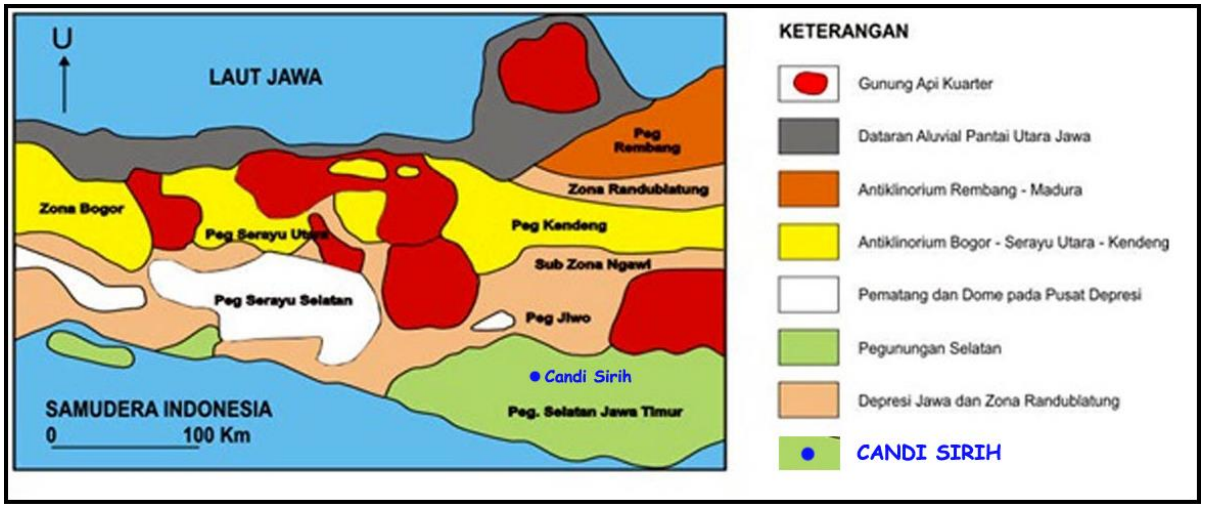

Figure 2: Central Java Physiography Division (**Source**: Bemmelen, 1949)

connected by North Serayu Mountain. Bandung Depression Zone, meanwhile, forms South Serayu Mountain (Bemmelan, 1946, p. 732). Central Java Depression Zone stretching from Majenang, Ajibarang, Purwokerto, Jatilawang, to Wonosobo is the link between South Serayu Mountain and that of the north. The span of distance between Purwokerto and Banjarnegara is about 15 kilometers, but it gets wider in Wonosobo area where Sindoro Mountain (3115 m) and Sumbing Mountain stand (3317 m). The Zone comes back to observation around Temanggung area and Magelang (Bemmelan, 1946, p. 732).

The Central Java is divided into seven categories in terms of physiography: 1) Volcano Quarter; 2) Alluvial Plain of North Coast of Java; 3) Rembang-Madura Anticlinorum; 4) North Serayu Anticlinorum-Kendeng; 5) Pematang Dome on Depression Center; 6) South Mountain and; 7) Java Depression and Randublatung Zone (Bemmelan, 1946, p. 732). Based on the presented categories, Sirih Temple is encompassed in the South Mountain Zone stretching from Yogyakarta, Wonosari, Wonogiri, Pacitan, South Malang and Blambangan, characterized by a landscape of mountain of west-east orientation of volcanic materials (Mulyaningsih, 2016, pp. 77–94; Mulyaningsih, Husadani, Sanyoto, & Purnamawati, 2011, pp. 64–78; Prasetyadi, 2007, pp. 91–107; Triana, 2013, pp. 10–27).

