*A*rchaeologia

JOURNAL OF ARCHAEOLOGY

PART 02 VOLUME 01 2011

Content

Archaeologia
Part 02 Volume 01 2011 (Page 03-26)

Description and interpretation of Site C112:
Infilled Moat at a Double-platform Monastic Site, Anuradhapura Hinterland, Sri Lanka

Krista Gilliland, Ian Simpson, Prishanta Gunawardhana and R.A.E. Coningham

Abstract

We present the results of stratigraphic analysis, soil micromorphology, and optically-stimulated luminescence (OSL) measurement of an infilled moat at an abandoned monastic site within the Anuradhapura hinterland. Large-scale rice cultivation within the hinterland produced an agricultural surplus that sustained Anuradhapura's urban and monastic populations during its primary occupation, ca. 400 BC-AD 1017. Site C112 is one of eleven sites in our study that focuses on the onset, operation, and abandonment of large-scale irrigation within the Anuradhapura hinterland. Moat infill sediments at C112 document the abandonment of the monastery.

Keyword : Micromorphology, Sediment, Lithology

Introduction

Located about 19.8 km south of the Anuradhapura citadel at 8°11.735 N, 80°28.227 E, Site C112 (Marathamaduwa) is an abandoned monastic site consisting of several double platforms and bridges with associated rock-cut cisterns and moats (Figure 1). This site is a Padhanaghara Parivena-type monastery, a well-known architectural style that dates to the 8 -10 centuries AD (Figure 2), frequently associated with a sect of reclusive forest- dwelling meditational monks, the Pamsukulika (Bandaranayake, 1974, pp.130; Wijesuriya, 1998, pp. 148, in Coningham et al., 2007, pp. 708-9). Site C112 was unrecorded prior to the 2005-2006 field seasons, and although it does not appear to be connected to any large-scale irrigation works, it is possible that water from the cisterns may have fed into the moat.

A vertical stratigraphic section of a moat between two platforms was exposed to a maximum depth of 1.5 m, after which bedrock was encountered (Figures 3, 4). Excavated sediments include brick and tile that are the remains of collapsed adjacent structures, and field observations suggest that

Figure 1. Site C112 during excavation in 2007

Figure 2. The ruins of a Padhanaghara Parivena-type monastery, Western Monasteries, Anuradhapura

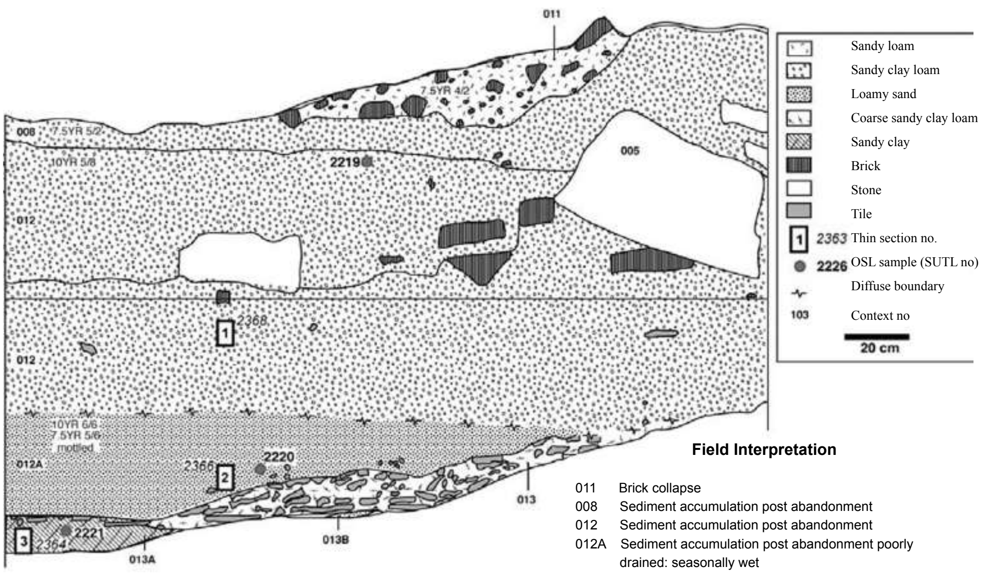


Figure 3. Stratigraphy, Site C112.

Figure 4. Field stratigraphy showing sampling locations, Site C112.

the moat was originally about 50 cm deep (Burbidge et al., 2008). Six stratigraphic units were identified during field recording. Textures range from loamy sand to sandy clay, and colours range from 7.5YR 5/2 and 10YR 6/6. The sandy clay at the base of the stratigraphy (Context 013A) was interpreted in the field as sediment accumulation in the moat prior to abandonment. This horizon underlies a layer of tile collapse following abandonment (Context 013B). These deposits were subsequently sealed by about 120-130 cm of largely undifferentiated loamy sands and sandy loams/sandy clay loams with brick and tile inclusions, representing post-abandonment deposits (Contexts 012A-008). Mottling in the lower 45 cm of the profile indicates alternating wetting/drying has been an active process at the site.

Results from OSL dating are reported in detail in Burbidge et al., 2008 and are briefly summarized here to provide a context for discussion of micromorphological results. The base of the moat infill (i.e. Context 013A) dates to AD 1090 ± 100 (error at 2 sigma), documenting an accumulation of sediments within the moat at about the same time as the abandonment of the city of Anuradhapura. The overlying Context 012A sediments contain debris from the adjacent structure collapse and date to AD 300 ± 400, which is not stratigraphically consistent with the underlying date. The large scatter in equivalent dose distribution for this sample suggests it represents sand grains with mixed OSL ages; however, this date could provide an approximate age of tile manufacture. An OSL date of AD 1860 ± 40 was obtained for sediments at approximately 30 cm depth (i.e.

Context 012). These sediments could have been deposited during the late 19th century as a result of landscape disturbance due to tank restoration and renewed irrigation activities in the Anuradhapura region during the early British colonial period. However, this sample also demonstrates a large scatter in equivalent dose distribution, and could represent sediments disturbed by near-surface bioturbation, which resulted in mixed OSL signals that produced an overall younger date (Burbidge et al., 2008).

Micromorphology of Site C112

The lower part of Context 012 as well as Contexts 012A (both post-abandonment sediments) and 013A (pre-abandonment or early post-abandonment sediments) were sampled for micromorphological analysis (hereafter C112-1, 2, and 3, respectively). Slides were subdivided if deemed necessary, based on macromorphological or micromorphological differences (Figure 5). A summary of the main micromorphological characteristics can be found in Table 1, and detailed micromorphological descriptions are in the Appendix at the end of this document.

Summary of micromorphological descriptions

Groundmass

Microstructures are highly interconnected vughy and vughy, with all samples demonstrating a crumb or granular component. Porosity varies 10-30%, with the lowest porosity in the pre- or early post-abandonment sediments (C112-3). The c/f20μm ratio varies between 3:2 and 4:1, and the c/f related distribution is primarily single-spaced porphyric and chitonic or gefuro-chitonic/chito-gefuric in the post-abandonment accumulation sediments (C112-1 and C112-2); the lower third of sample C112-3 also includes porphyro-enaulic c/f distribution.

Coarse mineral content consists predominantly of poorly to moderately sorted quartz, quartz aggregates, feldspar, amphibole, biotite, anorthic nodules of iron, clay and/or manganese, a brownish yellow mineral or clay nodule, and an opaque mineral (possibly magnetite, ilmenite or haematite?). Angular mineral grains are dominant in sample C112-1. Although all three samples contain angular and rounded anorthic fragments of clay coatings and nodules, C112-3 is notable because of its relatively high concentration of these fragments (i.e. few). Silica microfossils (sponge spicules and phytoliths, including globular echinate palm-type), cryptocrystalline quartz, and silt- to very fine sand-sized calcite nodules of probable biogenic origin are present in trace amounts in all samples. Rounded ceramic fragments are present in trace amounts in C112-3, increasing to very few in C112-2, and to few in C112-1. In situ fracturing of the coarse groundmass and general disturbance of the sediments by bioturbation and/or pedoturbation is common (C112-2, 3) to dominant (C112-1). Mineral alteration, taking the form of Fe-based products or limpid materials (probably clay) with high-order interference colours, and/or dissolution ranges is very few throughout the samples, with few minerals demonstrating alteration in C112-2B. A trace of textural continuities and soil fragments are present in all samples, and there are a few anorthic coatings on mineral grains in C112-2 and 1; these consist of limpid to slightly dusty clays and/or Fe.

The organic portion of the coarse groundmass of all samples consists predominantly of roots and plant tissues (very few, with few appearing in C112-1A) and rootlets with either low-order gray or high-order pale yellow interference colours. C112-1 has evidence of fresh or partially fresh plant tissue remains and has the highest concentration of fresh rootlets. Charcoal (including wood charcoal in C112-2A) and/or charred plant material is present in trace (C112-1, 2B) to very few (C112-2A, 3) amounts. Spores, cells, and/or eggs occurring as individuals or aggregates are present in trace amounts in all samples.

The fine portion of the groundmass in all slides includes humified organic material in trace amounts (C112-3) to very few areas (C112-2B, 1), with the addition of minor organic pigment in C112-3 (bottom).

Micromass

All samples are composed of speckled and dotted clays with stipple-speckled b-fabric and a combination of grano-, poro-, mono- and/or mosaic striations.

C112 (*Marathamaduwa* ' Moat infill) MICROMORPHOLOGICAL SUMMARY

	Mineral material																**Organic material**				**Other**		**Pedofeatures**																		**Structure**	
	Coarse (>20µm)														Fine		Coarse (>20µm)			Fine			Textural									Fabric		Other								
Thin section	Quartz	Black mineral, metallic lustre (OIL)	Quartz aggregate	Feldspar (plagioclase)	Amphibole (hornblende)	Biotite	Anorthic nodules/nodule, coating fragments (clay and/or Fe)	Mineral or clay nodule, high interference colours, brownish yellow (PPL, OIL)	Silica microfossils (phytoliths, sponge spicules)	High relief mineral, high interference or gray colours	Cryptocrystalline quartz (chalcedony?)	Clear/pale yellow mineral, high interference colours	Limpid isotropic mineral, normal relief	Limpid pinkish gray (PPL) high relief isotropic mineral	Colour, nature (OIL, PPL)	b-fabric (XPL)	Roots and tissues (+ % fresh)	Spores	Charcoal/charred plant material	Humified (black, reddish brown)	Ceramic fragments	Inherited textural discontinuities and soil fragments	Anorthic coatings on mineral grains (limpid to slightly dusty clays, Fe)	Limpid to slightly dusty clay coatings	Slightly dusty to dusty clay coatings, nodules	Dusty isotropic and slightly anisotropic clay coatings*	Compound juxtaposed Fe and limpid to dusty clay coatings, nodules *	Limpid to opaque clay/Fe coatings*	Amorphous particulate coatings, intercalations (light-dark red; biogenic Fe?)	Dusty black coatings, possibly biogenic	White/pinkish white (OIL; black [PPL]) coating	Loss/reduction of anisotropy	Compaction	Fe nodules, coatings	Fe enrichment, depletion of groundmass	Organic coatings superimposed on clay coatings	Organomineral excrements (% organic)	Mineral alteration to clay or Fe-based products*	Fractured/disturbed groundmass (including bioturbation)	Fracturing around minerals (concentric referred orientation)	Micro-structure, porosity	C/f ratio, related distribution, sorting, orientation
1	●●●●	●	●	●●	t	●	A: ●●; B: ●	●	t (sp)	t	t	t	●	●●	Light greenish gray (A) and pale yellow (B) speckled and dotted clays	Stipple-specked + grano- and porostriations (●●●); B: + monostriations ●	● (<5%)	t	t (A)	●	●●	t (A)	●●	●●	●●	●●	●	●	t	●	●●●●	●	-	●	●	-	●●●	●	●●●●	●	Spongy (A: + crumb); 20% (B) - 30% (A) porosity	A: 5:2; B: 3:1; single-spaced porphyric + chito-gefuric (A ± single to double-spaced chito-enaulic); poorly sorted, random
2	●●●●	●	●	●	t	●	●	t (A)	t (sp, ge, sk)	t	t (A)	t (B)	A: ●; B: t	●	Light greenish gray, (A: + yellow; B: + reddish yellow, pale yellow) speckled and dotted clays	Stipple-speckled + grano-, porostriations (●●●); B: + parallel, mosaic striations (●)	A: ●●; B: ● (<5%)	t (A)	A: ● (w); B: t	● (B)	●	t (B)	●●	A: ●●●; B: ●●●●	A: ●●●; B: ●●●●	●●	A: ●●; B: t	●	t	●	A: ●; B:●●	●	-	●	●●●	● (B)	A: ● (5%); B: ●●	A: ●; B: ●●	●●●	t	Spongy, crumb, granular (A: + vughy); 20-30% porosity	A: 6:1, B: 4:1; single-spaced porphyric + gefuro-chitonic; (A: + chitonic); poorly sorted (A: + moderately), random
3	●●●●	●	●	●	t	●	●●	●	t (ge, sp)	t	t	●	t	●	Pale yellow, light greenish gray speckled and dotted clays	Stipple-speckled + grano-striations + poro-striations (●●●), mono-striations (●)	● (<5%)	t	●	t	t	t	-	●●	●●	●●	●●	●	t	●	●●	●	●	●	●●●	-	●● (top, middle); ●●● (bottom; <1%)	●	●●●	●	Vughy and spongy (top, middle) + crumb (bottom). Porosity is 10-15% (top, middle) and 10-30% (bottom)	3:1-2:1; single-spaced porphyric (top, middle), + open fine and equal porphyro-enaulic (bottom); poorly sorted, random + weak parallel referred orientation (●)

Abundance classes refer to the appropriate area of the section (Bullock et al. 1985) : ●●●● dominant/very dominant (>50%); ●●● frequent/common (15-50%); ●● few (5-15%); ● very few (1-5%); t trace (<1%); Silica microfossils: observations include cb=cuneiform bulliform; ge=globular echinate phytolith (palm-type); sp=sponge spicules; sk= silica skeleton; T=U-shaped feature, possible tool mark; C= compaction feature; w= includes wood charcoal * indicates a portion of the feature may be anorthic; letters in parentheses indicate that the feature is found only in that area of the slide

Abundance classes for textural pedofeatures (Bullock et al. 1985): ●●●●abundant/very abundant (>10%); ●●●many (5-10%); ●●occasional (2-5%); ● rare (1-2%); t trace (<1%)

Pedofeatures

Organomineral excrements and laminated and nonlaminated clay and/or iron pedofeatures dominate Site C112. Excrements range from silt- to very coarse sand-sized and are common (C112-1 and 3) to very few (C112-2A). Limpid to dusty moderately to well-oriented clay pedofeatures range from occasional (C112-1 and 3) to dominant (C112-2B). Iron enrichment and depletion is common (C112-3, 2) to very few (C112-1), and compound juxtaposed pedofeatures, consisting of clays and/or iron range from rare (C112-1) to occasional (C112-2 and 3); a portion of these may be anorthic.

Other pedofeatures include occasional isotropic or slightly anisotropic coatings throughout the profile; a portion of these may be anorthic. Limpid to opaque clay and iron coatings on mineral grains are rare, and a portion of these may be anorthic. Dusty black coatings are also rarely present. All slides contain a trace of light red to dark red opaque coatings and intercalations; these features consist of material that appears limpid, amorphous and pellicular at high magnification (400x). White to pinkish white (OIL) opaque coatings and intercalations range from rare (C112-2A) to very abundant (C112- 1). Organic coatings, superimposed on clay coatings, are rare and present only in C112- 2B.

Fabric pedofeatures are also present, consisting predominantly of a loss or reduction of micromass anisotropy (very few) or compaction pedofeatures (very few, in C112-3 only).

Discussion and Interpretation

Micromorphological features within the C112 profile include indications of sediment transport processes, geochemical weathering, movement of materials within the profile (particularly clay movement), waterlogging, disturbance of sediments, and biological activity, including human activity. The following is a summary of the primary processes taking place in profile C112.

Sediment transport

The lowest sample in the profile, C112-3, contains a relatively high proportion (i.e. up to 15% of the slide area) of angular and rounded well-oriented clay nodule or coating fragments (Figure 6). The abundance of these clay fragments suggests they were transported into the moat from areas where the landscape was once stable (i.e. underwent pedogenesis and was subject to illuvial processes), but was subsequently disturbed, as indicated by the coating fragments.

The coarse mineral fraction in C112-2B is poorly sorted and becomes slightly better sorted in A, near the top of the slide. C112-2A also features a higher c/f ratio and chitonic c/f related distribution, suggesting that there may have been a depositional hiatus following deposition of C112-2B. This inference is supported by the presence of organic coatings on planar voids in C112-2B only (see below). These sedimentological differences may reflect alluvial deposition under differing energy regimes, with higher energy deposition taking place in C112-2B. Alternatively, the poorly sorted C112-2B sediments may reflect a mixture of colluvial and alluvial sediments. The increased c/f ratio and chitonic distribution in C112-2A may indicate relatively rapid deposition of the sediment. Although the boundary between the two areas of the slide is diffuse and faint, C112-2A and B are partially separated by a planar void with subparallel referred orientation, along which there are very few minerals and nodules that exhibit fracturing and some vertical and horizontal displacement. Shrink-swell processes working in slightly different fashions due to the differences in sorting may be responsible for creating these features along the boundary.

The lithology of C112-1 differs from that of previously studied sites (i.e. F517, D339, C009, and Z021A) and from the lower samples C112-3 and 2, in that it includes slightly higher percentages of feldspar and of the pinkish gray high relief isotropic mineral. Sample C112-1 also incorporates a noticeably higher proportion of angular clasts (i.e. more than 40% of the coarse fraction; Figure 6), and more than 50% of the coarse mineral fraction in this sample is very coarse sand-sized or larger. The clast angularity suggests that the C112-1 sediments were deposited from relatively nearby, and the coarse nature of the sediments likely indicate that the mode of deposition was a rapid pulse of relatively high energy, such as a local influx of high-energy water, or a minor colluvial episode. Together, these sedimentological characteristics indicate that the source and mode of deposition for the C112-1 sediments was different than what came before.

Geochemical weathering

Weathering and/or dissolution of the coarse mineral fraction is dominant in C112-2, suggesting that the sediments were subject to near-surface or surface weathering processes. C112-2A contains more weathering of the opaque black mineral (possibly haematite or ilmenite) in the groundmass than C112-2B, but C112-2B has a slightly higher proportion of dissolved quartz; these variations could point to differences in weathering that may help in discerning subsurface and near surface weathering processes. When under the influence of weathering, quartz aggregates in the samples are frequently fractured along the boundaries of the mineral contacts, which are often coated with iron and clay; accumulations of these coatings may have aided disaggregation of the quartz aggregate. In addition, clay coatings are often present along the intermineral fissures within the aggregates; therefore, sequences of mineral weathering and pedogenesis may be reconstructed using these features (Figure 7).

A particular type of mineral dissolution is present in trace amounts in C112-1.This dissolution leaves behind a very angular mineral edge that is coated with a dusty black material that is superimposed on an isotropic limpid yellow coating (Figure 7). The dusty black coating is a textural pedofeature that may be biogenic, and it is possible that mineral dissolution could also be the result of biogenic processes (i.e. acids excreted by organisms). Alternatively, geochemical dissolution could have taken place, followed by deposition of the dusty black and limpid yellow coatings by soil organisms. However, the dusty black coating may not be of biological origin, and may represent charcoal dust or some other textural pedofeature; identifying the coating is key to its interpretation.

Movement of materials within the profile

Very few compound pedofeatures of limpid and dusty clays and iron are present throughout the profile, and include very few compound pendents at the bottom 10 mm of slide C112-1. The bottom of the slide is ca. 55-60 cm from the bottom of the moat, which approximates the field estimate of the original moat depth. The evidence for frequent wetting and drying of C112-2 (see below) supports the interpretation that moat sediments are frequently saturated within 50-60 cm from the moat base, and the lower abundance of iron depletion/enrichment features within C112-1 indicates that there is less wetting and drying taking place within these sediments. Therefore, the pendents formed within the lower C112-1 sediments likely mark the upper boundary of seasonal saturation within the moat.

C112-2 has many to abundant limpid to dusty clay pedofeatures. Some of these are limpid and slightly speckled clay pedofeatures with internal vermicular or crescentic patterns delineated by clay-width opaque lines, possibly indicating fine internal fracturing or depositional patterns (i.e. slight halt in deposition, indicating stages of deposition; Figure 8). In all samples, limpid clays may be juxtaposed with dusty clays, clays with reduced anisotropy, or iron in compound pedofeatures, demonstrating illuvial sequences.

C112-2B is the only part of the sampled profile that contains organic coatings and hypocoatings superimposed on clay coatings (Figure 9). These coatings are present on the bottom of elongated voids that have parallel referred orientation and appear to be compacted or striated, indicating both illuviation and forces operating on the sediments. Compaction and striations could be the product of shrink-swell processes or due to root intrusions (bioturbation), although there are no root remains nearby. Alternatively, gas release during wet/dry episodes may be responsible. In any case, the presence of these coatings indicates surface disturbance following a period of relative stability.

Coatings with reduced anisotropy appear to be composed of clays with an internal b- fabric that is inconsistent with the groundmass, and are superimposed on the groundmass in all samples (Figure 9). Their reduced anisotropy may be the result of waterlogging, or their composition (i.e.

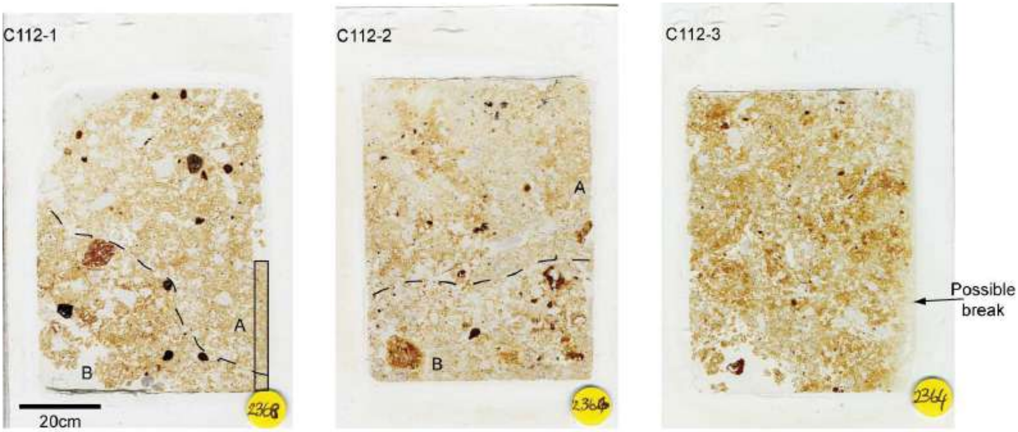


Figure 5. Slide maps for micromorphological samples, Site C112. The rectangle on the lower right side of C112-1 denotes and area of single- to double-spaced fine chito-enaulic c/f distribution.

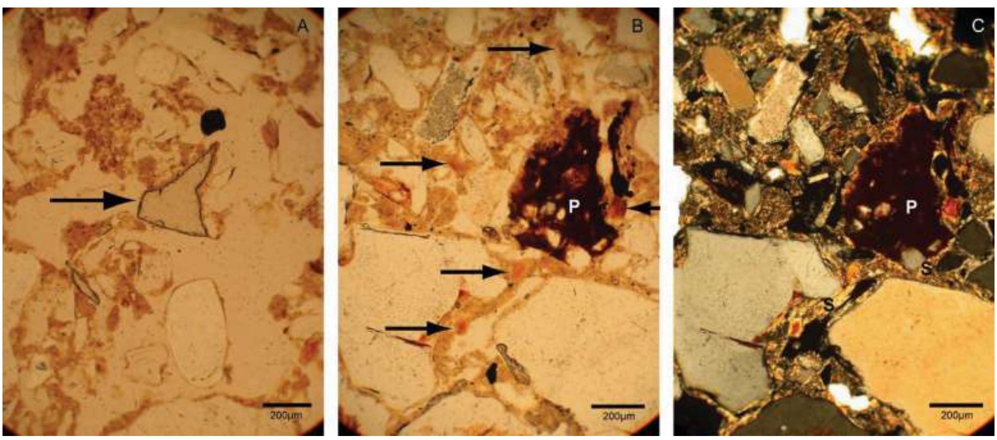


Figure 6. Features in the coarse groundmass. A: angular fragment of isotropic mineral, C112-1, PPL; B: clay fragments (arrows) and pottery fragment (P) within the groundmass, C112-3, PPL; C: same as B but in XPL, note granostriated b-fabric (S) . All: 100x magnification.

