Luminescence dating of brick stupas: an application to the hinterland of Anuradhapura, Sri Lanka

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The domed stupas are among the most distinctive of South Asia's religious monuments and have been shown to be sensitive indicators for their society. Since arguments for economic and political change depend on accurate dating, and since the stupas are largely composed of brick, the authors here assess the potential for dating building sequences by applying optically stimulated luminescence to brick fabric. As so often, good scientific dates obtained from specimens must be tempered by their context: brick may be replaced or recycled during repair and embellishment. Nevertheless, the method promises important insights by distinguishing different episodes of building, and so writing 'biographies' for stupas with different functions.

Keywords: Sri Lanka, Anuradhapura, Buddhism, stupas, OSL, hinterland

Method

Introduction

Buddhism swiftly became established as the state religion in Sri Lanka following its introduction in the third century BC (Paranavitana 1946), and this change was accompanied by the rapid development of Buddhist sites in both urban and rural settings (Coningham 1995). Identification of these sites is reliant on the presence of one or more architectural

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features, the stupa, the *griha* (sanctuary) and the *vihara* (monastery) being prominent types (Coningham 2001, 2011). The stupa is the most distinctive and durable of the monuments and, as the focal point of many monastic sites, it has become a prominent symbol of Buddhism in Sri Lanka (Silva 1986: 8). The origin of the stupa is thought to be pre-Buddhist, with a development traced back to megalithic mounds (Silva 1986: 6). Typically formed as a solid mound, the stupa was built primarily as a monument to enshrine relics or to commemorate important events or places in the life of the Buddha (Silva 1986; Coningham 2001). In Sri Lanka, the main building material used in the construction of ancient stupas was fired clay brick, a technology that, along with tile, was notionally restricted to religious or royal structures (Bandaranayake 1989).

The fortified city of Anuradhapura, a pivotal urban centre in Sri Lanka from the third century BC until its abandonment in AD 1017, witnessed a sustained and vigorous development of both secular and religious monumental architecture during this period (Coningham 1999, 2006). In the hinterland, monastic establishments developed a key economic and political role, acting as agents for the management of land and water, and providing an administrative infrastructure linked to the great urban *viharas* as an extension of their religious and secular influence (Coningham 2011). These rural monasteries were often located on granite outcrops, providing visually distinctive structures within the landscape of the hinterland, the topographic positioning of which has been linked to the concept of establishing intervisibility in the religious landscape as a means of increasing the visual prominence and authority (Shaw 1999). Recent archaeological work in the Anuradhapura hinterland (Anuradhapura (Sri Lanka) project phase II: the hinterland) has focused on the relationship between urban and rural communities and the role of the development of Buddhist *viharas* within a broader landscape setting, including formulation and refinement of the monastic architectural chronology (Coningham *et al.* 2007; Coningham 2011).

However, the dating of stupas based on the use of architectural typologies is frequently not feasible in rural areas because historically original features were not preserved during renovation (Paranavitana 1946). Moreover, many stupas remained abandoned for centuries and were reduced to amorphous mounds, often structurally damaged by looting or robbed for the reuse of building materials. This is a problem common to the stylistic dating of many brick Buddhist monuments in South and Southeast Asia, as discussed by Ali and Coningham (2002) working in Pakistan, Shaw (2007) in central India and by Stark *et al.* (2006) working in Cambodia, and there is a general need for a method of dating the construction of brick structures that is based on a direct analysis of the building materials.

This paper reports a study that examined the potential of optically stimulated luminescence (OSL) dating to test the chronology of a selection of brick-built stupas in the hinterland of Anuradhapura. Earlier work by Abeyratne (1994) on the application of thermoluminescence (TL) dating to archaeological sites in Sri Lanka included the testing of bricks from two urban stupas within Anuradhapura (Jetavanaramaya and Mirisewetiya) and a further stupa at Polonnaruva, and obtained good agreement with historical dates. However, no previous attempts have been made to apply scientific dating methods to stupas within the urban hinterlands.

