Journal of Nordic Archaeological Science 13, pp. 27–42 (2002)

Sediment and soil characteristics and an evaluation of their applicability to the irrigation history in Sigiriya, Sri Lanka

Jan Risberg, Eva Myrdal-Runebjer & Urve Miller

Palaeoecological studies were conducted in the Sigiriya area in 1992–1995. This paper reports on pilot studies and tentative interpretations regarding sediments deposited in tanks and canals, together with buried soil surfaces under embankments, i.e. bund-fillings. Various types of *in situ* sediments and accumulations served as reference material. The methods applied comprise siliceous microfossils, pollen, organic carbon, carbonate content, grain size distribution, plant macrofossils and measurements of mineral magnetic concentrations. Oxidising conditions constitute a problem for the preservation of organic microfossils and macrofossils. The results of the analyses of siliceous microfossils in sediments from the abandoned post-mid-5th century AD reservoir Sigiri MahaVäva and its transbasin canals are in accordance with earlier archaeological interpretations, suggesting that the basin was quickly abandoned and hardly ever put to use again. It also seems possible to identify the abandonment of the irrigation canals in the diatom assemblages, but the definition of water-laid sediments in functioning canals by diatom analyses seems less promising. Studies of a village irrigation tank indicate possibilities for future tank sediment studies in combination with archaeological excavations of settlements in order to enhance our understanding of land-use development.

Introduction

Co-operation between the Sri Lankan/Swedish *Settlement Archaeology Research Collaboration Project* (SARCP) and the Department of Quaternary Research (now the Department of Physical Geography and Quaternary Geology), Stockholm University, led to investigations into the possibilities for using sedimentary sequences and terrestrial accumulations from different environments for palaeoecological research. This field of research is of special importance to studies related to the pre-colonial development and subsequent decline of irrigated agriculture. The dates of the construction and utilisation of large-scale irrigation structures in Sri Lanka have mostly been inferred from literary sources and epigraphic material. Irrigation engineers and archaeologists have noted various limitations on this approach, however (Parker/1909/1981, Prickett 1994, Myrdal-Runebjer 1996; see further below). One problem concerns field identification of the structures mentioned in the written sources, and another is physical identification of the stage of the work referred to in such sources (Ievers 1899, Gunawardana 1971).

It is difficult to ascertain from the literary sources whether irrigation structures have been used continuously or whether there were phases of abandonment and subsequent repair and re-use. W.I. Siriweera (1971)points out that no chronology of abandonment of the large irrigation systems has been worked out. The decay of the large-scale irrigation structures is presumed to have started in the 13th century, but there are some known examples of tanks clearly above the scale of a village tank which remained in use after the “collapse of the Rajarata civilisation”, and even up to the early 19th century (Brohier/1934/1979, Ievers 1899, Parker /1909/1981).

Furthermore, there is the vast body of field material consisting of village tanks in the form of sediment accumulations which are out of focus with the literary and epigraphic sources. Many of today’s c. 25,000 minor irrigation schemes in Sri Lanka (watering less than 40 ha each) have been reclaimed (Wijesuriya & Kamaladasa 1988).

The stratigraphy of sediment accumulations in tanks and canals could be one important source of information related to questions of utilisation phases (studied by diatom analysis) and land use patterns (recorded by pollen, phytoliths and indications of erosion) through time. The possibilities of dating the phases identified could also be considered.

The aims of the present work were:

- to become acquainted with existing and past environmental conditions in an area in the dry zone,
- to develop field methods for determining sediment characteristics, and
- to evaluate the applicability of these methods to research into irrigation history.

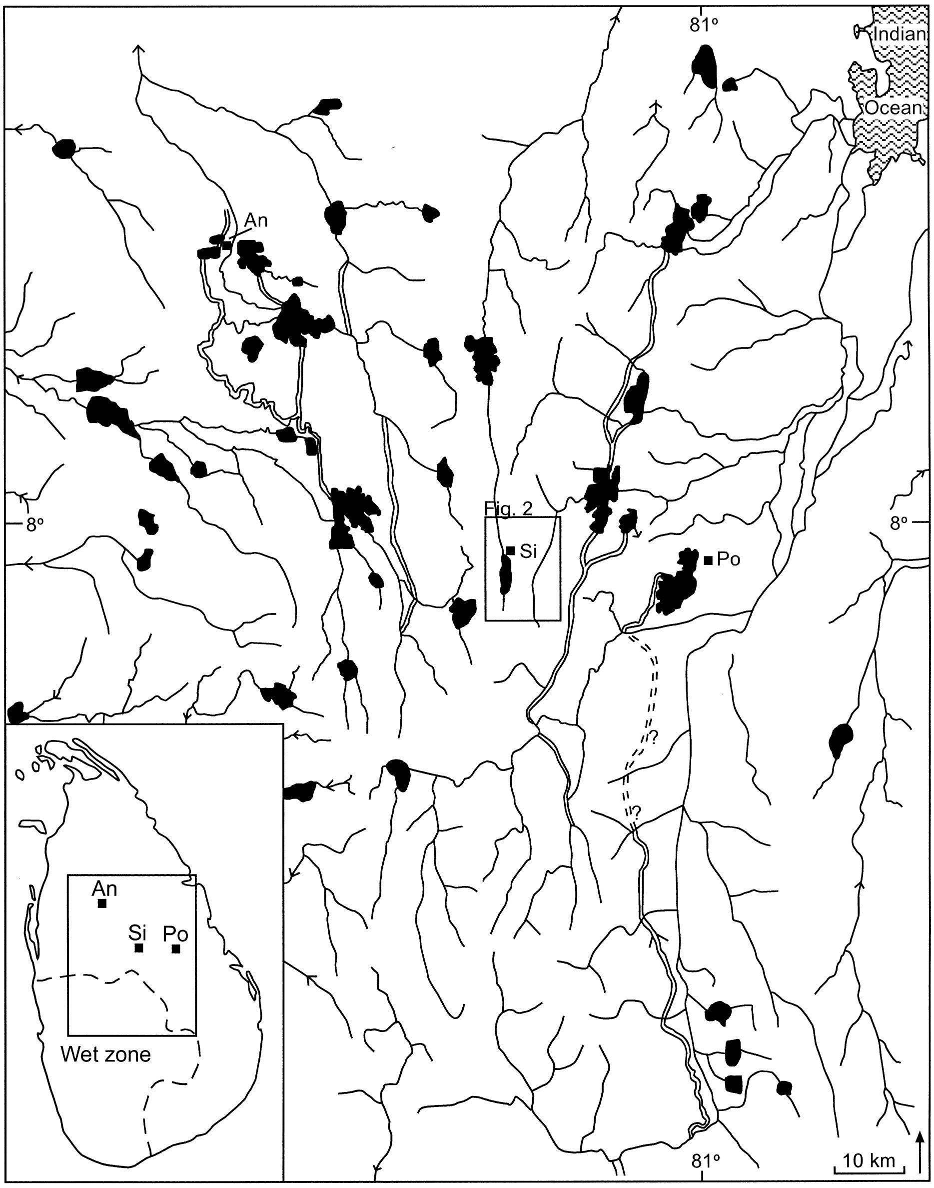

Figure 1. Location of Sigirya (Si) and the surrounding main drainage system (simplified from Myrdal-Runebjer 1996). Water from the wet zone is clearly directed towards drier areas in the north. The mountains in the southern part reach heights of around 1800 m a.s.l., while the Sigiriya area is situated at approx. 200 m a.s.l. Dark areas represent tanks and parallel lines man-made canals. An = Anuradhapura; Po = Polunnaruva.

It is our hope that this project will be continued and that the results can be used for deducing the irrigation history of the "dry" zone of Sri Lanka.

Location and geology of the area

The sites investigated are situated in central Sri Lanka (fig. 1). Climatically, the area is part of the "dry" zone, receiving c. 1000–1500 mm of rainfall per year (Swan 1983). The Sigiriya area is situated at the boundary between the Precambrian Highland Series, consisting of metasediment and charnockitic gneisses, and the Wanni Complex, consisting of gneisses, migmatites, granite gneisses and scattered metasediments and charnockitic rocks (Cooray 1991). East of Sigiriya is a thick limestone band running in a NNE–SSW direction, interbanded with narrow, well exposed beds of khondalite and paragneisses (Vitanage 1957). Geomorphologically, the area consists of undulating plains with insular heights ("inselbergs"; Swan 1983). The soil type is characterised as a deep weathered, reddish brown earth (Cooray 1967).

Historical context

The past hundred years of archaeological documentation and research have shown that people have lived in the Sigiriya area for various periods since prehistoric times. The earliest radiocarbon dates so far obtained, for a stone-age habitation site at the foot of the Sigiri rock, range from the 4th to the 3rd millennium BC (Karunaratne & Adikari 1994). Inscriptions from the Early Brahmi period and continuing through the Brahmi-Sinhala transition, conventionally dated from 300 BC to AD 1200, have been recorded. There is an abundance of architectural and artefact material from monastic contexts in the same periods. The focus of archaeological and historical research, however, has been on the 5th century AD royal palace and water gardens on and around the Sigiri rock. According to current interpretations

