Evolution of Microliths at Batadomba-lena, Sri Lanka

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Abstract

Unresolved questions about the nature and coherence of microlithic production in Sri Lanka underlay many discussions about the microlith tradition in this region as well as the origins of those technologies and norms. Previous studies have not examined whether there were changes over time in the form of the microliths themselves, and in this paper, we conduct a geometric morphometric (GM) assessment of the shape differences over time at the Batadomba-lena site in the Wet Zone of Sri Lanka, excavated by Deraniyagala and Perera. We show that there were complex shifts in microlith shapes, with diversification of forms over time. This finding challenges conventional typological depictions of sameness within microliths and introduces a new approach to studying the evolution of microlith form.

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Introduction

In this paper we begin an exploration of the evolution of the Sri Lankan Microliths by studying the specimens recovered from the deep sequence at Batadomba-lena. Both subjects, the microlithic in Sri Lanka and the study of this site have a long history and reflect the foundational contributions of Siran Deraniyagala. The microlithic of Sri Lanka has been extensively discussed, with Deraniyagala (1992) establishing a baseline of morphological variation and antiquity for the phenomenon (Figure 1).

More recently ideas of cultural traditions and migration have gained prominence. It has now become common to think of the microliths themselves as part of a broad package of behaviours that might covary as a ‘microlithic tradition’, such as other small lithic tools, distinctive lithic core reduction, ground bone tools, and even foraging strategies (e.g., Roberts et al 2015; Wedage et al., 2019). These are difficult propositions to evaluate. Lists of modern traits are typically *ad hoc*, compiled without any compelling reason as to why we would associate them with modern social and cognitive lives (see Wadley, 2001; Hiscock, 2015). Furthermore, the traits claimed to be associated with modernity varied regionally both within and beyond Africa, as well as accumulated and changed over time, so that their status as a ‘package’ has not been demonstrated. This was the reason Lewis and colleagues were concerned that the concept of ‘microlithic industries’ as a unit of analysis might be hiding, or as they said ‘homogenising’, significant behavioural variation (Lewis et al., 2014).

Ideas that there was a ‘microlith tradition’ that was a package are especially vulnerable to concerns that we may be bundling components that are not integrated as a coherent behavioural set, but simply co-occurred sometimes in response to conditions (see Hiscock, 2015). For this reason, and while we acknowledge that many different characterisations of the ‘microlithic’ have been previously used (see review in Roberts et al., 2015), we are concerned in this paper only with the microliths themselves, rather than other lithic or non-lithic artifacts found in the same sites.

Our goal is to isolate a single artifact form, microliths, and to explore the uniformity of those kinds of artifacts within Sri Lanka. This study presents data from only a single site sequence and hence we regard it only as an initial statement of variability in Sri Lankan microliths. Nonetheless, a study of chronological change in microliths in a major archaeological sequence provides critical tests of existing claims of uniformity within the microlithic phenomenon.