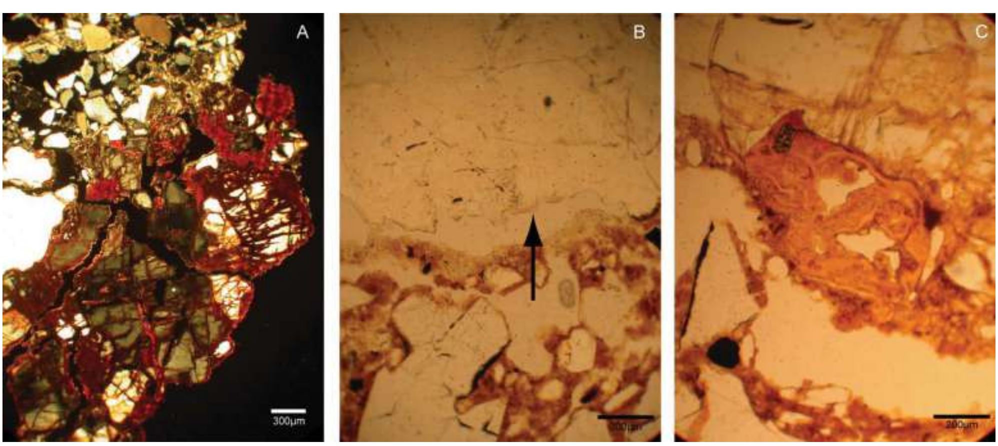


Figure 7. A: compound coatings and hypocoatings on intermineral contacts within a quartz aggregate. The buildup of illuviated coatings may have contributed to the physical disaggregation of the aggregate. Note the reddish clays with radial extinction patterns (seen in the Fe-based internal hypocoatings throughout the study sites) in the upper right quadrant of the slide. C112-2, 40x magnification, XPL. B: angular dissolution of quartz with isotropic pale yellow and dusty black internal hypocoating. Dissolution could be geo- or biochemical, C112-1, 100x magnification, PPL. C: compound clay nodule, C112-1, 100x magnification, PPL.

may have more iron content) may be the determining factor. These may be anorthic coatings (i.e. were deposited into the moat along with the mineral grains that they coat).

C112-3 features a trace of coatings depleted in fine materials, which could represent depletion hypocoatings documenting the movement of fine material out of the profile (Figure 9). Alternatively, these coatings could represent pulses of sediment originally deposited with little or no accompanying fine material.

Waterlogging

Sediment waterlogging is documented in the iron enrichment and depletion features that are present throughout the profile. The greatest concentration of these is in the lower two samples, indicating that the lower sediments experience more fluctuations in hydrological regime than the upper sediments.

Coatings and hypocoatings with reduced anisotropy in the groundmass (excluding the clays with reduced anisotropy mentioned above), particularly around voids and of infills of excrements and soil material, are likely depletion hypocoatings that indicate waterlogging (Stoops, 2003, pp. 111-112). Very few of these are present throughout the profile.

Sediment disturbance

Disturbance features include striated b-fabric and compaction (Figures 6, 8). Weakly to strongly expressed striations occur frequently throughout the profile in all samples, and are likely the result of shrink-swell forces that occur during wet-dry cycles (Stoops, 2003, pp. 96).

C112-3 is the only sample that demonstrates compaction features as well as lenses in which long axes of the coarse groundmass and elongated voids have parallel referred orientation (Figure 8). These features may partially be the result of shrink-swell processes, as they commonly also demonstrate striated b-fabric. However, they could be indicators of depositional hiatuses that alternate with sediment influxes. Excremental pedofeatures (see below) within this sample indicates that biological activity took place in these sediments suggesting that episodes of nondeposition accompanied by incipient pedogenesis likely occurred. The sedimentological differences between the three samples (i.e. sorting, angularity, c/f related distribution) document frequent breaks and changes in the mode of deposition and support this hypothesis. Alternatively, compaction features may reflect the forces inflicted on the C112-3 sediments from above by the progressive and periodic collapse of the adjacent building into the moat.

Biological activity

Evidence for biological activity includes excrements, plant remains, and the possible biogenic dusty black coatings (Figures 12, 13).

Sample C112-2A contains the highest proportion of plant roots and tissues, and all samples contain very few fresh plant remains. C112-1 contains the highest abundance of excrements, suggesting that these sediments are more susceptible to bioturbation and may represent a surface or near-surface horizon. The lens of fine enaulic c/f distribution on the right hand side of sample C112-1 (Figure 5) may be sampling a nest of some sort (e.g. Kourampas et al., 2009).

Fractured and intact phytoliths and sponge spicules are present in trace amounts throughout the profile. C112-3 and 2 contain several globular echinate phytoliths (Madella, et al., 2005) that are likely palm phytoliths (i.e. date palm or coconut; Campos et al., 2001, pp. 138; Vrydaghs et al., 2001, pp. 244; Figure 11). Although these may be used to support statements regarding the type of vegetation in the surrounding landscape, the phytoliths are not abundant and likely have been redeposited and are thus limited in what they can say about the site's immediate surroundings. However, the presence of sponge spicules does suggest that there was fresh water in the area.

Indicators of human activity

Rounded to subrounded ceramic fragments are present in C112-1b and C112-3 (Figure 13). These were likely deposited as the adjacent structures collapsed. The rounded nature of the fragments suggests that they have undergone substantial physical alteration, and could have been transported

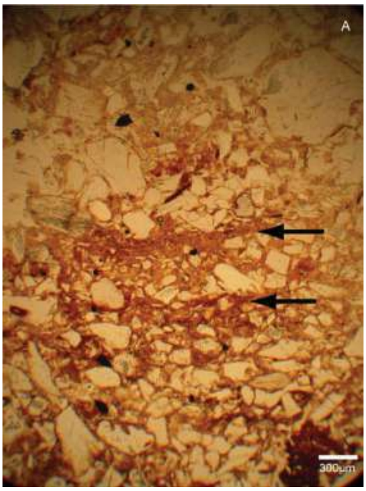


Figure 8. Compaction pedofeatures, probably due to pedoturbation during wet/dry cycles, C112-3, 40x magnification, PPL.

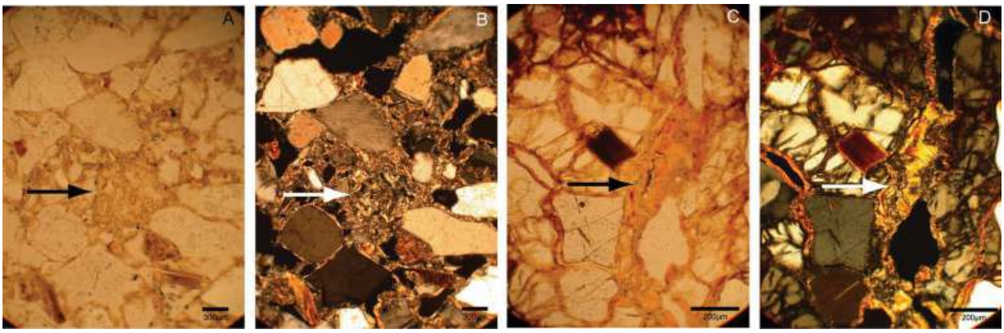


Figure 9. Clay pedofeatures. A: well-oriented dusty and limpid clay nodule or lens with vermicular internal structure, C112-2 40x PPL; B: same as A, XPL; C: well-oriented limpid clay infill and hypocoating with opaque clay-width inclusions that delineate internal structure and possible fracturing due to disturbance, C112-2, 100x magnification, PPL; D: same as C, XPL.

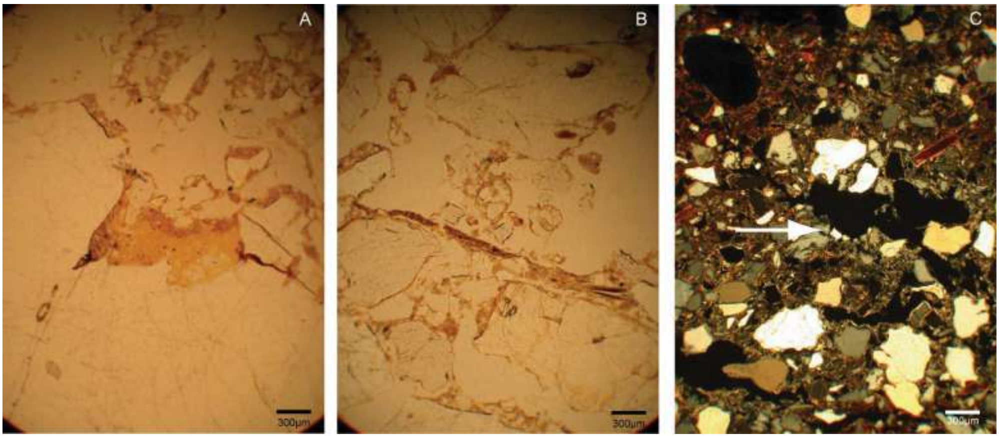


Figure 10. A: compound juxtaposed clay coating documenting episodes of relative stability and disturbance. The lighter yellow coating has reduced anisotropy and is slightly speckled and dotted with reduced anisotropy; the brownish yellow coating documents a greater abundance of speckles and dots in the clays, indicating increased landscape disturbance, C112-1, PPL; B: organic coating superimposed on clay coating on a planar void, demonstrating increased landscape disturbance, possibly cultivation activities near the moat, C112-2, PPL C: possible hypocoating depleted in fine groundmass (arrow), or could document natural variability of the sediment due to pulses of sediment entering the moat, C112-3, XPL. All: 40x magnification.

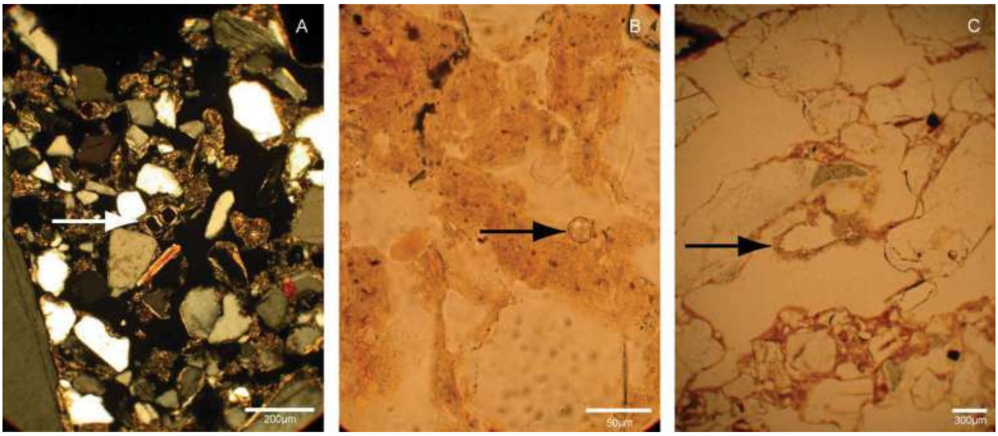


Figure 11. Indicators of biological activity. A: possible straw or other fresh plant remains, C112-1, 100x magnification, XPL; B: globular echinate phytolith, probable palm-type (Campos et al., 2001, pp. 138; Vrydaghs et al., 2001, pp. 244), C112-2, 400x magnification, PPL; C: compound isotropic coating of pale yellow superimposed with dusty black particulate coating, possibly biogenic and phosphatic, C112-2, 40x magnification, PPL.

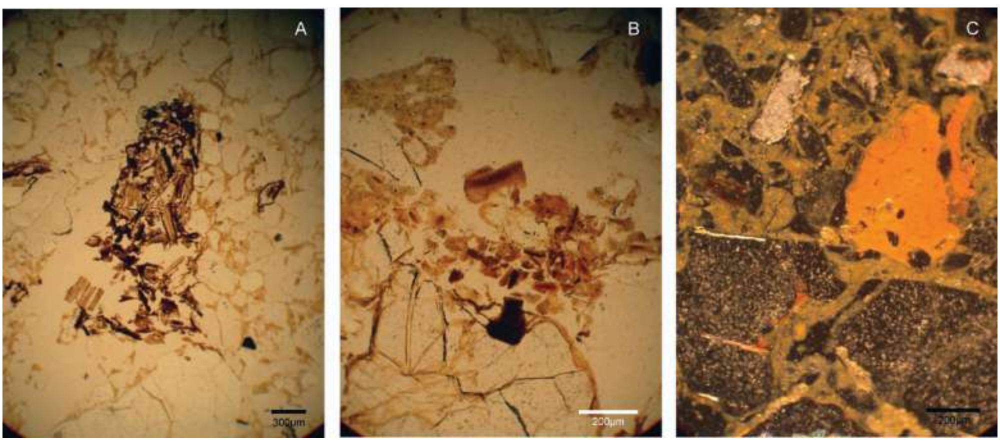


Figure 12. Indicators of biological activity. A: 2.32mm-long excrement, of vegetal material, C112-2, 40x magnification, PPL; B: clay fragments, possibly excremental, C112-2, 100x magnification, PPL; C: rounded pottery fragment (fragment same as that noted in Figure 6), C112-3, 100x magnification, OIL.

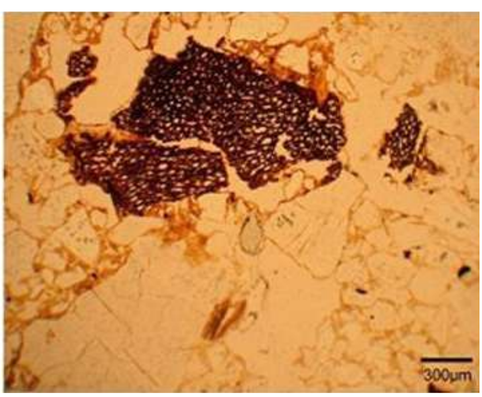


Figure 13. Wood charcoal, C112-2. 40x magnification, PPL

Figure 14. A silica skeleton, possibly from a rice husk (Rosen, 2001, pp. 195, Alison Weisskopf, pers. comm.). C112-2, 400x, PPL.

from further away. Alternatively, they could have been exposed to relatively lengthy episodes of weathering at or near the land surface prior to deposition within the moat. In C112-2, fragments are subangular to angular, and may have been deposited from closer to the moat, or have undergone less physical modification prior to deposition. The coarse mineral content of the ceramics is the same as that of the sediment groundmass, suggesting that the ceramics were constructed using local materials. Limpid clay coatings on the voids within the ceramics indicate that illuviation occurred subsequent to deposition.

Charcoal is present in trace to very few amounts throughout the profile, with the higher abundance in C112-3 and 2A. The fragments within these lower samples are rounded to subangular, and thus likely represent physical erosion, possibly deposition from further away, although soil biogenic or mechanical effects may have reduced angularity over time. C112-2 contains two rounded pieces of wood charcoal, one of which is fractured in situ and slightly dispersed in the groundmass (Figure 14). These fragments are likely indicators of chena activity occurring within the catchment, as their rounded nature suggests they have been redeposited. Following deposition in the moat, shrink-swell processes likely put stress on the fragment, fracturing it further, and moving it slightly. Charcoal fragments are angular in C112-1, suggesting (like the angular coarse minerals in that sample) that it was deposited with minimal physical alteration, probably from relatively close by.

C112-2 also contains a silica skeleton that likely represents a husk from a cereal grain, possibly Oryza (Rosen, 2001, pp.194-5, Alison Weisskopf, pers. comm.), which, when combined with the wood charcoal evidence, provides a stronger case for cultivation activities in the immediate site area during the post-abandonment period.

Site interpretation and landscape reconstruction

Interpretation of micromorphological features allows the reconstruction of the landscape immediately surrounding Site C112 prior to and during the formation of the moat infill, as follows:

1). There was relatively little surface disturbance at the site (including cultivation activities) prior to the onset of moat infill. This is inferred from the relatively abundant clay coating fragments in the basal infill sediments (C112-3). The formation of limpid well-oriented clay coatings typically requires landscape stability and pedogenesis. The relatively high abundance of these fragments within the basal infill sediments suggests either that the landscape had not previously been significantly disturbed, resulting in greater abundances of clay coatings fractured during subsequent disturbance. The fragments may also indicate a change in the intensity of human activity at the site (i.e. increased intensity), prior to their deposition in the moat.

2). The OSL date for the sediment at the bottom of the moat (i.e. sample C112-3) indicates that the moat began to infill shortly after Anuradhapura was abandoned, documenting abandonment of the monastery also around that time. As mentioned, the limpid, well-oriented clay coating fragments at base of the moat infill indicate increased landscape disturbance in the hinterland during Anuradhapura's early post-abandonment period and following the discontinuation of large-scale irrigation in the hinterland. This disturbance likely represents human activity (i.e. chena cultivation) in the immediate area surrounding the site; however, the lack of very dusty clay coatings and lack of an impure micromass in the sediment suggests that these activities may have been intermittent and short- lived. The upper portion of sample C112-3 demonstrates an increase in concentration of the fragments within the sediments, which may indicate increased instability and erosion of the catchment landscape during the immediate post-abandonment period.

3). Sample C113-3 also features occasional intact clay coatings, suggesting that the landscape stabilized following sediment deposition, and may have undergone incipient pedogenesis, which is supported by the presence of organomineral excrements that document biological activity.

4). The collapse of the roof of the adjacent building resulted in deposition of roof tiles. As mentioned previously, the OSL date produced by the C112-2 sediments is AD 300 ± 400, which is not stratigraphically consistent with the date for the underlying sediments, or with the expected age of the adjacent structure (based on architectural style and affiliation). The large scatter in equivalent dose distribution for this sample suggests it represents sand grains with mixed OSL ages. This date could document the ages of the sediments beneath the monastic structure, or it could provide an approximate age of tile manufacture. The presence of very few ceramics within the sediments may support this interpretation. Of course, given the range of dates within the error estimate (i.e. 100 BC-AD 700), the OSL date may indeed reflect the age of the soil surface just prior to construction of the monastery (i.e. 8th century AD).

5). Following the collapse of the roof, moat sedimentation continued (Figure 3). The wood charcoal fragments and the silica microfossil evidence for rice or cereal grains probably reflect chena activity within the catchment, which may be related to the disturbance of the land surface documented in C112-3 (i.e. preparations for chena/cultivation activity). Given the isolated nature of Site C112, these activities likely took place in the immediate vicinity of the site. As there is only a trace of silica microfossils, it is likely that cultivation activities at this location were brief. Anorthic clay fragment abundances are very few in sample C112-2, suggesting the major period of disturbance and erosion of the surrounding landscape came to an end following deposition of C112-3

.

6). Following deposition of C112-2 sediments, landscape stability took place, as documented in the abundant limpid to dusty clay coatings. These coatings are rarely superimposed by organic coatings in C112-2B, which likely indicate renewed disturbance, possibly during a depositional hiatus (i.e. after deposition of C112-2B sediments). However, the low abundance of these organic coatings suggests that disturbance was temporary.

7. Several sedimentary features suggest that slide C112-2 samples a near-surface horizon, which suggests a halt in sediment deposition. These features include the presence of large roots and tissues and vegetation-rich excrements (Figure 12A). The differences in sorting, angularity, and lithology documented in the C112-1 sediments also support the interpretation of a sedimentary break following deposition of the C112-2 sediments.

8). Sediment deposition continued, with deposition of sample C112-1 sediments likely from a nearby source. Signs of bioturbation are dominant in this sample, suggesting another near-surface horizon and a possible depositional hiatus.

Conclusions

The moat infill sediments at Site C112 document brief intermittent episodes of human activity and disturbance in the immediate area during the period that followed the abandonment of large-scale irrigation in the Anuaradhapura hinterland. Activities at the site likely involved chena and possibly small-scale rice cultivation; however, the lack of very dusty clay coatings and low abundance of organic coatings suggests that human disturbance at the site was minimal, and landscape stability dominated.

The transportation and deposition of sediments into the moat continued throughout the post-abandonment period, although the development of pedofeatures suggests that sediment deposition was interrupted several times, during which soil formation processes were active. Moat sedimentation suggests movement of materials across the landscape during times of instability. However, the fact that the micromass is relatively free of impurities and contains a low abundance of soil and sediment fragments suggests that landscape disturbance may have been due to local responses to climate; for example, rapid sediment transport during flooding of the nearby rock-cut cisterns during monsoon season.

References

Burbidge, C.I., D.C.W. Sanderson, I.A. Simpson, and W.P. Adderley 2008. Luminescence dating of sediments from ancient irrigation features, and associated with occupation of the hinterland around Anuradhapura, Sri Lanka. Second Phase Report. East Kilbride: Scottish Universities Environmental Research Centre.

Campos, S., L. del Puerto, and H. Inda 2001. Opal phytolith analysis: its applications to the archaeobotanical record in eastern Uruguay. In Phytoliths: applications in earth sciences and human history, edited by J.D Meunier and F. Colin, pp. 129-142. A.A. Balkema, Lisse.

Coningham, R., P. Gunawardhana, M. Manuel, G. Adikari, M. Katugampola, R. Young, A. Schmidt, K. Krishnan, I Simpson, G. McDonnell, and C. Batt 2007. The state of theocracy: defining an early medieval hinterland in Sri Lanka. Antiquity 81: 699-719.

Kourampas, N, I. Simpson, N. Perera, S. Deraniyagala, and W. Wijeyapala 2009. Rockshelter sedimentation in a dynamic tropical landscape: late Pleistocene-early Holocene archaeological deposits in Kitugala Beli-lena, southwestern Sri Lanka. Geoarchaeology 24(6): 677-714.

Madella, M., Alexandre, A., Ball, T. 2005. International Code for Phytolith Nomenclature 1.0. Annals of Botany 96: 253-260.

Piperno, D. 2006. Phytoliths: a comprehensive guide for archaeologists and paleoecologists. AltaMira Press, Oxford.

Rosen, A. 2001. Phytolith evidence for agro-pastoral economies in the Scythian period of southern Kazakhstan. In Phytoliths: applications in earth sciences and human history, edited by J.D Meunier and F. Colin, pp. 183-198. A.A. Balkema, Lisse.

Stoops, G. 2003. Guidelines for Analysis and Description of Soil and Regolith Thin Sections. Madison: Soil Science Society of America.

Verdin, P., J-F. Berger, and J-A Lopez-Saez 2001. Contribution of phytolith analysis to the understanding of historical agrosystems in the Rhône mid-valley (southern France). In Phytoliths: applications in earth sciences and human history, edited by J.D Meunier and F. Colin, pp. 155-172. A.A. Balkema, Lisse.

Vrydaghs, L., H. Doutrelepont, H. Beeckman, and E. Haerinck 2001. Identification of a morphotype association of Phoenix dactylifera L. st lignified tissues origin at ed-Dur (1 AD), Umm al-Qaiwain (U.A.E.). In Phytoliths: applications in earth sciences and human history, edited by J.D Meunier and F. Colin, pp. 239-250. A.A. Balkema, Lisse.

Appendix

Descriptions of samples from Sites C112: Moat infill at double-platform monastic site

Size classes

Size class	Size limits (µm)
Silt	2-63
Very fine sand	63-100
Fine sand	100-200
Medium sand	200-500
Coarse sand	500-1000
Very coarse sand	1000-2000
Gravel	>2000

Slide C112-1 Moat infill at double-platform monastic site

Thin section no. 2368

Vertical thin section

Context 012: Sediment accumulation, post abandonment (field interpretation)

Field texture is sandy clay loam with tile inclusions.

Abbreviations: g: gravel; vcs: very coarse sand; cs: coarse sand; ms: medium sand; fs: fine sand; si: silt

Microstructure and porosity

A: Complex: spongy with crumb microstructure comprising about 30% of area A. Porosity is 30%, dominated by highly interconnected voids, with common vughs (si-cs) and complex packing voids, and very few channels (fs-ms) and planes (fs), with very few planar voids around mineral grains.

B: Spongy microstructure. Porosity is 20%, dominated by vughs (si-cs) and highly interconnected voids, with few complex packing voids, very few chambers (ms), including a vermiform chamber with parallel referred orientation, and a trace of planar voids around mineral grains.

Voids in A and B are 10-20% infilled with soil material or possible algal-based

organisms.

A/B boundary: Diffuse and faint, primarily distinguished by slightly increased Fe content in groundmass of B.