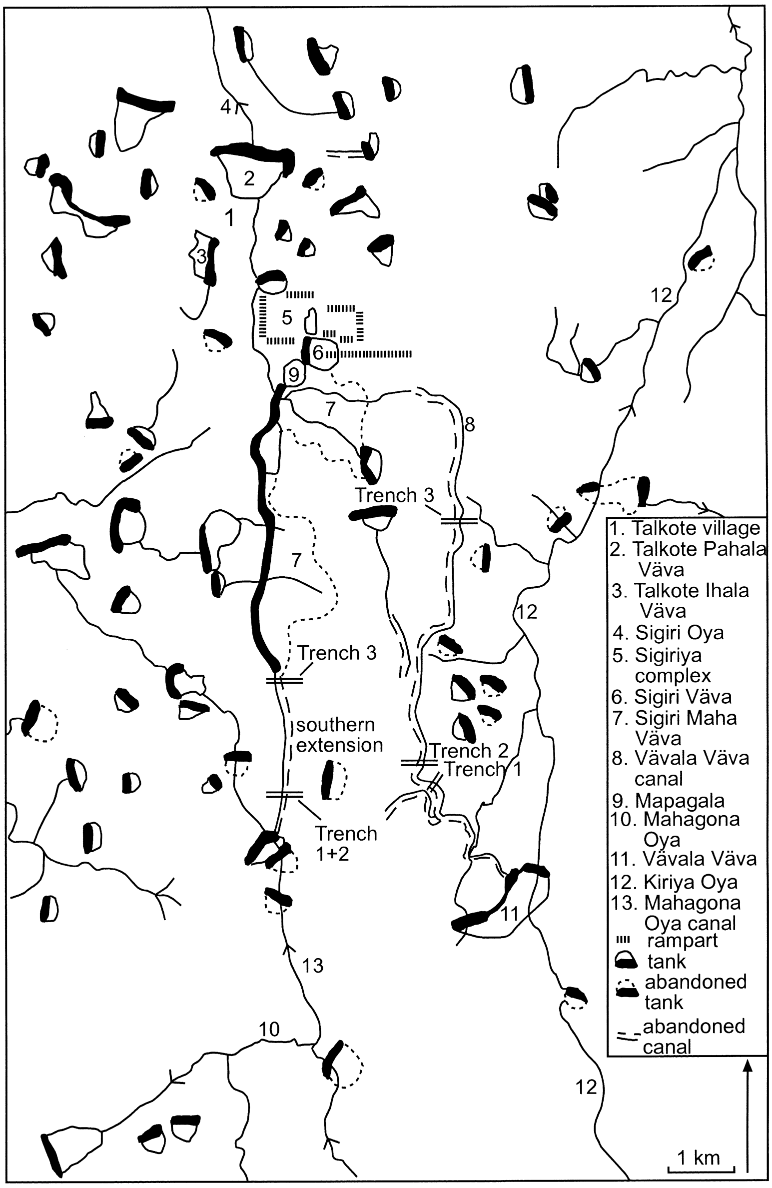

Figure 2. Map of the present-day landscape of village-based irrigation in the Sigiriya area. The abandoned reservoir (7) and its supply canals (8, 10, 13) are seen south of the Sigiriya complex (simplified from Myrdal-Runebjer 1996). Dark areas represent tank bunds.

of archaeological and literary material, the Sigiriya complex was built during a period of only 18 years between AD 477 and 495. The royal palace was then abandoned, but the constructions were partly used by the monastic community until the 11th or 13th century. The structures related to the religious and secular elite are then interpreted as having been abandoned from the 13th to the 16th century. Sigiriya and the surrounding villages are mentioned in historical records for the 17th to 19th century as outposts of the kingdom of Kandy (Bandaranayake 1984).

The rural hinterland of the Sigiriya complex came into the focus of research when the "Settlement Archaeological Research and Collaboration Project" started in 1988. The associated fieldwork revealed a much more highly differentiated land-use pattern than had previously been known. Iron production was documented both as a small-scale undertaking in a settlement context from the 5th century BC to the 5th century AD and as large-scale production from the 2nd century BC to the 2nd to 4th century AD (Karunaratne 1994a; Forenius & Solangaarachchi 1994).

The agrarian landscape, in particular the village-based irrigation structures, shows indications of abandonment and re-use, though there is so far hardly any chronological control for the phases recognised. The 20th century is known to have been a period of reclamation and enlargement of the village tanks. Parallel to village-based irrigation, the peasants also engaged in swidden cultivation. The relative importance of the small-scale paddies and the swiddens has varied with time at a given location (Myrdal-Runebjer 1994). Swidden cultivation has not been studied in Sri Lanka from an archaeological or palaeoecological point of view.

Sigiri Maha Väva, the abandoned reservoir at the foot of the Sigiri rock, represents an emphasis on paddy cultivation. It has a *terminus post quem* date referring to the mid-5th century (Myrdal-Runebjer 1996). In the 19th and 20th centuries some parts of its "bund" were re-used as an embankment

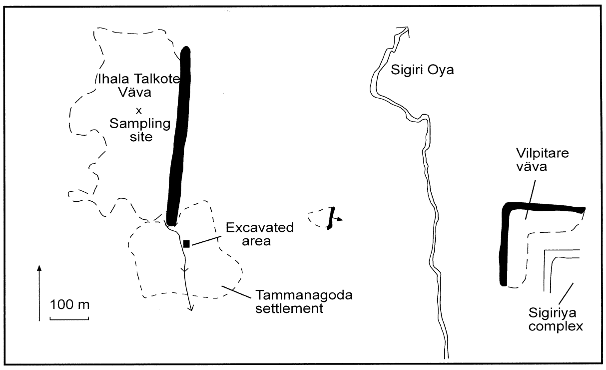

Figure 3. The Ihala Talkote Väva and its sampling site. The dark areas represent tank bunds. The coarse stippled line denotes the approximate maximum extent of the water surface in the Ihala Talkote Väva, and the fine stippled line the extent of the Tammanagoda settlement.

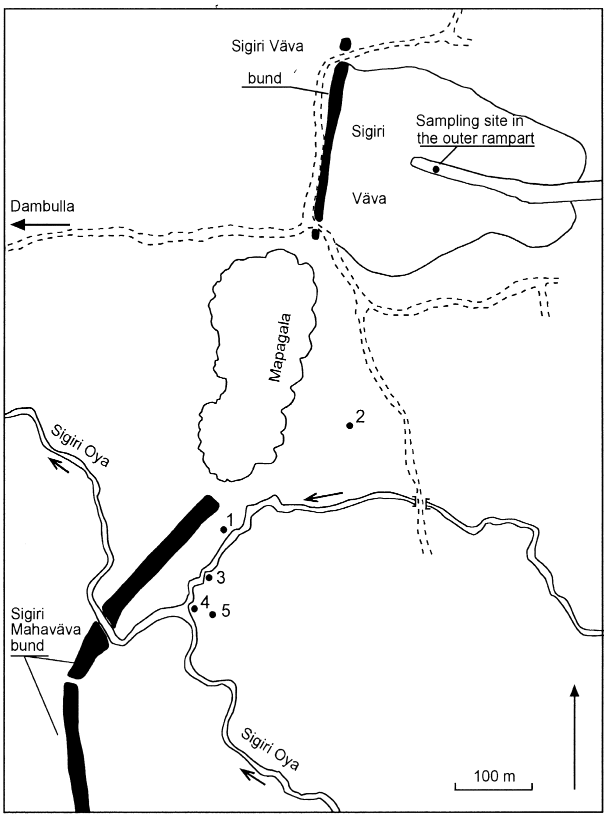

Figure 4. Location of the sampling site in the outer rampart of the Sigiriya complex in Sigiri Väva and the northern part of Sigiri Maha Väva. Coring sites in the Sigiri Maha Väva sediments are numbered 1–5. The area to the south of the present-day Sigiri Väva is elevated, causing a natural water divide. Mapagala is a bedrock outcrop. Dark areas represent man-made tank bunds.

for rain-fed village tanks. The term "bund" is defined as an embankment (earthen wall) constructed in topographically strategic places in order to retain water. Abandoned paddy fields are detectable in the abandoned tank bed itself in places where the monsoon rains create water-soaked conditions.

Site descriptions, sampling methods and lithology

The sites are described below with regard to their prehistory and their geographical and geological settings. Sampling was performed in various ways, both from open sections and using coring equipment. When necessary, colours were determined using Munsell Soil Colour Charts (1975).

Talkote Ihala Väva

This rain-fed tank with a 500 m long man-made bund, a maximum circumference of 1400 m and a maximum water depth of 3–4 m is situated within the Sigiri Oya basin, close to the Talkote village and 1600 m WNW of the Sigiriya complex (fig. 2). It is dry for about 6 months per year, during which time the bottom is covered with vegetation, mainly *Nelumbium* sp., Poaceae (Graminae) and *Hydrilla* sp.

An abandoned settlement site was identified on the southern shore in 1988 (fig. 3). Three phases of occupation could be recognised in the stratigraphy on the basis of radiocarbon dates and artefact analyses,. Phase 1, defined by Black and Red Ware (BRW) pottery, iron nails and paste beads, is dated to cal. AD 134–444 (Ua-5506; 1730±65 ^{14}C years BP, 2σ) And Phase 2, defined by Plain Red Ware (PRW) pottery, iron nails and pieces of slag, to cal. AD 434–654 (Ua-5507; 1500±65 ^{14}C years BP, 2σ). The latter phase is interpreted as the major period of habitation, being partly contemporaneous with the major phase in the construction of the Sigiriya palace and water gardens. Phase 3 is defined by iron slag, terracotta and glass fragments and is dated to cal. AD 760–1008 (Ua-5505; 1170±70 ^{14}C years BP, 2σ) (Somadeva & Kasthurisinghe 1994). A basin was found cut into the rock above the site (Mogren 1994).

A 50 cm long sediment core was collected from a raft approximately in the middle of the tank using a Hiller corer (fig. 3) at a water depth of c. 2.8 m in April 1994. The sediment sequence consisted of clayey silt and silty clay. A sand layer that could not be penetrated with the equipment used occurred 50 cm below the sediment surface.

Sigiri Maha Väva

This is an abandoned tank situated just south of the Sigiriya complex (fig. 2). It was once connected to two trans-basin canals: the Vävala Väva canal from the south-east and the Mahagona Oya canal from the south. The northern part of its bund rises 8–10 m above present ground level for a distance of c. 270 m and is 40–44 m broad at the base. Elsewhere the bund rises 0.1–3.0 m above present ground level and is 8–26 m broad at the base. The total length of the embankment is c. 7.4 km of which 750 m consists of natural high ground and low north-south-oriented gravely ridges.

