INDONESIAN JOURNAL ON GEOSCIENCE
Geological Agency
Ministry of Energy and Mineral Resources

Journal homepage: http://ijog.geologi.esdm.go.id
ISSN 2355-9314, e-ISSN 2355-9306

The Ancient Borobudur Lake, History, and Its Evidences to Develop Geo-archeotourism in Indonesia

Helmy Murwanto[1] and Ananta Purwoarminta[2]

[1]Faculty of Mineral Technology, UPN "Veteran" Yogyakarta, Indonesia
Jln. SWK 104, Condongcatur, Kabupaten Sleman, Daerah Istimewa Yogyakarta
[2]Research Center for Geotechnology, Indonesian Institute of Sciences,
Jln. Sangkuriang, Kompleks LIPI, Bandung, Indonesia 40135

Corresponding author: ananta.purwoarminta@lipi.go.id
Manuscript received: October 23, 2017; revised: June 22, 2018;
approved: February 7, 2019; available online: April, 04, 2019

Abstract - In 2015, the number of international tourists who visited Borobudur temple declined and did not reach the government target. It was because there was only one attraction in the temple. After visiting Borobudur, most of tourists move to another place such as Yogyakarta. They know about the temple, but not its past environment when the temple was built. The history and past environment of Borobudur temple could be developed as additional tourist attractions to make them stay longer in that area. Geological condition and the evidences of an ancient lake could be developed as tourist objects. It is very interesting and could be developed to educate visitors in geo-archeology. The aim of this research is to develop archeological (temple) tourism based on geology and past environment. Although many researches on geo-archeology have been done, the results which relate to tourism are still not widely applied yet. The methods used are secondary data analysis and a field survey to investigate the potential of tourist stop sites. The potential tourist attractions were determined by geomorphology, lithology outcrops, stratigraphy, environment, and accessibility. The result is ten stop sites which could be used to describe the paleoenvironment in Borobudur based on geosciences. These tourist objects could explain the environment in the past related to the temple reliefs and ancient human activities.

Keywords: ancient lake, geo-archeology, tourism, Borobudur

How to cite this article:
Murwanto, H. and Purwoarminta A., 2019. The Ancient Borobudur Lake, History, and Its Evidences to Develop Geo-archeotourism in Indonesia. *Indonesian Journal on Geoscience*, 6 (1), p.103-113. DOI: 10.17014/ijog.6.1.103-113

Introduction

Tourism is currently being explored and developed by the Indonesian Government by further developing existing tourisms and seeking new locations. Tourism is expected to boost the government income and increase the social welfare. The number of visitors at many tourist destinations are now decreasing, and their development appear to be stagnant, because there is nothing new to deliver from the locations. This has an impact on the economy of the surrounding communities.

UNESCO has established this temple as a world cultural heritage site in 1991, and consequently the temple becomes more well known worldwide. The beauty of the temple attracts many tourists, both

foreign and domestic. In 2015, the number of foreign tourists visiting Borobudur temple declined or did not reach the expected target. The report from P.T. Taman Wisata Candi Borobudur (2015) stated that the cause of the decline in tourist arrivals was the world economic crisis. The tourism problem in Borobudur is that most of tourists did not stay long and tend to choose another place, because they have changed their interest in another kind of tourism (P.T. Taman Wisata Candi Borobudur, Prambanan, and Boko, 2015). Based on traveler trend interest, one of the efforts to enhance the Borobudur tourism is by relating the temple as an archaeological object to the surrounding environment, and its change in time (*i.e.* emphasize the geological aspects of the area).

Borobudur temple is located between 110°05' - 110°20' East Longitude and 7°30'-7°38' South Latitude in Magelang Regency, Central Java. The temple site is located in a basin, surrounded by some volcanoes and hills, such as Mount Sindoro, Sumbing, Merbabu,Merapi, Menoreh, and Mount Tidar. Borobudur was built in the eight to ninth centuries and rediscovered then by Raffles in 1814 who found it falling into gentle ruin (Tanudirjo, 1991). Previous studies stated that the past environment of Borobudur plain was a lake, and the temple was built on a hill in the centre of the lake (Nieuwenkamp, 1933; Nossin and Voute, 1986). Although the existence of the ancient lake was not described in the inscriptions, lacustrine sediment (black clay) is found very thick and large in some areas of Borobudur plain (Murwanto *et al*., 2004; Murwanto, 2014; Murwanto *et al*., 2015a).