Figure 3: Plain Morphology Unit at the researched area (**Source**: Balar DIY, 2019)

Figure 4: Wavy Morphological Unit at the researched area (**Source**: Balar DIY, 2019)

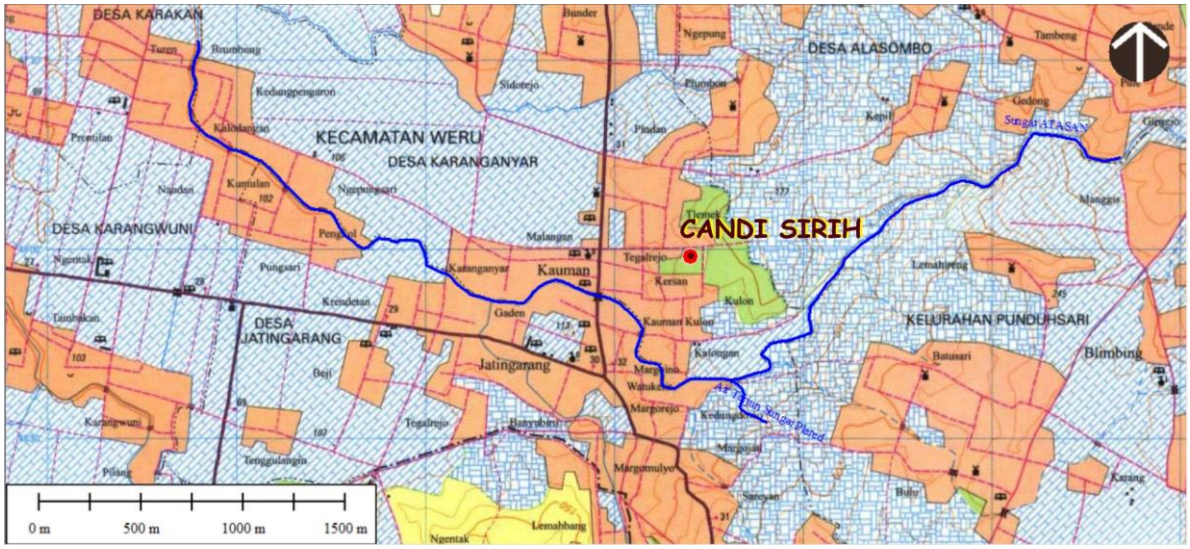

Figure 5: Atasan River (blue line), being the main river with east-west flow, to the south of Sirih Temple as indicated on *Peta Rupa Bumi Indonesia Lembar Manyaran*, *1408-323, Edisi-I/2001*, with a scale of 1:25,000. (**Source**: Bakosurtanal, 2001)

Figure 6: Kedungguling River, to the east of Sirih Temple (**Source**: Balar DIY, 2019)

Figure 7: Kedungdowo River, to the south of Sirih Temple (**Source**: Balar DIY, 2019)

The landscapes of a territory are the consequences of four aspects: lithology, geological structures, area stages, and erosive level (Thornbury, 1964, p. 594). The morphology of Sirih Temple can be split into the following details (Desaunettes, 1977, p. 111; Todd, 1980, p. 560).

a) Plain Morphological Unit with a slope percentage range of 0-2%, characterized by flat and highly sloping texture, greatly fit for settlement and agricultural purposes (Figure 3).

b) Wavy Morphological Unit with a slope percentage range of 2-8%, characterized by sloping hill, soft reliefs and vast valley, suitable for settlement and forest (Figure 4).

Surface drainage pattern runs through, following the landscape of the area. The main river flowing around the surveyed area is Kali Atasan (the name tagged in Peta Rupa bumi) (Figure 5), with east-west orientation. Locally the river is also referred to as Kedungguling River (Figure 6), or Kedungdowo River (Figure 7), Platar River, Kauman Kauman and some others. Other

small rivers streaming in the area are Plered, Margoino, Atas Aji, Sidorejo, Ngepung, Plumbon, Jatingarang, and some others unnamed.

Most of the rivers at the researched area are under the category of old-mature river (Lobeck, 1939, p. 731; Thornbury, 1964, p. 594); their drying pattern can be counted as dendritic, radial and rectangular. On water volume side of things, the rivers are considered periodic and permanent (Lobeck, 1939, p. 731; Thornbury, 1964, p. 594).

b. Stratigraphy

The rocks forming the researched area and its neighboring ones are tuff and alluvial rocks, with the following details:

Alluvial, consisting of clay, silt, sand, gravel, pebble, and cobble (Figure 9), is a result of weathering, being easily found in the rivers and other plain morphological units, dating to Holocen period (Intan, 2019).