The Sigiri Maha Väva has been studied from archaeologically with regard to its constructional features and date of construction (Myrdal-Runebjer 1996). The northernmost section of the bund (now the Sigiri Väva) has been *terminus post quem* dated to cal. AD 434–648 (Ua-5563; 1510±60 ^{14}C years BP, 2σ)

Immediately south of the insular height Mapagala, the Sigiri Maha Väva bund overlies a cyclopean wall, the construction of which is assigned to the 5th century AD (Kumaradasa 1994), the latest *terminus post quem* date being cal. AD 310-604 (Ua-5220; 1630±80 ^{14}C years BP, 2σ). The wall was *terminus ante quem* dated to cal. AD 406-618 (Ua-5501; 1565±55 ^{14}C years BP, 2σ).

The area is situated on the western boundary of the Batuoyakande-Sudukande Charnockite-Khondalite Belt as defined by Vitanage (1957), and the dominant assemblages are typical pre-Cambrian metasedimetary rock types, e.g. limestone, quartzite, garnetiferous-sillimanite schists, amphibolites, paragneisses and charnockites. Studies of the geology of the area indicate that the tank is located on the Nalanda-Kalmianes limestone belt (Perera 1984).

In February 1995, the lithostratigraphy of five sites (fig. 4) was investigated using a jackhammer fitted with a split-spoon sampler (∅ 38 mm). Four cores were taken at a point in the lowest part of the tank bed close to where a small tributary enters the Sigiri Oya. This tributary rises where the Vävala Väva canal ends, so that it once formed the connection between the Sigiri Oya basin and the Kiri Oya basin to the east, carrying water from the canal to the reservoir. The

Table 1. Lithostratigraphy of the five coring sites in Sigiri Maha Väva.

Site 1. Approx. 25 m E of the bund and 10 m W of a small meandering stream (connected to Vävala Väva canal further NE). All depths are in cm from the ground surface.

000–010 No recovery
010–030 Silty clay. 10YR 3/2.
030–060 Silty clay with occasional granules. 10YR 3/2.
060–075 Silty clay. 10YR 4/2.
075–090 Silty clay with pebbles. 10YR 4/2.
090–110 Clayey silt with granules and pebbles. 10YR 4/4.
110–125 Clayey silt with granules and pebbles. 10YR 5/1. Fe precipitation. Very stiff.
125–155 Clayey silt with granules and pebbles. Charcoal at 125 cm. Fe precipitation in patches and Fe nodules.
155–170 No recovery.
170–185 Clayey silt with granules and pebbles. Fe precipitation in patches. Probably weathered bedrock.
185–215 Bedrock (?) less and less weathered downwards.

Site 2. In the village of Sigiri. Approx. 100 m E of Mapagala (northern rock). Below the yard of a house, above (N of) abandoned paddy fields.

000–040 Clayey silty gravel. Granules and gravel consists of quartz. 10YR 5/6.
040–060 Gravel.
060–080 Clayey silty gravel. 10YR 5/6.

Site 3. Approx. 4 m E of a small meandering stream, 50 m from the confluence of this stream with Sigiri Oya, 11 m from rising ground. Surface slopes gently from the rising ground towards the coring site, which is situated on flat land adjoining the stream.

000–035 Silty clay. 10YR 4/1.
035–075 Silty clay. 10YR 4/2.
075–100 Silty clay. 10YR 5/4.
100–115 Coarse sand. Pottery. 10YR 5/4.
115–150 Sandy silty clay. 10YR 4/3. Coarse nodules with $CaCO_3$. Pottery at 150 cm.
150–160 Clayey sandy silt. 10YR 4/3.
160–165 Clayey silty sand. 10YR 6/2.
165–195 Weathered crystalline limestone bedrock. 10YR 8/1.

Site 4. Approx. 5 m E of the confluence between Sigiri Oya and the small meandering stream.

000–035 Clayey silt with occasional pebbles. 10YR 5/1. $CaCO_3$ present.
035–075 Clayey silt with occasional pebbles. 10YR 4/2. Carbonate granules.
075–115 Clayey silt. 10YR 4/2. Fe precipitation. Increasing amount of $CaCO_3$ downwards.
115–150 Clayey silt. 10YR 4/1. Increasing amount of Fe precipitation and $CaCO_3$ downwards.
150–155 Granules and pebbles in clay. Weathered bedrock. 2.5YR 8/1.

Site 5. Approx. 23 m E of coring site 4, up-slope rising ground.

000–040 Clayey silt. 10YR 4/1. $CaCO_3$ present. Charcoal at 40 cm.
040–075 Clayey silt 10YR 4/2. $CaCO_3$ present.
075–155 Clayey silt. 10YR 4/6 and 10YR 6/2. Increasing amount of $CaCO_3$ and changing colour downwards: 10YR 6/4.
155–165 Clayey silty sand. 10YR 6/4.
165–195 Weathered bedrock. Quartz sand, limestone.

two streams meet in the ancient väva-bed east of the highest section of the embankment. In general, the sediment consists of clayey silt with varying amounts of sand and pebbles. Pottery fragments and charcoal were found as deep as 150 cm in one core and charcoal at a depth of 125 cm in another (table 1). The fifth core was taken at a site south of the present day Sigiri Väva, where high ground east of the insular height Mapagala today forms a natural watershed for the abandoned reservoir.

The outer rampart of the Sigiriya complex

The tank bed of the northernmost section of the Sigiri Maha Väva (now Sigiri Väva) features a low earthen bund (1–1.5 m) running perpendicular to the tank bund (fig. 4). This starts about150 m from the present tank bund and continues eastwards for some 2 km, at which point it joins a natural ridge stretching north-south and runs almost parallel to the southern inner rampart of the Sigiriya complex. This southern bund has been interpreted as part of the southern outer rampart of the Sigiriya complex (Blakesley 1876, Bell/1899/1904; Karunaratne 1994b).

The southern gateway through the inner rampart facing the tank bed itself and the outer rampart situated in the tank raised the question of the chronological relationship between the tank and the assumed urban area. The bund was trenched during the field season 1992 to establish the chronological relation between the rampart and the tank, the aim being to test, through analyses of microfossil content and composition, the possibility of defining the underlying layers as being an ancient soil surface or a tank bottom sediment.

The trench was approximately 3 m deep and revealed several stratigraphic sequences of clayey strata mixed with layers containing coarser grains (fig. 5, table 2). The samples studied consisted of sand (sample No. 14) and gravelly sandy clay (sample No. 16), having been collected from underneath what was interpreted in the field as bundfill.

Vävala Väva canal

A 11 km long abandoned earthen canal runs from Vävala Väva in the south to a point 800 m E of the presumed water-spread of the ancient Sigiri Maha Väva (fig. 2), where it connects with a tributary of the Sigiri Oya (see above). The canal runs more or less parallel to the contour lines, thus having a bund only on its eastern side.

The canal bed and its bund were trenched perpendicularly to the bund at three sites in September/October 1992 (fig. 2), the purpose, apart from obtaining samples for palaeo-environmental analyses, being to study the constructional features

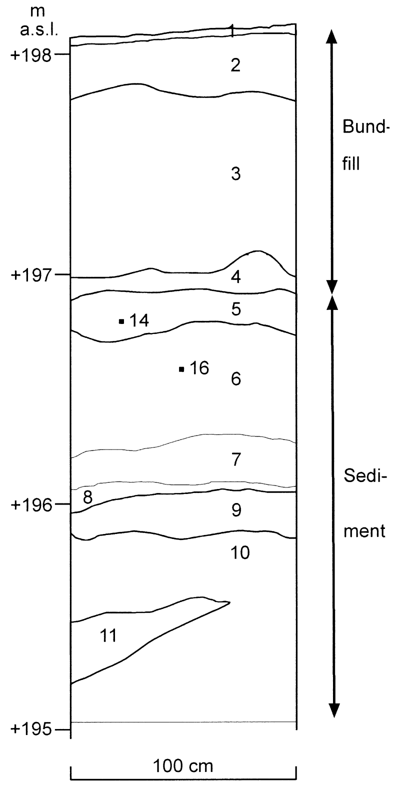

Figure 5. Generalised sediment stratigraphy in and below the southern outer rampart of the Sigiriya complex. Sampling sites are indicated. Lithological descriptions according to table 2.

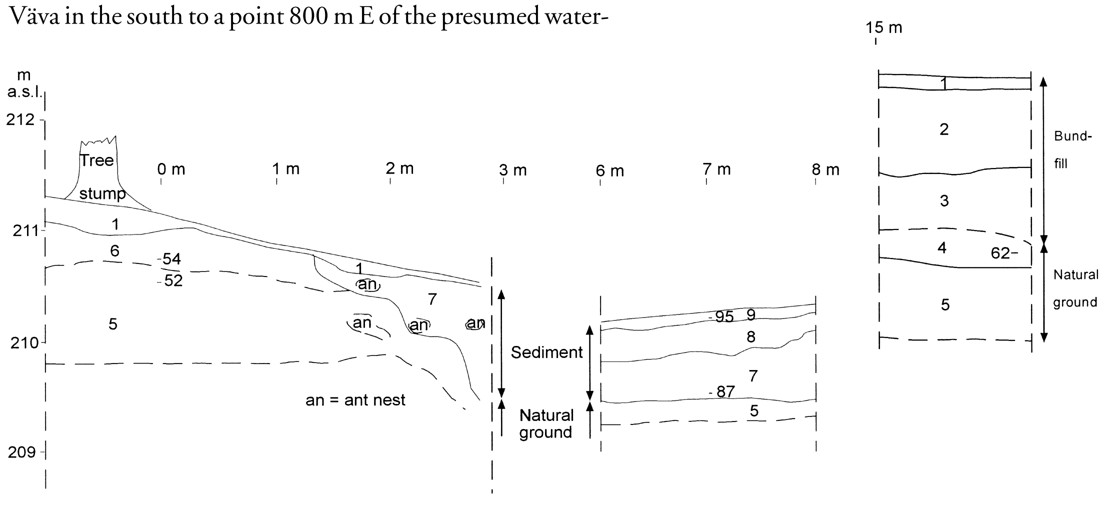

Figure 6. Generalised sediment stratigraphy in Trench 1, exposed in the Vävala Väva canal and canal bund. Sites of the samples analysed are indicated. Lithological descriptions according to table 3.