Groundmass

c/f20µm ratio, related distribution: A: 5:2; single-spaced porphyric and chito-gefuric with addition of fine and equal single- to double-spaced chito-enaulic in areas of crumb microstructure. B: 3:1, single-spaced porphyric and chito-gefuric, with addition of fine single- to double-spaced chito-enaulic.

Coarse material:

Mineral: Poorly sorted, randomly oriented polymictic sand (fs-ms); about 40% of mineral grains are larger than vcs. Angular mineral grains are dominant in this slide, significantly more than than all other previously described sites (i.e. F517, D339, C009, Z021A) and in slides C112-2 and 3. Very few (minerals exhibit alteration products that appear to be dominantly Fe-based or clays with high-order interference colours; a portion of these may be anorthic. The groundmass is dominantly bioturbated and disturbed. A trace of textural continuities and soil fragments are present in A, and there are a few anorthic coatings on mineral grains, consisting of limpid to slightly dusty clays and/or Fe.

Angular and subangular quartz grains (dominant, si-g), commonly undergoing irregular linear, pellicular, dotted, or tubular alteration and dissolution, and very few of which appear to be undergoing alteration to 10 μm-diameter pellicular material with white interference colours (possibly gibbsite), and 1 cs quartz grain has undergone partial dissolution, leaving a very angular altered edge with an isotropic dusty black and pale yellow coating that is mirrored in the groundmass opposite the mineral; rounded to subangular opaque black mineral with metallic inclusions (OIL, possibly haematite or ilmenite; very few, si-vcs),very few of which have a pinkish-white/white patina-like coating, a red internal hypocoating, pellicular dissolution/alteration, or a combination); angular feldspar grains (few, fs-cs); rounded to angular amphibole (trace, si- ms); angular elongate grains of biotite (very few, si-cs); rounded limpid and slightly speckled moderately to well-oriented anistropic and faintly anisotropic anorthic clay nodules (very few, si-fs; very few of the well- oriented nodules demonstrate b-fabric with a radial pattern similar to the limpid to opaque clay/Fe coatings on grains, or a vermiform internal fabric resembling excrements); rounded strongly impregnated Fe ± Mn nodules (very few, fs); angular to rounded clay nodule or coating fragments (very few, fs-ms, anisotropic to faintly anisotropic); rounded to subrounded quartz aggregate (very few, ms-cs), very few of which are undergoing dissolution or alteration and have limpid to dusty well-oriented clay and nonbirefringent Fe coatings on intermineral fissures; rounded brownish yellow (PPL, OIL) mineral or anorthic clay nodule or nodule with high-order interference colours (very few, fs-ms); intact and fractured silica microfossils (trace; observed morphologies include serrated, circular with central depression and rectangular phytoliths, and sponge spicules); rounded possibly biogenic calcite nodules and coatings commonly found in and on voids (trace, si-fs); angular to rounded limpid pinkish gray to clear limpid (PPL) high relief isotropic mineral (few, ms-cs), very few of which appear to be fractured or undergoing dissolution; rounded high relief limpid mineral with gray or high interference colours (trace, si-fs); limpid clear isotropic mineral (angular to subangular) appearing similar to quartz in PPL (very few, fs-vcs, possibly garnet); subangular to angular clear to pale yellow limpid mineral with high- order pale yellow interference colours (trace, fs-ms); rounded and subangular cryptocrystalline quartz (trace, ms-cs, probably chalcedony); rounded ceramic fragments (few, fs-g, see Table 1).

A: 1 possible angular mineral or soil or nodule fragment (cs).

Organic: Degraded roots (very few, fs-cs, rounded, 1 of which has whewelite crystal inclusions); plant material with high interference colours indicating cellulose and that they are fresh (trace, cs, includes 2 rounded items that may represent straw or stalks); fresh rootlets with low-order gray or high-order interference colours (very few, slightly more in B than A); indeterminate very pale brown to black (OIL) plant tissues, (A: very few, B: trace; fs-ms); dark reddish brown and black (OIL) humified organic matter (A: very few, B: trace, fs-ms); gray fibrous elongated material with very high interference colours that do not extinguish, possibly plant material or mineral (trace, cs); spores or eggs, rounded and 1- and 2-part ellipsoids, (trace, si, with slightly more in A, in which there are 2 fs groups of spores/eggs).

A only: Very faint dusty pale yellow (OIL; undetectable in PPL) anisotropic masses that may represent rootlets or neoformed clay, with pinkish white and white interference colours, appears unoriented or amorphous (trace); angular charcoal (trace, si); angular charred plant material (trace, si-fs).

Feature	Micrstructure and porosity	C/f ratio, related distribution, coarse groundmass	Micromass colour (OIL), character; b-fabric	Pedofeatures, boundary (PPL, XPL, or OIL)	Comment, interpretation	Abundance (of relevant sectio)
Ceramic 1	Vughy, 5%	4:1-6:1, close to single-spaced porphyric; well-sorted dominantly subangular fs	Brown, strong brown and dark brown opaque clays, but reddish yellow to yellow around the edges; undifferentiated and poro- and granostriated	Has a striated dusty clay coating; boundary is diffuse and prominent	Fragment is rounded, probably coated with RBE soil material	C112-1A: ●
Ceramic 2	Vughy, 5%	3:1, close to single-spaced porphyric; moderately sorted rounded to subrounded fs; phytoliths (t)	Reddish yellow to yellowish red dusty to opaque clays; undifferentiated + porostriated (● ● ●)	Partially coated with dusty clay coating similar to Ceramic 1; boundary is diffuse and distinct	Fragment is rounded but appears fragmented or in the process of disaggregation/dissolution	C112-1A: ●
Ceramic 3	Vughy, 5-7%	4:1-6:1, single- to double-spaced porphyric; moderately sorted dominantly subrounded fs-ms; phytoliths (t)	Reddish yellow opaque clays; undifferentiated + porostriated	Contains limpid to slightly dusty, well-oriented pale yellow to yellow clay coatings that are probably anorthic (● ● ●); Boundary is sharp and prominent	Fragments are subrounded (C112-1B,- 3) to angular and subangular (C112-2) and appear to have an orthic dusty clay coating	C112-1B: ●; C112-2: ●; C112-3: t

Table 1 Table 2. Micromorphological characteristics of dominant ceramic types in C112 samples.
Note: In Pedofeatures column, symbols denote abundances as they pertain to rare pedofeatures (i.e. ● ● ● ● is abundant [>10%], etc.); in all other columns, symbols denote abundances as they pertain to the coarse mineral fraction (i.e. ● ● ● ● is dominant [>50%], etc.). Pedofeatures are described only if they are thought to be anorthic (i.e. specific to the lens or fragment) and not the result of pedogenesis acting on the entire sample. RBE=Reddish Brown Earths; LHG=Low Humic Gleys.

Micromass:

Speckled and dotted clays (A: light greenish gray, B: pale yellow [OIL]) with stipple-speckled b-fabric and grano- (A: frequent weak to strong, B: few weak to moderate) and very few weak porostriations. B: Also includes very few moderately to strongly expressed monostriations.

Pedofeatures:

Limpid and slightly speckled yellow and red (PPL) moderately to well-oriented clay infills, intercalations, nodules and coatings (occasional; yellow and red interference colours) .

♦ Dusty yellow (PPL) poorly oriented clay nodules and coatings, predominantly appearing as hypocoatings or as isolated birefringent lenses in the groundmass (occasional; pale yellow and yellow interference colours).

♦ Dusty to slightly speckled brownish yellow to reddish yellow (PPL) poorly to well-oriented clay infillings, nodules (fs-ms, rounded), hypo- and quasicoatings, and intercalations (occasional, yellow to red interference colours; several of these demonstrate isotropy or reduced anisotropy, and a portion of these may be anorthic).

♦ Limpid clear clay coating or mineral with high interference colours, poorly oriented (trace).

♦ Particulate clay coating or mineral alteration product appearing as silt-sized speckles on mineral grains, indistinguishable in PPL and OIL, but with white/pale yellow interference colours (occasional).

♦ Fe internal hypocoatings on mineral grains with parallel, cross, or irregular linear pattern, some with slight metallic lustre (OIL) (very few, nonbirefringent and white to strong brown [OIL]).

♦ Fe coatings and hypocoatings on mineral grains, voids and groundmass, undifferentiated and differentiated, isotropic and faintly anisotropic (very few, moderately to strongly impregnated, yellow and red to strong brown [OIL]).

♦ Compound limpid to opaque internal hypocoatings of Fe and clay, nonbirefringent or faintly anisotropic, a portion of which may be anorthic (very few; red, yellow, and strong brown [OIL]).

♦ Fe rounded orthic nodules, moderately to strongly impregnated, microlaminated and nonlaminated; (fs-g, very few, yellow, red, strong brown [OIL]).

♦ Fe enrichment and depletion of the groundmass (very few; red, reddish yellow, strong brown impregnations; light greenish gray depletions [OIL]).

♦ Light red to red (OIL) opaque isotropic particulate inclusions as aggregates or dispersed in the groundmass; amorphous and limpid at 400x magnification, (trace; possibly biogenic Fe?).

♦ Compound nonbirefringent nodules and coatings of Fe-impregnated organic material (very few, fs-cs, rounded).

♦ Compound microlaminated and nonlaminated coatings, nodules, and pendents of Fe and/or limpid to dusty, poorly to well-oriented clays; anisotropic, slightly anisotropic, nonbirefringent and isotropic elements are juxtaposed or superimposed (rare; yellow, light red and brownish yellow [OIL]).

♦ Excremental pedofeatures: organomineral and organic (si-vcs, frequent, very porous to very dense, spherical; includes 1 vcs elongated probable excrement with relatively uniform silt-sized voids and well sorted mineral content, vughy microstructure and single-spaced porphyric c/f distribution).

♦ Textural pedofeature: white to very pale brown (OIL) opaque isotropic coating on mineral grains, increases in thickness in middle and bottom of slide (many [top of slide] to abundant [middle and bottom]).

♦ Textural pedofeature: coating of anomalous colours, usually vivid blue, green, red, purple, predominantly on si-fs calcite nodules but may appear on Ca-based "string" (trace).

♦ Textural pedofeature: dusty black isotropic coatings around voids, in a limpid very pale brown coating, or on high interference masses of rootlets possible Ca- based plant material (PPL, OIL; rare; includes 1 case where coating is along the very angular edge of quartz undergoing dissolution).

♦ Textural pedofeature: impregnative coatings and hypocoatings that appear superimposed on the groundmass in PPL, and in XPL they reduce anisotropy but allow underlying b-fabric and well-oriented clays to be discerned; these could be part of the coatings. Coatings are yellow and pale yellow with a slight reddish tint in PPL; in OIL, these coatings are light yellowish brown and light greenish gray, and they have pale yellow interference colours in XPL (rare).

♦ Fabric pedofeature: change in b-fabric to faint (i.e. reduced anisotropy) stipple- speckled (very few, probably an Fe or clay depletion hypocoating or lens, but may be related to biological activity, as some excrements demonstrate this fabric).

A:

♦ Textural: clear limpid to dusty yellowish brown (PPL) clay coating or mineral alteration product with high interference colours and radial, fanlike or fibrous appearance (trace)

♦ Fabric pedofeature: 1-1.8mm long lens with close to fine enaulic c/f distribution (indicates biological activity?).

B:

♦ Textural pedofeature: loose discontinuous infill of ms void of silt-sized particles of Fe/clay nodules (yellow [OIL], nonbirefringent or slightly anisotropic), organics (dark brown/black OIL), minerals and clays (slightly anisotropic to anisotropic), probably due to biological activity.

♦ Limpid pale yellow clay coating or mineral alteration product with high interference colours, poorly oriented (trace).

Slide C112-2 Moat infill at double-platform monastic site

Thin section no. 2366

Vertical thin section

Context 012A: Sediment accumulation, post abandonment; seasonally wet, poorly drained (field interpretation). Field texture is loamy sand with tile inclusions.

OSL date from sample taken near thin section is AD 300 ± 400 (2 sigma). Given the later date for C112-3 sediments lying below this context (i.e. AD 1090 ± 100), this date may reflect the age of tile manufacture, rather than the age of sediment deposition within the moat.

Abbreviations: g: gravel; vcs: very coarse sand; cs: coarse sand; ms: medium sand; fs: fine sand; si: silt.

Microstructure and porosity

A: Complex: spongy and vughy, with crumb and granular microstructure near contact with B. Porosity varies 20-30%, dominated by highly interconnected voids and vughs (fs-cs), with frequent complex and compound packing voids, few channels and chambers (ms-cs), and a trace of planar voids around mineral grains.

B: Complex: spongy, crumb and granular microstructure. Porosity is about 30%, dominated by highly interconnected voids, with common vughs (fs-cs) and complex and compound packing voids, with very few chambers and channels (ms-cs) and a trace of planar voids around mineral grains.

Voids are between 10-30% infilled with soil material and possible algal-based organisms in both A and B.

A/B boundary: Diffuse and faint; at 40x, the two sections are separated by a planar void that is about 20% infilled by soil material with crumb, granular and spongy microstrtucture. Along and within the A/B boundary, there are very few minerals and/or nodules that exhibit fracturing and some vertical and horizontal displacement.

Groundmass

c/f20μm ratio, related distribution: A: 4:1; chitonic and single-spaced porphyric with local gefuro-chitonic. B: 2:1, single-spaced porphyric and gefuro-chitonic.

Coarse material:

Mineral (A and B unless otherwise noted): A: Moderately sorted fs-ms sand (top), with sorting becoming increasingly poor closer to B, which is poorly sorted. Mean grain size decreases slightly as you progress up the slide (i.e. from B to A). Few minerals exhibit anorthic coatings of limpid to slightly dusty clays and/or Fe. A trace of textural discontinuities and soil fragments are present in B only. Very few (A) to few (B) minerals exhibit alteration products that appear to be dominantly Fe-based or clays with high-order interference colours; a portion of these may be anorthic. The groundmass is commonly disturbed and bioturbated.

Angular to subrounded quartz grains (dominant, si-g; B: demonstrates slightly more altered grains than A as well as a trace of quartz grains with a pellicular coating or alteration product with high white interference colours [possible gibbsite]); rounded to subangular opaque black mineral with metallic inclusions (OIL, possibly haematite or ilmenite? very few, si-ms), a portion of which have a pinkish-white/white patina-like coating, a red internal hypocoating, pellicular dissolution/alteration, or a combination [A: very few; B: trace]); subangular quartz aggregate (very few, ms-g), very few of which demonstrate in situ fracturing and/or clay/Fe coating on intermineral fissures;

angular to subrounded feldspar grains (very few, fs-vcs); rounded to angular amphibole (trace, fs-ms); angular elongate grains of biotite (very few, si-cs); subangular speckled moderately to well-oriented anistropic anorthic clay nodules (trace, cs); angular laminated and nonlaminated well oriented to isotropic anorthic clay and/or Fe nodule or coating fragments (very few, fs- ms, with slightly more in B than in A), 1 of which has been fractured in situ after deposition); intact and fractured silica microfossils (trace; observed morphologies include circular with central depression and rectangular phytoliths. In A, sponge spicules and a silica skeleton, possibly of a cereal grain husk were also observed. Globular echinate palm-type phytolith were also observed in B); rounded possibly biogenic calcite nodules and coatings commonly found in and on voids (trace, fs); angular to rounded limpid pinkish gray to clear limpid (PPL) high relief isotropic mineral (very few, fs-vcs, frequently fractured in situ); rounded high relief limpid mineral with gray or high interference colours (trace, vfs); limpid clear isotropic mineral (subrounded) appearing similar to quartz in PPL (A: trace; B: very few; possibly garnet); subangular to angular ceramic fragments (very few, see Table 1).

A: Subrounded cryptocrystalline quartz (trace, ms, possible chalcedony); rounded mineral or anorthic clay nodule or nodule fragment with parallel linear cleavage pattern (pale yellow to reddish yellow [OIL], brownish yellow to yellowish brown [PPL]), fractured in situ and with concave referred orientation around the top of a quartz grain (trace, vcs).

B: Rounded strongly impregnated anorthic Fe nodules (trace, fs-ms); rounded anomalous green (PPL) isotropic mineral (trace, vfs); angular clear to pale yellow limpid mineral with high pale yellow interference colours (trace, fs- ms).

Organic: Degraded roots (very few, ms, rounded); indeterminate very pale brown to black (OIL) plant tissues, (very few, fs-ms); angular to subrounded probable charred plant material (A: very few; B: trace, fs-ms), few of which demonstrate dissolution or fracturing; rootlets with low-order gray or hig- order interference colours (trace, as individuals 15µm wide or as masses in the groundmass).

A: Subangular charcoal (very few, ms-g), including 2 probable wood charcoal fragments, 1 of which has been fractured in situ and dispersed slightly in the groundmass; spores or eggs (trace, si); brown (PPL) elongated angular silt- width mineral or plant material with high reddish brown interference colours and internal laminations (trace, cs).

B: Dark reddish brown and black (OIL) humified organic matter (very few, includes 1 vfs aggregate of silt-sized particles that appear biogenic).

Micromass:

Speckled and dotted clays (A: light greenish gray and yellow, B: reddish yellow, pale yellow, and light greenish gray [OIL]) with stipple-speckled b-fabric and frequent weak to strong grano- and porostriations . B: Also includes very few parallel striations and possible mosaic striations.

Pedofeatures:

♦ Limpid and slightly speckled yellow and red (PPL) moderately to well-oriented clay infills, nodules, lenses and coatings, occasionally microlaminated and/or demonstrate a crescentic internal pattern in PPL, possibly indicating minute fractures or multiple phases of deposition (A: many, B: abundant; yellow and reddish yellow interference colours).

♦ Slightly dusty to dusty clay unoriented to moderately oriented clay coatings (A: many; B: abundant).

♦ Dusty red to reddish yellow (PPL) clay coatings and nodules (fs-ms, rounded), most appearing as fractured or as aggregates of particles that are beginning to separate (trace).

♦ Dusty isotropic to slightly anisotropic (with faint stipple-speckled b-fabric) pale yellow to reddish yellow (PPL; light greenish gray [OIL]) clay coatings, hypocoatings and pendents (occasional, a portion of which may be anorthic; rarely the coating is differentiated internally by colour).

♦ Compound clay coatings, hypocoatings, and nodules consisting of juxtaposed limpid and dusty well and poorly oriented clays (A: rare, B: occasional).

♦ Fe internal hypocoatings on mineral grains with cross or irregular linear pattern, some with slight metallic lustre (OIL) (trace, nonbirefringent and yellow to strong brown [OIL]) .

♦ Fe coatings and hypocoatings on mineral grains, voids and groundmass, undifferentiated and differentiated, isotropic and faintly anisotropic (very few, moderately to strongly impregnated, yellow and red to strong brown [OIL]).

♦ Fe rounded orthic nodules, moderately to strongly impregnated, microlaminated and non-laminated; (fs-cs, very few, yellow, red, strong brown [OIL])

♦ Compound limpid to opaque internal hypocoatings of Fe and clay, nonbirefringent or faintly anisotropic, a portion of which may be anorthic (rare; red, yellow, and strong brown [OIL])

♦ Light red to red (OIL) opaque isotropic particulate inclusions as aggregates or dispersed in the groundmass; amorphous and limpid at 400x magnification, (trace; possibly biogenic Fe?)

♦ Fe enrichment and depletion of the groundmass (common; red, reddish yellow, strong brown impregnations; light greenish gray depletions [OIL])

♦ Compound nonlaminated coatings of Fe-impregnated organic material (very few, yellow to strong brown [OIL])

♦ Compound microlaminated and nonlaminated coatings, hypocoatings, and nodules of Fe and limpid to dusty, poorly to well-oriented clays; anisotropic, slightly anisotropic, nonbire-fringent and isotropic elements are juxtaposed or superimposed (A: occasional, B: trace, a portion of the total may be anorthic; yellow to red [OIL])

♦ Excremental pedofeatures: si-vcs sized spheroidal and irregular blocky very porous to dense organomineral (A: very few; about 5% of which are organic [si- fs, spheroidal and ellipsoidal]; B: few, particularly along contact with A and at the very bottom of the slide; in very few cases, excrements appear to consist of fragments of limpid and dusty clays)

♦ Textural pedofeature: white to very pale brown (OIL) opaque isotropic coating on mineral grains, increases in thickness in middle and bottom of slide (A: rare; B: occasional])

♦ Textural pedofeature: coating of anomalous colours, usually vivid blue, green, red, purple, predominantly on si-fs calcite nodules but may appear on Ca-based "string" (trace

♦ Textural pedofeature: dusty black isotropic coatings around voids (rare)

♦ Fabric pedofeature: Loss or reduction of anisotropy; slightly anisotropic areas are faintly stipple-speckled (very few, probably an Fe or clay depletion hypocoating or lens, but may be related to biological activity, as some excrements demonstrate this fabric)

♦ Fabric pedofeature: change in c/f ratio and distribution; c/f20µm ratio 8:1, with monic to chitonic c/f distribution and well-sorted fs grains (trace; vcs to g-sized lenses up to 5mm diameter, may represent movement of fines out of these areas, but in 1 case (area B), may represent disaggregation of quartz aggregate (i.e. possibly sandstone?)

<u>A only:</u>

♦ Amorphous-looking (at 400x) Fe coatings and hypocoatings with silt-sized spheroidal inclusions (very few; may represent Fe-impregnated organic matter)

♦ Clear limpid (PPL) coating or mineral alteration product with silt-sized particulate appear-ance and gray interference colours, discernable only in XPL (trace)

<u>B only:</u>

♦ Organic coatings of silt-sized isotropic to faintly anisotropic brown to yellowish brown and black material (OIL) along voids with parallel referred orientation (rare, includes very few compound coatings in which organic material is juxtaposed with limpid clays or mixed with dusty clays)

♦ 1 loose discontinuous channel infill of whewelite and soil material with reduced anisotropy

Slide C112-3 Moat infill at double-platform monastic site

Thin section no. 2364

Vertical thin section

Context 013A: Sediment accumulation in moat prior to abandonment or collapse, mottled (field interpretation). Field texture is sandy clay with tile inclusions.

OSL date from sample taken near thin section is AD 1090 ± 100 (2 sigma).

Abbreviations: g: gravel; vcs: very coarse sand; cs: coarse sand; ms: medium sand; fs: fine sand; si: silt

Microstructure and porosity

Complex microstructure: vughy and spongy (top and middle), grading into crumb in the bottom ¼ of the slide.

Porosity: 10-15% (top and middle), dominated by vughs (fs-cs) and highly interconnected voids, with common channels (fs-g), few voids or vesicles (si-fs), very few planes (si), and very few planes round mineral grains. In the bottom ¼ of the slide, porosity varies 10-30%, with the addition of frequent compound and complex packing voids. Voids are 10-40% infilled (loose, discontinuous) with soil material and possible algal-based organisms.

Groundmass

c/f20µm ratio, related distribution: 3:1-2:1; single spaced porphyric; bottom ¼ of slide has addition of open equal and fine porphyro-enaulic in areas of crumb microstructure.

Coarse material:

Mineral: Poorly sorted polymictic sand (fs-ms). The sample contains a trace of soil fragments and textural discontinuities. Very few minerals exhibit alteration products that appear to be dominantly Fe-based or clays with high- order interference colours; a portion of these may be anorthic. The groundmass is commonly disturbed and bioturbated.

Subangular to rounded quartz grains (dominant, si-g), a portion of which are undergoing alteration (few irregular linear, very few pellicular, tubular, or dotted); rounded to subangular opaque black mineral with metallic inclusions (OIL, possibly haematite or ilmenite; very few, si-ms), a trace of which have a pinkish-white/white patina-like coating; subangular to rounded quartz aggregate (very few, ms-cs); subrounded to rounded feldspar grains (very few, fs-ms); rounded to angular amphibole (trace, fs-ms); angular elongate grains of biotite (very few, si-cs); angular elongate grains of brownish yellow (OIL) mineral, nonbirefringent except for high interference colours along the edges (very few, fs-ms); angular to rounded limpid to slightly speckled well-oriented anisotropic anorthic clay nodules (very few, fs); angular to rounded laminated and nonlaminated moderately to well oriented limpid to dusty anorthic clay and/or Fe nodule or coating fragments (few, si-ms, with slightly more near the top of the slide than at the bottom); intact and fractured silica microfossils (trace; observed morphologies include square with central depression, serrated,rectangular, and globular echinate palm-type phytoliths, and sponge spicules); rounded possibly biogenic calcite nodules and coatings commonly found in and on voids (trace, fs-ms); angular to rounded limpid pinkish gray to clear limpid (PPL) high relief isotropic mineral (very few, ms-cs), few of which are fractured in situ; rounded high relief limpid mineral with gray or high interference colours (trace, vfs); subangular limpid clear isotropic mineral appearing similar to quartz in PPL (trace, ms, possibly garnet); subrounded cryptocrystalline quartz (trace, ms, possible chert and chalcedony); angular clear to pale yellow limpid mineral or clay coating with high pale yellow interference colours (very few, fs); 1 subrounded ceramic fragment (ms, see Table 1);

1 vermicular object near the bottom of the slide, high interference colours (possible biological organism); 1 pink and reddish yellow (OIL) aggregate coating or nodule, appears similar to the white to very pale brown patina on the ubiquitous black mineral (ms).