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Stupa chronology

A rich source of written accounts of the building and foundation of the large, and often gigantic, urban stupas of Anuradhapura is provided within the Pali chronicles of Sri Lanka, produced in the fifth and sixth centuries AD, but there are scant details within these records of the building of *viharas* beyond the limits of the city (Longhurst 1992). In seeking to find a systematic materials-based dating technique for stupas, Parker (2001 [1909]) attempted to demonstrate the feasibility of establishing a chronology based on brick size. However, although finding a trend of diminishing size over time, he recognised that there were irregularities in the correlation, and later attempts to use this method were unsuccessful, leaving the approach largely discredited.

Paranavitana (1946) laid the foundations for a detailed approach to the analysis of individual monastic building units, and attempted to trace the architectural development of the stupa by connecting Sinhalese and Pali literature with the archaeological evidence. While this approach did not provide a chronological basis for the evolution of a stupa typology, it was recognised that repairs and enlargement were potentially important factors when examining stupas.

Bandaranayake (1974) and Gunawardhana (2009) have more recently provided a means of assigning broad occupational phases to monastic complexes—in particular those located in the hinterland—that employs a scheme of monument periodisation, architectural typology and the presence of diagnostic artefacts. These methods are significant in that they are grounded on the use of material remains rather than having a reliance on surviving textual records. The earliest monastic structures identified are rock-cut caves or *lenas,* which often display early Brahmi inscriptions (EBI), and are dated to between the third century BC and the first century AD (Paranavitana 1970; Coningham 1995). Organic, or hub, monasteries, dating from *c.* AD 1 to *c.* AD 600 in an urban setting, were planned around a colossal stupa and often founded in locations already associated with local deities (Bandaranayake 1974). A significant shift in monastic architecture occurred with the introduction of 'focal' stupas, dated by Gunawardhana to AD 400–700 in south-east Sri Lanka, and identified as small rural stupas on high outcrops (2009). The introduction of larger monastic complexes, such as the *Pabbata Vihara* or *Padhanaghara Parivena*, both dated to between the eighth and twelfth centuries AD and representing pre-planned monastic institutions, is another significant development (Bandaranayake 1974: 58).

The most recently developed chronological scheme developed and applied in the Anuradhapura project is based on a broad system of chronological phasing for 755 sites identified within the hinterland of Anuradhapura. It was developed from ceramic typologies from excavations in the citadel itself (site ASW2; Coningham 2006), the monastic typologies mentioned above (Bandaranayake 1974; Gunawardhana 2009) and chronometric dates from the individual excavated sites. Eight broad phases have been defined: the Early Historic (340 BC–AD 200), Late Historic (AD 200–600), Early Medieval (AD 600–1200) and Late Medieval (AD 1200–*c.*1500) being the most relevant to the present study (Table 1). Whilst these phases have relatively well-defined boundaries, they are derived primarily from the structural and artefactual sequences at ASW2, which was an excavation in the secular core of Anuradhapura. In terms of monastic architecture in the hinterland, the boundaries

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Table 1. Anuradhapura project chronological scheme, showing phases relevant to this paper.

Period	Architecture	ASW2 Sequence	Key ceramic indicators	Script	Sculpture
Early Historic (*c.* 340 BC–AD 200)	Caves/*Lena*	Structural periods I, H, G	Northern Black Polished Ware, Rouletted Ware	Early Brahmi	Aniconic
Late Historic (AD 200–600)	Organic/hub monasteries	Structural period F	Glazed Sassanian ceramics	Late Brahmi, Transitional Brahmi	Iconic
Early Medieval (AD 600–1200)	Focal monasteries, *Pabbata Vihara*, *Padhanagara Parivena*	Structural periods E, D, C, B	East and west Asian ceramics	Sinhalese and Tamil script	Iconic

are not as well defined. The availability of an independent method of dating stupas within the monastic complexes of the hinterland could therefore provide a key link in the interpretation of the archaeological relationship between urban and rural developments.