The ancient lake began to dry in eight centuries (Murwanto *et al.*, 2004). due to the combination of tectonic, volcanic, and anthropogenic activities (Murwanto, 2014). Even though the lake (surface water) has strong correlation with climate, the shallowing of the lake is not only linked to local or global climatic variations, but also to non-climatic influences, such as tectonic activities, changes in local catchment morphology, and human activities (Coulthard *et al*., 2005; Dietze *et al*., 2010; Zhang *et al*., 2013;Wünnemann *et al*., 2015). Gomez *et al*. (2010) stated that the hydrographic network in Borobudur was strongly disrupted by volcanic activities, generating an alternation of fluvial and lacustrine settings in the basin. Tectonic evidence shows non-surface morphology and river pattern creates a beautiful view. Environment influences human activities, and it makes people adjusted to surrounding condition (Rodning, 2010). This also occurred in the past where the ancient humans chose Borobudur area for living. Environment is always related to geological situation, and people then depicted/ described their environment and activities on the reliefs of the Borobudur temple.

Many reliefs on temple panels depict water environment indicating that there was a swamp near the temple. The temple past environment has not yet been introduced to travelers. The relation of geology and archeology is very interesting, and may develop and improve Borobudur tourism. The aim of this research is to increase tourist attractions based on geosciences where this is not widely applied yet in Indonesia. The biggest expectation is to create Borobudur as Geo-archeoscience Park for education and tourism.

Methods

The research used many secondary data comprising geology, hydrology, pollen, and carbon dating which were validated by the field survey in 2013. Many maps and satellite images were analyzed, such as Indonesia base maps, geological maps, Aster GDEM, Landsat, and Google Earth to identify detailed morphology and geology as indicators of paleoenvironment. Pollen analysis was used to provide paleoecological information (Fletcher *et al*., 2007). The pollen analysis was conducted in the Centre for Geological Survey, Bandung, Indonesia. Maps and satellite images were analyzed using ArcGIS 10. Then the field survey was conducted to investigate the field condition and to choose tourism sites. Tourist destinations were determined based on geomorphology, lithology, stratigraphy, environment, and accessibility. Paleolake sediment and silt process sites could give

more explanations to make the tourists understand and easy to imagine the paleoenvironment.

Results and Discussions

The evidences of the ancient lake around Borobudur temple could be revealed by geomorphological features and lacustrine sediment outcrops as well as the pollen analysis. Borobudur Lake shallowing process could describe that lake sediment outcrops were overlain by Mount Merapi materials, Menoreh Hill materials, and tectonic activities. Those outcrops could be used to develop geoarchelogical tourism related to the temple. There are ten sites on the map below as tourist destinations (Figure 1).

Progo-Elo River Confluences

The Progo-Elo River intersection area is found as lacustrine sediment outcrops (black clay) (Figure 2) overlain by lahar materials of Mount Merapi. It shows that in the past, the area was a swamp, then became shallower due to lahar flows. The swamp availability in this area is predicted only one period, because a high volcanic intensity produced large lahar materials filling in the lake.

Sileng River (Black Clay and Salt Spring)

Sileng River is located between Borobudur temple and Menoreh Mountain. In the river valleys, black clay sediment is found in more than 2 m thick. The carbon dating record shows that the swamp sediment age is 25,110±560 yrs. (Murwanto and Purwoarminta, 2015). Based on the pollen analysis, the sediment contains *Commelina sp, Cyperaceae, Gramineae*, *Amaranthaceae, Nuphar sp., and Nymphaea sp.* In the Sileng River valley, there is also tectonic activity trails which is shown by folded and faulted black clay (Figure 3).