Tuff Rock Unit, The tuff rocks observed at the area being researched on are:

a) **Tuff** (**rough**) including sediment rocks with fresh yellowish white color which turn into brownish yellow when weathering, being rudite in texture. It is non-stratified, good sorted, sub-rounded, being 2-4 mm in granule. The main minerals contained are kuarsa, feldspasd, volcanic glass (Intan, 2019). Rough tuff is in the category of volcanic sediment (pyroclastic) (Huang, 1962, p. 480) (Figure 10).

b) **Tuff** (**smooth**) including sediment rocks with fresh yellowish white color which turn into brownish yellow when weathering, being lutite in texture. It is stratified, mild sorted, sub-rounded, the grain of which is 1/256 - 1/16 mm. The main minerals contained are kuarsa, feldspasd, volcanic glass (Intan, 2019). Smooth tuff is under the categry of volcanic sediment (*pyroclastic*) (Huang, 1962, p. 480) (Figure 11).

c) **Shale** including sediment rocks with fresh grey color which turn into brownish grey when weathering, being lutite in texture. The grain is very fine silt (1/128 - 1/256 mm), mild sorted and rounded-subrounded. It is thin-stratified, with the dominant minerals like kuarsa, feldspar, clay, and iron oxide (Intan, 2019). It belongs to mechanic sediment (epyclastic) (Huang, 1962, p. 480) (Figure 12).

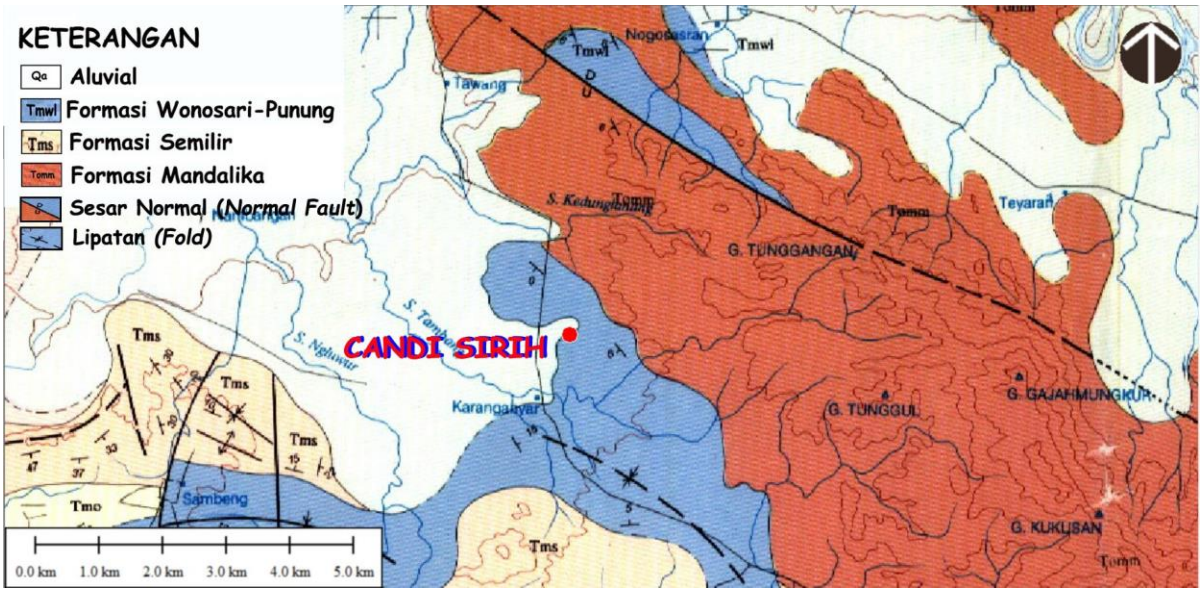

Figure 8: Regional Map of the researched area (**Source**: Surono, B. Toha, I. Sudarno 1992)

Figure 9: Alluvial sediment at the researched area, used for agricultural purposes (**Source**: Balar DIY, 2019)

Figure 10: Tuff rocks (rough) in Kedungguling River (**Source**: Balar DIY, 2019)