Organic: Degraded roots (very few, fs-ms, rounded); indeterminate very pale brown to black (OIL) plant tissues, (very few, fs-ms); rootlets with low-order gray interference colours (trace); subangular charcoal (very few, cs); rounded charred plant material (trace, fs); spores or eggs (trace, si, includes black isotropic [OIL] and limpid yellow [PPL] anisotropic); black (OIL) humified organic matter (trace, includes 1 vfs aggregate of silt-sized particles that seem biogenic); brown and yellowish brown (OIL) organic pigment (bottom only: trace)

Micromass:

Speckled and dotted pale yellow and light greenish gray clays with addition of possible limpid yellow clay lenses in the top ¼ of the slide. Stipple-speckled with few to frequent weak to strong grano- and porostriations (these dominant in areas with si-fs voids), and very few isolated monostriations.

Pedofeatures:

♦ Limpid to slightly speckled yellow (PPL) moderately to well-oriented clay infills, nodules (fs-ms) and coatings (occasional; yellow and reddish yellow interference colours).

♦ Slightly dusty to dusty clay unoriented to moderately oriented clay coatings (occasional).

♦ Dusty isotropic to slightly anisotropic (with faint stipple-speckled b-fabric) pale yellow (PPL; light greenish gray [OIL]) clay coatings (occasional).

♦ Compound clay coatings, hypocoatings, and nodules consisting of juxtaposed limpid and dusty anisotropic and isotropic clays (occasional, presence is increased slightly at bottom)

♦ Fe internal hypocoatings on mineral grains with cross or irregular linear pattern, some with slight metallic lustre (OIL) (very few, nonbirefringent and yellow to strong brown [OIL]).

♦ Fe coatings and hypocoatings on mineral grains, voids and groundmass, laminated and nonlaminated, nonbirefringent and faintly anisotropic (very few, moderately to strongly impregnated, yellow and red to strong brown [OIL]).

♦ Fe rounded orthic nodules, weakly to strongly impregnated, microlaminated and nonlaminated; (fs-cs, very few, yellow, red, strong brown [OIL]).

♦ Compound limpid to opaque internal hypocoatings of Fe and clay, nonbirefringent or faintly anisotropic (rare; red, yellow, and strong brown [OIL]).

♦ Light red to red (OIL) opaque isotropic particulate inclusions as aggregates or dispersed in the groundmass; amorphous and limpid at 400x magnification, (trace; possibly biogenic Fe?).

♦ Fe enrichment and depletion of the groundmass (common; top, middle: moderately to well-expressed; bottom: moderately expressed; red, reddish yellow, strong brown impregnations; light greenish gray depletions [OIL]).

♦ Compound microlaminated and nonlaminated nodules of Fe and limpid to dusty, poorly to well-oriented clays; anisotropic, slightly anisotropic, nonbirefringent and isotropic elements are juxtaposed or superimposed (occasional); includes 1 layered Fe and clay nodule with well-oriented limpid and slightly anisotropic speckled clays and nonbirefringent Fe/clay complexes. About 30% of the nodule made of silt-sized spheroids that are porous to dense (may be excremental in origin) and are slightly anisotropic, with possible extinction lines. The nodule, the clay lenses, and the minerals within the nodule all have parallel referred orientation.).

♦ Excremental pedofeatures: si-vcs sized very porous to very dense organomineral (spheroidal and irregular blocky) and organic (spheroidal and ellipsoids) excrements, dominated by fs-cs size range (top, middle: few; bottom: frequent; only a trace are organic).

- ♦ Textural pedofeature: white to very pale brown (OIL) opaque isotropic coating on mineral grains, increases in thickness in middle and bottom of slide (occasional)
- ♦ Textural pedofeature: coating of anomalous colours, usually vivid blue, green, red, purple, predominantly on si-fs calcite nodules, but includes an elongated purple object that appears fibrous (trace).
- ♦ Textural pedofeature: dusty black isotropic coatings around voids (ms), in a limpid very pale brown to pale yellow isotropic coating (occasional; includes 1 dusty brown quasicoating around a clay nodule that is also incorporated into the nodule).
- ♦ Textural pedofeature: dusty black, gray coating (PPL; light gray [OIL]) nonbirefringent coating over mineral or possible biogenic calcite with high interference colours; appears to be part of an excremental pedofeature.
- ♦ Textural pedofeature: depletion of fine groundmass in ms lens and as coating on void (i.e. <5% of the lens/coating is fine groundmass).
- ♦ Textural pedofeature: particulate coating on mineral grains, undetectable in PPL, OIL but with white/gray interference colours in XPL (trace).
- ♦ Textural pedofeature: limpid and gray (PPL; white opaque [OIL]) isotropic hypocoating with high relief (trace).
- ♦ Fabric pedofeature: compaction and layering of groundmass with alternating fine groundmass layers separating layers of silt-sized minerals, fs-ms minerals, and si-vfs minerals; total pedofeature is 1653μm thick; layers and pedofeature have parallel referred orientation.
- ♦ Fabric pedofeature: Slight compaction of groundmass with the long axes of coarse mineral fraction weakly oriented with parallel referred orientation.
- ♦ Fabric pedofeature: Change in c/f distribution to gefuro-chitonic (lens is 3.19 x 0.6mm and has parallel referred orientation).
- ♦ Fabric pedofeature: 1-10 x 0.6mm lens of moderately sorted fs-ms sand and elongated voids with weak to moderate parallel referred orientation of long axes and striated b-fabric (grano- and poro-); possible compaction surface.
- ♦ Fabric pedofeature: Loss or reduction of anisotropy, particularly around pores; slightly anisotropic areas are faintly stipple-speckled (very few, probably an Fe or clay depletion hypocoating or lens, but may be related to biological activity, as some excrements demonstrate this fabric).

Editors' Note:

Krista Gilliland - *Research Fellow, School of Biological and Environmental Sciences, University of Stirling, Stirling, FK9 4LA, Scotland, U.K. (k.m.gilliland@stir.ac.uk)*

Professor Ian Simpson - *School of Biological and Environmental Sciences, University of Stirling, Stirling, FK9 4LA, Scotland, U.K. (i.a.simpson@stir.ac.uk)*

Professor Prishanta Gunawardhana - *Department of Archaeology, University of Kelaniya, Sri Lanka. (prishantagunawardhana@yahoo.com)*

Professor R.A.E. Coningham - *Pro Vice-Chancellor, Durham University, U.K. (pvc.ssh@durham.ac.uk)*

Archaeologia
Part 02 Volume 01 2011 (Page 27-31)

Multi-storey Constructions In The Unconsolidated Quaternary Deposit

K.N.J. Katupotha and Priyalal Dias

Abstract

The Quaternary stratigraphy of the western coastal belt provide soft sub-surface conditions for raft foundations. Within the City of Colombo such raft foundations have been successfully constructed at or below the ground water table, and typically were placed on dense sand beds and on soft sandstones. A well-balanced loading of a raft helps to prevent any tilt during long-term settlements in loose sands and cohesive clays. When the Profiles below the raft are unconsolidated sands, settlements will be mainly instantaneous, during construction loading of the raft. During excavations for a raft below the ground water table, shoring sheet piling and dewatering mechanisms will be necessary.

Keyword : Stratigraphy, unconsolidated sands, Quaternary, sheet piling

Introduction

The western coastal belt has a variable stratigraphy of Quaternary deposits based on palaeo-environment. A geotechnical drilling investigation can establish the different beds, their thicknesses and load bearing properties. In addition when cohesive clays are present their expected settlements are evaluated by the relevant laboratory tests on undisturbed samples.

It is from an overall engineering appreciation of the sub-surface profile that the depth of founding a raft is recommended. In addition deep rafts have been stable when placed on clayey sands and sandy clays. However placement of a raft on beds of peat is avoided due intense continuous settlements over long periods. Soft sandstone of the western coastal belt affords the best founding for deep rafts. Often loose and compressible clayey strata are excavated to reach a bed of sand and sandstone or clayey sand. Therefore the selection of the formative level of the raft is of utmost importance.

In unconsolidated formations above and below the groundwater table excavations for a deep raft require special engineering techniques. In the western coastal belt the water table is shallow seated, and bordering the coast in Colombo the ground water table is shallow seated, where it will range from 0.5m down to 5.0m depths. Therefore sheet pilling and dewatering was adopted during excavations for deep rafts at Hotel Galadari and Crescat of Hotel Oberoi in Colombo (Figure 1).

The dewatering surrounding the excavation need to be efficient in order to prevent "sand boiling" during the placement of the raft. For major projects as above, dewatering tube wells continuously operated

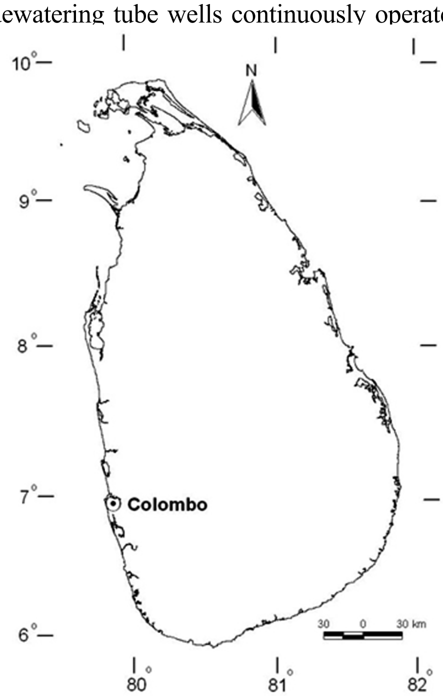


Figure 01: Location of Hotel Galadari and Crescat of Hotel Oberoi in Colombo.

to lower the groundwater table during the raft emplacement.

Geological setting

The western coastal belt of Sri Lanka has Quaternary beds, which form as the basement for raft construction. These Quaternary deposits include marine, lagoonal and terrestrial deposits. Whereas areas of marine deposits constitute sands and sandstone, the lagoonal and terrestrial deposits have variety of sedimentary beds such as sandy clays, clayey sands, organic clays, peat, lean clays, plastic clays and sands (Cooray and Katupotha, 1992).

The sequence of the stratigraphy is essentially based on fluctuations of the mean sea level (MSL). These beds have been estimated up to Late Pleistocene, which is around 18,000 yr. B.P; called the Last Glacial Maximum. In this stratigraphic sequence the beds of peat in the area have been already dated at 5790+ 80 yr. BP, which is at a depth of around between 0.30cm to 0.50cm below MSL (Katupotha, 1988).

In founding of a raft, a bed of sand is normally preferred. In the western coastal belt these sand beds can be of marine of fluvial in origin. In order to achieve a good compaction of such sand the particle size distribution is critical. Sand beds of fluvial origin, which are well sorted normally, have a good particle size distribution and makes such beds well compact. Conversely the marine sand beds are less dense. However when marine sands have been consolidated to sandstone these beds make an excellent formative basement for rafts, especially when such sandstone is followed by in-situ weathered rock. All these overburden Quaternary formations lie unconformably on the Precambrian metamorphic crystalline gneiss. This unconformity leaves a hiatus of at least 600 million years in the geologic history of Sri Lanka.

The in-situ basement rocks are identified as the Vanni Series of Granitic gneisses (Cooray, 1984). These granitic gneisses mainly include granites, biotite gneisses, biotite hornblende gneisses and charnockitic gneissess. These gneisses are crystalline rocks of high uniaxial compressive strength, which makes them ideal for load bearing, especially for pile foundations.

Case studies

Within the City of Colombo, along the western coastal belt, two major raft constructions were for the Hotel Galadhari and Crescat for Hotel Oberoi (Dias and Gunasekera, 1983; Dias and Tennakoon, 1993; Dias, 1995). Both these rafts have been placed on dense sands and semi-consolidated sandstones (Figures 2 and 3).

For the Hotel Galadhari the loose and soft strata were excavated within a sheet piled area to reach the depth of firm sands of 'N'=10 to 15 at a depth of about 08 meters. Geothchnical investigations revealed an adequate thickness for the dense sands, and therefore the pressure bulb of the loaded raft did not reach any soft beds below the sands.

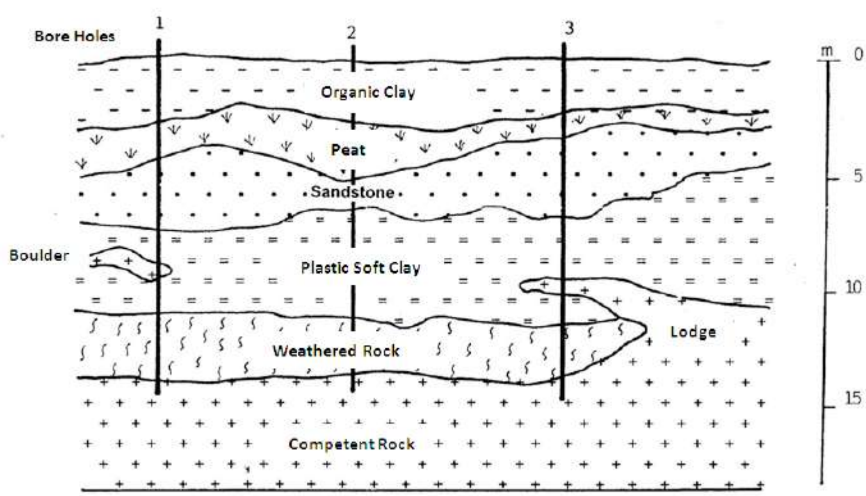


Figure 02: Typical Quaternary Profile

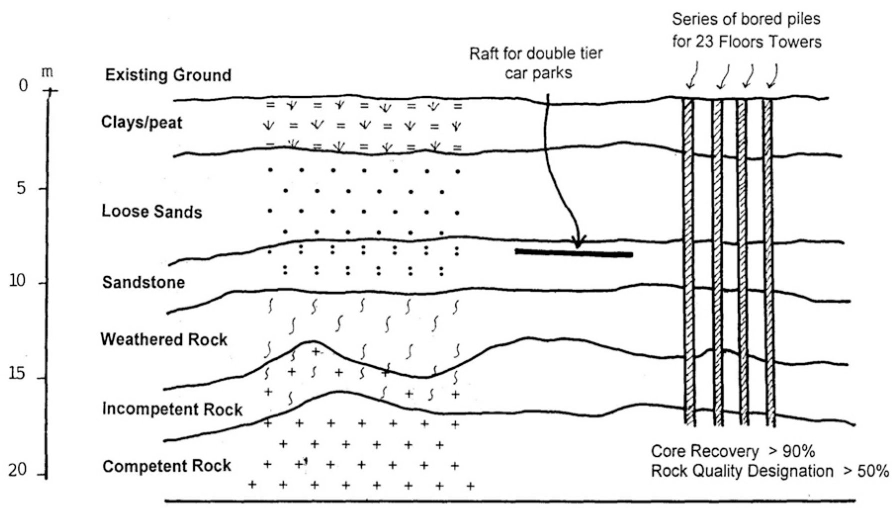


Figure 03: Foundation for Hotel Oberoi

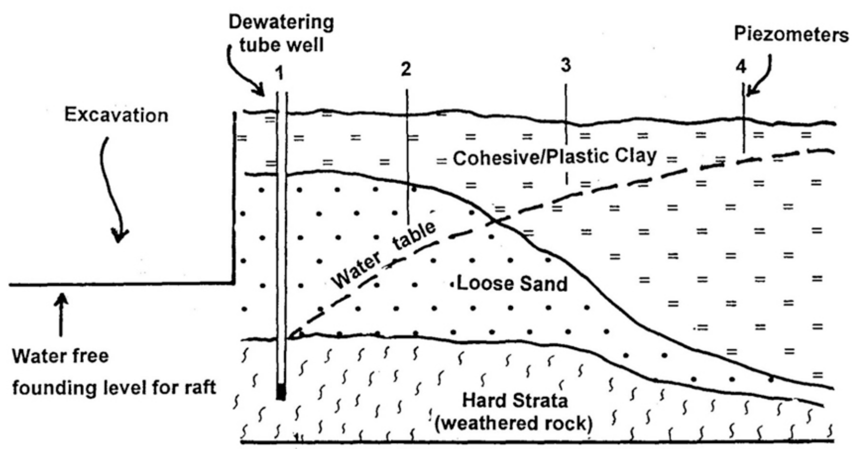


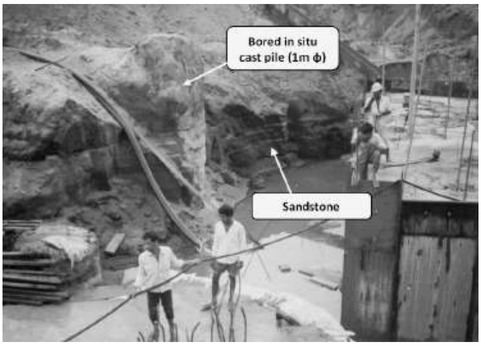
Figure 04: Dewatering for Raft Foundations

A series of shallow tube wells drilled down to about 15.00m, were placed strategically surrounding the sheet pile area, which ensured dry excavation down to a depth of about 12.00m and ensured a water free surface without “sand boiling” for the raft construction.

Similarly for the Crescent Development of the Hotel Oberoi an extensive double tier underground car park is on a deep raft, where the formative level is on friable sandstone at a depth of around 10.00 m (Dias and Tennakoon, 1993). It is interesting to note that for this project whilst a deep raft is suitable for the double tier car park, heavy loads of the 23 floor tower is placed on end bearing bored piles (Figure 3), where the pile base is rock socketed into fresh rock. For the placement of this raft on the sandstone sheet piling and dewatering was adopted for satisfactory construction.

For the construction of such deep rafts, sheet piling and an intensive dewatering programme is undertaken (Figure 4). Interlocking sheet piles are driven to firm strata at least 3-5m below formative level of the raft. Mechanical excavation is terminated well above the bottom depth of the sheet piles, so that there will be no collapse of sheet piles into the excavation by lateral soil pressures.

Prior to the dewatering programmes the behavior of the soil types and quantum of groundwater that requires pumping out should be evaluated. This is normally done by dewatering a test-tube well on a step up pumping basis. By monitoring a series of spaced out piezometers, the drawdown curves of the water table can be plotted for different rates of pumping (Figure 4). From the above investigation the spacing and depth of dewatering wells surrounding the sheet piled excavation is designed, along with the required quantum of pumping. The pumped out water is diverted to a long distance, in order to avoid seepage back, to replenish the groundwater table.



Figuer 05: Deep bored pile founded and rock socketted in bedrock for 23 storey structure.

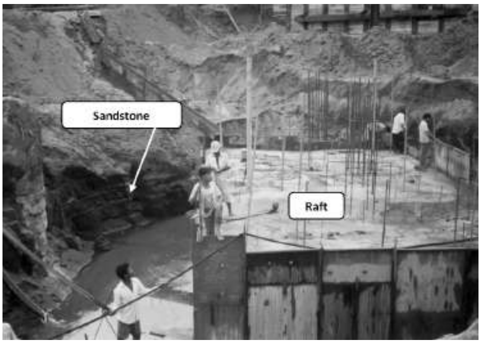


Figure 06: Exposed sandstone upon which raft is founded.

Problems and issues

In sheet piling unconsolidated formations with a shallow water table, pile verticality, proper interlocking, and sometimes bracing will be important criteria in construction. When verticality is not maintained buckling of sheet piles can occur resulting in the collapse of the excavation. In the absence of proper interlocking, saturated clays and peat will flow into the excavation terminating disturbing all excavation operations. To hold the sheet piles together as a rigid “box structure” proper bracing is essential.

The depth of the sheet piles should be well below the depth of excavation, which is normally 3m to 5m depending on the unconsolidated formation at depth. In dense granular formations 3m can be sufficient, while is soft clayey sandy strata at least 05m will be preferred.

During excavation within the sheet piled area below the water table, efficient dewatering is necessary. Dewatering is normally from tube wells located just outside the sheet piled perimeter. On reaching the formative level of the raft, the surface need to be unsaturated and undisturbed. The water table has to be to be drawn below this surface. On a sandy basement “sand boiling” due to hydrostatic pressure will occur if the water table is not properly drawn down. After laying of the raft, if the normal water table is above the raft structure, continuous dewatering will be necessary for the construction of the basement of the structure.

In the coastal sand belt of the west coast excessive long duration dewatering should be avoided, to prevent adverse environmental impacts. Two major impacts are drying up of shallow dug wells in the vicinity, and salt water intrusion. Long duration excessive pumping in sands bordering the coast causes the inland migration of the saline water wedge, whereby the perched fresh water lens is depleted. The other environmental impact is the potential threat for the subsidence of adjoining foundations by the reduction of hydrostatic pressure due to dewatering.

A significant environmental impact in dewatering for the Galadhari Hotel raft was salinity intrusion (Dias and Gunasekera, 1983). Here the delays in construction of the raft entailed a long period of fresh water dewatering. Thereby shallow dug wells in the vicinity (Colombo Fort and the Galle Face) were rendered saline for a period of about 2 years.

Conclusions

Dense sand formations and sandstone horizons of the western coastal belt afford a suitable basement for the construction of deep raft foundations. Therefore it is essential that a geotechnical-drilling programme be conducted to identify the different beds of strata for their safe load bearing capacities. Thereafter a suitable bed for founding can be identified for load distribution.

For foundations supporting heavy loads per unit area to the underlying soil a deep raft can be suitable for load distribution over the entire area. One must ensure soft beds at depth receive minimal loads, and thereby settlements are limited. Most instantaneous settlements occur during the construction loading. For minimal long-term settlements the R.C. concrete raft acts as a whole unit in accommodating settlements. Therefore structural failures are avoided, including any tilt of the raft. Any tilt of a raft can occur due to non-horizontality of stratigraphy due to dilation or pinching out of soft compressible beds.

For construction projects, which involve heavy loads over an extensive area, raft foundations on unconsolidated formations are more economical than end-bearing piles, especially when the bedrock is deep seated. However for high concentrated loads such as multistory towers (Figure 3) bored piles end bearing on bedrock can be the only option.

To obtain an undisturbed water free surface for a deep raft, shuttering and dewatering can be essential. In built-up urban surroundings dewatering requires caution. Excessive lowering of the groundwater table can cause subsidence of adjoining shallow foundations, and the drying up of dug wells. In areas bordering the coast excessive dewatering often causes salinity intrusion, which can be an environmental hazard for the raft construction.

References

Cooray, P.G., 1984, An Introduction to the Geology of Sri Lanka. 2nd Revised Edition, Ceylon National Museum Publication, Colombo, pp 77-80.

Cooray, P.G. and Katupotha, J,1992, Geological evolution of the coastal zone of Sri Lanka. Proceedings, Symposium on "Causes of Coastal Erosion in Sri Lanka". CCD/GTZ, Colombo, Sri Lanka, 9-11, Feb. 1991, 5-26.

Dias, D.P. and Gunakekera, H.A.S.N., 1983, Soil investigation for the construction of Hotel Galadari. Foundation and Waterwell Engineering (PVT) LTD, Katubedda, Sri Lanka (unpublished report).

Dias, D.P. and Tennakoon, B.L, 1993, Soil investigation for redevelopment of Hotel Lanka Oberoi (Crescat Development). Foundation and Waterwell Engineering (PVT) LTD, Katubedda, Sri Lanka (unpublished report).

Dias, D.P., 1995, Soil investigation practices in Sri Lanka-a geologist's perspective based on case studies. Hand book on Geology and Mineral Resources of Sri Lanka, K . Dahanayake (ed.) (GEOSAS II, Colombo, Sri Lanka, January 19-24.

Katupotha, J., 1988, Hiroshima University radiocarbon dates 2, west and south coasts of Sri Lanka. Radiocarbon, 30(3), 341-346.