In Sileng River, salty water spring is also found which is identical to seawater. The spring is very attracting with electric conductivity (EC)

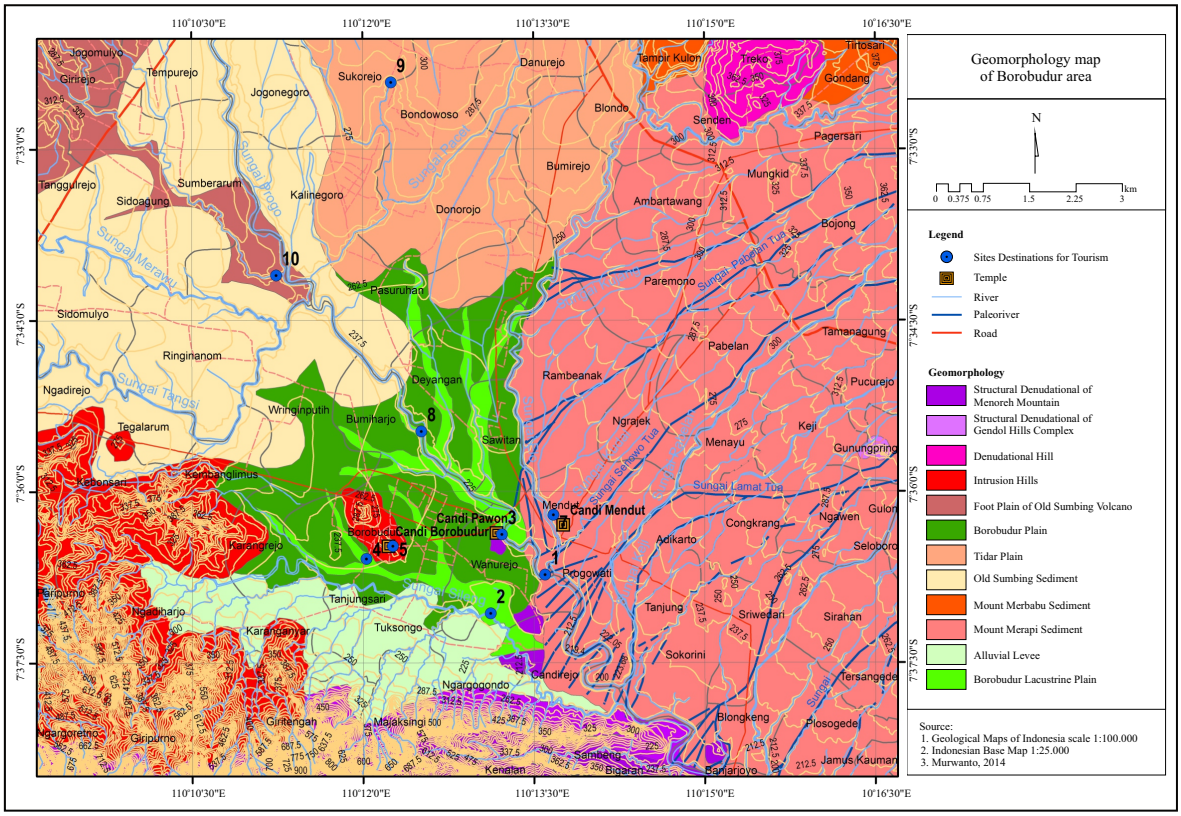

Figure 1. Locations of tourist destinations on Geomorphological Map of Borobudur.

Figure 2. Lacustrine sediments (black clay) in Progo-Elo intersection.

up to 33.8 mS/m (salty). The emergence of this spring becomes an interesting question and can be answered by a geological analysis. In general, the tectonic factor had a strong role for the emergence of this spring to the surface. Drilling data show that the salty water blows out at 90 m depth (Murwanto (2001). This indicates that salty water layer is situated at that depth. There is also gas bubbles in the spring that indicates it is controlled by tectonic (Figure 4). Salty water can only come out to the surface through any media, and one of which is fault. The lineaments of this area cause the community wells to be brackish.

Pawon Temple and Progo River

Pawon temple is located in Progo riverside with a low hill morphology. This location could become a tourist stop site, because lake sediment outcrops are found in the river cliff. The basement

Figure 3. Faulted black clay sediments on Sileng River.

Figure 4. (Left) Sileng River with fault structure cutting Tertiary Old Breccia "OAF".(Right) Salty spring water outflows through joint and fault followed by swamp gas (Murwanto, 2014).

of this area is composed of "OAF" Tertiary breccia, part of Menoreh Mountain which is faulted. The breccia is unconformably overlain by lake sediments (Figure 5). Based on the pollen analysis, the lake sediments contain *Commelina* sp., *Cyperaceae, Gramineae*, and *Labiateae*. The pollen was deposited in a fresh a water environment (Figure 6). Based on the pollen type, it could be estimated that the sample was located in an shallow swamp. Carbon dating ^{14}C describes that the sediment age is 27,070±710 yrs. with sample location was in 12 m depth.