The sample sites

The monastic complexes containing the stupas that were sampled are located in two regions, *c.* 30km to the south (C508, Etenawatunagala; A155, Veheragala; C527, Nawagala) and *c.* 20km to the south-east (D340, Nikawewa; A030, Thalaguru; Z001, Parthigala) of Anuradhapura (Figure 1). In common with many abandoned monastic monuments, stupas in the hinterland are usually partially or wholly overgrown with vegetation (Figure 2), and in many cases the interior cores of the structures have been exposed by episodes of looting. In view of these potential issues of degradation, the brick stupas in the six monastic complexes were selected as being potentially suitable on the basis of previous survey work. Evidence of occupation at the monasteries was categorised using the broad architectural phases outlined above, and bricks were sampled from locations associated with a particular phase of each stupa (Table 2).

Dating procedure

Samples for dating were obtained by fracturing whole bricks taken from contexts of interest; in most instances the sample was taken from the inner part of the brick (Figure 3). A detailed record of the location and orientation of the brick was made in each case, and the remaining piece of brick was replaced. The OSL measurements were performed on grains of quartz extracted from the interior of the sampled brick fragments and hence they are not affected by exposure of the bricks to sunlight. This measured the cumulative radiation dose received

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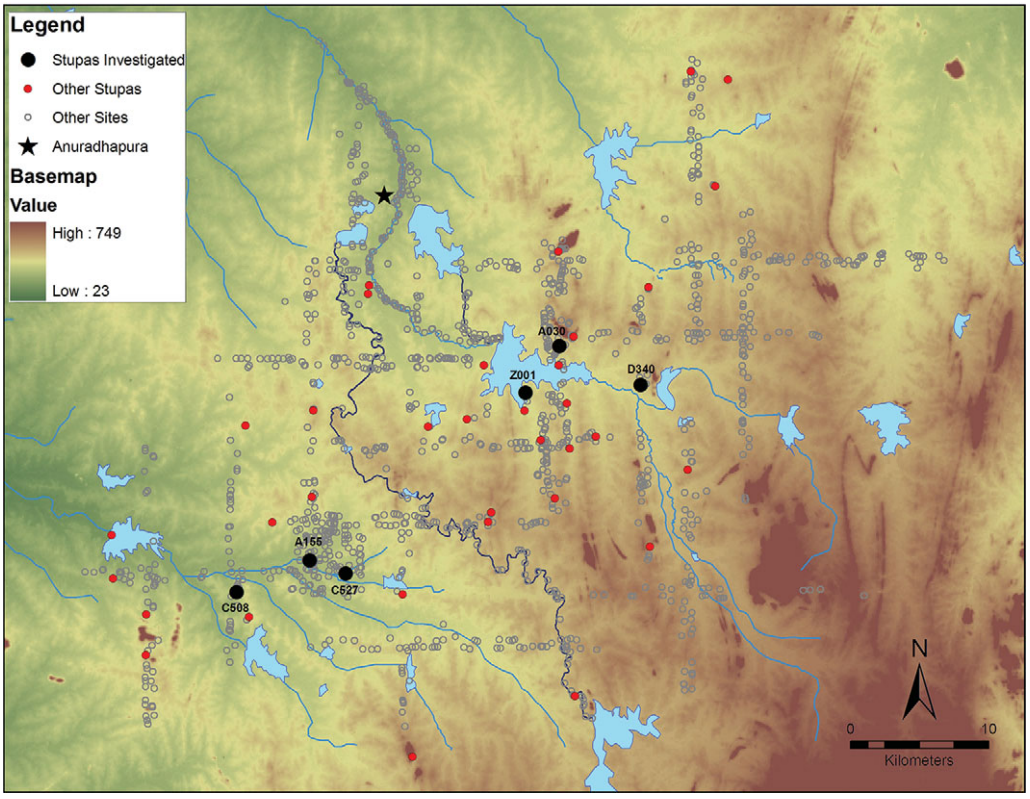

Figure 1. Map showing the location of the six sites investigated within the two main areas of the Anuradhapura project survey that are to the south-east and south of Anuradhapura. Three (A030, Thalaguru; Z001, Parthigala and D340, Nikawewa) are in the vicinity of Nachchaduwa tank and the remaining more southerly three (C508, Etenawatunagala; A155, Veheragala and C527, Nawagala) are in the Veharagala zone. The star represents the location of Anuradhapura.

