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Borobudur monument (Java, Indonesia) stood by a natural lake: chronostratigraphic evidence and historical implications

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Abstract: The ninth-century world-heritage Buddhist monument of Borobudur (Java, Indonesia) stands above the floor of a dried-out palaeolake, but it remains uncertain as to whether it was ever constructed on a lake shore. Here we reveal through new chronological and palaeoenvironmental data on the extant sediment record of the area that Borobudur intentionally stood by an existing lake. For the first time, evidence of this conjunction validates quite literally the debated cosmological interpretation of the edifice as an aquatic lotus symbol upon which Buddha is seated. The fluctuating life history of the lake spanned at least 20000 years.

Key words: Lake chronostratigraphy, volcanic sedimentology, environmental change, Buddhist cosmology, Borobudur temple, Indonesia.

Introduction

Hundreds of studies in several languages have been dedicated to understanding the history, architectural meaning and location of Borobudur in the Kedu plain of south-central Java, which at the time of construction was the richest agricultural region of maritime Southeast Asia. In spite of successive phases of excavation and restoration (1907–1911: under the supervision of Th. Van Erp; 1968–1983: conducted by UNESCO), uncertainty continues to surround the palaeoenvironmental context in which this world-class monument was constructed between AD c. 760 and 830 (Miksic, 1994).

Borobudur stands at 265 m a.s.l. on a low bedrock hill rising 15 m above the top of lake sediments. It has never been established whether the lake existed at the time of construction, nor why the Mataram kingdom of central Java at Borobudur suddenly declined. The exact time at which the Mataram government resettled in East Java is unclear: according to van Bemmelen (1949) this occurred in AD 1006 due to a major volcanic disaster affecting the Kedu plain, but based on a chronology of volcanic events (Nossin and Voûte, 1986; Newhall et al., 2000) and archaeological reconstructions (e.g., Soekmono et al., 1990; Miksic, 1994) most scholars have subsequently doubted this categorical affirmation. The majority view today is that the centre of Javanese power moved from the Kedu plain to the valley of the Brantas river in East Java in the middle of the tenth century (possibly AD 928), i.e., before the purported AD 1006 volcanic event occurred.

The design of Borobudur is meant to represent the universe according to Buddhist cosmology. Beyond this superficial consensus, no single explanation enjoys universal acceptance among scholars who have studied the meaning and purpose of the edifice and its geographical setting (Soekmono et al., 1990). Two speculative interpretations incorporating naturalistic considerations have been put forward regarding the nature of the site. (1) The Dutch painter and scholar of Hindu and Buddhist architecture, W.O.J. Nieuwenkamp, was the first to visualize Borobudur as symbolizing Buddha seated on a lotus flower floating on a lake which had since dried up (Nieuwenkamp, 1931/32). This view, hotly debated between Nieuwenkamp and Van Erp in Dutch magazines between 1932 and 1937 (related in Harloff and Pannekoek, 1940), was consistent with the conventional layout of many similar sanctuaries in Southeast Asia (e.g., Angkor: Cambodia), where an artificial moat around the stupas represents the cosmic ocean from which...
the Earth was created. Here, however, the aquatic environment of Borobudur was believed to be a natural rather than a man-made setting. The lotus is found in almost every Buddhist work of art, often serving as a throne for buddhas and a base for stupas. Moreover, in the context of Borobudur this vision is particularly consistent with the interpretations of P. Mus (1935), a French scholar who produced the answer to two longstanding enigmas: (i) the unusual depiction, at Borobudur, of six rather than the conventional five buddha postures among the statues placed on the uppermost terraces surrounding the central stupa; and (ii) the circular shape of those uppermost terraces in relation to this. The sixth buddha suggests that the architecture of Borobudur symbolizes the 'Lotus Sutra', which derives from a text dating back to early Mahayana Buddhism (school of Buddhism most widespread in East and SE Asia). Round terraces may thus represent the rounded lotus leaf. These interpretations have further been confirmed more recently (J.J. Boeles, 1985, quoted in Miksic, 1994).

(2) Geologists also argued the possibility of a palaeolake in the area based on the occurrence of clayey sediment near the site (van Bemmelen, 1949). Supporters of this belief, however, disagreed over whether the lake was created after the construction of the temple – for instance in AD 1006 by accidental damming and flooding in relation to a cataclysmic eruption from Mt Merapi (van Bemmelen, 1949) – or whether it was much older and had dried up by the time of construction (Harloff and Pannekoek, 1940; Nossin and Voûte, 1986). In either hypothesis, Borobudur was never intentionally built near water.