Borobudur Lacustrine and Toponym

This location is a paleo-swamp valley that is currently used by the community for agriculture. The beautiful landscape is accompanied by meandering valley with Borobudur temple in the north (Figure 7). In this area, swamp deposit is found at 1-3 m depth with aged 1,700 + 160 yrs. The paleo-environment makes people name this areas with water environment toponym, such as *Bumisegara* (*bumi*: land and *segara*: sea), *Sabrangrawa* (across the swamp), and *Gopalan* (*nggo*: use, *kapalan*: ship/boat). Toponym has

Figure 5. (Left) Outcrops of Tertiary Old Andesit Formation (OAF) overlain by Quaternary lake sediments. (Right) Black clay of Borobudur Lake sediments is cut by joints.

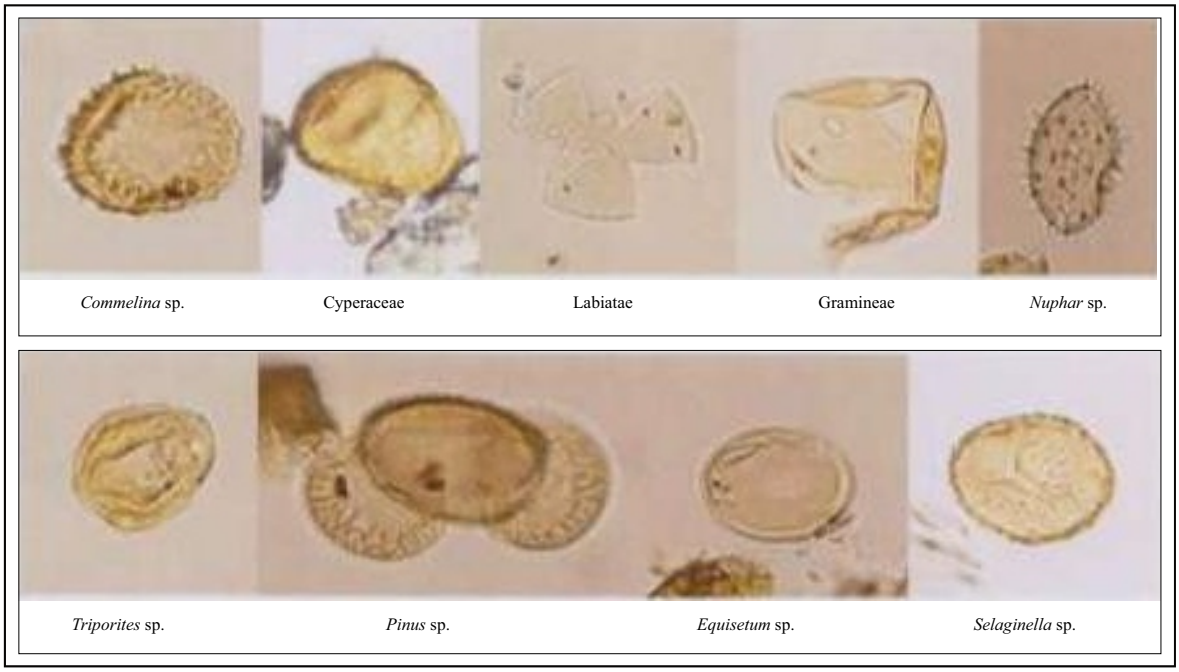

Figure 6. Photomicrographs of pollen contained within lake sediments in Progo River near Pawon Temple (Laboratory Analysis, 2013).

Figure 7. Ancient swamp environment between Sabrangrawa and Bumisegara Village.

relevance with the environment (Zhu *et al*., 2018), both in the past and present.