(the paleodose) since the manufacture of the brick (Aitken 1998; Duller 2008). The local radiation dose received by the grains per year (the dose rate) is determined by a combination of experimental methods, including direct experimental measurement of the dose rate at the sample location, using a dosimeter capsule (put in place for around nine months) and laboratory analysis of the sample and associated burial medium for their radioactive isotope content. The luminescence age is obtained by evaluating the quotient of the paleodose and the dose rate. A summary of the technical data associated with this calculation is given in Table 3.

The OSL dates have two error terms, σ_A and σ_B, where the former (type A) is only used when examining differences between OSL dates produced by the same laboratory (i.e. the group of dates discussed in this paper). The second term (type B), which is also referred to as the overall error (Aitken 1998), is used when comparing OSL dates with dates obtained using all other methods (see also note to Table 3); the uncertainties are conventionally given at the 68% level of confidence ($\pm 1\sigma$). When comparing OSL dates, Ward and Wilson's (1978) test statistic T was used (inserting values for σ_A for OSL date comparisons and σ_B

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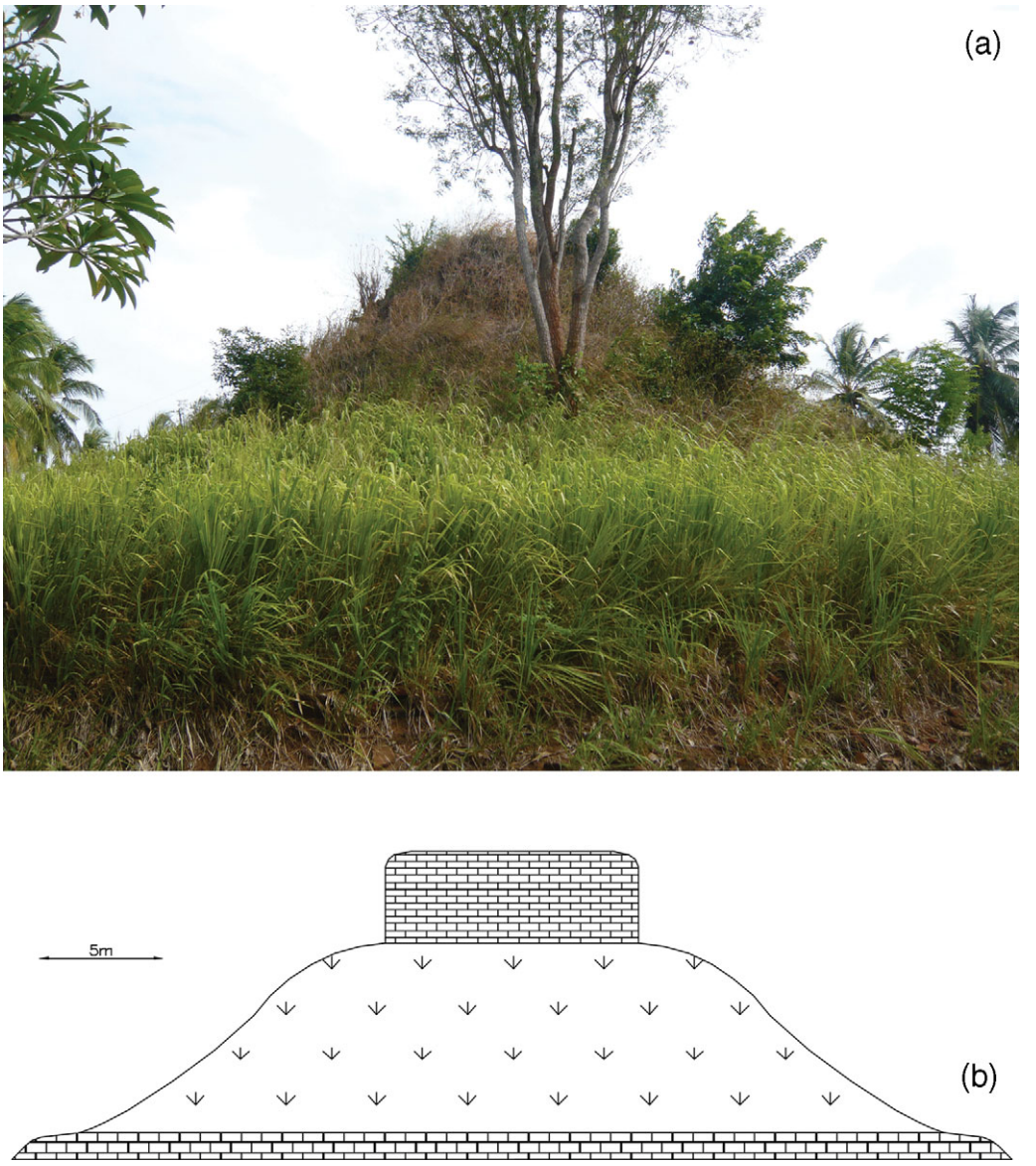

