Journal of Archaeological Science 36 (2009) 504–512

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Reconstructing late Holocene palaeoenvironments in Bangladesh: phytolith analysis of archaeological soils from Somapura Mahavihara site in the Paharpur area, Badalgacchi Upazila, Naogaon District, Bangladesh

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ARTICLE INFO

Article history:
Received 19 March 2008
Received in revised form 29 August 2008
Accepted 29 September 2008

Keywords:
Phytoliths
Archaeology
Bangladesh
Palaeoenvironment
Paharpur
Late Holocene
El Niño Southern Oscillation

ABSTRACT

Palaeoenvironmental reconstruction based on phytolith analysis of late Holocene-aged soils in and around the Somapura Mahavihara archaeological monastery site in the Paharpur area, Badalgacchi Upazila of Naogaon District in northwestern Bangladesh was undertaken. Results indicate five climate zones marked by alternatively cool and temperate events. The phytolith assemblages of Zones 1, 3 and 5 are clearly characterized by a higher proportion of Pooideae phytoliths. The climate indices for these zones are all greater than 50, indicating cooler climatic conditions. In contrast, the phytolith assemblages of Zones 2 and 4 are typified by a higher proportion of Panicoideae phytoliths; their climate indices are 42 and 44, respectively, indicating the presence of a warmer, more temperate climate. In general, the dominance of grasses over broad- leaved trees throughout the sequences suggests that generally cool to temperate and dry conditions with some cyclical variability persisted around Paharpur and the surrounding region throughout the Pala Dynasty from AD 730 to 1080. The question of whether these shifts in vegetation might be linked with El Niño Southern Oscillation events, and whether these might in turn have cultural responses, is raised.

1. Introduction

Palaeoenvironmental reconstruction is a fundamental component of any archaeological research project. Since the publication of a seminal paper by Rovner (1971), palaeoenvironmental reconstructions using phytolith analysis have made increasing contributions to our understanding of both archaeology and palaeoecology. Phytoliths (also known as plant opals or opaline silica) are siliceous microfossils that form through the process of silica precipitation in and/or between the cells of living plant tissues. They occur in many, though not all, plant families but are especially abundant and diverse in the grass family (Poaceae), assuming shapes diagnostic of the grasses in which they are found (Twiss et al., 1969; Blackman, 1971; Clifford and Watson, 1977; Brown, 1984; Piperno and Pearsall, 1998; Piperno, 2006). Owing to their differing morphologies, in some cases grass phytoliths can be indicative of either the C3 or C4 photosynthetic pathway and can therefore be used to help establish palaeoclimatic conditions (Twiss et al., 1969; Tieszen et al., 1979; Livingstone and Clayton, 1980; Twiss, 1992, 2001; Wu et al., 1992); C3 grasses are dominant in cool regions with high latitudes or elevations, while C4 grasses tend to occur in semi-arid to arid, sunny and warm regions.

Beyond their morphological variability, the other strength of phytoliths lies in their durability; being inorganic in nature they are not broken down by bacteria such as are many other microfossils. They are stable across a wide pH range (3–9) and preserve well in both wet and dry, as well as alternating wet and dry conditions (Piperno, 2006). Hence, unlike organic plant remains, they do not rely on exceptional conditions for survival and are therefore widespread in sediments and soils.

As a consequence of their abundance, durability and diagnostic morphologies, phytoliths have been increasingly used to reconstruct aspects of Late Quaternary palaeoenvironments in numerous sediment types, including loess (Lü and Wang, 1991; Lü et al., 1996; Madella, 1997; Blinnkov et al., 2002); lake muds (Carter, 2002; Thorne, 2004); sand dunes (Horrocks et al., 2000; Boyd, 2005); tephra sequences (Sase et al., 1987; Parr, 1999; Lentfer et al., 2001), and coastal plain sequences in addition to other sediment types (Fredlund and Tieszen, 1997; Carter and Lian, 2000; Prebble and Shulmeister, 2002; Lü et al., 2002; Abrantes, 2003; Piperno and

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doi:10.1016/j.jas.2008.09.038

Jones, 2003; Charles and Isabel, 2005). However, their reliability as palaeoenvironmental indicators in soils has been less well studied (but see for example Kelly et al., 1991; Piperno and Becker, 1996; Alexandre et al., 1999; Prebble et al., 2002; Strömberg, 2004; Strömberg et al., 2007). Similarly, numerous studies have been reported on phytoliths extracted from archaeological sediments and artefact surfaces (e.g. Bowdery, 1998; Barboni et al., 1999; Grave and Kealhofer, 1999; Kealhofer et al., 1999; Mercader et al., 2000; Piperno et al., 2000; Wallis, 2000, 2001; Vrydaghs et al., 2001; Ishida et al., 2003) but the analysis of phytoliths recovered from archaeological soils is less common (Rovner, 1971; Pearsall, 1978; Lewis, 1981; Delhon et al., 2003; Sullivan and Kealhofer, 2004).

Similarly, owing to a lack of locally based researchers, our existing knowledge about the Holocene climatic history of Bangladesh is limited (but for exceptions see Ahmed, 1993; Choudhury, 1994); hence there is "an urgent need for further study to better understand and forecast El Niño teleconnections" in the region (Glantz, 2000: 23).