Borobudur Temple

The Borobudur temple was built in an intrusion hill with bed rock of andesitic breccia in a strong alteration. The hill evelation is 250 m asl. surrounded by plain of paleo-swamp. The view from Borobudur Hill shows that the temple is surrounded by a large plain and bordered by mountains. Borobudur temple has reliefs with the total length of 2,500 m and 1,460 narrative panels (Gunarto, 2007). The swamp availability is also shown at many panels on the temple walls. The ancient lake environment around the Borobudur temple was interpreted by Munandar (2012), and is depicted on the panel No. 147 (Figure 8) of the temple wall. The reliefs show that the pond is filled with lotus flowers near the temple. The pond was depicted vertically, so the pond itself does not look impressive. However, since the lotus is usually associated with lakes, the association of the temple and the lake becomes very closely correlated.

An overview on the existence of the lake was carried over by Miksic (1991). The interpretation is based on Awadana relief at Borobudur temple which describes that Kinnaras Manohara was bathing in the lake and standing on a lotus which was situated on the lake (Figure 9). This illustrates that the paleo-environment around the temple was a pond or lake with lotus flowers growing on it. These data are strongly supported by the existence of the lake around Borobudur temple.

The existence of lotus on the temple reliefs is corroborated by palynology evidence, as the sediments contain pollen *Nymphaea sp*. which derived from lotus. Lotus (*Nymphaea*) is a plant that grows in calm water environments, such as lakes, swamps, or ponds. Based on the pollen, it is known that the environment around Borobudur was aqueous as depicted in the reliefs. Therefore, there is a strong correlation between the stories sculpted on the reliefs on the temple walls and the geological evidence obtained from the surrounding areas.

Menoreh Mountain as Natural Dam

Menoreh Mountain is located in the south of Borobudur temple which is composed of "OAF" Tertiary breccia. Menoreh is a product of Tertiary volcanic activities. The mountain was faulted,

Figure 8. Karmawibhangga reliefs at Panel No. 147 in the temple footwalls illustrating lotus flower in the middle of the pond (Munandar, 2012).

Figure 9. Awadana relief on Jataka wall level one just below panel network, No. 1 illustrates Kinnara Manohara was bathing in the lake and standing on lotus flowers (Photo: Miksic, 1991).

and in some parts form hilly morphology *i.e*. Borobudur Hill, Pawon Hill, Blongkeng Hill, and Gunung Lemah Hill. The tectonic products make Menoreh has a beautiful view with steep morphology (Figure 10).

Progo River flows are controlled by tectonic, and flowing between Menoreh Mountain and Blongkeng Hill which is part of Menoreh. In this segment, the channel is narrow causing river water flow slowly and leads to an inundation in Borobudur area. This segment is as outlets of the Borobudur Lake. The narrow channel made colonial goverment build a bridge in this part, then opened the outlet and made water flow fast. The river shows the cliff with human influence. The opened lake outlet made Borobudur Lake dry. Thus, this area could be used as a tourist destination to explain the drying process of the lake.

Figure 10. The beauty of Menoreh right lateral transform fault can be defined as a tourist destination in the east side of Menoreh or southeast of Borobudur temple.

Mendut Temple and Elo River

The Mendut temple is located between Elo River and paleoriver of Pabelan. This area is composed of lahar of Mount Merapi (Figure 11). Lacustrine sediments were buried by lahar materials which were shown in the Elo riverside. This location is an intersection of Elo River and paleoriver of Pabelan with Mount Merapi as the upstream. Mendut temple wall reliefs depict animals of the water environment, such as crocodile and stork bird (Figure 12). This indicates that the environment around Mendut temple is large water like a swamp or lake.

Progo River in Sigug Village

Lacustrine sediment outcrops are found in Progo River, Sigug Village. The lake sediments are characterized by more than 25 m thick of volcanic materials (Figure 13). The tectonic activities were controlled by the river flow. The pollen analysis result shows that this swamp

Figure 11. Lahar flows of Mount Merapi in Elo River, west part of Mendut temple.

Figure 12. Reliefs of Mendut temple depict crocodile and stork bird life.

Figure 13. Black clay sediments in Progo River overlain by volcanic materials.

sediments contain *Commelina sp.,* Cyperaceae, Gramineae, *Amaranthaceae,* and *Nuphar* sp. (Figure 14; Murwanto and Purwoarminta, 2015b; *in*: Kanki *et al*., 2015).

Gending Spring

The Gending spring is located in Magelang City which is a foot slope of Tidar Hill. The spring has a large discharge and is presumed as a source of Borobudur swamp water (Figure 15). The water flows through Gending River then meets Progo River.