Figure 2. The Nawagala stupa showing (a) the extent of overgrowth in 2010 and (b) a scaled illustration of the monument showing the focal stupa mounted on a large stupa.

for OSL date and architectural date comparisons) and the value of χ^2 is given at the 5% level of significance unless indicated otherwise.

Results (Table 2; Figure 4)

At Etenawatunagala, structural assessment indicated a single-phase construction, and a robbed section of the stupa revealed an interior built with stone and brick from which

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Table 2. The monasteries and sampled stupas.

			Chronological phase					
Name	**Site no.**	**Lab no.**	**Early Historic 340 BC–AD 200**	**Late Historic AD 200–600**	**Early Medieval AD 600–1200**	**Stupa type**	**Height (m)**	**Diameter (m)**
Etenawatunagala	C508	375 -1	Y	Y	N			
				■		Focal?	3.7	-
Nawagala	C527		N	Y	Y			
		6		■		Large	14.5	39.6
		7			□	Focal	3.6	8
Veheragala	A155		Y	Y	Y			
		5		□		Large	7.8	18.5
		4			□	Focal	4.9	0.7
Thalaguru	A030		N	Y	Y			
		12		■		Large	10.1	20.3
		11			□	Focal	0.7	3.3
Parthigala	Z001		N	N	Y			
		13			■	Large	5.1	41.9
Nikawewa	D340		N	N	Y			
		10			■	Undiagnostic	1.0	3.3

Note: the position of brick samples is indicated as interior (■) or exterior (□) and Y/N indicates whether evidence of occupation had been found within the site for the architectural phase indicated (Coningham *et al.* forthcoming).

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Method

Figure 3. A section of the base of the focal element of the stupa at Thalaguru showing (a) the brick extracted to allow a fragment (b) from the inner section of the brick to be removed for OSL measurements (375-11). Before the brick was replaced, a dosemeter capsule was placed in the gap between the inner bricks that can be seen at the rear of the cavity.

one sample was taken, giving a date of AD 390±110. The site conforms to the setting in Gunawardhana's model for a focal monastery and the OSL date is consistent with his initial typology (AD 400–700), although earlier than expected within the Anuradhapura project chronology (2009). If the date does not represent an outlier in this scheme, it could represent a new variant of the urban/centric-type monastery applied in the hinterland (Coningham *et al.* forthcoming).