New data on palaeolake Borobudur

Our study combines surface and subsurface data to generate time-sliced maps of palaeolake Borobudur (Figure 1), and sheds new light on its life history. Ground-checked aerial photographs (1979, 1994; 1:30 000 scale) were used to map the surface geology and drainage. The stratigraphy and contours of the palaeolake were plotted and correlated after completion of an electrical resistivity and very low frequency (VLF) electromagnetic survey. Textural, mineralogical and pollen analyses were performed on claystone surface exposures and two 50 m deep cores in order to establish environmental fluctuations, sediment provenances and flooding events. Radiocarbon ages bracket the ages of some of these events and set the claystone stratigraphy, and therefore the history of Borobudur, in a new chronological timeframe.

Outcrops across the Kedu plain consist of Tertiary andesite, and Quaternary volcaniclastic and lacustrine deposits. An extensive black claystone formation is interlayered with sandy lahar (volcanic debris flow) deposits. Its thickness ranges between 5 and 88 m, and the depth to its top varies from 0 to 120 m. It is exposed in the 15 to 20 m deep incised channels of the Progo, Elo and Sileng rivers. Core drillings along these river banks reveal interlayered sequences of fluvial and palustrine units (Figure 2), which indicates fluctuating palaeoenvironments. Organic clays from the Sileng core (Figure 2) yielded ages of 22 040 ± 390 and 19 520 ± 340 ^14C yr BP (due to well-known confidence problems in ^14C calibration beyond c. 11 000 yr BP; Pleistocene ages are expressed here in yr BP; other ages are tree-ring calibrated to calendar years following Stuiver and Reimer, 1993). An in situ tree-stump at the surface of the Sileng claystone provided an age of cal. yr AD 1163–1251. At the surface of the Progo claystone, another fossil stump yielded an age of cal. yr AD 1285–1393. A further age (3030–2880 cal. yr BC) obtained from a stratigraphically lower position (Figure 1) differs from an existing ^14C date of 1851–1676 cal. yr BC (given in Newhall et al., 2000). However, the samples in each case having been collected at different sites, both could easily be correct considering the fluctuating nature of the lake both in space and time as argued in the present study.

![Figure 1 Palaeolake Borobudur through space and time: a preliminary reconstruction.](https://example.com/figure1.png)
Although no suitable material for dating has been found in the Sileng River deposits to show exactly the time of temple construction, the stratigraphy of the Sileng core shows that intermittent sedimentation of clays was ongoing since the late Pleistocene c. 20000 yr ago (Figure 2). The lake may therefore not have dried up for very long periods at this key locality. Based on the other fossil wood data in the vicinity, it apparently persisted until the twelfth to fourteenth centuries AD (Figure 1). Combined VLF and geoelectric stratigraphy has allowed preliminary contouring of the lake area in its late stages (twelfth to fourteenth centuries AD: Figure 1). The data suggest two separate lakes during that period, each located in the confluence areas of the Elo and Progo, and Sileng and Progo rivers, respectively. Borobudur hill and two others stood as islands in between. The low mean sedimentation rates (0.5 mm yr$^{-1}$) for the clay recorded by the Sileng core since c. 20000 yr BP are surprisingly low for an active volcanic region. We interpret this in reference to the fact, the context confirmed by mineralogical signatures from the core, that the Sileng river descends not from Pleistocene volcanoes but from the Menoreh Hills. These represent the eroded and thickly forested stumps of more ancient Cenozoic volcanoes, which correspond (save for a few localized landslides related to human interference in recent decades) to comparatively more stable terrain than anywhere else in the Progo basin. This river’s low turbidity contrasts with the relentless influx of clasts conveyed by the Elo and Progo rivers from the steep active volcanoes (Sumbing, Sundoro, Merbabu, Menoreh), which are clad in unconsolidated debris (Figure 2).

With a pH KCl of 4.5–5.2 (this expresses potential effective acidity, measuring Al$_3^+$ related acidity in addition to the conventional H$^+$: as a result, pH KCl < pH H$_2$O), the claystone contains 1.58–5.17% organic matter and compares in this respect with soils in the swamps of the south Java coast. The organic content (0.91–4.16% C and 3.16–5.77% N) is derived from the biotic communities deposited in the lake. Pollen counts from ten borehole and riverbank samples define two qualitative groups: (i) land plants include Rhododendron, Vaccinium, Podocarpus neriifolius, M. acaranga and Casuarina; (ii) wetland plants are dominated by Typha-Cyperaceae associations, also including Barringtonia, Acacia, Palmae, Euphorbiaceae, Bromelia, Calamus, Pandanus, Typha, Gramineae and spores of Acrostichum aureum, Verrucatosporites, Monoletesporites, Sphagnum and Pteris. The pollen and spores, though not at this stage of the project in sufficient number to produce quantitatively acceptable pollen diagrams, are fairly well preserved and suggestive of an anoxic and oligotrophic open water body.