Warm Spring in Teluk

A warm spring is found in Kasuran, Sumberarum Village, northwest of the Borobudur temple (Figure 16). Based on a field survey in 2013, the spring has discharged water around 0.5 l/ sec, with electrical conductivity (EC) 2.7 mS/m and the temperature of 34.9^{o} C. The high temperature of the spring associates with tectonic activities (Cox *et al*., 2016) which are also responsible for the outflows.

Conclusions

Borobudur temple has the grandeur of history and culture. That is why it becomes a UNESCO World Heritage site and an international tourist destination. The geological data related to the environment around Borobudur temple can be used as the basis to relate its history to the local community and to tourism. The ancient lake environment history has been substantiated by the existence of lacustrine sediments (geology), geomorphology, hydrology, toponym, and the reliefs sculpted on Borobudur temple. Traces of Borobudur ancient lake can assist the development of tourism activities with geosciences. When these data are wrapped up into a tourism package with an interesting story, it may attract more attention of tourism. The relationship between the temple as a whole and its surrounding environment can be a very attractive composition for tourists. For this reason, the tourism development should be combined with geological (geo) and archaeological aspects into one package called "Geo-archeotourism".

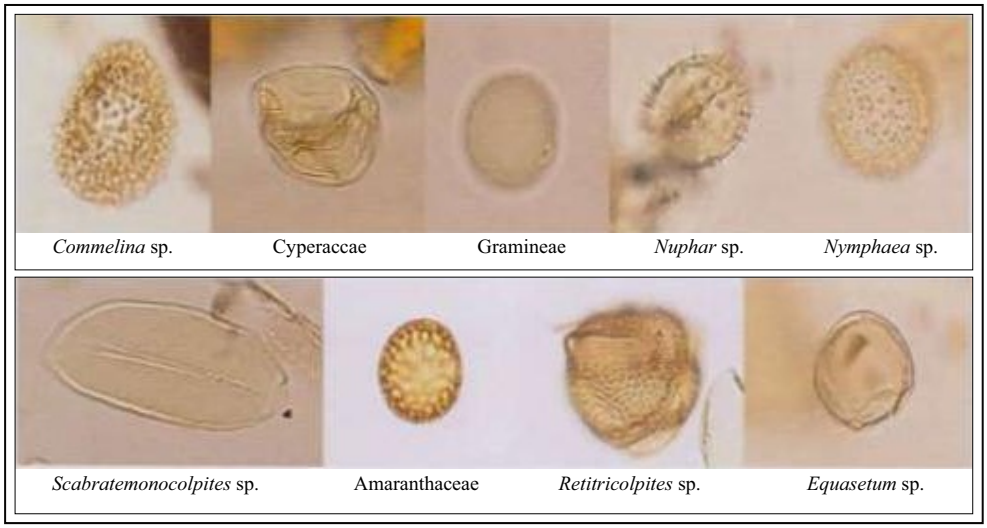

Figure 14. Photomicrographs of pollen of swamp plant in Progo River.

Figure 15. Gending spring in a foot slope of Tidar Hill.

Figure 16. Warm and salty springs with swamp gas bubble in Teluk, Kasuran Village, Tempuran District.

Acknowledgements

The authors would like to thank the University of Pembangunan National "Veteran" Yogyakarta and Research Center for Geotechnology LIPI, which gave us a trust and an opportunity to conduct this research. The authors also would like to express special thanks to Prof.

Dr. Sutikno and Prof. Dr. Sunarto (Faculty of Geography, UGM), Prof. Dr. Sutanto, DEA, (UPN "Veteran" Yogyakarta), Prof. Dr. Sumijati, Prof. Dr. Timbul Haryono (Department of Archaeology UGM), and Adi Patria for discussion to finish this paper.

References

Coulthard, T.J., Lewin, J., and Macklin, M.G., 2005. Modelling differential catchment response to environmental change. *Geomorphology,* 69, p.222-241.

Cox, S.C., Menzies, C.D., Sutherland, R., Denys, P.H., Chamberlain, C., and Teagle, D.A.H., 2016. Changes in hot spring temperature and hydrogeology of the Alpine Fault hanging wall, New Zealand, induced by distal South Island earthquakes. *Geofluids,* p.228-248. DOI:10.1002/9781119166573.ch19.