Editors' Note:

Professor K.N.J. Katupotha - *Department of Geography, University of Sri Jayewardenepura Gangodawila, Nugegoda, Sri Lanka. (katupotha@gmail.com)*

Dr. Priyalal Dias - *Managing Director, Foundation and Waterwell Engineering (PVT) LTD, No.48/14th Cross Lane, Jaya Mawatha, Rathmalana, Sri Lanka. (swweng@sol.lk)*

Archaeologia
Part 02 Volume 01 2011 (Page 32-34)

Morphological and Morphometric Analysis of Prehistoric Human Skeletal Remains From Sigiriya Potana, Sri Lanka

K.M. Chandimal, S.G. Yasawardene and Gamini Adikari

Abstract

The excavation carried out at the prehistoric site at Sigiriya yeilded the habitat, subsistence and mortuary rituals of extinxt Potana man. The complete skeletal remains of two individuals who were discovered in a foetal position and one cranium were excavated. This was an important asset to reconstruct the skeletons of the Sigiriya Potana inhabitants. A comparative morphometrical analysis of skeletal remains discovered from other prehistoric sites such as Bellanbendi Pelessa and Batadombalena Sri Lanka reveiled the contemporary mesolithic inhabitants of Sri Lanka.

Key words: Potana, Homo sapiens, Mesolithic

Introduction

The prehistoric site at Sigiriya Potana cave complex situated in the Matale District Sri Lanka and is located about 5 km away from Sigiriya on the road leading to Inamaluwa (see.Map 01). In 1990 an excavation and exploration team from the Postgraduate Institute of Archaeology (PGIAR) identified Potana as a prehistoric site based on evidence of stone and bone tools and other cultural remains (Bandaranayake 1994). The most exciting finding of this excavation had been of two complete human skeletons found in context no. 10 lying about a meter apart, in a doubled up sleeping posture and one cranium in context No. 3 as reported by Adikari (1994, 1998 and 2007).

The Potana skeletal remains

One skeleton labeled as specimen No. 1 in context No. 10 is represented by the skull along with part of the mandible and post cranial bones namely a fragmented clavicle, sternum, ribs, vertebrae, scapula, pelvic bones and long bones with their shaft, proximal and distal ends intact. The Potana prehistoric human remains dated back to 6000 years BP and the calibrated age ranges from cumulative probability (using one sigma) 3913-3727 BCE (ua 5685) and 3913-3709 BCE (ua 5686) as reported by Adikari 1998. As detailed morphological and morphometric analysis of skeletal remains has not been done, our objective of this study was to carry out a detailed morphological and morphometric analysis of one of the excavated human skeletons (figure 01).

The conventional morphological and osteometric analysis was based on methods described by Brothwell (1951) and Bass (1971). The stature calculation was done using long bones, femur, tibia, humerus, ulna and radius and was based on regression formulae derived by Trotter and Gleser (1952).

By adopting the method described by Krogman, 1962, the stature was calculated using fragmented long bones, tibia and humerus. The sex and age determinism of this skeleton was based on the techniques described by Bass (1971). The sex determination was done using available fragmented pelvic bones, skull and long bones. Most of the long bones either individually or in groups were subjected to metrical and morphological analysis for the purpose of determining the sex. The age of the skeleton was based on tooth eruption patterns and dental wear patterns reported by Bass (1971).

Cranial features such as relatively high and elongated vault of the skull, well developed

Figure 01: Potana prehistoric human skeletal remain i in context No.10

mastoid processes, well marked external occipital protuberance, well marked muscular ridges on occiput observed in this skeleton was suggestive of male sex. Although the pelvic bones were fragmented the available fragments showed a narrow and deeper sciatic notch which was comparable with the male sex. The femur was heavier, robust, muscular impressions were well marked and the linear aspera was prominent. The maxillary third molars, right and left were completely erupted and negligible dental wear of first molar was noted in the available maxillary dentition of the skeleton. The maximum length of complete right femur was 460 mm, right radius was 258 mm and left radius was 255 mm. The reconstructed maximum length of fragmented right humerus was 327 mm, left humerus was 326 mm, right ulna was 262 mm, left ulna was 261 mm and right tibia was 367 mm. The stature of extinct man was reconstructed by applying Trotter and Glesser formulae for a white male. The reconstructed stature figure of the Potana skeletal remains are as follows. Skeleton 1 is 172.6 cm, 172.3 cm based on right and left humeri; 177.2 cm, 176.06 cm based on right and left radii, 174.06 cm, 173.68 cm based on right and left ulna, 172.25 cm based on right femur 170.74 cm based on right tibia.Considering the morphological features of cranial, pelvic and long bones the extinct individual should be male and the estimated age is around 25-30 years considering tooth eruption and dental wear patterns. The reconstructed height of the extinct human skeleton labeled as skeleton No. 01 is 173.61 cm.

Conclusions

Kennedy (1965) using complete long bones of femur, humerus radius and ulna and by using the same regression formulae of Trotter and Glesser (1952) had reported the mean stature of the Balangoda male as 164.7 cm and female as 164 cm. The reconstructed height of the extinct prehistoric man in Potana is higher than the recorded heights of the Kennedy's study on Balangoda man. The total height of the male and female *Homo sapiens balangodensis* had been estimated by Kennedy et al (1986) based upon lengths of humeri, radii, ulnas, femur tibia and fibula. The estimated stature figure of Batadombalena specimen No. 1 (male) is reported as 165 cm based on the length of right humerus. The stature estimations for radial and ulna length of female specimen No. 2 were 171 cm, 172 cm respectively. The estimated stature of Bellanbendi Pelessa skeletal remains were 161.8 cm for specimen BP2/17 (male), 169.4 cm for BP4/8 (male) and specimen BP3/27-35 165.9 cm for females according to Kennedy et al (1986). These mean stature figures were calculated using available data reported by Kennedy et al (1986).

On comparing the reported stature figures from both prehistoric sites of Batadombalena and Bellanbendi Pelessa the extinct contemporary prehistoric male skeleton found in Potana (skeleton 1) is taller. The reconstructed mean height of the prehistoric young male Potana skeleton 1, being 173.61 cm is higher than the mean height of present modern population, male of 164.19 cm reported in Somasundaram (2004). This confirms Kennedy's (1965) observation that Balangoda man appears to have been taller than the present modern Sri Lankan population.

References

Adikari, G. 1994. "Excavation at Sigiriya-Potana Cave complex: a preliminary account" in S. Bandaranayake, M. Mogren (Eds.) *Further Studies in the settlement archaeology of the Sigiriya and Dambulla Region*, Postgraduate Institute of Archaeology, Colombo: 65-70 .

Adikari, G. *1998. Aspects of the prehistory of the Sigiriya-Dambulla Region*, Postgraduate Institute of Archaeology, Colombo

Adikari, G. *2007, Dry Zone prehistory in Sri Lanka: Potana Cave MO14 in Sigiriya Region*, Archaeo Heritage Investigation Bureau, Kadawatha

Bandaranayake, S. 1971. "Traversing the Archaeological Landscape" in S. Bandaranayake, M. Mogren (Eds.) *Further Studies in the settlement archaeology of the Sigiriya and Dambulla Region*, Postgraduate Institute of Archaeology, Colombo: 9-21.

Bass, W.M. *1981. Human Osteology: laboratory and field manual of the human skeleton* Colombia Missouri Archaeology Society, USA

Brothwell, D.R. 1965. "Digging up bones the excavation, treatment and study of human skeletal remains" *British Museum (Natural History),* Oxford University Press, UK

Kennedy K.A.R. 1986."Human skeletal material from Ceylon, with an analysis of the islands prehistoric and contemporary populations" *Bulletin of British Museum (Natural History)* Vol. II No. 4 London

Kennedy, K.A.R.; T. Disotell; W.J. Roerigen, J. Chiment, J. Shervy 1962. "Biological Anthropology of Upper Pleistocene Hominids from Sri Lanka" *Anceint Ceylon* Vol. 6

Krogman, W.M. *2004. The Human skeleton in Forensic Medicine* (third ed.) Charles C. Thomas, Springfield, Illinois, USA

Somasundaram, M. *1952. Mandibular variation from prehistoric to modern population in Sri Lanka* Unpublished BA dissertation, Department of Anatomy, University of Sri Jayawardenapura, Sri Lanka

Trotter, M. and G.C. Glesser "Estimation of stature from long bones of American Whites, Negroes "American Journal of Physical Anthropology" *Washington* 10: 463-514.

Editors' Note:

K.M. Chandimal - *Lecturer, Department of Anatomy, Wickckramarachchi Ayurveda Institute, University of Kelaniya, Sri Lanka. (chandimal06@yahoo.com)*

Professor S.G. Yasawardene - *Department of Anatomy, Faculty of Medical Sciences, University of Sri Jayawardenapura, Sri Lanka. (surangiy@hotmail.com)*

Professor Gamini Adikari - *Postgraduate Institute of Archaeology, University of Kelaniya, Sri Lanka. (osteologypgiar@yahoo.com)*

Archaeologia
Part 02 Volume 01 2011 (Page 35-40)

A Comparative Study of Design of Bampur Ceramics and the Modern Handmade Textiles in the Bampur Valley

Mehdi Mortazavi and Mehdi Fallah

Abstract

This paper, which is based on fieldwork and documentary studies, aims to compare design of the Bampur ceramics with those designs of the modern handmade textiles in the Bampur Valley, in the Iranian Baluchestan. Tepe Bampur, which is located 15 km west of modern city of Iranshahr, is a third millennium BC settlement. De Cardi, the excavator of Tepe Bampur, was able to determine six cultural sequences in this important site in 1966. Ceramic studies of this paper are also based on her classification. According to the comparison between ceramics and handmade textiles, which was based on ethnoarchaeology, many similarities were observed between designs of the above evidence. In this study, Middle Range Theory enabled us to make a reasonable connection between the ancient and modern designs. Four different types of designs, including geometric, celestial bodies, animal and vegetative designs, were identifies in this study. Geometric designs, in both abstractive and truthful forms, which are probably affected by historical, environmental, cultural and folklore conditions of the Iranian Baluchestan, are the most important and popular designs in both textiles and ceramics during time.

Key words: ceramics, textile, handmade, Bampur, Baluchestan, design

Introduction

Archaeology, to the extent that it is a discipline interested in processes of cultural variation and change, must include comparative methods. One cannot identify or investigate variation unless one has examples spanning a range of variation; one cannot examine change unless one has examples spanning a range of time. And one cannot simultaneously examine a set of examples if one does not employ comparative methods (Peregrine 2004: 281). As stated, in this paper, we discuss a comparison between designs of ceramics of Tepe Bampur during the third millennium BC with those designs of the modern handmade textiles in the Bampur Valley, in the Iranian Baluchestan.

In the 1970s a movement linked to the "new" archaeology and its emphasis on Middle-Range Theory (i.e., research focused on linking artifacts and artifact pattern to human behaviors) and involving field research among living peoples was initiated. This approach was designed specifically to develop means to interpret the archaeological record. Termed 'Ethnoarchaeology," or "living archaeology," many saw this as the answer to the long-standing problem of ethnographic analogy in archaeological interpretation (Gould and Watson 1982). As Peter Kosso notes: "Evidence in Archaeology," since it is an informational link between the unobservable past and observable data in the present, must be accountable to justification that the link is secure and accurate" (Kosso 1993: 163). Before archaeology engaged in anthropology, it had to secure the relationship between observations of data and past human behaviors. The theorizing, and the theory building, designed to deal with the empirical aspects of archaeological practice came to be known as Middle Range Theory (Binford 1977; Raab and Goodyear 1984; Kosso 1993). As stated above, this paper aims to examine similarities between designs of Tepe Bampur ceramics with those designs of the modern textiles by applying Middle Range Theory.

The Study Area

Baluchistan covers a broad region between the Iranian Plateau and the Indian Subcontinent but has been politically divided between Iran, Pakistan and Afghanistan (Costantini & Costantini Biasini 1985: 17) and the Bampur valley is a natural thoroughfare linking Pakistan to central Iran. The route passes the Kashan oasis and then runs parallel to the Kerman mountain range and follows the course of the Halil River, flowing into the Bampur river through the Jaz-Murian lake (Tosi 1974a: 30). The Bampur Valley is situated in the Iranian Baluchistan linking the Iranian Plateau settlements with those in the Indus Valley (Shaffer 1986: 63). The valley, which links Central Iran to Pakistan, is a natural highway (Tosi 1974b: 30; De Cardi 1970: 239). This highway was connected to the west along the Bampur Valley, which drains into the marshy Jaz Murian Basin. Prehistoric settlements along the Bampur River were connected to the west through Chah-Hussaini and the Jaz Murian Basin (Tosi 1974b: 30).

Tepe Bampur is located inside the city of Bampur, which is situated at 61o 25' east longitude and 27o 90' north latitude, in Iranian Baluchistan (Abdollah-Garoosi 1995: 9). This city was called the "traditional capital of the Persian Baluchistan" by Stein (Stein 1937: 105). The mound of Bampur has a circular shape and is crowned by an Islamic period castle (Tosi 1974a: 30). De Cardi carried out a preliminary survey of the site and recorded prehistoric potsherds in an area of about 370 x 302 m to the North West of the fortress (De Cardi 1967: 35). She also dug two small trenches in this site in 1966 (Tosi 1974a: 30).

Discussion

De Cardi believed that Bampur ceramic studies were of significance because they demonstrated cultural relations between the region of Persian Baluchistan and the bordering countries of Afghanistan and Pakistan during the third millennium BC. She stated that there were also relationships between Bampur and the shores of the Persian Gulf (De Cardi 1970: 237). The stratigraphical sequence at Tepe Bampur has been divided into six periods, designated Bampur I, II, III, IV, V and VI (Lamberg-Karlovsky & Schmandt-Besserat 1977: 114). This chronology is mostly based upon a pottery classification compared with other sites in Iran (Tosi 1970c: 12), demonstrating similarity over the whole sequence. With this low percentage of variation, it is more suitable to consider phases rather than periods particularly when the small area of the excavated trenches is considered (Tosi 1974a: 30). Therefore, the excavator reconsidered her final stratigraphy and presented two cultural complexes visible in the sequence, which are Bampur I-IV and Bampur V-VI (Tosi 1970c: 12; Shaffer 1978: 85).

At Tepe Bampur, it has been argued that all wares of the period I, and most of its forms, and its design, continued into period II (De Cardi 1970: 279). In period II, decorations include shallow wavy comb incising and geometric designs. Multiple chevron bands and angular stepped patterns (figure 1) (De Cardi 1970: 281-284), are important decorations of period II pottery. Chevron bands are also visible on the carpet of the Bampur Valley in modern day (figure 2).

Like period II, decoration of period III is almost geometric (De Cardi 1967), including hatched curvilinear diamonds (figure 3) (De Cardi 1970: 287). The same patterns are also visible in modern carpets of the Bampur Valley (figure 4). It seems that modern craftsmen of the Bampur Valley attempted to use the same patterns that were designed by their ancestors during the third millennium BC.

Solid black checker (figure 5) was set either straight or diagonally in panels and continuous bands during phase 1 of period IV (De Cardi 1970: 289). Solid chromatic checker is the most important pattern, which is used by craftsmen of the Bampur Valley as design on their textiles (figure 6). Hatched crescent shapes either singularly in bands or opposed on the shoulder of large jars (figure 7) have been seen in the first phase of period IV (De Cardi 1970: 289), consisting of the earlier intrusive elements with the traditional patterns in phase 1 of period IV (De Cardi 1970: 289). It is interesting that palm design is also important design of this period, which could be seen in fig. 7 no. 2. Palm is the most popular tree in the Bampur Valley. This tree, which also provides food of people the valley, could be seen along the Bampur River. Nowadays, modern craftsmen of the

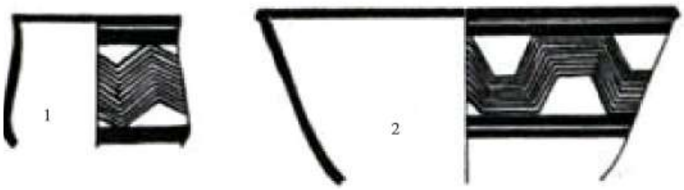


Figure 1: Period II, Tepe Bampur, Multiple chevron bands and angular stepped patterns (After: De Cardi 1970: 280)

Figure 2: Chevron design on the carpet of the Bampur Valley (Pattern and Picture by the authors)

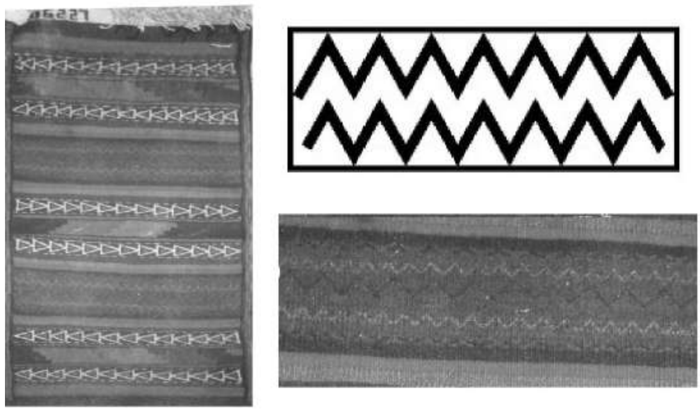


Figure 3: Period III, Tepe Bampur,Hatched curvilinear diamond (After: De Cardi 1970: 286)

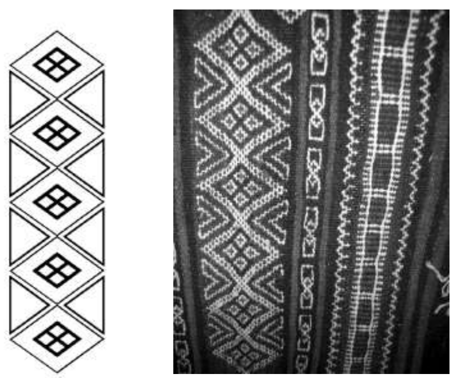


Figure. 4: hatched curvilinear diamond on the carpets of the Bampur Valley (Pattern and Picture by authors)

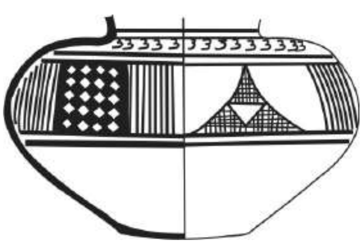


Figure 5: Period IV, Tepe Bampur, Solid black checker (After: De Cardi 1970: 291)

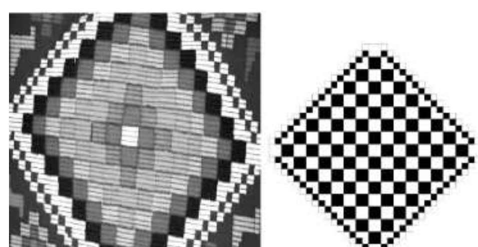


Fig.ure 6: Solid Chevron on the textile of the Bampur Valley

Bampur Valley also use palm design as the main design on their carpets and textiles (figure 8).

There was clearly a demand for certain new designs (De Cardi 1968: 144), consisting of the earlier intrusive elements with the traditional patterns in phase 1 of period IV (De Cardi 1970: 289). This combination can be seen in a sample decorated with the fringed M's of period II set above curvilinear design (figure 9) (De Cardi 1970: 289). The fringed M's design has also been identified at Mundigak, while the curvilinear design has been reported both at Mundigak and Jai Damb, in Pakistan Makran (De Cardi 1970: 289). This important design is also famous in modern day of the Bampur Valley. Many weavers draw M's design on their textiles and carpets (figure10). It is notable to state that M's designs are seen in both vertical and horizontal position in both ceramics and carpets.

Decorated pottery of period IV phase 2 with star on the body of the wares has been discovered from Tepe Bampur (figure 11) (De Cardi 1970:292). This kind of design was also seen on the body of many other wares during this period. Star design is also used by weaver of the Bampur Valley in modern time (figure 12). Scorpion is also popular design of Tepe Bampur ceramics. A number of ceramics were discovered from peiod IV of Tepe Bampur. Figure 13 shows two scorpions on a fragment of the above period (figure 13). (De Cardi 1970: 290). Scorpion mostly is visible on the ceramics of periods IV-VI of Bampur sequences. This design is also visible on the carpets of the Bampur Valley (figure 14).

As stated, M's design is common design of Periods II-V of Bampur sequences. Figure 15 also shows M's design in Period V. Many ceramic fragments have been discovered that showing M's design. One of the most important fragments, which was discovered by De Cardi, showing M's design in its shoulder. It is interesting that in this fragment, a goat is also visible (figure 15) (De Cardi 1970: 304). Goat is also a popular design, which is visible in different periods

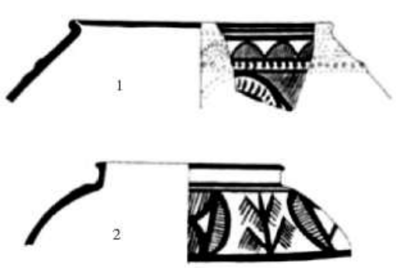


Figure 7: Period IV, Tepe Bampur, Hatched crescents and palm (After: De Cardi 1970: 288)

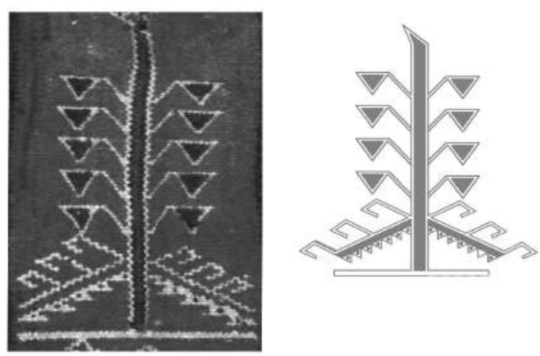


Figure 8: Palm pattern on the carpet of the Bampur Valley

Figure 9: Period IV, Tepe Bampur, fringed M's design (After: De Cardi 1970: 288)

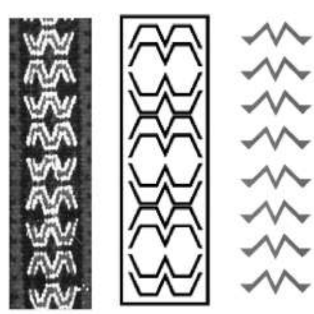


Fig.ure 10: M's designs on carpets of the Bampur Valley

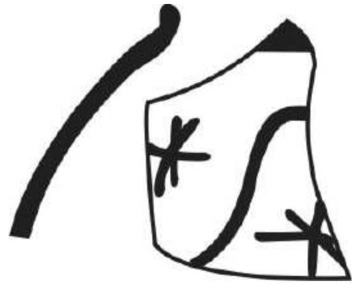


Figure 11: Period IV, Tepe Bampur, Star design (After: De Cardi 1970: 294)

Figure 12: Star design on the Bampur carpets

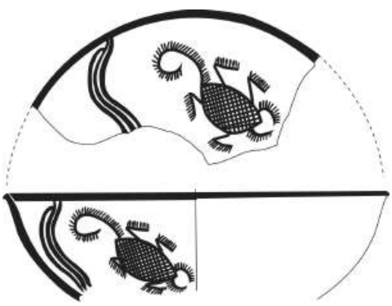


Figure 13: Scorpion design, Period IV, Tepe Bampur (After: De Cardi 1970: 302)

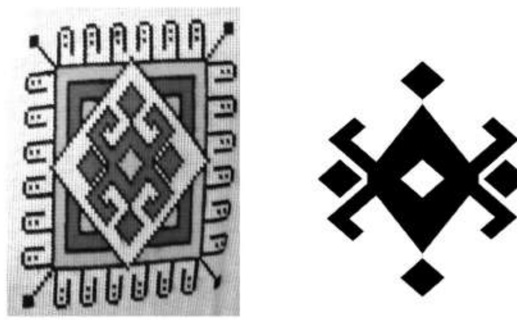


Figure 14: design of Scorpion on the carpet of the Bampur Valley

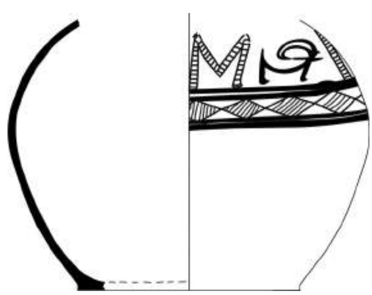


Figure 15: Period V, Tepe Bampur, M's design and goat design (After: De Cardi 1970: 304)

Figure 16: goat design on carpet of the Bampur Valley

of Bampur sequences. Modern carpets of the Bampur Valley show goats in different styles (figures 16 & 17).

