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The dry tank: development and disuse of water management infrastructure in the Anuradhapura hinterland, Sri Lanka

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ABSTRACT

We identify and offer new explanations of change in water management infrastructure in the semi-arid urban hinterland of Anuradhapura, Sri Lanka between ca. 400 BC and AD 1800. Field stratigraphies and micromorphological analyses demonstrate that a complex water storage infrastructure was superimposed over time on intermittently occupied and cultivated naturally wetter areas, with some attempts in drier locations. Our chronological framework, based on optically stimulated luminescence (OSL) measurement, indicates that this infrastructure commenced sometime between 400 and 200 BC, continued after Anuradhapura reached its maximum extent, and largely went into disuse between AD 1100 and 1200. While the water management infrastructure was eventually abandoned, it was succeeded by small-scale subsistence cultivation as the primary activity on the landscape. Our findings have broader resonance with current debates on the timing of introduced 'cultural packages' together with their social and environmental impacts, production and symbolism in construction activities, persistent stresses and high magnitude disturbances in 'collapse', and the notion of post 'collapse' landscapes associated with the management of uncertain but essential resources in semi-arid environments.

1. Introduction

Archaeological surveys and excavations at the Anuradhapura UNESCO World Heritage Site and its hinterland are yielding new insights into the transformations of South Asian urban-fringe landscapes. These studies suggest that beginning ca. 400 BC, Anuradhapura emerged as an increasingly populous urban area to become the island's secular capital and Buddhist religious centre, and that hinterland monasteries and a transient worker group ensured the flow of staple resources to the urban population (Coningham et al., 2007). Resilient and expanding throughout the first millennium AD, it is generally recognized from historical sources that Anuradhapura and its hinterland were abandoned and the population dispersed ca. AD 1017 as a result of South Indian invasion, after which the capital ultimately moved southeast to Polonnaruva (de Silva, 2005).

As yet, there is little documentation of the timing and nature of hinterland management transformations required to support the developing urban centre, and no understanding of the process of hinterland abandonment and its aftermath. Because the Anuradhapura region is located in the semi-arid region of Sri Lanka, effective capture and storage of water was, as today, critical to staple rice production (Dharmasena, 1994; Panabokke et al., 2002). Features associated with water management are therefore likely to be among the most sensitive indicators of landscape change. Our survey work has identified a number of such features – a water management infrastructure – in the early Anuradhapura hinterland landscape, including bunds and associated water storage tanks, water transport channels and moat sites. Typically, the bunds are constructed earthen dams that from archaeological survey range from ca. 1.75–4.0 metres (m) in height and from ca. 70–200 m in length, producing water storage areas (reservoirs) several hectares (ha) in extent (Fig. 1); water transport channels are

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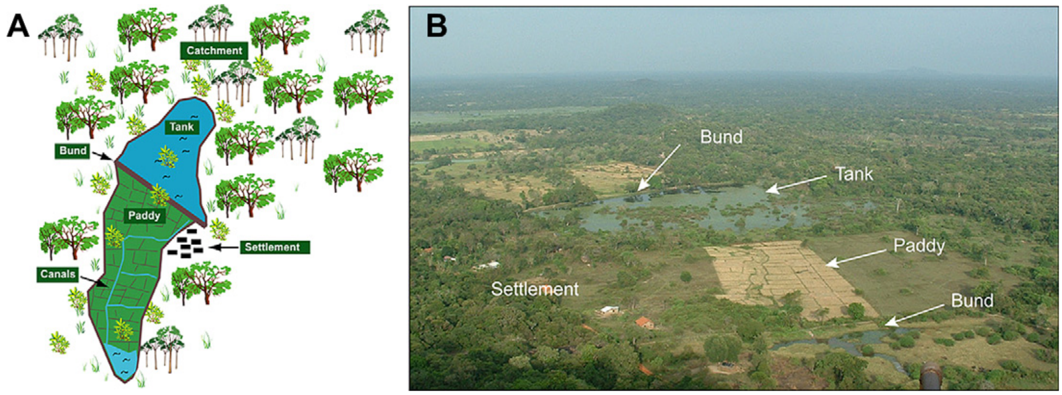

Fig. 1. Water management structures. **A**: Schematic based on Ulluwishewa (1991b, p. 97) demonstrating the relationship between bunds, tanks, paddy, and canals. **B**: Photograph of water management structures in the Nachchaduwa wewa region, Anuradhapura hinterland.

typically ca. 3 m across and now infilled, and moat sites consist of double platforms constructed over surrounding water storage areas up to ca. 1.5 m in depth.