Dietze, E., Wünnemann, B., Diekmann, B., Aichner, B., Hartmann, K., Herzschuh, U., Ijmker, J., Jin, H., Kopsch, C., Lehmkuhl, F., Li, S., Mischke, S., Niessen, F., Opitz, S., Stauch, G., and Yang, S., 2010. Basin morphology and seismic stratigraphy of Lake Donggi Cona, north-eastern Tibetan Plateau, China. *Quaternary International,* 218, p.131-142. DOI: 10013/epic.33916

Fletcher, W.J., Boski, T., and Moura, D., 2007. Palynological evidence for enviromental and climate change in the lower Guadiana valley, Portugal, during the last 13,000 years. *The Holocene,* 17, p.481-494. DOI:10.1177/0959683607077027

Gomez, C., Janin, M., Lavigne, F., Gertisser, R., Charbonnier, S., Lahitte, P., Hadmoko, S.R.,Fort, M., Wassmer, P., Degroot, V., and Murwanto, H., 2010. Borobudur, a basin under volcanic influence : 361,000 years B,P to present. *Journal of Volcanology and Geothermal Research,* 196 (3 - 4), p.24-264. DOI: 10.1016/j.jvolgeores.2010.08.001.

Gunarto, H., 2007. Preserving Borobudur's Narrative Relief Wall of UNESCO Cultural World Heritage. *Ritsumeikan Center for Asia Pacific Studies* (RCAPS) *Occas Journal Paper.*

Murwanto, H., Gunnell, Y., Suharsono, S., Sutikno, S., and Lavigne, F., 2004. Borobudur monument (Java, Indonesia) stood by a natural lake: chronostratigraphic evidence and historical implications. *The Holocene,* 14, p.459-463. DOI: 10.1191/0959683604hl721rr.

Murwanto, H., 2015. *Rekonstruksi Danau Purba Borobudur dengan Pendekatan Paleogeomorphology. Disertasi*, Fakultas Geografi Universitas Gadjah Mada, Yogyakarta.

Murwanto, H. and Purwoarminta, A., 2015a. Rekonstruksi Danau Purba Borobudur dengan Pendekatan Spasiotemporal. *LIMNOTEK Perairan Darat Tropis Indonesia,* 22, p.106-117.

Murwanto, H. and Purwoarminta, A. 2015b. Borobudur ancient lake side. *In*: Kanki, K., Adishakti, L.T., and Fatimah, T. (eds.), *Borobudur as Cultural Lanscape*. Kyoko University Press, Japan.

Nieuwenkamp, W.O.J., 1933. Het Boroboedoermeer, Algemeen Handelsblad, Denhaag, 9 September 1933.

Nossin, I,J. and Voute, C., 1986. Notes on the Geomorphology of The Borobudur Plain (Central Java Indonesia) in an archeological historical context). *Simposium an Remote Sensing for Resources Development and Environmental Management/Enschede*, Netherland

P.T. Taman Wisata Candi Borobudur, Prambanan, dan Boko, 2015. *Annual Report 2015* Yrly.

Rodning, C., 2010. Place, landscape, and environment: Anthropological archaeology in 2009. *American Anthropologist,* 112 (2), p.180-190. DOI: 10.1111/j.1548-1433.2010.01217.x

Tanudirjo, D.A., 1991. Changing perspectives on the relationship between heritage, landscape and local communities: A lesson from Borobudur. Book Chapter: Transcending the Culture-Nature Divide in Cultural Heritage, DOI: 10.22459/TA36.12.2013.05

Wünnemann, B., Yan, D., and Ci, R., 2015. Morphodynamics and lake level variations at Paiku Co, southern Tibetan Plateau, China. *Geomorphology,* 246, p.489-501.

Zhang, Y., Wünnemann, B., Bezrukova, E. V., Ivanov, E. V., Shchetnikov, A.A., Nourgaliev, D., and Levina, O. V., 2013. Basin morphology and seismic stratigraphy of Lake Kotokel, Baikal region, Russia. *Quaternary International,* 290-291, p.57-67.

Zhu, Z., Zhang, H., Zhao, J., Guo, X., Zhang, Z., Ding, Y., and Xiong, T., 2018. Using toponyms to analyze the endangered Manchu language in Northeast China. *Sustainability,* 10 (2), p.563. DOI: 10.3390/su10020563.