Conclusions

As stated, the aim of this paper was to compare design of the Bampur ceramics with those designs of the modern handmade textiles in the Bampur Valley, which is located in the Iranian Baluchestan. This comparison enables us to have a better understanding of continuity of some designs in the Bampur Valley. Four groups of design were studies in this article. These designs, including geometric, celestial bodies, vegetative and animal designs, were observed on both ceramics and handmade textiles. It was attempted to have one example of each group design, while there are many other designs in different period of Bampur sequence and modern day of the Bampur Valley.

In geometric group of design, Chevron bands, hatched curvilinear diamonds, Solid black checker, M's fringed designs were of most important. There are compound designs in different periods.

The only vegetative design, which was studies in this article, is palm. This kind of design is common between the Bampur Valley and the Sistan Basin during the third millennium BC. In modern day, people of the area use this design as the main vegetative design in their handmade textiles. It seems that they try to use environmental factors in their handmade textiles.

Third group of designs are animal designs, which are included scorpion and goat in this article, however snake is also seen in both ceramics and textiles in different periods. There are many scorpion, goat and snake in the environment of the modern day of the Bampur Valley.

The final group of designs, which used by craftsmen, are celestial bodies, including star, moon and sun. In this article, star was just studies in both ceramics and textiles. Celestial bodies' designs demonstrate people belief to these elements during both the prehistoric and modern times.

Middle-Range Theory was applied to make a bridge between the past and modern day of the Bampur Valley. Based on the above comparison, it could be stated that people of the valley used those patterns as the main designs for their ceramics and textile, which were available in their environment. Some geometric designs could also remember us environmental factors of the Bampur valley, such as chevrons bands as mountain. To sum up, all designs that were used by both craftsmen of ceramics and handmade textiles were their beliefs during long time in the same environment.

References

Abdollah-Garoosi, A.1995. Historical Geography of Bampur Area, Baluchestan. (In Persian). Tehran: Jahad-i-Daneshgahi.

Binford, L. R. 1977. For Theory Building in Archeology : Essays on Faunal Remains, Aquatic Resources, Spatial Analysis, and Systemic Modeling. New York: Academic Press.

Costantini. L & L Costantini Biasini. 1985. Agriculture in Baluchistan between the 7th and the 3rd millennium BC. Newsletter of Baluchistan Studies: 2: 16-30.

De cardi, B. 1967. The Bampur Sequence in the 3rd Millennium B.C.Antiquity XLI (161): 31-41.

De Cardi, B. 1970. Excavations at Bampur. A third Millennium B.C Settlement in Persian Baluchistan, 1966. Anthropological Papers of the American Museum of Natural History 51(3): 232-355.New York.

Gould, R. A and P. J. Watson. 1982. A Dialogue on the meaning and use of analogy in ethnoarchaeological reasoning. Journal of Anthropological Archaeology. 1: 388-381.

Kosso, P. 1993. Middle-Range Theory in Historical Archaeology. Studies in History and Philosophy of Science. 24: 163-184.

Lamberg-Karlovsky, C.C. & D. Schmandt Besserat. 1977. An Evaluation of the Bampur, Khorab and Chah Hosseini Collections in the Peabody Museum and Relations With Tepe Yahya. In C.Young and l. Levine (eds.). Mountains and Lowlands: 113-134. Malibu: Undena Publications.

Peregine, P. N. 2004. Cross-Cultural Approaches in Archaeology: Comparative Ethnology, Comparative Archaeology, and Archaeoethnology. Journal of Archaeological Research. 12 (3): 281-309.

Raab, L. M. and A. C. Goodyear. 1984. Middle Range Theory in Archaeology: A Critical Review of Origins and Applications. American Antiquity. 49: 255-268.

Stein, A. 1937. Archaeological Reconnaissances in North-western India and south-eastern Iran. London: MacMillan.

Tosi, M. 1974a. Bampur: A Problem of Isolation. East and West 24 (1-2): 29-50.

Tosi, M. 1974b. The Problem of Turquoise in the 3rd millennium BC Trade across the Iranian Plateau. Memorie dell'Istituto Italiano di Paleontologia Umana 2: 148-62.

Tosi, M. 1974c. The Lapis Lazuli trade across the Iranian Plateau in the 3rd Millennium B.C. In G. Tucci (ed) Gururajamanjarika: .3-22. Napoli: Studi in onore di Giuseppe.

Shaffer, J. G. 1986. The Archaeology of Baluchistan: a review. Newsletter of Baluchistan Studies 3: 63-111.

Editors' Note:

Professor Mehdi Mortazavi - *Archaeology department, University of Sistan and Baluchestan, Iran. (mmor-2002@yahoo.com)*

Dr. Mehdi Fallah - *Archaeology department, University of Sistan and Baluchestan, Iran.*

Archaeologia
Part 02 Volume 01 2011 (Page 41-45)

A Gemological Perspective of Gem Beads of Jetavana World Heritage Site, Sri Lanka

Pathmakumara Jayasingha

Abstract

Gem beads are attractive objects used not only for bodily ornamentation but also to decorate royal palaces and religious places in ancient time. The Jetavanaya Bead collection contains considerable amount of natural gem beads which are made up of gems coming from six main gem families found in Sri Lankan gem fields. The most common gem beads are made up of Garnet and Quartz family gems while Corundum, Beryl and Feldspar beads are somewhat rare in the collection. Having both unfinished beads and raw materials give an idea that beads had been made locally. The different shapes, well polished facets and sharp edges of beads evidence the advance ancient technology of bead making.

Key words: gems, beads, Jetavana

Introduction

Beads were used as bodily ornaments by ancient people. Bead making is an art and a variety of materials like stones, gems, corals, shells, amber, wood, metals etc have been used since prehistoric time (Dubin 1987). The use of natural materials varied from region to region, country to country and place to place. Later the bead making process has been developed as an industry with better knowledge and advanced technology that created synthetic beads and properly faceted natural beads. After the beginning of long distance trade, knowledge and techniques of bead making were circulated and different kinds of materials and beads were distributed around the world. As a centre for trading in ancient times, Sri Lankan culture was enhanced and gained different techniques, materials and beads from different countries. Sri Lanka is rich in raw materials for making either natural or synthetic beads.

Ancient chronicles of Sri Lanka have mentioned the use of gems as decorative materials from ancient times (Mahavamsa 300 AD, Thupavamsa 300-600 AD). Gems, are minerals which have specific characteristics. Beauty defined by its colour, degree of transparency, lustre, reflective effect, rarity and durability of a gemstone decide the class of a gemstone, indicating if it is either precious or semiprecious. The main gem varieties found in Sri Lanka are Corundum, Chrysoberyl, Zircon, Garnet, Tourmaline, Beryl, Moonstone, Topaz and Quartz family. Sri Lankan people have used gems not only to create jewellery but also to decorate royal palaces and religious places. One of the best examples is the "Pabalu Wehera" in Polonnaruva which was said to be decorated with beads. There are evidencs of using gems for making beads. In subsequent periods, beads were also manufactured synthetically.

Sources of gems for bead making

In comparison, Sri Lanka is rich in gem deposits and diverse in varieties. Around 20% of the total land mass of Sri Lanka are gem bearing zones (Dissanayake & Chandrajith 2003). Most of the gem fields are confined to the central, southern and southwestern parts of the Island. According to Dissanayake and Rupasingha, (1995) most gem bearing areas are associated with stream sediments and restricted to several river zones. Rathnapura, Elahera, Walawe river basin, Okkampitiya-Badalkumbura, Opanayake, Bogawanthalawa, Bakamuna-Haththota, Kotmale and Menik river are the main gem fields of Sri Lanka (Dissanayake & Chandrajith 2003).

Among the three complexes of metamorphic rocks which cover around eighty percent of Sri Lankan terrain, the Highland complex is the main source for gems. Cordierite Gneisses, Garnet Silimanite Gneisses, Calc Silicate Gneisses and Biotite Gneisses are some of them (Cooray 1984, Katz 1972, Munasingha and Dissanayake 1981, Silva and Siriwardhana 1988). In addition to discovering gems from metamorphic origin, magmatically originated gems have also been recorded from pegmatite and dykes (Gunarathne and Dissanayake 1995, Kumarathilaka and Ranasingha 1992, Jayasingha 2004). A wide variety of gems can be found in Sri Lanka. The most famous gems such as Sapphires, Rubies, Spinals, Garnets, Tourmaline, Topaz and rare varieties such as Sinhalite, Ekanite, Iolite, Tafeite and Axinite have been found in Sri Lankan gem fields. The exact location of the origin of most of the gems cannot be traced since the distribution of gem beads varies. But very few and specific places can be identified such as Meetiyagoda which is famous for Moonstone mining.

Beads either natural or synthetic have been recorded from excavations carried out in Sri Lanka (Schussater et al 2001). The Jetavanaya archaeological site of the Central Cultural Fund is one such place where large amount of beads were discovered from excavations. Among its huge collection of beads made up of various kinds of materials gem beads are quite small in number. This study is a gemological identification of some gem beads of the Jetavanaya bead collection.

Materials and methods

Among some of the unidentified bead collections of the Jetavanaya World Heritage Site, natural and synthetic beads were separated by naked eye observations. Natural beads made up of gems were identified by using gemological properties such as colour, lustre, inclusions, specific gravity and refractive indices (Deer et al 1992). Some raw materials were also recorded and identified by using shapes, crystal faces and hardness where applicable.

Results and discussion

Gem beads are common types of beads among the natural beads found in the Jetavanaya bead collection (Figure 1). The following types have been identified as the main families of gems used to produce the beads of the collection. They are Corundum, Garnet, Quartz, Feldspar, Beryl and Tourmaline. Corundum family and Beryl are the only precious types identified in this collection of beads where as all the others are semi precious varieties.

Corundum beads are the rare variety in the collection. Three types of gems belonging to the Corundum family were identified. They are Blue Sapphires, Yellow Sapphires and Geuda (Figures 2, 3). Blue Sapphire beads are the commonest and have clear crystals, as well as light blue in colour. Each gem was pierced for threading. Most have been pierced along the long axis (C axis) of the crystal. All the beads which are rounded and well polished were shaped by following their natural crystal faces. The corundum beads are devoid of sharp edges or specific cut. The beads made up of Garnet are the most common type and the colour of gem beads varies from deep red to light red (Figure 4). The only variety identified in the collection is Almandine Garnet. All the beads are nicely faceted to different shapes and well polished. Size and shape of beads also vary, while disc shaped and rod shaped ones are common. Few uncut specimens which measure a few centimetres can also be found. One of it is deep red in colour and has nice octahedral crystal shape (Figure 5). Other uncut specimens are clear and transparent with light red colour.

The other common type of gem beads is made up of gems of the Quartz family. Both crystalline and cryptocrystalline minerals of Quartz have been used. Among the crystalline type, Amethyst (Figure 6), Clear Quartz (Figure 7), Smoky Quartz (Figure 8) and Rose Quartz were identified. Amethyst beads have a variety of shapes. Few Amethyst pendants were also observed in the collection. In addition a special ornament that was used for the "Kothkerralle" (finial) of the stupa is in collection. The Smoky quartz is black/brown in colour. Carnelian, Chalcedony and Agate are cryptocrystalline gem beads. Carnelian gem beads are the commonest in this group of gem beads (Figure 9) and they are red, reddish brown and yellow in colour. Among the different shapes, barrel shape is the common shape of Carnelian beads. Only few specimens of raw Chalcedony gems were found (Figure 10). The banded type which is collectively known as Agate has alternate black and white bands (Figure 11). These are known as Onyx in the bead industry. A large specimen of

Figure 01:Some natural and synthetic beads of Jethawanaya bead collection

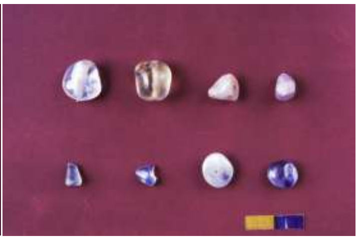


Figure 02: Corundum family gem beads. The second specimen of the first raw is a Geuda bead and the others are Blue Sapphires

Figure 03: A Yellow Sapphire bead

Figure 04: Garnet beads with different shapes

Figure 05: Amethyst with both finished and unfinished beads

Figure 06: Some raw tourmaline crystals

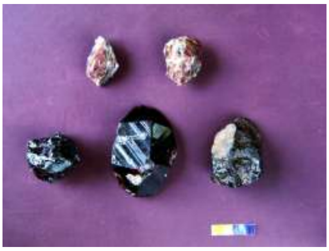


Figure 07: Garnet bead rough outs

Figure 08: Pieces of uncut Moonstone and beads

Figure 09: A large piece of Chert

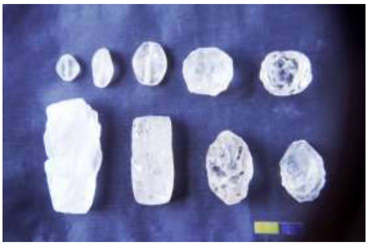


Figure 10: Clear Quartz bead rough out

Figure 11: Smoky Quartz bead rough out

Figure 12: Onyx beads of the Agate family

Figure 13: Chalcedony beads and piece of raw material

Figure 14: Carnelian beads

Figure 15: Beryl beads

Chert (Figure 12) was also identified in the collection but no chert beads were found. Both unfinished and finished beads of each gem type described above were recorded from this collection.

Moonstone beads belonging to the Feldspar family have different shapes (Figure 13). But most are rounded. Beads from this family are quite rare in the collection. A large specimen of green Fldspar possibly a Microcline type which can be used for making synthetic or natural beads was also found. Some green colour beads of the Beryl family (Figure 14) which is a rare gem mineral in Sri Lanka were also recorded. Beryl beads are deep green with black colour inclusions. This variety of Beryl is grouped as Emerald. The beads were well faceted and polished and have a hexagonal barrel shape. Specimens of uncut Beryl, as well as Tourmaline, another semiprecious gem type used to fashion beads were also recorded. The specimens recorded in the Jetavana collection are black in colour, although Tourmaline depicting a variety of colours can be found. These have nice crystal faces and typical Tourmaline crystal habit (Figure 15). But beads fashioned out of Tourmaline were rarely found.

Conclusions

Among the large number of beads discovered from the Jetavanaya Archaeological site, beads made of natural materials outnumber those made from synthetic material. Gem beads are the common type of beads in the natural collection. Six main gem families which were the main raw materials for gem beads were identified. They are Corundum, Garnet, Quartz, Feldspar, Beryl and Tourmaline families. The beads from precious families; Corundum and Beryl, are rare where as the semi precious varieties which were commonly used to make beads. Garnet and Quartz family are the most common types of semi precious gems used for natural bead production. Having unfinished gems and uncut pieces of gem minerals in the collection gives an idea that beads had been made locally. Since gems of all above families are found from Sri Lankan gem fields, it can be inferred that sources of gem beads from the Jetavanaya collection are indigenous. According to the study, the availability of gem varieties in nature is also shown by the abundance of gem beads in the collection. Each and every bead except corundum beads is well faceted in various designs and all are well polished. Garnets and Quartz have rather low hardness than the Corundum which is the second hardest mineral in the world. Therefore it is not easy to carve and pierce such beads easily. The use of Corundum to make beads is a good indicator of the advanced bead making technology in ancient times. Finally it is also possible that such a great number of beads either natural or synthetic had been used for religious purposes.

Acknowledgement

I would like to acknowledge Prof. Sudharshan Seneviratne, Former Director General of Central Cultural Fund, Sri Lanka for giving me the opportunity to study the bead collection at Jetavanaya Project. Also mis. Malkanthi research officer and the research - technical staff of the Jetavanaya site office, Anuradhapura is gratefully acknowledged for giving their invaluable assistance during this study.

References

Cooray, P.G., 1984. *The Geology of Sri Lanka (Ceylon)*, National Museums of Sri Lanka Publications

Deer, W.A, R.A. Howie and J. Zussaman., 1992. *An introduction to the rock forming minerals.* Longman Scientific and Technical, Longman Group (FE) Ltd, England

Dissanayake, C.B. and R. Chandrajith, 2003. *Gem bearing stream sediments of Sri Lanka;Geology and Geochemisrty* Gem and Jewellery Research and Training Institute and National Gem and Jewellery Authority, Sri Lanka

Dissanayake, C.B and M.S. Rupasingha 1995. *Classification of gem deposits of Sri Lanka*, Geologic en Mijnbouw 74: 79-88

Gunarathne, H.S. and C.B. Dissanayake, 1995. *Gems and gem deposits of Sri Lanka*. National Gems and Jewellery Authority, Colombo, Sri Lanka

Jayasingha, J.P. 2004. *A report on primary gem deposits in Badulla district-Gem exploration project*, Gem and Jewellery research and training Institute (unpublished)

Katz, M.B. 1972. "On the origin of the Rathnapura gem deposits of Ceylon" *Economic Geology*, 67,113-115

Kumarathilake W.L.D.R.A., U.N. Ranasingha, 1992. *Unusual corundum bearing gem pockets at Avissawella and Getahetta, Sri Lanka*, Z. Dt.Gemmol. Ges, 41: 7-15.

Munasingha,T and C.B. Dissanayake 1981. "The origin of gemstone in Sri Lanka" *Economic Geology*, 76: 1216-1224 Dubin, L. 1987 *The history of beads* Thames and Hudson Ltd. London.

Schusster,U. Rosch, C. and Hock, R. 2001. "Beads from ancient Sri Lanka-First results of a systematic material analysis" in H.J.Weisshar, H.Roth and W.Wijayapala (Eds.) *Ancient Ruhuna*, Sri Lanka-German Archaeological Project in the Southern Province.Volume 1.

Silva, K.K.M.W and Siriwardhana, C.H.E.R. 1998. "Geology and the corundum bearing skarn at Bakamuna, Sri Lanka" *Mineralium Deposita*, 23: 186-190

Editors' Note:

Pathmakumara Jayasingha - *Research Scientist / Geologist, Research Laboratary, Central Cultural Fund, Sri Lanka. (jpathma@yahoo.com)*

Archaeologia
Part 02 Volume 01 2011 (Page 46-51)

Nittaewo: The Cursed Child of the Veddah

Wasantha S. Weliange

Abstract

The aim of this paper is to discuss an elusive hominid species referred to as the Nittaewo, in the light of literary and and archaeological evidence. Sri Lanka has many legends concerning the Nittaewo, who are thought to be small in stature. Although no physical evidence has been recorded from excavations carried out so far, it is possible that such a group of hominids did exist. Their small stature could be explained by a genetic disease, or they could be a hominid species similar to the recently discovered H. floresiensis of Flores, Indonesia.

Key Words: Nittaewo, Maha Lenama. Homo floresiensis

Introduction

In the recent past, not more than 350 years ago, a hominid species had existed in the Sri Lankan forests. Their adult males were not more than three to four feet tall, and females were shorter than males. They were stout, perfectly upright like *Homo sapiens,* and had hairy skins. They were not apes like Chimpanzees or Gorillas, but Homonids like an ordinary man. They are called "Nittaewo".

Maha Lenama

According to Veddah legends obtained after 1880's, Nittaewo were totally eliminated after a fierce battle from their own land - that is the Maha Lenama area (Fig.7) in the Eastern province some 350 years ago from today; that is nearly four to five generations ago. Therefore, no man alive today has seen a Nittaewo.

Maha Lenama is situated in the Eastern province, Ampara district (about 360 km from the capital city of Colombo to the East Coast of Sri Lanka); the area belongs to Yala East Intermediate Zone and Thamankaduwa area according to the present political map of Sri Lanka (6-10°N, 80-82°E) (Map 1).

There is no any physical evidence found by means of skeletons, food debris, tools or graves that are associated with them.

All information today we have about Nittaewo are either collected from folklore and Veddah legends or literature written after 1880's by local and foreign explorers which are only reconstructions with scientific assumptions. Until today their existence were not scientifically proved. This article is an attempt to compile the information about the legendary creature and to discuss the facts further through ecological and pathological points of view.

Map 1: Maha Lenama

Hominids

Humans belong to the order of Mammalia,family of Hominidae, class of Primata and scientifically known as *Homo sapiens*. The relatives of modern man are *H.erectus*, *H. floresiensis*, *H. antecessor*, *H. heidelbergensis*, *H. neanderthalensis*, *H.*

rhodesiensis and *H. cepranensis,* and none of these relatives exist any more.

Nittaewo are not yet classified into any of these groups as their physical evidence have not been identified. If any physical evidence were found, DNA tests can be done and the species to which Nittaewo belonged could be determined. They could belong to one of the known species or could be a totally new species. Therefore studying and exploring the four corners of Sri Lanka through various disciplines such as Archaeology and Ethnography to find any clues of Nittaewo is of significance.

Since 1885 foreign and Sri Lankan writers have attempted to explain the existence of the Nittaewo. Classification of Nittaewo is confusing, but some assume that they are Hominids (Neville 1886, Lewis 1914, Hill 1945, Rambukwella 1963 & Wijeyasekara 1964) and others have (Spittle 1963) described them as similar to red-haired brown bear (*Ursus inornatus*) which is known in Sinhalese as *Rahu Walaha*.

There are several theories about the Nittaewo descent. Hill (1945), Rambukwella (1963) and Wijeyasekara (1964) believe that Nittaewo could be descendents of Pithecanthropus (Java Man), Australopithecus or Negritos respectively. Pithecanthropus and Australopithecus are Hominds and lived 500,000 years before today. Negritos of South and Southeast Asia have lived in the recent past in Andaman Islands till 2004. Negritos are also *Homo sapiens.* After the Tsunami of 2004 December hit the Andaman Islands many of the Negritos have disappeared.

Morphology and ecology

According to literary sources and legends, Nittaewo are dwarfs, had short hands with long talons and walked upright. Complexion was dark. Skin was hairy with dark and reddish-brown long hair. They remained naked and had self sustaining populations. They moved about in groups of 10-20, and lived in cracks, crevices, caves or on the platforms built on the treetops. There is no evidence of them having made or used tools, but have captured small animals such as hares, squirrels, tortoises, crabs, bird eggs and lizards for food. Their spoken language was like a twittering of birds. There is no evidence about their cooking and usage of fire other than that they stole the food left for drying by the Veddahs.

Physical evidence

Archaeological excavations have been carried out in Sri Lanka for the past 125 years in caves and in open landscapes, but no physical evidence has been found that Nittaewo existed in Sri Lanka. The reasons could be many folds, only a few people today have heard about Nittaewo, therefore the Nittaewo remain a fiction or a myth, not even suspicions were made about any artifact or archaeological findings etc.

There may have been bone fragments of food debris and the artifacts which were utilized by Nittaewo that were not identified correctly until now. Identification of bone fragments of Nittaewo using visual methods is not easy as anatomy of the skeleton could be similar to modern humans, particularly to the young. Only a DNA test would help recognize the skeletal remains if they belong to Nittaewo. Otherwise misinterpretations could occur and would be grouped into "children" as the Nittaewo were short creatures.

Rambukwella (1968) discovered a special rock arrangement in the middle of the jungle in Maha Lenama, near Panama in the Amapara District, Sri Lanka. He believed that it was used by Nittaewo for some rituals. Accordingly that is the only physical evidence so far we have found in Sri Lanka about Nittaewo, but it is not scientifically proved that the place was arranged or used by Nittaewo. The researchers of the Postgraduate Institute of Archaeology of the University of Kelaniya, planned an exploration into the area in January 2009 and unfortunately it was turned down due to security reasons.

Folklore

Folklore provides the strongest evidence about Nittaewo. There are folk stories, and names of villages that depict the presence of Nittaewo. One story from the Badulla district (230 km from Colombo towards the eastern slopes of central hills) is that; if unripe fruits had fallen in the night, the villagers say that Nittaewo have come to play and dropped them. Similarly there are several such folk stories from other areas of the island which needs further detailed investigations.

Place names

There are several suburbs in Sri Lanka, which depict the presence of the Nittaewo. Nittawela is a village name which indicates the presence of Nittaewo in paddy fields. Nittawela is situated in the Kandy district about 4 km from the Kandy city towards Katugastota. Nittambuwa in the Gampaha district is also believed to be another name that could have had a link to Nittaewo. According to lore, a Nittaewo and his wife (Sinhalese *ambuwa*) is the link for the origin of the name; Nittambuwa. Nittawewa, is situated in the dry zone of Sri Lanka, which signifies the relationship between a Nittaewo and a reservoir.