During the twelfth to fourteenth centuries AD, the pollen record suggests short-term fluctuations between lake high (77% of non-arboreal lakeshore plants) and low stands (63–80% fungal spores reflecting decomposing vegetation on a dried-up lake bed). The Borobudur site thus stood in a small ‘mesopotamia’ between the Progo and Sileng rivers. Where the major rivers meet, lake conditions were periodically generated throughout the Holocene epoch. This finding contradicts previous pollen studies around Borobudur in which no indication of a wetland palaeoenvironment had been identified (Thanikaimoni, 1983).

**Discussion**

The stratigraphic, sediment and pollen characteristics of the claystone support the existence at Borobudur of an intermit-
tent palaeolake between the late-Pleistocene glacial maximum and late-Mediaeval times. During the 22,000–19,000 yr BP interval, the lake extended far to the north and east. Around 3000 cal. yr BC the lake area narrowed in a SE to NW direction due to an influx of volcanic material from the N–NE, with a few islands between the Sileng and Progo confluence. Habitat changes occurred repeatedly from standing water to dry land, although with a much higher frequency in the north (Elo core), which is more exposed to volaniclastic outwash and high sediment concentrations in stream flow, than in the south (Sileng core). Here, lodged in a topographic low in the scarfoot angle of the Menoreh Hills, lake conditions were relatively more permanent. This appears clearly during the thirteenth to fourteenth centuries AD, when the lake was separated into two parts (Figure 1). Periodic lakeshore retreat occurred under the impact of a Progo fan delta progressing in response to fluctuating sediment input further upstream. Related studies have revealed the long-term persistence of fluctuating lakes in other volcanic regions such as the Bandung basin of West Java (Dam, 1994; Nossin et al., 1996), affected mostly by lahars; and a recent lake near Mt Pinatubo (Philippines), affected by pyroclastic flows and lahars (Umbal and Rodolfo, 1996).

Our stratigraphy of the Borobudur plain corroborates the doubts raised by archaeologists and geologists (Nossin and Voïte, 1986; Newhall et al., 2000) over the notion (van Bemmelen, 1949) that a single Merapi eruption in AD 1006 caused the desertion of Borobudur. c. 180 years after it was constructed. Reports on a thickness of ash covering parts of Borobudur when it was first rediscovered in 1815 are inconsistent (Soekmono, 1976; Nossin and Voïte, 1986): rather than any positive identification of volcanic fallout, the chronicles and diaries of nineteenth-century travellers usually indicate a mix of dust, human detritus, soil, crumbling masonry and woodland undergrowth, all of which would be expected after 800 years of disrepair. Furthermore, abundant 14C-correlated evidence from across the region indicates that Mt Merapi was active before, during and after several other Mediaeval Hindu and Buddhist temples were constructed in the Kedu plain (Newhall et al., 2000). This is confirmed by structural damage and by the overburden of sediment removed when those temples were restored. Despite repeated partial burial by volcanic debris, after the construction of Borobudur, of some 43 smaller satellite temples, these remained occupied until at least the thirteenth century. This also left them exposed to the Muslim pillages that occurred in the fourteenth to fifteenth centuries (Dumargay, 1986). Finally, the unimodal <2 mm grain-size curves from the Elo and Sileng cores (Figure 2) are typical of either hyperconcentrated (>20% vol. sediment) or normal stream flow (<20% vol. sediment). The core stratigraphies therefore show no evidence of massive airborne fallout from Mt Merapi. This burden of evidence thus challenges the received view that the lake is primarily the consequence of a single event after the construction of Borobudur, for instance damming by a catastrophic eruption or debris avalanche as originally proposed by van Bemmelen (1949). Compared to other parts of the tropics, the sediments are furthermore not characteristic of erosive events related to anthropogenic land clearance, even though the presence of Macaranga pollen, a secondary tree species, in the uppermost layers of the claystone is suggestive of human interference with the land cover after the fourteenth century.

Conclusion

We conclude that the life history of lake Borobudur was influenced by far-field volcanioclastic deposits conveyed by turbid rivers from the active volcanoes in the northeast and northwest, and by near-field clearwater runoff from the Menoreh Hills in the west. The construction of the temple on a promontory extending into a lake (Figure 1) manifestly occurred by design. Seasonal lakeshore fluctuations, although not detectable in the sediment record, probably played an important part in conferring on the temple a semi-aquatic character, especially towards the end of the annual rainy season. Our findings directly support the independent interpretations of the visual artist W.O.J. Nieuwenkamp and his contemporary scholar P. Mus, which were initially dismissed by scientists but appear to be considerably more consistent with Buddhist cosmogony than if Borobudur had never stood by a lake. In this perspective, the shift of the Mataram government to East Java may have been caused by some water-related disease (the Kedu plain around Borobudur still is one of the few remaining pockets of malaria in Java today) rather than any given volcanic hazard.

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