At Nawagala, two external brick samples were obtained from the stupa, one from the base of the lower perimeter wall and the second from exposed brickwork of the upper section. The OSL date for the lower sample (sample 6, AD 130±165) is the earliest of the dates for the large stupas tested. The date from the summit of the stupa (sample 7, AD 860±85) is significantly later, the central values being separated by 730 years. These results fit the Anuradhapura project phase model, in which a large stupa is characteristic of the Late Historic period, and the surmounted focal stupa represents a later addition, suggested to be within the range *c.* AD 700–900.

However, a slightly different monument chronology for large stupas with surmounted focal elements is indicated by the results for Veheragala and Thalaguru. The OSL dates for the large stupas in these monasteries are similar (AD 480±105; AD 550±95), placing their construction towards the end of the Late Historic phase, which is much later than at Nawagala. The OSL dates for the focal components (AD 640±105; AD 690±75) are

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Table 3. Summary of technical data. For notes on this Table, see the Technical Appendix at the end of the paper.

Name	Site	Sample	P ± s.e. Gy	$\bar{D}_{tot}$ ± s.e. mGy a^{-1}	OSL date ± σ_A; ± σ_B AD
Etenawatun-agala	C508	375 -1	6.19±0.14	3.82±0.11 (69/31%)	390±60; ±110
Veheragala	A155	4	4.35±0.21	3.17±0.07 (73/27%)	640±75; ±105
	A155	5	4.52±0.17	2.96±0.07 (71/29%)	480±65; ±105
Nawagala	C527	6	5.80±0.37	3.08±0.07 (73/27%)	130±125; ±165
	C527	7	4.54±0.22	3.95±0.09 (69/31%)	860±60; ±85
Nikawewa	D340	10	2.01±0.04	3.14±0.09 (65/35%)	1370±25; ±45
Thalaguru	A030	11	3.94±0.02	2.99±0.07 (70/30%)	690±30; ±75
	A030	12	4.43±0.03	3.04±0.09 (67/33%)	550±45; ±95
Parthigala	Z001	13	3.61±0.03	2.42±0.07 (62/38%)	520±50; ±95

also similar, and provide a consistent indication that the focal element was built as a later modification. The difference between the OSL dates for bricks from the large and focal elements at Thalaguru (140 years) is statistically significant (T = 6.7; $\chi^2_{1,0.05} = 3.84$; σ_A), although the corresponding difference at Veheragala (160 years) ($T = 2.6$; $\chi^2_{1,0.1} = 2.7$; σ_A) is less clear-cut.

If the large stupa at Parthigala (AD 520±95) is a single phase structure, the OSL date indicates that it was built during a transitional or very early stage—the age range overlaps the AD 600 boundary in the Anuradhapura project chronology—of the Early Medieval period during which *Pabbata Viharas* were built. However, the early OSL date for the (core) brick indicates that the stupa was originally of the same phase as the large stupas of Veheragala and Thalaguru and so may have been enlarged as part of the resurgence of building activity at the site during the mid-eighth century. This practice of enlargement may be connected to intervisibility and the importance of 'divine seeing' at Buddhist sites, as investigated by Shaw at Sanchi (2007).

A stupa built in two stages would lend support to Bandaranayake's suggestion that monasteries of this type, located in suburban or rural areas, would not have been governed by the constraints of monumental urban complexes within Anuradhapura (1974: 69), and that a new phase of construction could incorporate earlier buildings. Whereas the *Pabbata Vihara* category has been widely assumed to reflect a later (seventh century onwards) investment by the kings of Anuradhapura to formalise and integrate the monastic landscape of the hinterland, the incorporation of an earlier monument within one may indicate the intention of using an established ritual site to legitimise or reassert authority over the landscape.