In this paper, our focus is on soils and sediments associated with water management features and 'reading' their stratigraphies to establish the dynamics of urban hinterland landscape change. More precisely, our first objective is to establish land cover conditions prior to the formation of water management features through analysis of underlying palaeosols and sediments, and our second objective is to consider the nature of disuse based on the sediments infilling these features. Our approach in addressing these objectives is to apply soil and sediment micromorphology supported by physical and chemical analyses. Our third objective is to establish these findings within a geo-chronological framework of water management features in the landscape, and in doing so set these features within the context of the origins, development and abandonment of Anuradhapura as an urban centre. To do so, we develop and apply optically stimulated luminescence (OSL) protocols and analyses.

Our findings have a wider resonance beyond establishing the dynamics of landscape change in the Anuradhapura urban hinterland, allowing us to test existing ideas and develop new aspects of regional Buddhist landscape models that endeavour to explain transformations in the development and demise of water management infrastructures. These aspects include testing working hypotheses that the creation of irrigated landscapes with artificial reservoirs in South Asia was initiated and driven by Buddhist introduction (Coningham et al., 2007; Shaw et al., 2007) and at the time of introduction were an entirely new system of land resource management. We consider hypotheses that water management infrastructure development had a role beyond food production, as symbolic construction activities (Mosse, 2005; Scarborough, 2003). We also consider notions of collapse (Brohier, 1935; Crumley, 1994; de Silva, 2005; Diamond, 2005), hypothesizing that that the conjunctures of multiple and interacting environmental and social factors are more likely than single factor explanations of water management infrastructure demise (Buckley et al., 2010; Evans et al., 2007; Kummu, 2009; Leach, 1959; Strickland, 2011). In doing so, we stimulate new ideas on introduced 'cultural packages' together with their social and environmental impacts, production and symbolism in construction activities, persistent stresses and high magnitude disturbances in 'collapse,' and the notion of post 'collapse' landscapes associated with the management of uncertain but essential resources in semi-arid environments.

2. Materials and methods

2.1. Study area and context

Sri Lanka is under the influence of a monsoonal climate regime modified by the effects of mountains in the centre of the island. The Southwest Monsoon (SWM) occurs from the middle of May until September; the Northeast Monsoon (NEM) runs from December to February (Panabokke, 1996). Anuradhapura receives most of its annual precipitation (ca. 1300–1450 mm) during the NEM, which is characterized by unpredictable variations in rainfall, spatially heterogeneous precipitation, and frequent cyclonic storms. The mean annual temperature of the region is 27.3 °C, and evapotranspiration is highest from May to September, exceeding 6 mm/day (Baghirathan and Shaw, 1978; Gunnell et al., 2007; Smithsonian Ecology Project, 1967).

Anuradhapura is located in Sri Lanka's northern lowlands, characterized by low-relief undulating topography varying ca. 50–400 m above sea level, with occasional inselbergs of greater elevation (Gunatilake, 1987). The region's major rivers, the Kala and Malwatu Oyas, are seasonal and drain northwest towards the Gulf of Mannar (Cooray, 1984; Haggerty and Coningham, 1999).

The geology of the Anuradhapura region consists predominantly of quartzites, schists, granites, and gneisses of Precambrian age (Cooray, 1984; Haggerty and Coningham, 1999). The Quaternary geology is dominated by the Red Earth formation formed on weathered bedrock or on bedrock-derived colluvium and is typically clayey sand or loam in texture. Minerals are predominantly rounded quartz grains and minor inclusions of ilmenite, magnetite, spinel and zircon embedded in a matrix of kaolinite clay and fine iron oxide (Cooray, 1984; Panabokke, 1996). Reddish Brown Earths (RBE; Chromic Luvisols, FAO, 1988) comprise the most common soil group occupying higher and mid-slope positions in the landscape, with illuviation the dominant pedogenic process. Low Humic Gleys (LHG; Gleysols, Eutric Gleysols, FAO, 1988) are developed on colluvium deposited from the slopes of low hills or on alluvial sediments along river valleys and channels. Their morphological characteristics include mottling and gleying, documenting continuous or seasonal waterlogging. Nodules of calcium carbonate (*kankar*) are frequently observed within the top few inches of the soil surface, although these can reach depths of more than 1 m (Cooray, 1984; Panabokke, 1996). Alluvial soils (Fluvisols, Eutric Fluvisols, FAO, 1988; Panabokke, 1974) are common in flood plains and river valleys.