Figure 11: Smooth Tuff in Kedungdowo River (**Source**: Balar DIY, 2019)

Figure 12: Shale Tuff at Dusun Kersan (**Source**: Balar DIY, 2019)

The age of tuff rock unit is measured from rock formation, area condition and lithology features, while considering the stratigraphy of Indonesia. A conclusion to be drawn thus far is that tuff unit can be discussed with those of Semilir Formation from Surono et al. (1992, p. 1), Surono (2008, pp. 28–41), Surono (2009, pp. 209–221), consisting of tuff, dacite pumice breccia, tuff sand rock and shale. With the comparison, it is safe to say that tuff roks at the researched area date to early Miocene (20-16 cal BP), from shallow sea to become plain area land). The thickness of Semilir Formation is 460 m, being located in the south of Klaten.

c. Geological Structure

The island of Java experienced three tectonic periods in Tertiary era resulting in fold and fault zone, indicating compression force of north-south orientation. The three periods include: 1) Upper Miocene tectonic period (Mio-Pliocene); 2) Upper Pliocene tectonic period (Plio-Plistocene) and; 3) Holocene tectonic (Bemmelan, 1946, p. 732).

The south mountain zone is a basin, moving from west to east, from Parangtritis to Parwo. It is a convergent point of Hindia-Australia plate and Micro Sunda plate (Daniel, 2011, p. 146; Subagio, 2018, pp. 187–200; Triana, 2013, pp. 1–27). Java is one of the islands in Sunda arch with the most active geodynamics. Evolution-wise, Java's tectonic evolution can be broken down into the following. a) Last lime period – Paleocene; b) Eocene period; c) Middle Oligocene period; d) Oligo-Miocene period

Figure 13: Water fall is a sign of normal fault, Figure taken at Dusun Kedungdowo, Desa Jatingarang, Kecamatan Weru (**Source**: Balar DIY, 2019)

and; e) Middle Miocene period – Late Miocene (Prasetyadi, 2007, p. 323). Sirih Temple area belongs to the fourth period, the Oligo-Miocene, drastic decline in movement to the north of India and Australia, caused by hard collision between India and Asia, later forming the Himalaya Mountain (Prasetyadi, 2007, p. 323).

Field examination confirmed that the geological structures around the researched area are fault, judging from the strikes and dips of stratification, fault scarps, crumble zone and milonitisation, fault breccia, slickenside, river bend od 90°, and the shift of rock stratification (Intan, 2019, pp. 1–20). In light of the observation on the field, it is of normal fault type (Biling, 1972, p. 514; Intan, 2019, pp. 1–20; Ragan & Donal, 2009, p. 602).

2. Sirih Temple

Sirih Temple (Figure 14) is an administrative part of Dusun Kersan, Karanganyar Village, Weru District of Sukoharjo, located at 07°48'01,2" S, 110°46'41,8" E, being 137 m above sea

Figure 14: Sirih Temple facing west (**Source**: Balar DIY, 2019)

Figure 15: Components of Sirih Temple made of rough tuff rocks (**Source**: Balar DIY, 2019)

Figure 16: Components of Sirih Temple made of smooth stratified tuffs (**Source**: Balar DIY, 2019)

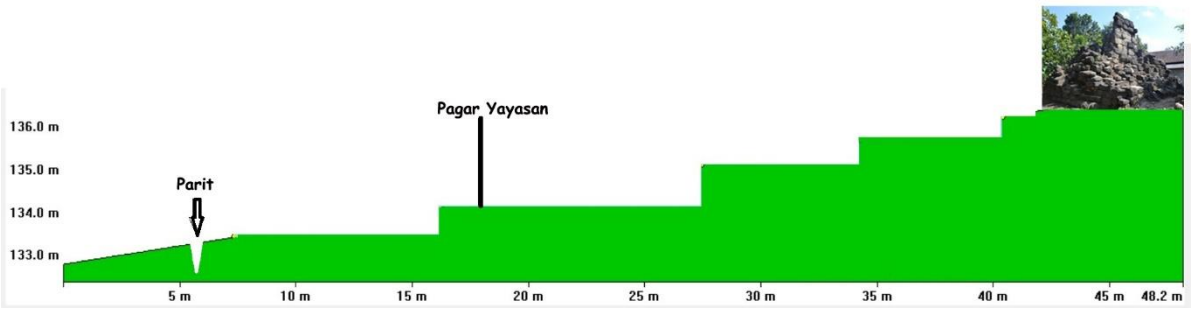

Figure 17: The westward face indicates four steps, with the foundation fence on the third one. (**Source:** Intan, 2019; Topographical data of Jarvis et al. 2008)