Table 2. Stratigraphical layers in the trench in the outer rampart of the Sigirya complex. Units 1–4 were interpreted in the field as representing bundfill, while the remaining units represent various sedimentary phases. Trench and sample numbers are according to the field report by Myrdal-Runebjer available at the PGIAR.

Unit	Lithology	Colour, dry	Colour, wet
1	Coarse sand with humus	10YR 4/1 (dark grey)	10YR 8/1 (dark grey)
2	Coarse sand	10YR 6/1 (grey)	10YR 3/1 (very dark grey)
3	Sandy clay with scattered stones	10YR 6/8 (brownish yellow)	10YR 5/4 (yellowish brown)
4	Clayey coarse sand with stones	–	(grey)
5	Sand	5YR 5/1 (grey)	5YR 3/1 (very dark grey)
6	Gravelly sandy clay	10YR 6/8 (brownish yellow)	10YR 5/6 (yellowish brown)
7	Sand	5YR 5/8 (yellowish red)	5YR 4/6 (yellowish red)
8	Clayey coarse sand	10YR 6/6 (brownish yellow)	10YR 5/6 (yellowish brown)
9	Silty sand	7.5YR 7/8 (reddish yellow)	7.5YR 5/8 (strong brown)
10	Sandy clayey silt with patches of fine sand	silt: 10YR 4/6 (dark yellowish brown) sand: 10YR 7/8 (yellow)	10YR 3/6 (dark yellowish brown) 10YR 3/6 (dark yellowish brown)
11	Clay	10YR 5/6 (dark yellowish brown)	10YR 5/6 (yellowish brown)

Table 3. Lithostratigraphy of the Vävala Väva canal, Trench 1, and its bund. Trench and sample numbers are according to the field report by Myrdal-Runebjer available at the PGIAR.

Unit	Lithology	Colour, dry	Finds
1	Gravel and coarse sand with humus	2.5YR 4/6 (red)	–
2	Coarse sandy gravel with scattered stones	2.5YR 4/8 (red)	Red ware potsherds
3	Gravelly coarse sand	2.5YR 4/6 (red)	–
4	Gravelly coarse sand (lenses of fine sand)	2.5YR 4/6 (red)	–
5	Coarse sandy gravel (stones in the lower part)	2.5YR 4/8 (red)	–
6	Sandy gravel (humus towards the top)	2.5YR 4/4 (reddish brown)	–
7	Gravelly silty sand	2.5YR 4/6 (red)	Red ware potsherds
8	Gravelly sandy silt	2.5YR 3/6 (dark red)	–
9	Sandy silt with scattered charcoal and soot	5YR 4/6 (yellowish red)	–

and inclination of the canal bed in relation to the sill level of the ancient sluice at the outlet from the Vävala Väva tank. Attention was also paid to evidence of de-silting operations and the finding of organic material for *terminus post quem* dating.

The construction of the canal bund was tentatively *terminus post quem* dated to AD 398–628 (Ua-3185; 1565±60 ^{14}C years BP, 2σ). Organic material taken from the bottom sediment layer of Trench 3 was dated to 614–878 AD (Ua-3186; 1 330±70 ^{14}C years BP, 2σ). The bund was found to have been built of soil excavated from the future canal bed. No bedding interfaces were observed between the units in the canal bed, nor was any indication found of de-silting operations in the form of water-laid sediment deposited on top of the bund . The canal-bed inclination (1.13 m/km) exceeded the usual for well functioning ancient canals (0.09–0.2 m/km) and the gradients used in modern praxis (0.1–0.3 m/km). The thickness of the lowermost sediment layer in the canal in Trenches 1 and 2 represents a much reduced capacity for transporting water. Cultural remains (three potsherds) were found only at the bottom of the lowermost sediment layer in Trenches 1 and 3. The tentative alternative interpretations are either that the canal was neglected and hardly ever used, or that it was abandoned because of low human activity in the surroundings (Myrdal-Runebjer 1996).

The samples for palaeoenvironmental analysis were collected from three parts of the trenches: from presumed natural ground to the west, from natural ground in the mid-canal bed, through the presumed sediments, and from natural ground in the east, through the bundfill. The aim was to test by means of diatom analyses the possibility of defining the stratigraphy in terms of sediment suspended in the canal water and terrestrial material derived from erosion of the bund and the natural slope above the canal bed. Furthermore, the soil underlying the canal bund was sampled with the aim of testing the possibility of using microfossils (phytoliths and diatoms) to identify the soil surface that had developed prior to construction of the bund.

Samples from Trenches 1 and 2 were selected for analysis based on field interpretation of the units as natural ground, overlaid soil surface, bundfill and sediments. Five samples were analysed from Trench 1 (fig. 6 and in table 3). Unit 7 was interpreted in the field as representing sediments deposited in the canal. It is more fine-grained than the natural ground (unit 5) and also contains artefacts in the form of PRW potsherds. Unit 4 in the eastern cross-section contained lenses of fine sand and was interpreted in the field as representing the boundary between the natural ground and the canal bund. All the layers in the western part of Trench 2

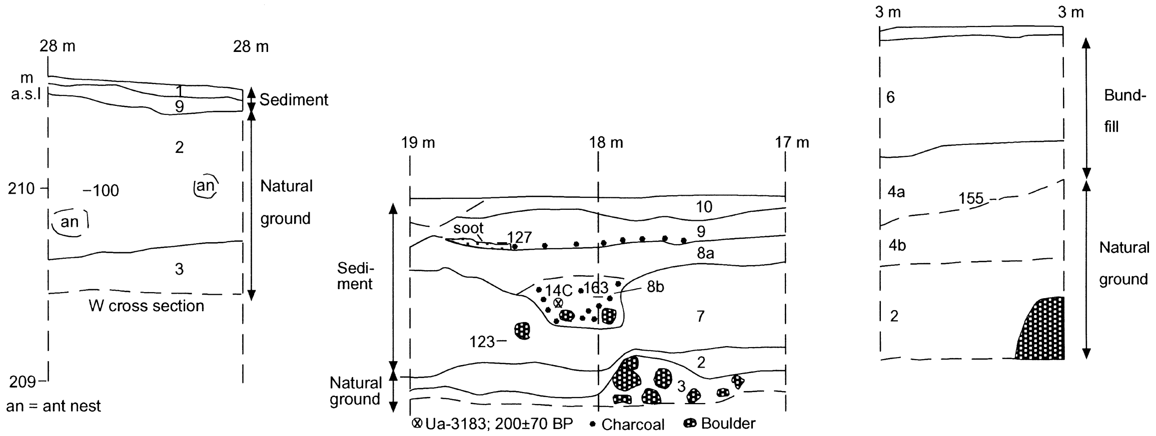

Figure 7. Generalised sediment stratigraphy in Trench 2, exposed in the Vävala Väva canal and canal bund. Sites of the samples analysed are indicated. Lithological descriptions according to table 4.

Table 4. Lithostratigraphy of the Vävala Väva canal, Trench 2, and its bund. Trench and sample numbers are according to the field report by Myrdal-Runebjer available at the PGIAR.

Unit	Lithology	Colour, dry	Finds
1	Coarse sand with humus	Grey/brown	–
2	Silty sand	Reddish/brown	–
3	Sand (weathered bedrock)	–	–
4a	Sand	Reddish/brown	–
4b	Fine sand	Dark reddish/brown	–
6	Stony sandy gravel	Red	–
7	Silty fine sand	Reddish grey	–
8a	Silty sand	Greyish red/brown	–
8b	Stony silty sand	Greyish/black	–
9	Silty sand	Grey/brown	–
10	Silty sand	Greyish red/yellow	–

Table 5. Lithostratigraphy of the Sigiri Maha Väva southern extension, Trench 3, bund side. Trench and sample numbers are according to the field report by Myrdal-Runebjer available at the PGIAR.

Unit	**Lithology**	**Colour, dry**	**Finds**
1	Sand	10YR 3/6 (dark reddish brown)	–
2	Sand	7.5YR 4/6 (strong brown)	–
4	Stony gravel	5YR 4/6 (yellowish red)	–
5	Sandy clay	5YR 4/6 (yellowish red)	–
8	Clayey sand	10YR 4/4 (dark yellowish brown)	–
9	Sandy gravel	5YR 4/4 (reddish brown)	–
10	Stony coarse gravel	2.5YR 4/6 (red)	–

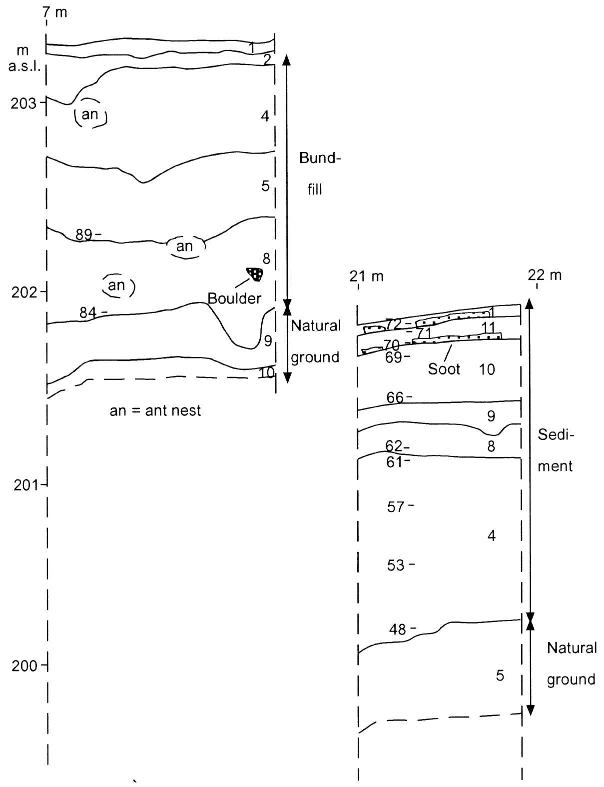

Figure 8. Generalised sediment stratigraphy in Trench 3, located over the southern extension of the Sigiri Maha Väva bund and the canal- bed. Sites of the samples analysed are indicated. Lithological descriptions according to table 5 (left section) and table 6 (right section).