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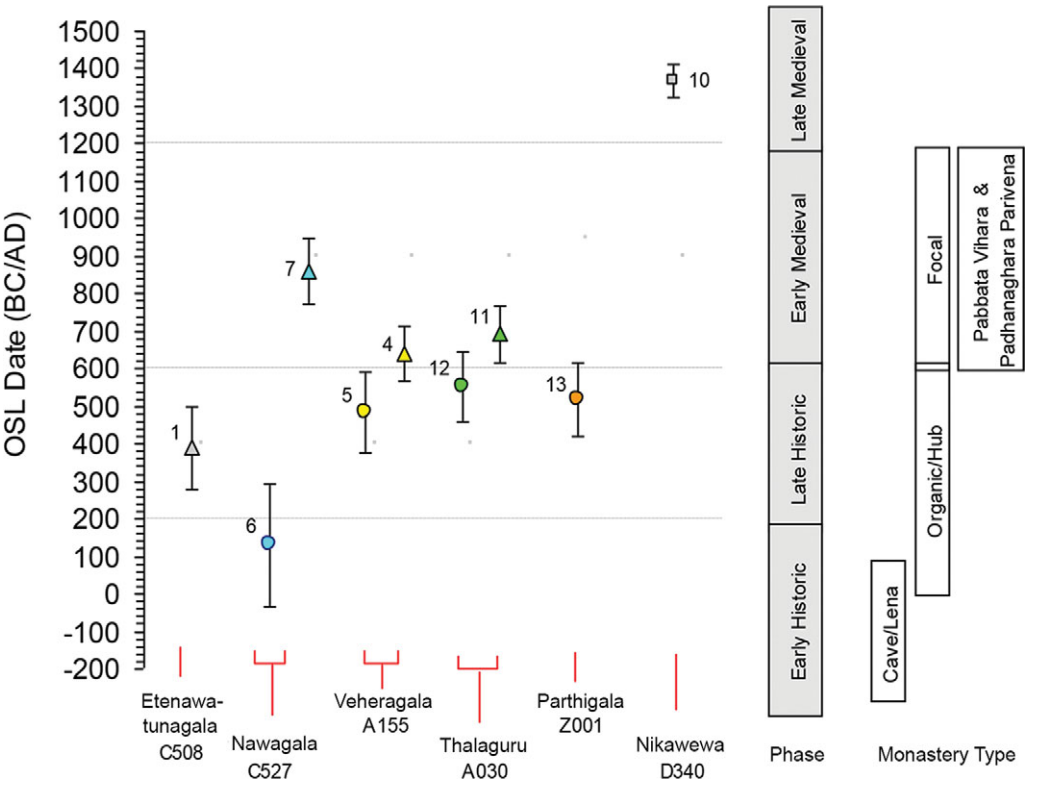

Figure 4. A plot of OSL dates for each stupa where the error bars correspond to the uncertainty term $\pm\sigma_B$ at the 68% level of confidence (see main text). The symbols indicate stupa type (○ large; Δ focal; □ not classified). The historical phasing and monastic architectural typology indicated to the right of the graph are those developed by the Anuradhapura project (Coningham et al. *forthcoming).*

The OSL date for the brick from the interior core of the small putative stupa at Nikawewa (AD 1370±45) places it much later than the Early Medieval phase attributed on the basis of associated artefacts (eighth–eleventh centuries AD) and therefore rules out the suggestion that, with the nearby terracotta site (D339), Buddhist and other ritual traditions were coexistent (Coningham *et al.* forthcoming). The OSL date is also much later than the thirteenth-century date proposed for the abandonment of the Anuradhapura plain on the basis of OSL dates from irrigation channel sediments (Coningham *et al.* forthcoming; Gilliland *et al*. 2013), and consequently this may be a structure other than a stupa. Moreover, activity in the hinterland indicated by this result suggests that further investigation of settlement during the Late Medieval phase would be worthwhile.

Discussion and assessment

Since the date of manufacture is determined using luminescence, the possibility of the replacement of bricks centuries after the original construction is a potential issue when sampling the external locations of any brick-built structure (Bailiff 2007; Bailiff *et al.* 2011). The risk of sampling secondary material was reduced by careful assessment of

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the context and condition of the bricks and, as indicated above and in Table 2, by obtaining samples from the stupa interior. In the case of the one exception at Veheragala, where the bricks sampled were from exterior locations of both the large and focal sections, the more severe weathering of the bricks in the lower large stupa was taken to indicate that they had not been drawn from the same stock used to construct the focal element.