Genocide of Nittaewo

According to legend there a continuous battle raged between the Veddahs and Nitteawo for a long time, and ultimately only one isolated group existed in the Maha Lenama area. According to the legend the Veddahs are said to have trapped the Nittaewo community in a cave and burnt them to death. This particular group of Nittaewo would have been the last in their line and it could be assumed that there had been no other groups of Nittaewo in Sri Lanka.

Mass execution of an animal group by another one is very rare in the animal kingdom. In attempting such an act, the Veddahs would have had an intense vengeance towards the Nittaewo. On the other hand knowing that a few number of Nittaewo cannot fight with Veddahs, who were equipped with bows and arrows, the Nittaewo would have fled. It is not known whether the Veddah tribes have been tolerating the interferences of Nittaewo for a long time and were only defending their occupied territories when it exceeded the tolerance level.

The conflict between Veddah and Nittaewo could not be only a fight for resources such as food and space, but also could be for power including political or social factors. All animals including man compete for basic resources which are essential for survival, yet among all animals, man is the only animal, who fights to spread and establish his thoughts or intellectual creativities.

Sharing the niche

According to all descriptions Nittaewo could be hominids. Therefore it can be assumed that the Nittaewo and Veddah are anatomically and physiologically similar, and therefore shared similar ecological niche. Two similar groups of animals can survive in the same locality if they can only segregate the natural resources such as food, space and time of the day for acquisition of the resources.

Veddahs were efficient hunters and gatherers. They have been hunting aquatic, land and arboreal animals for food using bows and arrows. Veddah were always known as master hunters. They also collected fruits, nuts, roots, honey and other edible plant structures as food. There is no record of Nittaewo using any particular tools for hunting. This indicates that Nittaewo were not as efficient or intelligent as the Veddahs. It is possible to argue that the Veddahs had little competition from Nittaewo. Veddah's efficiency in hunting would have been a serious problem for Nittaewo as Veddah utilize more resources in the forest compared to Nittaewo. This could be one of the reasons for the Nittaewo to steal food from the Veddah.

If the survival of one group of animal is threatened by another, the weaker group naturally looks for alternative habitation as it happens in nature.Risking life is not the answer for resource sharing and survival is the ultimate motive.

It is not reported and not known for how long these two groups; Veddahs and Nittaewo had been living in conflict. If both groups had lived for at least a few generations, then they would have learnt to segregate the natural resources for minimizing the conflicts, as it happens in the animal kingdom. If both groups encountered each other accidentally there would have no time for them to learn the strategies of resource sharing and to reduce the territorial conflicts.

It is reported that the Veddahs killed all members of Nittaewo population, including babies, children, and adults. But nobody who witnessed this mass execution was alive when the modern explorers reached the country and came into contact with later Veddah generations. This statement also suggested that Nittaewo were a self propagating community. If they had a self propagating population they would have existed a long time in Sri Lanka.

The sacrifice

An argument arises whether the Nittaewo were another animal group or an outcast of the Veddah. The theory of "Outcasts" is not discussed before in order to explain the existence of Nittaewo. Veddahs are people who marry even very close relatives or their own clan members. The biological and physical need of sex would not have been controlled until a sexually matured man found a woman from another group of Veddah who perhaps lived in a distant forest. They have had sexual relationships with even the family members, which could ultimately result in child birth. Many village peasants also get married to blood relatives in the past. The medical reports state that this intermarriage system could produce mutant progenies, who could be deformed in various ways. These deformed babies are considered as a curse even in modern societies. In Pakistan deformed babies are sacrificed to the church to be acolytes (Miles & Beer 1996). There is archaeological evidence about sacrifcing of deformed dwarfs in a 28000-8000 years old burial site in Europe (Whipps H. 2007).

Dwarfs are mostly associated with mountains, mines, and buried treasures in fictions. Fictional dwarves found in popular fairy tales such as "Snow White and the seven dwarves" were believed to have magic powers and to be sometimes malevolent. One can question if these creations were a result of any known creatures that lived in reality that were closely related. Even in tropical countries including Sri Lanka, there is a belief about the "cursed children" who looked odd at the birth.

Birth defects

According to Stevenson (1989) much is not known about the causes of birth defects. Genetic factors, excessive alcohol and certain drugs taken by pregnant women, and some illnesses, especially rubella (German measles), occurring during pregnancy have all been clearly identified as factors which result in birth defects in children. Older maternal age also predisposes the occurrence of some birth defects, particularly Down syndrome. All the known causes of birth defects together explain only 30-35% of them (Wilson 1973). There remains 65-70% of cases in which physicians must acknowledge that they have no explanation.

Illnesses such as Microcephaly, Larons syndromes are not treatable. Today's parents can spare some additional time and money to bring up children suffering from Microcephaly and other deformities. It would have been a miracle in the olden days if a family had time to give enough attention to a deformed child. It is possible that the parents left these "cursed babies" in the jungle for the demon to take care of or left as a "sacrifice" for guardian forces. Those abandoned deformed babies could have been brought up by other members of a deformed society; a deformed cult.

Microcephaly

According to the website (http://www.ninds.nih.gov/disorders/microcephaly/microcephaly.htm) Microcepahly is a medical condition in which the circumference of the head is smaller than normal because the brain has not developed appropriately or has stopped growing. Microcephaly can be present at birth or it may develop in the first few years of life. It is most often caused by genetic abnormalities that interfere with the growth of the cerebral cortex during the early months of fetal development. It is associated with Down's syndrome, chromosomal syndromes, and neurometabolic syndromes. Babies may also be born with Microcephaly if, during pregnancy, their mother abused drugs or alcohol, became infected with a cytomegalovirus, rubella (German measles), or varicella (chicken pox) virus, was exposed to certain toxic chemicals, or had untreated phenylketonuria. Babies born with Microcephaly will have a smaller than normal head that will fail to grow as they progress through infancy. Depending on the severity of the accompanying syndrome, children with Microcephaly may have mental retardation, delayed motor functions and speech, facial distortions, dwarfism or short stature, hyperactivity, seizures, difficulties with coordination and balance, and other brain or neurological abnormalities.

Laron Syndrome

Laron syndrome or Laron-type dwarfism causes severe pituitary dwarfism. Unlike growth hormone deficiency, growth hormone levels are increased (Ole 2009) but the body is unresponsive to it (Ben 2006). Its features include underdeveloped skull with small face and mandible and other skeletal changes. The disease is most often reported from

Middle Eastern children of consanguineous parents (Ole 2009) but it also occurs in some South-East Asian countries (Hershkovitz *et al* 2007). Consanguinity refers to the property of being from the same lineage as another person. In that respect, consanguinity is the quality of being descended from the same ancestor as another person.

Homo floresiensis

It is also possible that Nittaewo were another species of Hominids, who evolved from the main line of the evolutionary tree of hominids and later confined to Sri Lanka.

In 2004, a group of scientists discovered a set of hominid skeletons at the Liang Bua cave on the Indonesian island of Flores (Brown *et al*. 2004, Morwood *et al*. 2004, Lahr & Foley 2004). It was named as *H. floresiensis* which is a dwarf human and only about 1 meter in height and fully bipedal, with a very small brain size of 417 cc. The skull has human-like teeth with a receding forehead and no chin. *H. floresiensis* have lived 38,000 to 18,000 years before present. It used stone tools and fire, and hunted pygmy elephants (mostly juvenile ones), Komodo dragons, and the giant rats found on the island of Flores. The discoverers believe that *H . floresiensis* is a dwarf form of *H. sapiens,* it is not uncommon for dwarf forms of large mammals to evolve on islands. Scientists linked *H. floresiensis* to Nittaewo; quoting "the new findings was very similar to the Sri Lankan lost race of Nittaewo". This description about the latest findings of another member of the Hominids interprets the significance of dwarfism in small Islands.

Several investigations reported that *H. floresiensis* is not a new species but people suffering from Microcephaly (Martin *et al* 2006, Jacob *et al* 2006. According to Obendorf *et al* (2008), *H. floresiensis* suffered from Myxoedematous an endemic cretinism resulting from congenital hypothyroidism and that they were part of an affected population of *H. sapiens* on the island but not a new species. According to John (2007), American anatomist Gary D. Richards in June 2006 was the first to propose that the skeletons of *H. floresiensis* are the remains of people who suffered from Laron's syndrome. Herskovits *et al* (2007) reported that morphological features of *H. floresiensis* are essentially indistinguishable from those of Laron's syndrome. These publications interpret the significance of birth defects such as Microcephaly, Myxoedematous and Laron's syndrome for misinterpreting the human evolution.

Missing link

It is reported that there was a continuous battle between Veddah and Nittaewo. Perhaps when nomadic Veddahs trespassed the territories belonging to Nittaewo, conflicts started. It is possible the Nittaewo were stealing Veddah babies for food- that is usually the worst assault that can happen among the humans or animals.

Why did Nittaewo not approach the farmers to steal domesticated animals, stored grains and other food crops? There could be more stories about Nittaewo which have not come to light yet. There are many missing links in the storyline of Nittaewo. Finally archaeological evidence would be the primary link to help solve the mystery of Nittaewo.

Living fossils

Some animals like *Nautilus*; which is a marine mollusk have been considered a Living Fossil for a long time as it was believed to be completely extinct from the Earth but many years after it was again declared as a Living Fossil. So far many plant and animal species have been recognized as living fossils. Ten species of plants, one species of Fungi, 14 species of mammals, six species of birds, three species of reptiles, one species of amphibians, four species of fish, one species of shark, eight species of insects, three species of mollusks and five species belonging to other invertebrates have been declared as living fossils.

Total elimination of a species from its very native environment is not easy but mass execution is the ultimate attempt for controlling resource over lap with other species. There are other examples in the animal kingdom about the territorial conflicts which start due to the resource over lap. In territorial conflicts weak animal groups always escape in order to protect their own kind, and always there are some individuals in the group who are capable of escaping for survival.

Deep jungles in Sri Lanka are not accessible to the general public for many reasons and aboriginal Veddah is confined into smaller forest patches. The number of

Veddah communities at present is few in numbers and they are confined only to a tiny fraction of the land. They are non-migratory and semi-agricultural people and their behavior is different to those who lived in caves and migrated in a definite or indefinite route depending on the availability of natural resources and cultural taboos. Therefore sightings of Nittaewo even if they are present could be extremely rare for the Veddah in the past number of decades.

The rest of the Sri Lankan population either live an agriculture based life, or work for monthly payments in Government or private institutions or have their own businesses or industries. These fractions of the population have limited access to forests in Sri Lanka. This is an indication that general public do not have any opportunity to sight Nittaewo unless they penetrate the deep jungles in the country. Although people visit jungles they are cautious not to deviate from the walking tracks. Still there could be forest patches that have never been touched by humans. In those remote places deep inside the jungles unbelievable things still happen. Nittaewo may still be roaming.

Acknowledgement

I am grateful to Mr. Sampath Perera for telling me folk stories about Nittaewo and the village youth of the Maradankalla village near Hurulu Wewa, with whom we had a discussion about NIttaewo in 2004, and Mrs. Chintha Kossinna proof read the manuscript, made several suggestions and corrected the English text.

References

Ben H. 2006. “Did small hominids have a genetic defect?” *Science News*. 170 (3): 46.

Brown P., Sutikna T., Morwood M., Soejono R.P & Jatmiko Saptomo E.W. 2004. “A new smallbodied hominin from the late Pleistocene of Flores, Indonesia.” *Nature*, 431:1055-61.

Fredrick L. 1914. “Notes on an exploration in Eastern Uva and Southern Panama Pattu”. *Journal of Royal Asiatic Society.*

Hershkovitz I., Kornreich L & Laron Z. 2007,. “Comparative skeletal features between *Homo floresiensis* and patients with primary growth hormone insensitivity (Laron Syndrome).” *American Journal of Physical Anthropology* 134 (2): 198–208.

Hill W. C. O. 1945. “Nittaewo; an unsolved problem of Ceylon”. *Loris*.

Jacob T., Indriati E., Soejono R. P., Hsu K., Frayer D. W., Eckhardt R. B., Kuperavage A. J. , Thorne A. & Henneberg M. 2006. “Pygmoid Australomelanesian *Homo sapiens* skeletal remains from Liang Bua, Flores: Population affinities and pathological abnormalities”. *Proceedings of the National Academy of Sciences,* September 5, 2006. USA 103.

John H. 2007. “Another diagnosis for a hobbit” (online). http://johnhawks.net/weblog/fossils/flores/hershkovitz_laronsyndrome_2007.html. Retrieved on 2009-02-10. Journal of Scientifc Exploration. Vol. 3, No. 2, pp. 20 1-2 12.

Lahr M. M & Foley R. 2004, “Human evolution writ small; (Commentary on *Homo floresiensis*).” *Nature*, 431:1043-4.

Martin R. D., MacLarnon A. M., Phillips J. L., Dussubieux L., Williams P. R. & Dobyns W. B. 2006, Comment on “The Brain of LB1, *Homo floresiensis*”. *Science* 312 (5776): 999.

Miles M & Beer D. 1996.“Pakistan’s microcephalic chuas of Shah Daulah: cursed, clamped or cherished.” *History of Psychiatry*. 571-89.

Morwood M., Soejono R.P., Roberts R.G., Sutikna T., Turney C.S.M & Westaway K. E. 2004. “Archaeology and age of a new hominin from Flores in eastern Indonesia” *Nature,* 431:1087-91.

Neville, H. 1886, “The Nittaewo of Ceylon” *The Taprobanian*. 1(6).

Obendorf P. J., Oxnard C. E & Kefford C. E. 2008. “Are the small human-like fossils found on Flores human endemic cretins?” *Proceedings of the Royal Society of London, Biological Sciences*. June 7, 2008.

Ole Daniel E. 2009. “Laron’s syndrome; Who Named It?” (Online) http://www.whonamedit.com/synd.cfm/2825.html. Retrieved on 2009-02-10.

Rambukwella A. T. 1963. “The Nittaewo – the legendary pygmies of Ceylon” Journal of Royal Asiatic Society.

Spittel R. L. 1937. “Future of the Veddas” *Loris* 1 (32).

Stevenson I. 1989. *A case of severe birth defects possibly due to cursing.*

Whipps H. 2007. “Stone age Europeans may have practiced human sacrifices” Fox News.Com. http://www.foxnews.com/story/0,2933,281704,00.html. Retrieved on May, 16 2009.

Wijeskara N. 1964. *Veddas in Transition*. Ministry of Cultural Affairs, Sri Lanka.

Wilson, J. G. 1973. *Environment and birth defects*. Academic Press, New York.

Editors’ Note:

Dr. Wasantha S. Weliange - *Scientific Assistant, Postgraduate Institute of Archaeology, University of Kelaniya, Sri Lanka. (wasanthaweliange@yahoo.co.uk)*

Archaeologia
Part 02 Volume 01 2011 (Page 52-60)

Spatial Distribution Pattern of the Road Network in Polonnaruva and Suburbs in Ancient Sri Lanka

P. Vidanapathirana

Abstract

Archaeological and historical information signifies that the road network in Sri Lanka goes up to early historic time. The spatial distribution pattern of road system shows the boundaries of contemporary socio-cultural issues, power and politico-economic organisation in the state or regional framework. In locating and identifying the ancient roadways of abandoned settlement of the Dry Zone of Sri Lanka, climatic pattern and the natural landscape had been deciding factors.The abandoned roadways of historical times had been abstracted by forest vegetation or washed away by fluvial action or flooding. When the British started a new road system in the Dry Zone of Sri Lanka they found it advantageous to depend on the ancient road network that was already there. This paper is an attempt to reconstruct and make a scientific map on middle historic Sri Lankan administrative centre of Polonnaruva and the suburbs.

Keywords: Polonnaruva, roads, routes, streets, inner city

Introduction

Historical and archaeological evidence of a systematic road network can be identified in early and middle historic capital city centres, metropolis areas, port cities, regional city centres and urban monasteries. Information on ancient road network as revealed from excavations of ancient cities were mapped and recorded during British administration (Bell 1897; Hocat 1928; Codrington 1933; Paranavitana 1928, 1946, 1948; Geiger 1960). A little information is available on ancient road network in historical sources.

Spatial distribution pattern of Polonnaruva

Polonnaruva is covered from the west with the Sudukanda range, from the north-west with Giritalē range from south with Amban Ganga and from the southeast and the south with Mahaväli Ganga and from north by a valley that is broadly opened. The city spread towards the northern and the southern areas. Elevation of the city is 200 ft. above sea level. Parākrama Samuddra tank was built by connecting Minnēri Oya and its tributaries of Ulpota Āra, Havupädi Āra, Periya Āra, Giritalē Oya, Divulankadavala äla (tributary of Mahaväli Ganga) and a connecting stream of Alavatura äla. Water falls to Amban Ganga through Divulampitiya äla. Water is distributed from streams that flow from Sudukanda range, Radavege Oya, Gallembara äla and also from the tributaries of other rivers. When studying the geographical maps, one can notice that a large number of village tanks were built during ancient times by joining the capillarity water flowing system in the area. Nevertheless, most of these tanks are not seen today. During British rule, the restoration of the drainage system in the Dry Zone was changed or destructed. As a result, Minnēriya tank, Parākarama Samudra and many more tanks came under central irrigation board that commenced in 1887 (Brohier 1941,1951). The cultural landscape of this area was totally destroyed when the Dry Zone Colonization Scheme was implemented in the 1930s. Under the Scheme Minnēriya tank was reconstructed and the lands were allocated to the public. A new irrigation canal system was constructed, by which the ancient tanks and the irrigation canals were subjected to changes. At the same time, ancient settlements were disappeared from the landscape.

Polonnaruva became a landmark in the political arena of Sri Lanka due to its geographical location. Mahaväli Ganga was a natural boundary that separated Rajarata and Rōhana. The main road between Rajarata and Rōhana was in Polonnaruva, and this road went through Dāstota and Kasātota ferries of Mahaväli Ganga (Vidanapathirana 2009, 2010). Information on this area is recorded in archaeological sources (c. 4th century BC). Kalahanagara in countered in the episode of Pandukābhaya (c. 4th century BC), is presently know as Kalahagal. We must consider about Kalahanagara, Kasātota (P.Kacchatittha) and Dimbulagala (P. Dūmarakha pabbata) as mentioned in the Mahavamsa (Mv 10.42, 53). The Kalahanagara mentioned in Dūvegala inscription of king Lanjaka-Tissa (119-109 BC) could be the Kalahanagara that is mentioned in Mahāvamsa (Paranavitana 1983). This could be the Kalahagala situated 5 miles off Polonnaruva. Kasātota and Dāstota (P.Sahassatittha) ferries had been used in the political struggles as strategic points. It is mentioned that when king Kāvantissa fought against king Elāra, the forces were stationed at all the ferries in Mahaväli Ganga. Of these, Kasātota had been the most important ferry, which was given to prince Dīgabhaya (Mv 23.17). According to some historical sources, Polonnaruva was important as a Kandavuru nuvara or the Camp City (Paranavitana 1930; Geiger 1960). Polonnaruva has also been important in political and economic aspects during the Anurādhapura kingdom. The urbanization characteristics of Anuradhapura era has been found through the excavations among the ruins of Kaduruvela, a place 2 miles away to the east of Polonnaruva (Manatunga, pers.comm). Although, Tōpaväva temple dates back to the 3rd century AC, the ruins of a monastery complex which may be older than the temple could be seen in the area. Polonnaruva can be considered as an urbanization area even during the Anurādhapura kingdom. Tōpaväva, Dumbutuluväva, Erabnaduväva, Kalahagalaväva, and Būväva were tanks built in Polonnaruva during the Anurādhapura period. The Parākrama Samuddra was constructed in the Polonnaruva period adjoining these tanks. In the circumstances, the monastery complexes in and around had disappeared.

Amban Ganga, which is fed by the branches of the north and western hills of Knuckles mountain range (6112 ft) receive an annual rainfall of 4000mm. According to Mahāvamsa the Älahära yōda äla (main irrigation canal), which flows from Amban Ganga was constructed by King Vasabha (67-111AC). About 3rd century AC, the main tanks such as Minnōriya, Giritalē, Kavudulu, and Tōpaväva were constructed to be fed by the Älahara canal (Mv37. 47-50; Puj 24; EZ.232; Nicholas 1957). From the southern boundary of Mahaväli Ganga to the north boundary of Kavuduluväva and from south Periya Āru and the surrounding area of Polonnaruva with its limits up to Kavudulu Oya, and the area with the spread water flow area of the Dry Zone had been a developed agricultural area from the Anuradhapura era. With the development of the hydraulic technology of the island, the drainage systems and village tanks were linked to form a well developed an advanced water management system. Three main irrigation complexes were positioned in the island by about 5th century AC with Malvatu Oya and Kalā Oya in Anurādhapura area, Mahaväli Ganga and it's tributaries in Polonnaruva, and Kirindi Oya in Māgama (Gunawardena 1982; Bandaranayake 1997; Vidanapathirana 2007). By this time, Polonnaruva area which is fed by Minnēriya, Giritalē, Kantalē, Kavudulla, Tōpaväva and other tanks had become a main agricultural area.

Polonnaruva was an important city since the Anurādhapura kingdom. With the development of hydraulic technology and with a strong political and economic background, the kings of Anurādhapura made it a temporary ruling city starting from 7th century AC (Mv 48.74, 50.85) from time to time. King Vijayabāhu 1(1055-1110AC), who enthroned in Anurādhapura, shifted the ruling centre to Polonnaruva three months after the coronation. He built a great high city wall, security points, moats, temples and refectories (dānasala), a Temple of the Tooth (daladā maligāva) and a number of auxiliary units to constitute a complete city (Mv 46.34, 48.74, 79.50, 85.54-64). King Parākramabāhu (1153-1186AC) developed the city by constructing a city wall assuring the security from outside military forces, dānasāla in the four city gates, a royal hospital in the city, religious halls, ponds in the gardens, daladā māligāva, darmasalas for the monks coming from the four directions. The dharmasālavas were erected from gavua to gavua, (according to archaeological sources, the distance seems to have been measured by gavua in ancient Sri Lanka). There were different types of roads for the city completing with the urban characteristics (Mv 59.3,60.3-16). Inscriptions and the chronicles reveal that king Nissankamalla (1187-1196) further developed the city with constructions (Mv73.61, 148-150). These constructions featuring more urban qualities were found among the excavations. These must be further identified. The road system of the city is one such phenomenon. The Polonnaruva boundary may have spread from the Nandana uyana (royal garden) in the south to the Potgul vehera and Tivanka pilimagē in the north. The city is spread to about 4 miles in length and 1mile in width (Bell 1906).

In ancient Sri Lanka, a proper city plan and a systematic road network was a special characteristic feature. Features like road orientation to north, south, east and west, direct streets and parallel roadways of a width of about 15-20 feet were seen in the city of Anurādhapura. There had been cross roads and four way junctions in the city (Vidanapathirana 2008). It can be conjectured that these characteristics were visible in the city of Polonnaruva. It had a road system that joined roads of north-south, east-west and their four main city gates. According to Bell's mapping the ruined roads and paths of Anuradhapura may have been included in the map of Polonnaruva (Bell 1892, 1903, 1906). The four gates pointed to four sides were not striate lined. This architectural plan could have been as a protective tactic due to political background of the time (Gunawardhana 2009). The Inner City was equally divided to east and west and the main road lead to the north and south (Bell 1987; Paranavitana 1946). The other roads, which lead to east and south, are not directed on a straight path. Some straight paths that directed to east and south could also be identified. The main north-south street that goes eastwards in the city boundary may be the main street, which is similar to royal street in Anurādhapura (EZ vol. 2:84). All the sub streets that went to east and south within the city boundary joined the royal street making a complex of road network. It is mentioned in the chronicles that King Parakramabahu I constructed the streets joining up to the city wall and built two-storied and three storied buildings and stalls make the city beautiful. It is also mentioned that chaturanganī sēna (elephants, horses, chariots and the infantry) marched in these streets daily. During this period, king has renovated the streets of Anurādhapura, which were constructed by the former rulers. The streets were levelled with steps and placed necessary gavu kanu (mile stones). The wayside shelters or the ambalams were constructed in the areas around Anurādhapura as places of resting. Archaeological evidence reveal that there were resting places in the area north of Abhayagiriya, Elapatväva, old street junction boundary of Tissāväva at the site known as Dutugämunu māligāya (Vidanapathirana 2007, 2008). It is possible to assume that these characteristics would have also been in Polonnaruva. Information about the use of gavu kanu can be found in the boundary of Anurādhapura and in Rōhana area. King Nissankamalla had mentioned in Hatadagē inscription 'Tam hinduvā akuru kotavā Nissanka gavuyai nam kota' and this reveals that there had been a systematic road network in Polonnaruva (Bell 1892; Codrington 1930; Hocart 1930; EZ vol 2; Vidanapathirana 2008, 2010).