(fig. 7 and table 4) were interpreted in the field as representing the natural ground. In the middle part of the cross-section, over the canal-bed itself, the interface between units 2 and 7 marks the boundary between the natural ground and the sediment that accumulated in the canal, while in the eastern section of Trench 2, the bundfill (units 4a and 6) is underlain by natural ground (unit 2) and what was interpreted in the field as a topsoil layer (unit 4b) . Five samples were analysed from this trench.

The southern extension of the Sigiri Maha Väva (SMV) bund

South of the point where the SMV bund ends, the topographical maps show a low and partly much disturbed earthen

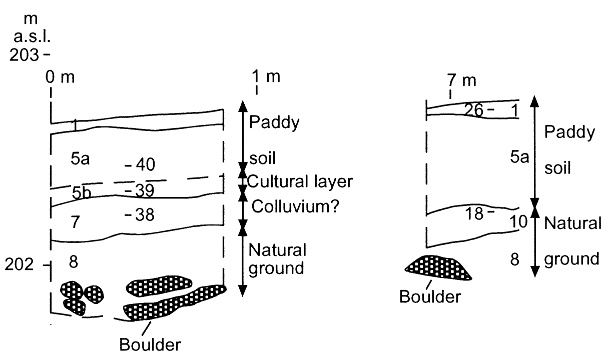

Figure 9. Generalised sediment stratigraphy in Trench 1, located over the presumed tank bed east of the southern extension of the Sigiri Maha Väva bund. Sites of the samples analysed are indicated. Lithological descriptions according to table 7.

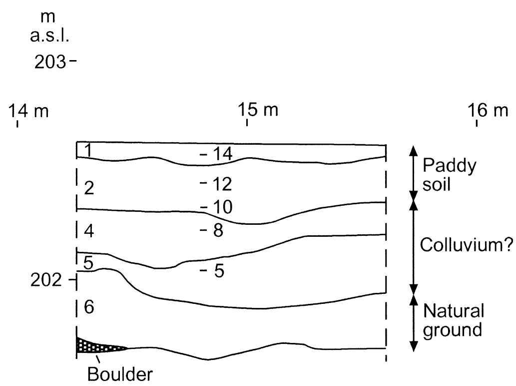

Figure 10. Generalised sediment stratigraphy in Trench 2 over the presumed tank bed east of the southern extension of the Sigiri Maha Väva bund. Sites of the samples analysed are indicated. Lithological descriptions according to table 8.

Table 6. Lithostratigraphy of the Sigiri Maha Väva southern extension, Trench 3, canal bed. Trench and sample numbers are according to the field report by Myrdal-Runebjer available at the PGIAR.

Unit	Lithology	Colour, dry	Finds
1	Sand	10YR 3/6 (dark yellowish brown)	–
11	Sandy clay with soot and charcoal	10YR 3/4 (reddish brown) and	–
		5YR 2.5 (black)	–
10	Fine sand and fine gravel	5YR 4/4 (reddish brown)	–
9	Gravel	5YR 5/8 (yellowish red)	–
8	Coarse sand	5YR 4/6 (yellowish red)	–
4	Coarse sand	10YR 5/8 (yellowish brown)	–
5	Gravel	5YR 5/8 (yellowish red)	–

Table 7. Lithostratigraphy of the Sigiri Maha Väva southern extension, Trench 1, cross-section to the south. Trench and sample numbers are according to the field report by Myrdal-Runebjer available at the PGIAR.

Unit	Lithology	Colour, wet	Finds
1	Sand with humus	5YR 3/4 (dark reddish brown)	–
5a	Clayey sand	2.5YR 3/4 (dark reddish brown)	Red ware pottery, few
5b	Clayey gravel	10YR 3/6 (dark yellowish brown)	Red ware pottery, several
7	Sandy clay	10YR 4/6 (dark yellowish brown)	Red ware pottery, few
10	Clayey fine gravel	10YR 3/4 (dark yellowish brown)	–
8	Clayey gravel, weathered limestone	7.5YR 8/2 (pinkish white)	–

bund that ends at the bund of the present day Vegolle Väva (fig. 2). This latter tank is fed by a canal taking its water from the Mahagona Oya in the south. Some sections of the southern extension seem to define the boundary of a tank (Myrdal-Runebjer 1996), and when passing close to high ground it defines the boundary of a canal, as do some sections of the SMV bund north of it. Fieldwork was carried out here in 1993, using a similar sampling method to that used in the Vävala Väva canal.

Trench 3 was located over the bund (fig. 2) and over what is here a canal bed just south of where the southern extension joins the SMV bund. On the bund side, units 10 and 9 were interpreted in the field as natural ground and the superimposed units as bundfill (fig. 8 and table 5), while all the layers above unit 5 in the canal bed section were interpreted as having accumulated in the canal (fig. 8 and table 6). The lower part of unit 11 displays a black, burnt interface with unit 10 (5YR 2.5/1). The twelve samples analysed for the parameters studied (table 9) consist of bundfill and sediments that accumulated within the canal.

Trench 1 was located over part of the presumed tank bed and over the southern extension of the SMV bund, which at this site constitutes a low, natural gravelly ridge. Trench 2 was dug over the presumed tank bed as a continuation of Trench 1, but 16 metres further north (fig. 2). The area to the east of the ridge becomes naturally water-soaked in the

Table 9. Methods employed at the sites studied. Figures refer to the numbers of sub-samples analysed. "no"= no samples analysed.

Methods	Site:	Talkote-Ihala Väva	Sigri-Maha Väva	Outer rampart Sigiriya complex	Vävala Väva canal			South. ext. of Sigiri Maha Väva bund		
	Trench:				1	2	3	1	2	3
Siliceous microfossils		26	3	2	10	no	no	2	5	12
Pollen		no	no	2	10	no	no	2	5	12
Plant macrofossils		no	no	no	no	no	no	1	2	1
Organic carbon		6	3	2	10	no	no	2	10	16
Loss on ignition		no	no	no	10	no	no	2	10	16
Carbonates		no	3	2	10	no	no	2	10	16
Grain size distribution		no	no	no	no	no	no	2	6	12
Mineral magnetics		26	no	no	no	no	no	no	no	no

Table 8. Lithostratigraphy of the Sigiri Maha Väva southern extension, Trench 2. Trench and sample numbers are according to the field report by Myrdal-Runebjer available at the PGIAR.

Unit	Lithology	Colour, wet	Finds
1	Sand with humus	10YR 3/6 (dark yellowish brown)	–
2	Clayey sand	10YR 3/4 (dark yellowish brown)	–
4	Gravelly clay	10YR 4/6 (dark yellowish brown)	–
5	Clay	10YR 5/8 (yellowish brown)	–
6	Clayey gravel	10YR 4/4 (dark yellowish brown)	–

rainy season, and shows traces of abandoned paddy fields. An unexpected early start of the monsoon in 1993 created a shallow water body in the excavation area and made pumping necessary in order to excavate and document Trench 2.

The paddy soil in Trench 1, from which six samples were analysed, covers a cultural layer (fig. 9 and table 7) which continues up the gravelly ridge and contains a large number of PRW potsherds. These were found to include from the remains of rice strainers and large storage vessels. A few of them had grain imprints, and a grain of rice was found in the wall of one. This was subsequently ^{14}C dated (see below). A few finds of PRW pottery were also made in the units below and above what was interpreted as the cultural layer proper.

The paddy soil in Trench 2, which was underlain by clayey and gravelly accumulations (fig. 10 and table 8), yielded no cultural remains. Five samples were analysed.

Laboratory methods

The laboratory analyses were focused on siliceous microfossils, pollen, plant macrofossils, measurements of organic carbon and loss on ignition, carbonate content and mineral magnetic parameters. These methods were used on soil samples from the various sites in the manner shown in table 9.

Siliceous microfossils (i.e. diatoms, phytoliths, sponge spiculae and Chrysophyceae stomatocysts) were prepared according to methods for diatom analysis compiled in Battarbee (1986). The sample sizes varied in the range 0.5–1.0 cm^3. Organic matter was removed using 30% H_2O_2, and clay particles by repeated sedimentation and decanting in 100 ml beakers at 2 hr intervals. The residue was mounted in Naphrax and studied under a microscope at ×400 and ×1000 magnifications. The floras of Krammer & Lange-Bertalot (1986, 1991a, b) and Foged (1976) were used for identification and ecological information.

Pollen was concentrated according to the methods compiled by Berglund & Ralska-Jasiewiczowa (1986). The samples were dispersed in NaOH and carbonates were dissolved with HCl. Acetolysis was applied in order to remove cellulose, and cold HF was added to remove minerogenic particles. The residue was mounted in glycerine and studied under a microscope at ×400 magnification.

Precursory plant macrofossil analyses of four sediment samples from one of the sites, the southern extension of the Sigiri Maha Väva bund, were carried out by Dr. Ann-Marie Hansson at the Archaeological Research Laboratory, Stockholm University.

Organic carbon content was measured in an Eltra Metalyt 80W. The dried (105°C) and homogenised samples were combusted in an oven at 550°C. The results are expressed in % of dry weight. Loss on ignition (LOI) was measured as the difference between the weights before and after ignition at 550°C. Three of the samples were treated with 10% HCl to remove Fe precipitations and ignited again at 550°C.

Carbonate content was determined by the Passon technique. HCl (10%) was added to the samples and the evaporated CO_2 measured (cf. Kezdi 1980).