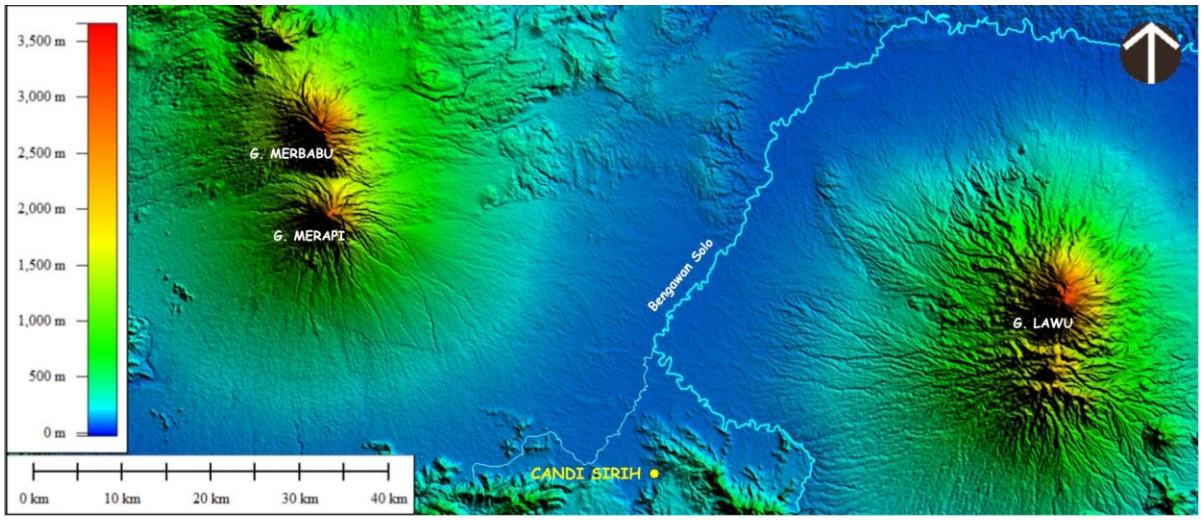

Figure 18: Two-dimensional picture of Sirih Temple and the landscape nearby (**Source:** Intan, 2019; Topographical Data of Jarvis et al. 2008)

level. It is made of rough tuffs (Figure 15), stratified smooth ones (Figure 16), and shale tuffs. Petrological analysis is presented on sub-chapter "Stratigraphy".