This paper presents the results from a study of phytolith assemblages recovered from the late Holocene-aged archaeological soils of the world heritage listed Somapura Mahavihara archaeological monastery site located in Badalgacchi Upazila of Naogaon District, northwestern Bangladesh. In addition, the palaeoenvironmental data thus obtained is compared with local clay mineralogical data (Alam et al., 2008) and global palaeo-temperature curves proposed by Warrick and Ahmad (1996), and the question of whether the El Niño Southern Oscillation (ENSO) has affected the patterning observed raised.

2. Study site location

The Somapura Mahavihara (meaning "large monastery") archaeological site is located in northwestern Bangladesh, and is arguably the most important and the largest known Buddhist monastery south of the Himalayas. The site is situated in the village of Paharpur, Badalgacchi Upazila of Naogaon District, between latitudes 25°1.79′–25°1.95′N and longitudes 88°58.50′–88°58.70′E (Fig. 1). Paharpur is situated in the monsoon region with a summer dominant rainfall, lying just north of the Tropic of Cancer. The climate of the area is generally warm and humid, though based on rainfall, humidity, temperature and wind pressure four seasons are recognized: (a) pre-monsoon, (b) monsoon, (c) post-monsoon and (d) winter. The maximum daily temperature ranges from 37 °C to 39 °C and the minimum from 7 °C to 10 °C. Rainfall is very light from November to February, increases somewhat in March and April and continues uniformly at about 250 mm/month during the monsoon months June to September. In May and October the rainfall average decreases to approximately 130 mm/month. The total average rainfall for the year is 5080 mm.

The Paharpur region is well-drained by numerous small, entrenched meandering streams and rivers. Approximately 4.5 km to the west of Somapura, the Old Jamuna River flows from north to south, maintaining a meandering course, forming many oxbow lakes. The traces of relict watercourses are detectable from the air and mostly run in a north–south direction, although an east–west arm appears to have extended laterally just south of the monastery (Chowdhury, 2003).

The Somapura Mahavihara site is currently surrounded by rich alluvial farmland with small open fields that are intensively cultivated, though small pockets of natural vegetation persist in some areas. Artificial cultivation platforms and homestead areas are used for growing vegetables and bananas, fruit trees and Betel leaf (*pan*). Mixed forest, scrub and replanted Gajari (Assam Sal) and Sal (*Shorea robusta*) occupy patchy areas of the higher ridges of the Barind terraces.

3. Archaeological background

The archaeological ruins of the Somapura Mahavihara monastery were discovered by Buchanan Hamilton who visited the site between 1807 and 1812 whilst surveying for the East India Company (Sanday et al., 1983) and the first excavations were conducted at the site later in the 19th century by Sir Alexander Cunningham (1879). The ruins were placed on the Bangladesh List of Protected Monuments in 1919, and inscribed to the World Heritage List in 1985.

The site is extensive, covering approximately 10 km^2 (10 ha). It occupies a quadrangular court measuring ca. 274 m on each side, with high enclosure walls ca. 5 m thick and between 3.6 and 4.5 m high. This gigantic establishment is dominated by a central shrine with 177 surrounding monastic cells and is conspicuous by its lofty height and unusual architectural design (Alam, 2003; see Fig. 2). The site lies surrounded by a slightly elevated terrace, meaning the area remained flood-free throughout historic times, a feature which it is thought may have been an important factor in allowing the Pala Empire to flourish.

The chronology of the occupation sequence at Sompura Mahavihara has largely been established on the basis of excavations undertaken from 1927–28 and 1933–34 (see Dikshit, 1938). With the support of UNESCO, the Department of Archaeology of the Ministry of Cultural Affairs, Bangladesh subsequently completed further excavations from 1981–82, 1984–85, 1988–89, and 1990–91, which have further contributed to our understanding of the sequence of events at the site. Such excavations have revealed that Somapura Mahavihara was occupied predominantly by the Pala Dynasty from the middle of the 8th century through to the early 12th century. Dharmapala, the second Pala monarch who ruled from about AD 770–810, founded Somapura Mahavihara in the second half of the 8th century. Towards the end of the 9th century the Palas were defeated by the Gurjara-Pratiharas, but roughly a century later the Pala Dynasty flourished once more. In the 11th century, the Pala again suffered a setback and were devastated by war, though towards the end of the century prosperity returned once more. In the 12th century the Senas, who were followers of Hinduism, replaced the Palas, and from this time onwards the human use of Somapura Mahavihara gradually declined before the monastery was permanently abandoned (Sanday et al., 1983).

The site sits on the Pleistocene–Holocene aged Barind Clay Residuum (Alam et al., 1990), which is the largest Quaternary physiographic unit of the Bengal Basin and comprises slightly elevated landform terraces within the alluvium. The underlying sediments—known as the Pleistocene–Holocene Madhupur Clay/Barind Clay—are considered to be marine–estuarine deposits (Brammer, 1996). The Barind Clay Residuum is a strongly iron-stained, clay-rich unit of weathered alluvial sediment that is compact and resistant to erosion. In the study area it consists of two zones: an upper zone comprising a grey to yellowish brown mottled clayey silt/silty clay, with a lower zone of red and brownish-yellow mottled clayey silt; the amount of sand increases gradually with depth. Both zones feature abundant pottery fragments, brick chips and plant roots, and are described as archaeological soils belonging to the Holocene epoch.

4. Materials and methods

4.1. Sampling

The archaeological soils of Somapura were sampled in May 2006 and later in August of the same year. For the collection of samples two trenches (labelled Trench 1 and Trench 2), were excavated from the surface to the first occupation level of the monastery. Trench 1 is located in the vicinity of the northern outer wall of the monastery