Mineral magnetic parameters were measured by Dr. Gustav Sohlenius at the Department of Quaternary Geology, Lund University. Magnetic susceptibility was measured using an air-coiled susceptibility bridge (Kappabridge), the samples being magnetised artificially with pulse magnetic chargers. Magnetic saturation was achieved by placing each sample in a high magnetic field of 1 Tesla (T) produced by a Redcliff pulse magnetic charger. The artificial remanence was measured on a Molspin spinner magnetometer (SIRM). After the saturation procedure, the samples were placed in a weak negative field of 0.1 T (IRM-0.1T), and the S-ratio was calculated as IRM-0.1T/SIRM. High Induced Remanent Magnetisation (HIRM) was calculated as (1-|S|xSIRM/2). Anhysteretic Remanent Magnetisation (ARM) was induced in an

Table 10. Siliceous microfossils in the 50 cm sediment core from Ihala Talkote Väva. "+" indicates single finds, "++" several finds and "+++" a high abundance. The organic carbon content of the six samples is noted as a % of dry weight.

Zones:				TIV 1										TIV 2							TIV 3					
Depth (cm):	50	48	46	44	42	40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2	0
Diatoms:																										
Aulacoseira distans (?) (Ehrenberg) Simonsen	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Eunotia spp Ehrenberg	–	–	–	–	–	–	–	–	–	+	+	–	–	+	–	+	–	–	–	+	–	–	–	–	–	–
Fragilaria capucina v. *mesolepta* (Rabenhorst) Rabenhorst	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	++	–	–	–	–	–	–	–	–
Gomphonema gracile Ehrenberg	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Navicula sp. Bory	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–
Neidium productum (W. Smith) Cleve	–	+	–	–	–	–	–	–	–	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Pinnularia sp. Ehrenberg	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	+	–	+	+	–	+	–	–	–	–
Stauroneis anceps Ehrenberg	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
Stauroneis sp. fragment Ehrenberg	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–
Sponge spiculae:	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
Phytoliths:	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
Organic carbon (%):		1.8					1.6				3.0						3.5					3.4				3.7

Table 11. Results of analyses of organic carbon and carbonate content in three samples collected at coring site 4 in the Sigiri Maha Väva.

Depth (%)	Organic carbon (% dwt)	Carbonate ($CaCO_3$) (% dwt)
25	1.4	0.4
50	0.9	3.1
75	0.8	4.9

Table 12. Results of analyses of siliceous microfossils and organic carbon content in samples collected from the outer rampart of the Sigiriya complex.

Sample no.	Phytoliths Bilobate	Elongated	Other	Diatoms	Chrysophyceae stomatocysts	Organic carbon
14	10	46	8	1	2	0.15
16	1	10	3	–	1	0.14

Table 13. Chemical and physical properties of soil and sediment samples from the Vävala Väva canal bund and canal bed. LOI = Loss on ignition. Siliceous microfossils were studied in some of the samples. Numbers refer to microfossils per 10 traverses. "++" indicates high abundance and "+" common presence.

Sample no.	Org. C (% dwt)	LOI %	LOI minus Fe-prec.	Phytoliths Bilobate	Elongated	Other	Diatoms	Chrysophyceae stomatocysts
Trench 1								
54	1.02	6.3	–					
52	0.24	14.8	6.5	1	2	18	1	–
95	2.62	8.4	7.0	++	+	+	not counted	not counted
87	0.38	8.1	–					
62	0.25	8.6	–					
Trench 2								
100	0.34	4.3	–					
123	1.09	9.6	–	2	30	16	7	1
163	3.23	25.8	9.0					
127	2.52	9.1	–					
155	0.21	2.6	–	1	30	135	–	–

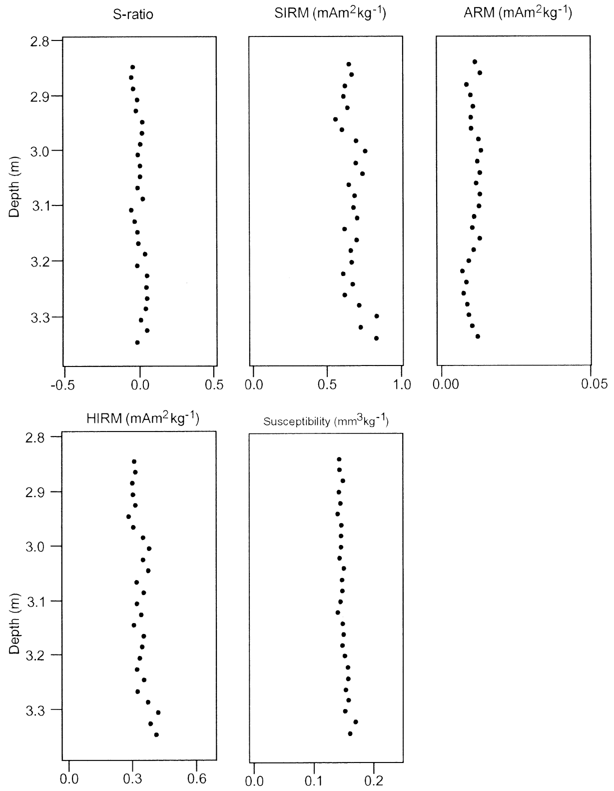

Figure 11. Variations in mineral magnetic parameters in the sediment core from Ihala Talkote Väva.

AC demagnetiser with a peak alternating field of 100 mT and a steady field of 0.1 mT. The remanence was measured on the spinner magnetometer. After completion of these tests, all the samples were dried to allow the determination of mass specific concentration parameters (cf. Thompson & Oldfield 1986).

Radiocarbon dates were obtained by the AMS technique at the Radiocarbon Dating Laboratory, Uppsala University (Possnert 1990) and calibrated according to Stuiver et al. (1998).

Results and interpretation

Talkote Ihala Väva (TIV)

The sequence analysed has been divided into three zones, TIV 1 to TIV 3, from the bottom upwards, based on variations in organic carbon content and the occurrence of diatoms (table 10). TIV 1 (50–33 cm) is almost devoid of diatoms, only one frustule of *Neidium productum* being found, and the organic carbon content is around 1.6%. Rather more diatom frustules were found in TIV 2 (33–11 cm), however, the dominant taxa being *Eunotia* spp. and *Fragilaria capucina* v. *mesolepta*, and the organic carbon content increased to around 3%. Zone TIV 3 (11–0 cm) was again very poor in diatoms, but the organic carbon content showed relatively high values (about 3.5%).

All the diatom species identified represent a shallow freshwater environment with oligotrophic conditions and a relatively low pH, although *Gomphonema gracile* can also tolerate some salinity (Krammer & Lange-Bertalot 1986). Sponge spiculae and phytoliths were present in great abundance throughout the sequence, the phytoliths often being bilobate and/or elongated, although other forms occurred as well. No Chrysophyceae stomatocysts were noted.

The mineral magnetic graphs show very uniform patterns, indicating a similar magnetic mineralogy and grain size throughout the sequence (fig. 11). The high S-ratios indicate a predominance of anti-ferromagnetic minerals, e.g.. haematite.

The tank partly dries out seasonally, except in the deeper part close to the bund, where it is used by water buffaloes for drinking and bathing. Sampling should therefore not be carried out in the deepest parts of tanks which dry out seasonally. During the dry season the exposed bottom is covered by plants, which are grazed by cattle. The low diatom content may be attributable to biological dissolving and uptake of silica during periods of low or no water in the tank , as growing plants use the easily accessible amorphous (biogenic) silica of which the diatom frustules are composed and accumulates it as phytoliths, the phytolith silica then remaining in the soil after decomposition of the plants. Conversely, the high abundance of sponge spiculae in the sediment may be explained by their chemical and biological insolubility (cf. Miller et al. 1992). The find of *Gomphonema gracile* may indicate that water with a slightly enhanced salinity could have occurred during some periods.

The sediment sequence was not dated, but Somadeva & Kasthurisinghe (1994) dated the oldest settlement close to the dam construction to cal. AD 134–444. On the assumption that the bund was constructed in connection with the oldest settlements and that the sand layer at 50 cm depth represents the original ground surface, this interval may represent the maximum age. This would indicate that the mean sediment accumulation rate in the Talkote Ihala Väva is of the order of 0.3 mm/year. Vermaat (1956) suggested on the basis of field studies that clay and silt are deposited in the "dry" zone tanks at a rate of about 1 mm/year.

On the assumption that the sequence is undisturbed and representative, one interpretation could be that zone TIV 2 represents a period with less drying-out of the tank. This would produce shorter periods with a vegetation cover on the tank floor and thus a more favourable environment for diatom growth and preservation. Such an environment may have been the result of a moister climate and/or a period when the tank bund was extended, thus creating a larger body of water. On a regional scale, a relatively wet period was defined between AD 1200–1400 using $\delta^{13}C$ variations in peat sequences from south-western India (Sukumar et al. 1993), while on a local scale, this zone may be correlated with the major habitation period radiocarbon dated to cal. AD 434–654. The tank may have been more extensively used at this time and thus kept in better condition. It might be possible to resolve the age of this zone by OSL.

Table 14. The southern extension of the Sigiri Maha Väva bund. Results of siliceous microfossil, pollen and chemical analyses.

Trench	Sample no.	Phytoliths spiculae	Diatoms & spores	Sponge carbon (%)	Pollen	Organic	LOI	Carbonates
1	26	–	–	–	yes	2.9	9.0	–
	18	–	–	–	–	0.4	4.1	–
1	40	yes	–	–	–	1.8	6.7	–
	39	yes	–	–	–	1.3	5.8	–
	38	yes	–	–	yes	0.8	5.0	–
2	14	yes	–	–	yes	2.6	7.9	–
	12	yes	–	–	–	1.6	5.7	–
	10	yes	–	–	–	0.9	4.8	–
	8	yes	yes	–	–	0.4	4.6	0.2
	5	yes	–	–	–	0.3	4.6	2.5
3	72	yes	yes	–	yes	2.5	9.5	–
	71	yes	yes	–	–	1.6	6.9	–
	70	yes	–	–	–	1.2	3.8	–
	69	yes	yes	–	–	0.6	3.2	–
	66	–	–	–	–	0.5	4.4	–
	62	yes	–	–	–	0.4	4.2	–
	61	yes	yes	–	–	0.4	4.1	–
	57	yes	–	–	–	0.3	4.2	–
	53	yes	–	–	–	0.3	5.0	–
	48	yes	–	yes	–	0.3	4.3	–
3	89	yes	–	–	–	0.5	4.6	–
	84	yes	–	–	–	0.3	3.5	–

Sigiri Maha Väva

The organic carbon content decreases downwards in the SMV sediment, while the carbonate content increases (table 11). The samples studied were poor in siliceous microfossils, containing only a few sponge spiculae and possibly simple forms of phytolith.