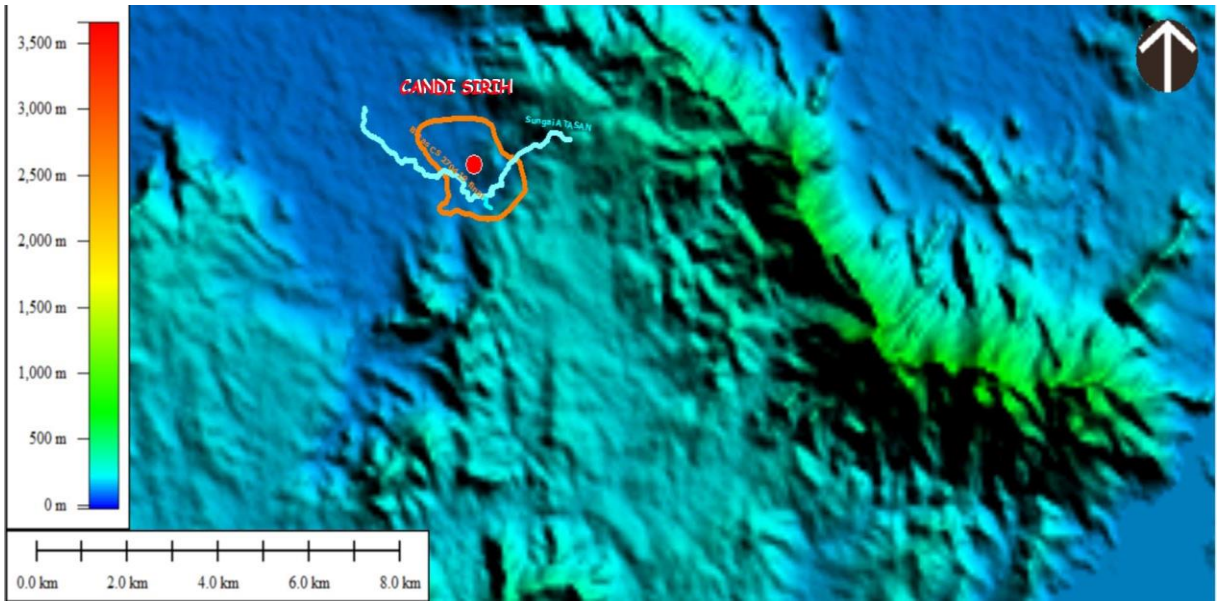

Figure 19: Three-dimensional picture of Sirih Temple and the landscape nearby (**Source:** Intan, 2019; Topographical Data of Jarvis et al. 2008)

As can be seen on Figure 17, Sirih Temple faces west with four steps. The Chandra statue being identified in one of the excavation boxes, Sirih is officially considered a Hindu temple.

On regional spectrum, the temple is located between Merapi volcano-Merbabu volcano to the west, Lawu volcano to the east, and Bengawan Solo comes between them all. It sits on the hill of South Mountain Zone (Jarvis, Nelson, & Guevara, 2008) (Figure 18 and Figure 19).

3. Rock Sources

The two main components of a temple comprise rocks and bricks; the former are mostly from andesite and tuff

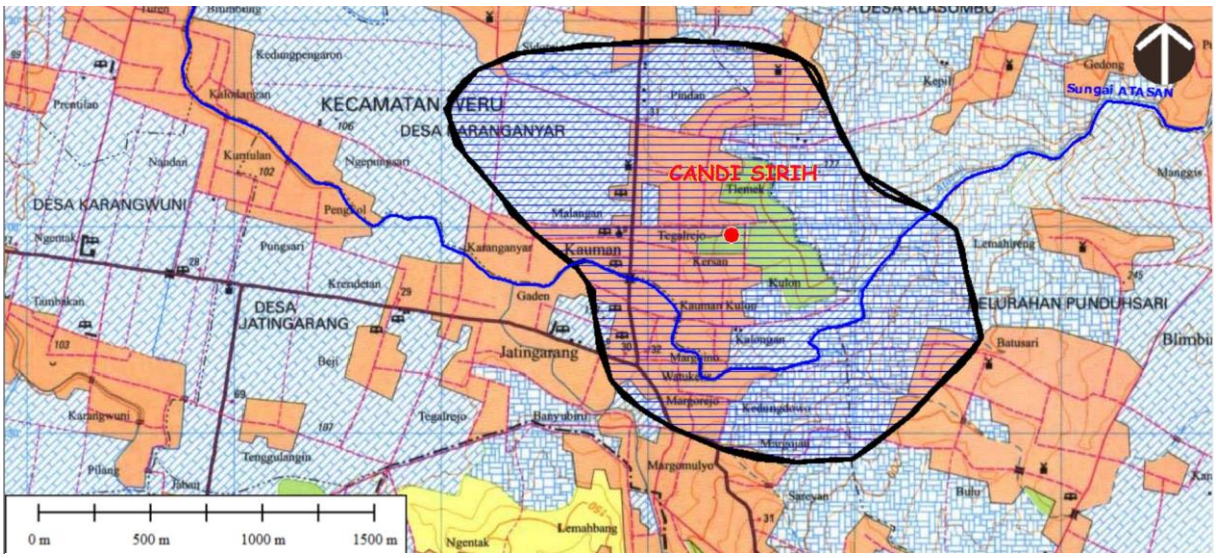

Figure 20: The layout of tuff rock souces taken into building of Sirih Temple according to *Peta Rupa Bumi Indonesia* (**Source**: Bakosurtanal, 2001)