Road network within the Polonnaruva city

The main road or the raja vīdiya that join the north and south gates of the inner city of Polonnaruva extends northward from northern gate in the outer city. Paranavitana has mentioned about this road in his records (Paranavitana 1946). Though there is no definite information about the southern gate, it is revealed that there was a southern gate to the east in the outer city. Most probably entrance to the Kumara pokuna (pond) from inner city must have been used as an entry from the east. As there was a road parallel to this road in the outer city the inner city may have been completely congested with buildings. We can reconstruct a road system by joining the ancient road tracks that goes through the palace and the other buildings, royal council chamber and the other special architectural buildings. Ruins of a road network of a junction where four roads met (hatara-man-handiya) can be identified from Bell's map and these roads extend from the inner city up to Parākrama Samudraya. From this junction one can reach Parākrama Samudraya from southern road, from inner city western wall to the road going northward, from tank bund to southwest, and to the inner city. According to the ancient road system another street that joined the western gate of inner city went eastward and westward from the square wall. The eastern street leads to Kasātota. The road that went southward reached Dasātota from the southeast. A road structure joining the royal street is identified as leading from the outer city buildings Daladā māligāva, Satmahal prasādaya, Vatadāgē, Siva dēvāla and etc. The streets extend towards the south from Pabalu vehera temples and Siva dēvāla in the main street from the north. According to the Bell's map information of ancient road track in Pabalu vehera area, north-south roads met at the cross road which passes out at the eastern gate near Siva dēvāla (Bell 1914). In his exploration in 1910, he found a ruined road track in the north of the Gal vihāra. The road track lead up to the Tivanka pilimagē in the north. There are archaeological remains of another road track connected to the southern gate of the city. This road extends from east to the inside the rampart. The road leading towards the east finally reaches Kasatota and the road to the south reaches the south east of Dastota (Bell 1910-11; Paranavitana 1948).

The ancient road system in city started from eastern cross streets pass Manik vehera, Rankot vehera, Ālāhanaperivena, Lankātilaka vihāra, Baddhasīmā prāsādaya, Kirivehera, Galvihāra, Damilatūpa and the Tivankapilimagē in the north (map 1). Evidence to confirm that there were roads connecting all the temples and the main streets and the streets that went parallel to it northward on western direction can be found from the ancient road track found up to north of the Tivankapilimagē. As in the streets those directed to east-west except the northern street there are three streets that go parallel along the northern urbanized area with the main street (figure 01).

The roads leading to the outer parts of the island from Polonnaruva

We can map nine roads that lead from the city to the north according to the ancient road signs. These roads join the northern and southern wall of the city.

1. The road from Polonnaruva to Anurādhapura.
2. Polonnaruva-Gōkanna road.
3. Road to Rōhana from Polonnaruva through Dāstota.
4. The road from Polonnaruva to Rōhana through Kasātota.
5. Road from Polonnaruva to Sīgiriya and Dambulla.
6. Polonnaruva-Sōmavatī and Sēruvila road
7. Polonnaruva, Mädirigiriya and Kantalē road.
8. The road to northern settlement area from Polonnaruva.
9. The road from Polonnaruva to Älahära and Matalē.

The road from Polonnaruva to Anurādhapura

There were two roads to reach Anurādhapura and they were connected to the northern rampart of the city. The first road was the road that started from Tōpaväva northern roadway junction and that goes to the northwest direction towards Divulankadavala. The present road exists on the same track of an earlier road from Polonnaruva to Jayanthipura, Hatamunē, and Hinguraggoda with a slight difference from the ancient road that continued up to Higuraggoda, Minnēriya finally joined Kiri Oya valley from the southern slope in Batu-oyakanda. This ancient street was used as a cart track in the 1940s. Later people travelled through road that goes via Minnēriyakanda and Batu-oyakanda passing the left bank of Kiri Oya, Talkotē Oya and this road at Ambagasväva joins the present road. It reaches Anurādhapura from the western slope of Habarana, Horivila, and Ritigala. This road was used to go to Rōhana from Anuradhapura through Polonnaruva ^Vidanapathirana 2010). The second route that leaves from junction where four roads met (hatara-man-handiya) in the north of Tōpaväva goes towards north -west. The ancient road joins Anuradhapura by running towards north from Giritalē (Bell 1910-1). The present Habarana Polonnaruva road is the same ancient road.

Polonnaruva-Gōkanna road

This is the trade route that led to port city of Gōkannatittha from northern gates of the inner city and the outer city. This was the main road of the city and this joined the royal street of the inner city. This street though it was

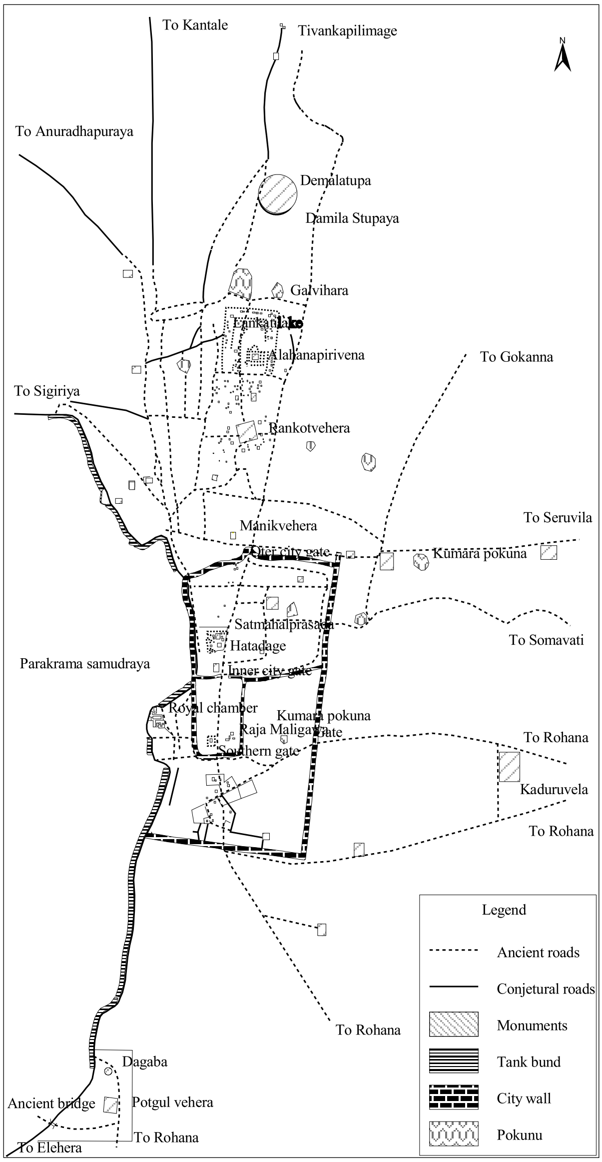


Figure 01 : Road network in Polonnaruwa city aera

straight in the inner city from north to south, tends towards east at outer city. This road was extends eastwards temples like Rankot vehera, Ālahana perivena, Galvihāraya, and Damila tūpa. The road which goes to north from Damila tūpa passes Tivanka pilimagē and goes to the northeast. The road must have been passing Veheragala, Diyasenpura (a sub street to go to Mädirigiriya started from here), Nikaväva going through Kantalē area in Dry Zone leading to Gōkannatittha. This road must have been the main road used for trading activities during the Polonnaruva Kingdom. It is believed that this road would have trade relationship with Gōkannatittha when Polonnaruva was under the Cholas. We can see that the temples in the north connected via this road to the sub streets and it would not have been the main entrance street for those temples.

The road from Polonnaruva to Rōhana through Kasātota

Ruins can be found of four roads that went to Kasātota from the Polonnaruva city boundary. According to the ruins of ancient road network from the southern gate of inner city and to eastern wall of outer city as well as the ruins of temple complexes in Mānikkampitiya this road joined Kasātota through Kaduruvela Gal-lälla. During the Polonnaruva period this would have been the main road that connected the royal relationship with the Rohana. The road was further used when Anurādhapura became a camping city. Another road leading to Kasātota connected north city wall of outer city and the road that lined from east to west facing the northern gate. The special feature of this road is that from the northern junction of Tōpaväva all roads joined to this road near the Tōpaväva bank. The road lay parallel to the wall of outer city. The road goes towards the east of the island joining most of the temple complexes closer to the city. This road must have been used to go to Rōhana as well as east and west of the country from Kasātota. According to Sōmavatī Cētiya and Mīnvila rock inscriptions of king Kanittha Tissa (167-186AC) totupola badda (ferry taxes) were collected at the Mahaväli Ganga at Kehigamakatota, Totagamakatota, Sumanagamakatota etc.(Paranavitana2001). The Kehigamakatota could most probably be Kasātota (Vidanapathirana 2010). The other ferries may have been used for the main temples of Sōmavatī cētiya and Mīnvila. The above roads can be connected to the ferries according to the geographical location of the area. Through this road a person can avoid the highly urbanized area when going to Rōhana and Sōmavatī cētiya across Kasātota from Rajarata. This road must have been used prior to the Polonnaruva kingdom. The third road can be identified from the ruins that are spread even across northern part of Pabalu vehera and across east and west of outer city. This road is connected to the junction in the north corner of Tōpaväva. By entering through western square wall, there is a great possibility to connect almost all the roads to Rajarata and northern roads through Minnēriya. Clear evidence of roadways can be found up to eastern city wall of the outer city. Ruins of road outside the city can be found from the area of Kālinga äla (Bell 1908). This road goes to Kasātota through Divulāna, which can also be used to go to Sōmavathi cetiya and Sēruvavila across the ruined tank bunds in the north of Divulāna and then through Periya Āra. These roads may have been used to have contacts with the coastal area in the south of Gōkanna. The fourth road that runs to Kasatota goes to the east parallel to the right square wall from the southern entrance of the city which is in right square wall and outer city and inner city. According to the archaeological ruins found in the urbanised area this road has been used for temple complexes. This road is also connected to Kasatota road, which goes through Gal-lälla village.

Road to Rōhana from Polonnaruva through Dāstota

The ruins of road tracks from the west gate of the inner city to west gate of outer city belong to the road to Dāstota. The road was constructed in the north east direction among the inhabited area. The remaining tank bunds and ruined irrigation canals in the area show that there was a highly urbanised and well developed agricultural system of the time. Generally, the banks and bunds of irrigation canals were connected to the road network. The shortest distance to Kasatota was from Polonnaruva through Rōhana road across Dāstota. From here, it had to cross both ferries of Amban Ganga and of Mahaväli Ganga. Angamädilla canal was built to carry water to Parakrama Samudra and Älahära äla (irrigation canal), which was built on the southern side of Dāstota. At the same time, it also controlled the water of Mahaväli Ganga (Brohier 1937; Mv. 79.40-57; Pj 34). Kālinga äla was built by king Parakramabahu 1(Nicholas 1955). This road could also have been used to go to Rōhana through Kalinga äla without going through Dāstota of Mahaväli Ganga. Some scholars are in view that this place was not a city even it is called as Kālinga nuvara, but a temple complex that upasampada vinayakarm (entering the higher order in the Priesthood). It is also believed that this was the place known as Dāstota (Mv. 89.65; Bell 1897). The Kālinga äla must have been a strategic place on the road to Rōhana during the Polonnaruva period as a person passing Dāstota had to across both Amban Ganga and Mahaväli Ganga.

Road from Polonnaruva to Sīgiriya and Dambulla

There were two ancient roads to go to Dambulla. The first road that started from the junction in the north corner of Tōpaväva goes to the north west and at Giritalē it turns to the south parallel to the Giritalē Älahära road and through Nēhinna äla and going to

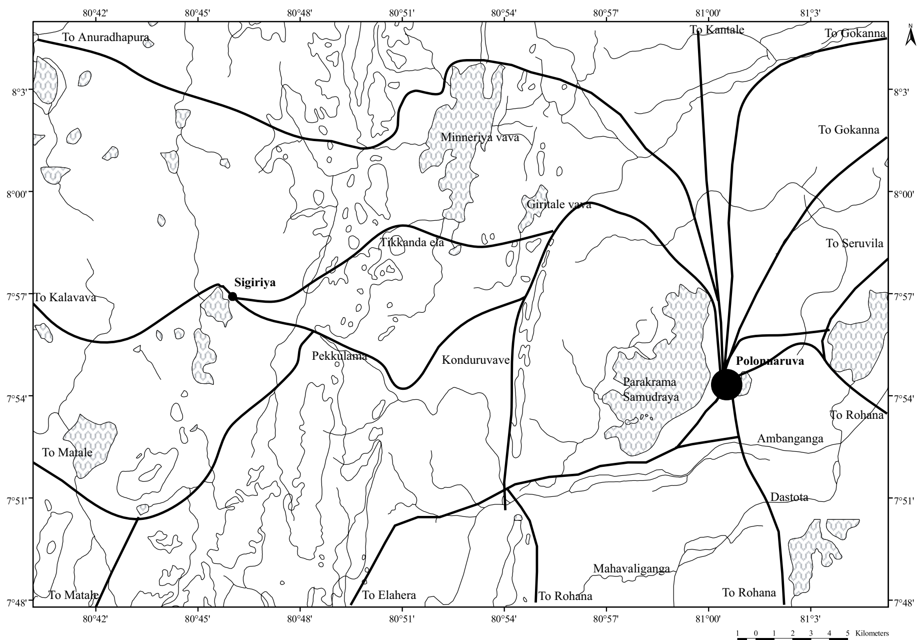


Figure 02 : Road network in Polonnaruwa city and suburbs

west and passes the west side of Minnēriya tank, passing Beddepanvila, Halmilläva, Katukeliyāva, Giritalēmullaväva, Ihakulaväva. It crosses the gap of Minnēriya kanda (1010ft) and Ihakulakanda (1288 ft) in the south of Dikkanda äla and falls to the valley of Kiri Oya. Then it passes Diyakäpilla, Pollatäva, Palutāva and meets Sīgiriya. This road is still in use. In Palutāva the road turns to the south and goes across Lēnāvala, Timbiriväva, and Kumbukkandavala and reaches Dambulla. Palutāva Dambulla road goes parallel to the present road. The second road moves towards Sīgiriya goes from Gititalē to south and at Koduruväva turns to the west. Later it crosses Mēgahaväva Pēkkulama gap (in between Vävalakanda and Ihakulakanda) and through Makarayavala Pottavala reaches Sīgiriya. This road must have been used to go to Kalā Oya as well as to Matalē through Dambulla and Lenadora. According to the geographical disparity, this road can be used to go to Älahära and to Rōhana through Dāstota from Sīgiriya. The present foot path that goes to the south east from Konduruväva must have been used then too. This road must have been used to go to Polonnaruva through Radevage Oya,, which is a branch of Amban Ganga and later passing Kalahagala and then through Dumbutuluväva joining the old street and finally turning to the north to reach Polonnaruva.

Polonnaruva-Sōmāvatī and Sēruvila road

Sōmāavatī Cētiya is a main monastery complex in the suburbs of Polonnaruva. The road starts from the northern gate of the inner city and outer city of Polonnaruva. It ends at Sōmāavatī Cētiya and Sēruvila. The northern road, which was mentioned above divided into two near Damilatūpa towards north and northeast. The road going towards northeast runs through the right bank of Minnēriya passing Tambalē and subsequently joining Sōmāavatī Cētiya and Sēruvila through the port, which goes via Periya Āra, a tributary of Mahaväli Ganga.

Polonnaruva, Mädirigiriya and Kantalē road

This is the third northern road that leading from the old street junction in the north of Tōpa väva to north. The roads still divide at Polonnaruva from this junction. The road goes to north through Tōpaväva vän-äla (spill) divides on to two in the southern area of Rankot vehera. One road has been used as an entrance road to temples like Rankot vehera, Ālahanapirivena, Baddasīma prāsādaya, Kirivehera and other temples. To the east and north streets from this road, there was a system of roads connecting the temples. The second road is the road that led to the north and goes through the western side of Damila tūpaya across the irrigation canal of Tōpaväva passing the eastern side of Nelumpat pokuna (Lotas pond), Tivanka pilimagē, Mädirigiriya and Kantalē. This road has a probability to connect to Gōkannatittha, the main trade route. The most important ancient road undertaken by the Department of Archaeology in 1940s was the road to Mädirigiriya. The whole length of the ancient road is about seven miles, four miles from the end of the irrigation road at Stage 3 of Colonization Scheme to Kavudulu Oya, and about three miles from Kavudulu Oya to Mädirigiriya (Paranavitana 1948).

The road to northern settlement area from Polonnaruva

This is the fourth road running parallel to the third road. It starts from the junction near the northern boundary of Tōpaväva. Ruins of two streets that are going across each other with the third road go towards Manik vehera and Gal vihāra (eastward). This is the road used to come to the temples in the northern settlement area as well as to the city. Even though, the landscapes are changed at present, evidence like middle scale tank bunds of village tanks and ruined irrigation canals suggest that this as a well developed irrigation area as well as a settlement and main economic area of the Polonnaruva city. There is no doubt that these tank bunds as well as bunds of irrigational canals were used as road systems. This area spreads up to Kantalē area.

The road from Polonnaruva to Älahära and Mātalē

A four way junction and roads that lead to south in the area spreading to Parakrama Samudra from the inner city could be identified in the Bell's map. It comes from the inner city to go via western square wall and along the tank bund of Tōpaväva and reaches to the southern area of Potgul vehera. There are ruins to indicate that there was a sub road connected to this road running from near Potgul vehera. This road also can be used to go to Rōhana because it goes from Parakrama Samudra through drainage canal and ancient bridge and falls to Kalahagala bund by Dumbutuluväva bund and from Kalahagala falling from Kotavala and from the amuna of Amban Ganga to Rōhana. When using this road one has to go across the Kālinga amuna. This road can also be used by the settlements in the left bank of Mahaväli Ganga. And this was also used to go to Älahära by turning towards south west from Kalahagala and going through the left bank of Amban Ganga. According to the ruins found from places such as Älahära city and the temple complexes nearby and in the areas where Kalu Ganga falls to Amban Ganga, Malavänna, Karakolapitiya and Attaragolläva, it can be concluded that they were urbanised areas. Sometimes the bank of Älahära -Minnēriya tanks might have been connected to this road through the ancient roads. This road may have been used to go to Mātalē from Polonnaruva. The gap between Dambagollagama and Vevemana hills found to the west from Älahära is a natural entry road. This road is three miles in length and used even at present as a cart road. From here onwards is the Pubbēliya road junction with the main road. The old road that falls from Älahära goes to the south from the left edge of Kumārigala (1917ft.) hill in Pubbēliya. The Kalugal-atta Oya which is a branch of Amban Ganga connects Nāula from the northern edge of Kosgahapataha (1947 ft.) mountain and goes to Mātalē through Nālanda. The systematic road network of the Polonnaruva period was as same as to the Anurādhapura period.

Conclusions

An archaeological survey of the city of Polonnaruva shows that it has no grid system of streets oriented in north-south and east-west directions. There is clear evidence of two main gateways by the city wall and at least passing aligned with them a vestigial road system. A complete road system connected the metropolitans to the outside with a sequence of gaps, ferries, bridges in a national road network spreading out in all directions of the island. The conjectural reconstruction of this road network on the basis of modern surveys, administration reports and one inch topographical maps and information in the ancient chronicles and historical text makes it possible to prepare a systematic map of the ancient road network especially in relation to the Polonnaruva and the suburbs.

References

Bandanayake, S. 1997. Historical thresholds: Sri Lanka in a long range perspective. Papers presented at a colloquium on Cultural Dynamics in South and South-east Asia, Bangalore: National Institute of Advanced Studies, May 8. 1997.

Bell, H.C.P. 1897. Archaeological survey of Ceylon: Annual Report, (North-Central Province). Colombo: Ceylon Government Press.

1914. Archaeological survey of Ceylon: Annual Report, (North-Centra Province). Colombo: Ceylon Government Press.

1908. Archaeological survey of Ceylon: Annual Report, (North-Central Province). Colombo: Ceylon Government Press.

1910-1911 Archaeological survey of Ceylon: Annual Report.(North-Central Province). Colombo: Ceylon Government Press.

Brohier, R. L. 1937. The inter-relation of ancient reservoirs and channels in Ceylon. The Journal of the Ceylon Branch of the Royal Asiatic Society, 24. pp. 64-88.

Brohier,R.L. & J.H.O. Paulusz. 1951. Lands, maps & surveys. 2. Colombo: Ceylon Government Press.

Burrows,S.M. 1886. Report on archaeological work in Anuradhapura and Polonnaruwa, Ceylon Sessional Papers-10.

Codrington, H. W. 1927-33. Gavuta pillars. Ceylon Journal of Science, (Sec. G). II, pp.129-135.

Gieiger, W. 1960 Culture of Ceylon mediaeval time, Wiesbaben : Heiuz,B. Otta Harrassowitz pp.105-110.

Gunawardana, R. A. L. H.1982. Social function and political power: a case study of state formation in irrigation society. In: Claessen, H. J. M. & P. Skalknik. (eds.) The Study of the State. The Hague. pp. 133-154.

Gunawardena, P.2009 Polonnaruva nagarekaranaya saha vastuvidyava In, Jayatunga, N.(ed.) Pulatisivamsaya, Sanskrutika urumayan pilibanda amatyansaya, Colombo.

Hocart, A. M. 1923.1924-28. Irrigation, The Ceylon Journal of Science, (sec. G.) 1. Colombo: The Archaeological Commissioner Ceylon. pp. 158-162.

1928-33. Archaeological summary, The Ceylon Journal of Science (sec. G.).1 pp. 1-12.

Nicholas, C.W. 1957. A short account of the history of irrigation works up to the 11th century, The Journal of the Ceylon Branch of the Royal Asiatic Society, 7 (New Series). pp. 43-69.

Paranavitana, S.1930. The Capital of Ceylon during the ninth and tenth centuries, Ceylon Journal of Science. 2 (2) 141-147.

1928-33. Epigraphical summary, Ceylon Journal of Science, (Sec. G) 11 pp.18-20.

1946. Archaeological survey of Ceylon: Ceylon Administrstion reports, Colombo: Ceylon Government Press.

1948. Archaeological survey of Ceylon: Ceylon Administrstion reports, Colombo: Ceylon Government Press.

1983. Inscriptions of Ceylon 2 (1). Colombo: Department of Archaeological Survey of Sri Lanka.

2001. Inscription of Ceylon 2 (2). Dias, M. (ed) Colombo: Department of Archaeological Survey of Sri Lanka.

Sri Sumangala, Ven & Batuvantudave. (ed.) 1967 Mahavamsa (in Sinhala), Colombo: Ratnakara Prakasakayo.

Vidanapathirana, P. 2007. Settlement Patterns of the Mavatu Oya and Kala Oya basins: A study from the perspective of Historical Geography, PhD dissertation, Pastgradute Institute of Archaeology, Colombo.

2008. The road network within the city of Anuradhapura and its suburbs, In, N. Chutiwongs and N.de Silva (eds) Roland Silva Felicitation Volume. Postgraduate Institute of Archaeology, Colombo.pp220-227.

2009. Polonnaru distrikkaya aitihasika janavasa vayaptiya In, Jayatunga, N.(ed.) Pulatisivamsaya, Sanskrutika urumayan pilibanda amatyansaya, Colombo.

2010. Rohana mahamaga: The southern highway in ancient Sri Lanka, In, P.Gunawardhana, G.Adikari and R.A.E.Coningham (eds.) Sirinamal Lakdusingha Filicitation volume, Nipune Publications (pvt.)Led. Sri Lanka.

Wickremesinghe, D.M.de Zilva.1927. Kukurumahada mana Pillar-Inscription, EZ 2, pp.19-25.

1927 Aitigevava Pillar-Inscription, EZ.2, pp. 34-38. London:

Editors' Note:

Dr. Vidanapthirana - *Postgraduate Institute of Archaeology, University of Kelaniya, Sri Lanka.*
(p.vidanapathirana@yahoo.com)