Despite the sparse occurrence of siliceous microfossils, an obvious interpretation to be drawn from the stratigraphical cores is that the uppermost silty clay and clayey silt (around 125–150 cm) should be classified as sediment. This is based on observations of pottery and charcoal at these depths. The low abundance of siliceous microfossils, i.e. sponge spiculae and/or diatoms, may indicate that no larger water body existed in the tank for any longer period of time. The downward increase in carbonate content probably indicates an underlying limestone bedrock (cf. Vitanage 1957).

The outer rampart of the Sigiriya complex

The high phytolith content of sample No. 14, in combination with low diatom numbers, indicates a former ground surface (table 12). This interpretation is strengthened by the lower phytolith content of the sample taken from the unit below. The low diatom numbers and lack of sponge spiculae do not support as the notion of a tank sediment. The low organic carbon content could result from sampling carried out somewhat below the old ground surface. Bilobate types of phytholiths, which may emanate from millet (*Panicum*), a dry land crop, were identified (see Barnes 1990).

One possible interpretation may thus be that the outer rampart was built on dry land before the tank was constructed.

Vävala Väva canal

None of the samples analysed contained carbonates. There are large differences in the loss on ignition measured before and after the removal of Fe precipitations (table 13).

The topmost sample from the canal bed in Trench 1 (No. 95) contained abundant phytoliths relative to the others (table 13), and also displayed the highest organic carbon content. This is the result of more moist conditions, allowing the present canal bed to support more vegetation during the rainy season, and the fact that the area is nowadays used for (bush) swidden cultivation. The occurrence of phytoliths in samples Nos. 52 and 54 from the presumed natural ground may be explained as reworking by termites and along root canals. The quantities of phytoliths in these samples were comparable with those found in the lower sample below the southern outer rampart (sample No.16).

In Trench 2, sample No. 100 was thought to represent natural ground not affected by human activities, as verified by the low organic carbon content. The lower sample from the canal bed contained fragments of seven diatoms, which may indicate that the sediment was of an aquatic character. The uppermost two samples showed a high organic carbon content, and organic material from one of these units was dated to 200 BP and from the other to the present time (Myrdal-Runebjer 1996). The high carbon content may be connected with swidden cultivation in the area. Sample No. 155 was taken in an assumed fossil soil surface below the canal bund, as suggested by the high phytolith content, although there are no increased values for organic carbon.

The southern extension of the Sigiri Maha Väva bund

Five samples were analysed from two sections in Trench 1, which extended over the natural gravelly ridge and the presumed ancient tank bed (table 14). Sample No. 18 was taken from below the paddy soil, in a unit supposedly unaffected by human activities. This assumption is verified by the lack of siliceous microfossils and the low organic carbon content. The sample from the present-day topsoil (No. 26) shows a high organic carbon content and the presence of pollen and spores. Samples Nos. 38–40, taken from a paddy soil, a cultural layer containing PRW pottery (see above) and the unit immediately below the cultural layer, contained phytoliths and had an enhanced organic carbon content, verifying their anthropogenic influence. One potsherd, found to the west of the sampling sections, contained a grain of rice in its wall. This was dated to 174 BC–AD 78 (Ua-3889; 2 035±55 ^{14}C age BP, 2σ).

Five samples from Trench 2, in the presumed tank bed, were analysed for siliceous microfossils (table 14), and were all found to contain phytoliths. In addition, the brackish water diatom taxon *Cocconeis scutellum* and the indifferent/halophilous taxon *Epithemia turgida* were identified in sample No. 8, i.e. from below the paddy soil. Organic carbon is low in the lower part and increases upwards, with an obvious increase at the transition from the gravelly clay to the paddy soil. Samples Nos. 5 and 8, from below the paddy soil, have a carbonate content of 2.5 and 0.2%, respectively, and sample No. 5 also contains soot, so that the carbonate may be a result of the burning of wood, causing calcium oxalate phytoliths to re-crystallise as calcite. As discussed above, the area is naturally water-soaked during the rainy season, and as this is most probably not a recent phenomenon, it may well explain the occurrence of diatoms.

Twelve samples were analysed from two sections in Trench 3, which extended over the canal bund and canal bed. All the samples from the canal bed except for No. 66 contained siliceous microfossils with a predominance of phytoliths. Samples Nos. 69, 71 and 72, taken from the uppermost units, which clearly represent the abandonment phase, contained the brackish water diatom taxa *Cocconeis scutellum*, *Hyalodiscus scoticus, Synedra tabulata* and *Bacillaria paradoxa,* together with the halophilous *Epithemia turgida* v. *westermanni*, with the aerophilous *Hantzschia amphioxys* also present in the uppermost sample (No. 72). Only the uppermost sample (No. 61) contained diatoms in unit 4, which was interpreted in the field as the oldest sedimentation layer. The bottom sample (No. 48) contained phytoliths and sponge spiculae, thus probably representing sediment.

Samples Nos. 89 and 84, obtained from the bundfill units, gave low values for organic carbon, but contained some phytoliths.

The occurrence of diatom taxa indicating brackish conditions could be explained by the presence of stagnant or very slowly flowing water, allowing evaporation and thus creating enhanced saline conditions. These diatom types were found in sediment units belonging to the abandonment phase, when precipitation in the rainy season created a seasonal flow and subsequent pools of standing water.

Four samples were studied for their macrofossil content of, two collected from Trench 1 (one from the cultural layer, unit 5b, and one from the paddy soil, unit 5a) and two from the bottom of the burned interface in unit 11 in Trench 3 and the ground surface east of Trench 3. Common to all four samples is the poor preservation of the plant macrofossils, i.e. seeds, fruits and plant remains, which could be connected with early land use and other human activities. The samples from Trench 1 (Nos 5 and 6) both yielded only fragments of charcoal, roots, straw and twigs, together with a few recent seeds and fruits. The surface layer sample from Trench 3 (No. 50) was of the same character as the samples from Trench 1, with the exception of a few seeds, which seemed to be burned. The sample from the bottom of the burned interface in Trench 3 (No. 35) was rich in plant remains and charcoal, and also had many unburnt seeds and fruits, mainly regarded as being of recent origin.

The predominant grain sizes in Trench 2 are clay and silt, while Trench 3 is dominated by coarse sand, with the exception of the uppermost sample, which has a higher clay content.

Concluding remarks

It is concluded that the occurrence of siliceous microfossils, particularly phytoliths, is connected with cultural layers, buried soil surfaces and tank bed and canal-bed sediments. Presumed *in situ* samples contain few or none of these microfossils. Thus, this method seems to provide a promising way of identifying layers that have a bearing on phases in the construction and utilisation of irrigation structures.

Phytoliths are common in ancient cultivated soils, and it seems to be possible to identify specific morphotypes representing millet (*Panicum*) and rice (*Oryza*) (cf. Barnes 1990). The millet type may be present in the sample from a pre-outer rampart context in the present Sigiri Väva, as discussed above. The identification of phytoliths to species needs to be developed further, however, before the method can be used for reaching conclusions on the type of vegetation at a given site.

Archaeologically, we may conclude that settlement-related activities were carried out on the gravelly ridge at the site of Trench 1 around 2000 years ago. The finds of sherds from rice strainers and a grain of rice in a potsherd wall indicate the use of rice at this site, and it is possible that the seasonally naturally water-soaked area below the ridge was used for paddy cultivation at that time. It seems impossible to ascertain this from the microfossil analyses at the site, however, as there is only one 0.4–0.5 m thick paddy soil layer, allowing no possibilities for chronological control (cf. Barnes 1990).

Diatoms occur sporadically and are sometimes represented by brackish-water taxa. They may possibly reflect an environment with stagnant and evaporating water, although preliminary studies of the recent diatom flora reveal only very slightly brackish taxa and ones indicative of pollution. Pollen and plant macrofossils are very badly preserved, due to the oxidising conditions, the latter being preserved only if charred.

Measurements of organic carbon indicated that the values always increase towards the soil surface, although high values have also been noted in buried units which have been affected by burning and deposition of coal and soot. Other buried ground surfaces show no enhancement. This is dependent on high temperature and high oxygen access, even in places well below the ground surface. The coarse-grained character of these accumulations accentuates the oxidation process.

The sediments in the two irrigation tanks give completely different results in terms of diatom content. Diatoms do occur in Talkote Ihala Väva, although in low abundance, while no frustules were observed in Sigiri Maha Väva. Sediment from Talkote Ihala Väva, which is still functioning, contains a high abundance of sponge spiculae and phytoliths, in contrast to that from Sigiri Maha Väva, which contains very few siliceous microfossils and has a much lower organic carbon content. How can these observations be interpreted in terms of the length of use of the two irrigation systems? One possibility is that Sigiri Maha Väva was never in use for any appreciable length of time. The sediment trapped behind the tank bund may have resulted from high-water discharge from the river Sigiri Oya, which now passes through a breach in the bund, and from its tributary. The type of sediment transported by such rivers is expected to contain few siliceous microfossils. If a large water body had existed after the construction of the tank bund, siliceous microfossils would have been more abundant. As indicated by the corings, the limestone bedrock is highly weathered, at least in the upper part. This, in combination with fracturing, would cause a high degree of leakage into the groundwater, so that it would be difficult for a tank to retain its water. These circumstances have to be taken into consideration when discussing the functioning of the tank.

It should be emphasised that measurements of loss on ignition (LOI) do not reflect the organic matter content, as high LOI values can be caused by laterite weathering products having a high iron (Fe) content. In the case of tropical soils it is therefore recommended to measure the organic carbon content instead. Grain-size distributions are also affected by laterite weathering, since it is known that recent processes have caused iron (Fe) to precipitate in nodules, leading to secondarily formed grains which have to be eliminated from granulometric analyses. Carbonate occurred in only a few samples, although several areas of limestone bedrock have been identified. This lack of lime in the soils is probably caused by secondary dissolving.