In a more detailed study, samples would be sought from several external locations and also interior locations where possible and appropriate. The availability of interior samples in this study also provided a means of testing for the presence of earlier structures that would otherwise remain obscure. The finding that the OSL date for brick from the core of Parthigala predates the accepted range of a *Pabbata Vihara* may represent the conversion of an earlier hub monastery and, if so, has important implications for the interpretation of other examples of the *Pabbata Vihara* category.

With this proviso, the study produced, for the first time, absolute dates for a range of brick stupas located within the hinterland of Anuradhapura, and the results demonstrate the potential of OSL to contribute to the further development of a brick monument chronology for the region. In addition to finding overall consistency with the proposed Anuradhapura project chronological scheme, the study revealed some interesting variations.

Although the three monasteries with similar architectural typology, comprising a large stupa surmounted by a focal stupa (Nawagala, Veheragala and Thalaguru), produced the expected interval between the base and the summit, this interval varied in length. These results emphasise the potentially complex structural histories of the monuments. The method could, for example, be applied to the stupa at Gotihawa in Nepal, which is considered to be a unique example of an early stupa built with moulded baked-clay bricks, and which underwent a series of renovations following its construction in the middle of the third century BC (Verardi 2007). The study also demonstrates the potential of directly dating brick monuments that lack distinctive typological features or where such features have been lost through structural erosion.

Although the number of dates produced so far is modest, they contribute further chronometric detail on the use of brick in South Asian architecture and, in particular, provide the means to examine the temporal relationships between similar traditions in South and Southeast Asia (Stark *et al.* 2006). Its application to testing for the reuse of building materials and redevelopment of structures also has relevance to the wider study of religious monuments and secular buildings across Asia.

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developed from a pilot study carried out by H.R. Lacey for an undergraduate dissertation at Durham University in 2010.

Technical Appendix

Notes to Table 3

1. The dating measurements were performed in the Durham Luminescence Dating Laboratory, Department of Archaeology, Durham University, and each date, if quoted, should be given the prefix DurOSLqi (e.g. DurOSLqi 375-1).

2. The paleodose, P, was determined using HF etched quartz grains in the size range 90–150μm and applying a single aliquot regeneration procedure (Bailiff 2007). For each sample, the value of P is given with its measurement uncertainty (type A); the range in values of P for individual aliquots obtained using preheat temperatures within the range 200–240°C were consistent with a normal distribution.

3. The total dose rate, $\dot{D}_{tot,}$ is given with its measurement uncertainty (type A) and the division in contributions from beta radiation vs gamma and cosmic radiation are indicated in parentheses (β/γ+cosmic %). An average burial moisture content of 5$\pm$1% was assumed; the values of the saturation uptake in brick measured in the laboratory ranged from 11–17% across all samples. The beta dose rate was measured using the technique of β-TLD and the combined gamma and cosmic dose rate was measured using *in situ* dosemeter capsules (γ-TLD). The beta dose rate component includes an allowance of 0.06 mGy a^{-1} for lithogenic sources within the quartz grains.

4. The OSL date is given with type A and type B uncertainties, ($\pm\,\sigma_A$) and ($\pm\,\sigma_B$) respectively, calculated using a procedure based on an analysis of the propagation of errors, similar to that described by Aitken (1998) and given at the 68% level of confidence (1σ). The error term σ_A is a type A standard uncertainty (ISO 1993) obtained by an analysis of repeated observations. The second error term, σ_B, equivalent to the overall error described by Aitken (1998), is the type B standard uncertainty based on an assessment of uncertainty associated with all the quantities employed in the calculation of the age, including those of type A, hence these error terms are calculated for each sample and are based entirely on assessments related to the experimental results and the sample conditions that potentially may affect the values of parameters used in the calculation of the luminescence age.

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