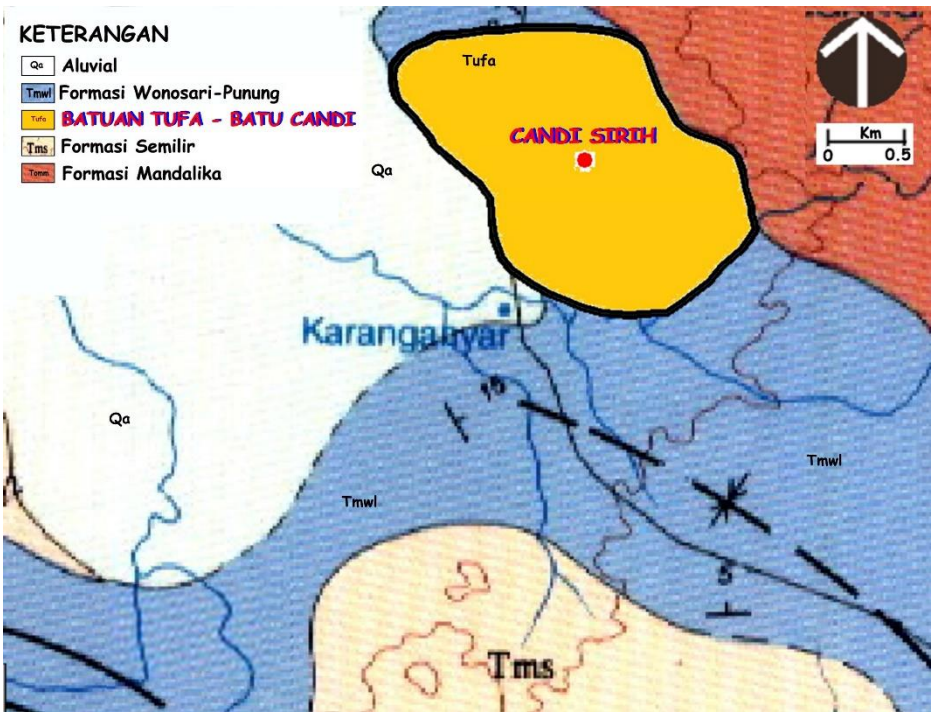

Figure 21: Detailed geological map of Sirih and its surrounding compounds (**Source**: Surono, B. Toha, I. Sudarno 1992)

rocks. Andesite rocks are more solid than tuffs.

Petrological analysis identified the types and names of the rocks making the temple. The analysis being through, the writer embarked on the survey around the location, in search of the sources from which the rocks were transported.

Speaking of regional geological map (see Figure 10), the area of research is on Wonosari-Punung Formation (limestone unit), bordered by alluvial unit; which requires the employment of micro scale.

Having covered the whole are from where the temple sits to other areas significant in the building process, it is found out convincingly that Sirih was made of tuff rocks, and so were its surrounding compounds (Figure 20), comparable to Semilir Formation as laid out by (2008, pp. 28–41, 2009, pp. 209–221).

The area about 5 square km having been examined, it is indicated that the three types of tuff rocks (rough, smooth, stratified) occupies an area of about 3.5 square km. The distinctive borders of tuff sources used at Sirih compound is shown in (Figure 21).

CONCLUSION

Sirih Temple was built on the plain morphological unit (0-2%), and weak wavy morphological unit (2-8%), sitting 110 - 170 meters above sea level. The surface drainage consists of Atasan River as the main river and other smaller rivers (confluent) of old-mature river stadium. Dendritic, radial, rectangular and periodic/permanent are some of the natural features on the streaming rivers. The surrounding compounds date to early Miocene (tuff) and Holocene (alluvial), with geological structures being normal fault.

The long-held view that all temples in Java were made of andesite rocks has been proven wrong this time: Sirih Temple had tuffs in the structures. The truth having been spoken. andesite rocks are more resilient to weathering as compared to tuffs. It is important to notice that people of the past did not insist on building a monument by using

certainly fixed material; a local wisdom they left behind insisted that existing materials be employed to the greatest extent.

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