Acknowledgements

The project was initiated by Professor Senake Bandaranayake at the Postgraduate Institute of Archaeology (PGIAR), University of Kelaniya, Colombo. The fieldwork was carried out together with researchers and staff members from PGIAR. Special thanks areextended to Dr. S. Epitawatte, T.R. Premathilake, Gamini Adikari, Chandana Weerasena, S. M. Nandadasa, Chitra Dambadeniarachchi and Asoka Perera. Ms. Britta Hörnström and Ms. Margareta Wihlborg, DQR, SU, prepared the samples and carried out the chemical analyses.

Financial support is acknowledged mainly from SIDA/SAREC, but also from the Swedish Natural Science Research Council.

English language revision by Malcolm Hicks.

References

Bandaranayake, S., 1984. *Director's report. Sigiriya project. First archaeological excavation and research report (January – September 1982).* Central Cultural Fund. Ministry of Cultural Affairs. Colombo, pp. 1–23.

Barnes, G.L., 1990. Paddy soils now and then. *World Archaeology* 22 (1). Soils and Early Agriculture, pp. 1–17.

Battarbee, R.W., 1986. Diatom analysis. In (B.E. Berglund, Ed.) *Handbook of Holocene Palaeoecology and Palaeohydrology*. John Wiley & Sons. Chichester, pp. 527–570.

Bell, H.C.P., /1899/1904. *Archaeological survey of Ceylon.* Annual report 1899. Government Printer. Colombo.

Berglund, B.E. & Ralska-Jasiewiczowa, M., 1986. Pollen analysis and pollen diagrams. In (B.E. Berglund, Ed.) *Handbook of Holocene Palaeoecology and Palaeohydrology*. John Wiley & Sons. Chichester, pp. 455–484.

Blakesley, T.H., 1876. "On the ruins of Sigiri in Ceylon". *Journal of the Royal Asiatic Society Ceylon Branch* 8, 53–61.

Brohier, R.L., /1934/1979. *Ancient irrigation works in Ceylon.* Part I. The Ceylon Government Press. Colombo.

Cooray, P.G., 1967. *An introduction to the geology of Sri Lanka.* Natural Museum of Ceylon Publication. The Government Press, Colombo, Sri Lanka.

Cooray, P.G., 1991. The geology of Sri Lanka – problems and perspectives. *Journal of the Geological Society of Sri Lanka* 3, 1–14.

Foged, N., 1976. Freshwater diatoms in Sri Lanka (Ceylon). *Bibliotheca Phycologica* 23. J. Cramer.

Forenius, S. & Solangaarachchi, R., 1994. Dehigaha-ala-kanda (KO.14) at Alakola Väva: An early iron production site with a highly developed technology. In (S. Banadaranayake & M. Mogren, Eds) *Further studies in the settlement archaeology of the Sigirya-Dambulla region.* The Postgraduate Institute of Archaeology, University of Kelaniya. Colombo, pp. 135–144.

Gunawardana, R.A.L.H., 1971. Irrigation and hydraulic society in early medieval Ceylon. *Past and Present* 53, pp. 3–27.

Ievers, R.W., 1899. *Manual of the north-central province, Ceylon*. George J.A. Skeen, Government Printer. Colombo.

Karunaratne, P., 1994a. A brief report of the excavation at Ibbankatuva, a Proto and Early Historic settlement site. In (S. Banadaranayake & M. Mogren, Eds) *Further studies in the settlement archaeology of the Sigirya-Dambulla region.* The Postgraduate Institute of Archaeology, University of Kelaniya. Colombo, pp. 105–112.

Karunaratne, P., 1994b. The eastern precinct of the Sigirya complex. In (S. Banadaranayake & M. Mogren, Eds) *Further studies in the settlement archaeology of the Sigirya-Dambulla region*. The Postgraduate Institute of Archaeology, University of Kelaniya. Colombo, pp. 145–158.

Karunaratne, P. & Adikari, G., 1994. Excavations at Aligala prehistoric site. In (S. Banadaranayake & M. Mogren, Eds) *Further studies in the settlement archaeology of the Sigirya-Dambulla region*. The Postgraduate Institute of Archaeology, University of Kelaniya. Colombo, pp. 55–64.

Kezdi, A., 1980. *Handbook of Soil Mechanics*. Vol. 2. Soil Testing. 260 pp. Elsevier Scientific Publishing Company. Amsterdam.

Krammer, K. & Lange-Bertalot, H., 1986. Bacillariophyceae. 1. Teil: Naviculaceae. In (H. Ettl, J. Gerloff, H. Heynig & D. Mollenhauer, Eds) *Süsswasserflora von Mitteleuropa 2/1*. Gustav Fischer Verlag. Stuttgart.

Krammer, K. & Lange-Bertalot, H., 1991a: Bacillariophyceae. 3. Teil: Centrales, Fragilariaceae, Eunotiaceae. In (H. Ettl, J. Gerloff, H. Heynig & D. Mollenhauer, Eds) *Süsswasserflora von Mitteleuropa 2/3*. Gustav Fischer Verlag. Stuttgart.

Krammer, K. & Lange-Bertalot, H., 1991b. Bacillariophyceae. 4. Teil: Achnanthaceae. Kritische Ergänzungen zu Navicula (Lineolate) und Gomphonema. In (H. Ettl, J. Gerloff, H. Heynig & D. Mollenhauer, Eds) *Süsswasserflora von Mitteleuropa 2/4*. Gustav Fischer Verlag. Stuttgart.

Kumaradasa, W.A., 1994. New information on Mapagala. In (S. Banadaranayake & M. Mogren, Eds) *Further studies in the settlement archaeology of the Sigirya-Dambulla region*. The Postgraduate Institute of Archaeology, University of Kelaniya. Colombo, pp. 113–134.

Miller, U., Hörnström, B., & Wasell, A., 1992. The origin and properties of biogenic and amorphous silica in laminated sediments. In (M. Saarnisto & A. Kahra, Eds) *Laminated sediment*. Proceedings of the workshop at Lammi Biological Station 4–6 June, 1990. Geological Survey of Finland, Special Paper 14, 103–104. Espoo.

Mogren, M., 1994. The archaeology of Talkote. In (S. Bandaranayake & M. Mogren, Eds) *Further studies in the settlement archaeology of the Sigiriya-Dambulla region*. The Postgraduate Institute of Archaeology, University of Kelaniya, pp. 70–90.

Munsell Soil Color Charts (1975). Edition Munsell Color, Baltimore, Maryland 21218, USA.

Myrdal-Runebjer, E., 1994. Food procurement: labour processes and environmental setting. In (S. Bandaranayake & M. Mogren, Eds) *Further studies in the settlement archaeology of the Sigiriya-Dambulla region*. The Postgraduate Institute of Archaeology, University of Kelaniya. Colombo, pp. 241–264.

Myrdal-Runebjer, E., 1996. *Rice and millet. An archaeological case study of a Sri Lankan transbasin irrigation system*. Göteborg University. Department of Archaeology. Series B. Gothenburg Archaeological Theses. No 6. 224 pp.

Parker, H., /1909/1981. *Ancient Ceylon*. Asian Educational Services. New Dehli.

Perera, M.P., 1984. The plain of Sigiriya in its geographical setting. In (S. Bandaranayake, Ed) *Sigiriya project. First archaeological excavation and research report (January – September 1982)*. Central Cultural Fund. Ministry of Cultural Affairs. Colombo, pp. 228–232.

Possnert, G., 1990. Radiocarbon dating by the accelerator technique. *Norwegian Archaeological Review* 23, 30–37.

Prickett, M., 1994. *Ancient irrigation systems and sustainable development. National Symposium on indigenous knowledge and sustainable development*. Abstract. University of Sri Jawardenepura, Nugegoda, pp. 13–14.

Siriweera, W.I., 1971. The decay of the dry zone reservoir system of ancient Ceylon. In (Indrapela, Ed.) *The collapse of the Rajarata civilization in Ceylon and the drift to the south-west*. Ceylon Studies Seminar, 89–98. University of Ceylon, Peradeniya, pp. 89–98.

Somadeva, R. & Kasthurisinghe, M., 1994. Excavations at Tammannagala. In (S. Bandaranayake & M. Mogren, Eds) *Further studies in the settlement archaeology of the Sigiriya-Dambulla region*. The Postgraduate Institute of Archaeology, University of Kelaniya. Colombo, pp. 93–104.

Stuiver, M., Reimer, P.J., Bard, E., Beck, J.W., Burr, G.S., Hughen, K.A., Kromer, B., McCormack, G., van der Plicht, J. and Spurk, M. 1998. Instcal98 radiocarbon age calibration, 24,000–0 cal BP. *Radiocarbon* 40 (3), 1041–1083.

Sukumar, R., Ramesh, R., Pant, R.K. and Rajagopalan, G., 1993. A $\delta^{13}C$ record of late Quaternary climate change from tropical peats in southern India. *Nature* 264, 703–706.

Swan, B., 1983. *An introduction to the coastal geomorphology of Sri Lanka. Natural Museum of Ceylon Publication*. The Government Press, Colombo, Sri Lanka.

Thompson, R. & Oldfield, F., 1986. *Environmental magnetism*. Allen & Unwin. London.

Vermaat, J.G., 1956. *Report on soil and paddy problems in Ceylon*. Sessional paper XIX. Government Press Ceylon. Colombo.

Wijesuriya, L.T. & Kamaladasa, G.B.U., 1988. Irrigation schemes. In (T. Somasekaram, M.B.G. de Silva, L.A.G. Perera, M.M. Karunaratne, M.P. Perera & D.S. Epitawatte, Eds) *The National Atlas of Sri Lanka*, pp. 92–93.

Vitanage, P.W., 1957. The geology and water supply of the country around Pollonaruwa. I – Geology and structure. *Bulletin of the Ceylon Geographical Society* 11 (1–4), 30–45.