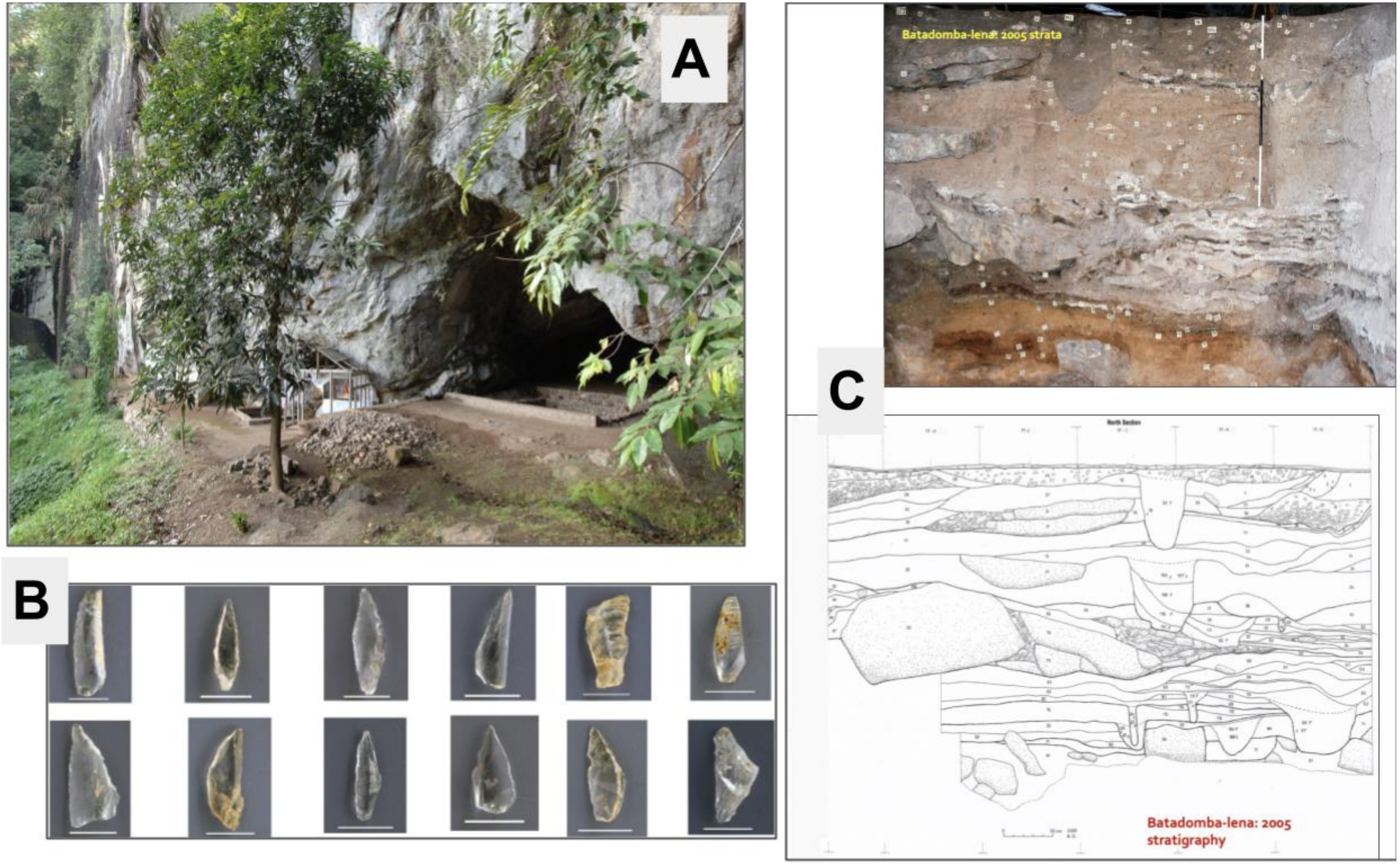

Figure 1. Batadomba-lena: site (A), microliths from Batadomba-lena (B), and stratigraphic section at Batadomba-lena (C).

In recent studies researchers have argued that the microliths, and their roles, were extremely constant over time. For example, Roberts et al., (2015:102) concluded that "...the Sri Lankan Micro-lithic tradition appears to have been a specific and stable environmental and cultural adaptation". In a somewhat similar vein (Lewis et al., 2014) considered the size and shapes of microliths at Batadomba-lena were "remarkably constant". Those interpretations unambiguously predict stability over time in the character of microliths. Wedage et al., (2019) notes that there have been very few tests of temporal change in Sri Lankan microliths. They sought to examine chronological change at Fa-Hien Lena, but since that site contained only three microliths they were not able to evaluate changes in microliths themselves. Nevertheless, the point made by Wedage and colleagues remains valid, and an analysis of the microliths at sites with adequate samples would be an important step towards evaluating impressions that there was constancy in the form of microliths over time.

The importance of testing whether there was constancy or change in microliths can be understood in terms of the evolutionary implications. Sri Lankan Microlithic have been recovered from strata dating to as old as mid-MIS3, almost 40 kya (e.g., Perera et al., 2011; Roberts et al., 2015; Wedage et al., 2019). That antiquity is locally early and yet is far younger than the oldest microliths known from Africa. That pattern has underpinned the idea that microliths may have been associated with modernity in Africa and subsequently transported across South Asia by dispersing *Homo sapiens* (e.g., Mellars, 2006). One version of that general proposition is that in Sri Lanka, the arrival of modern humans is primarily the colonisation of rainforests, with microliths perhaps being a critical tool facilitating early rainforest adaptation (e.g., Roberts et al., 2015; Wedage et al., 2019). That claim encounters empirical difficulties in several ways. At less than 40 kya the dates for the earliest microliths in Sri Lanka may well be long after the first movement of modern humans through the broader region. Australia, much farther from Africa, was colonised well before this date (Clarkson et al., 2017), and it is therefore likely the dispersal of modern humans through South Asia was earlier. The same conclusion was reached by researchers working elsewhere in South Asia, who concluded that out of Africa dispersion of modern people and the appearance of microliths were not associated, and that the earlier, pre-microlithic, arrival of *Homo sapiens* was marked by other technological changes (Haslam et al., 2010; Clarkson et al. 2012; see also Clarkson et al., 2020).

Equally problematic is the proposition that microliths were an unchanging phenomenon. That idea, reified in Mellars' (2006) concept of a microlith 'tradition' as an externalised expression of modernity that is carried with *Homo sapiens* from Africa to the edges of East Asia. This broad proposition, as well as the subsidiary claim that within Sri Lanka microliths served to allow modern foragers to be successful within rainforests, is framed as a claim that the tools gave an 'adaptive advantage' to modern humans. And yet the claim for uniformity of microliths through time and space is not easily reconciled with an adaptive role, which is specific to a single environment. For microliths to be made the same way for tens of thousands of years, repeatedly creating the same sizes and shapes, we would predict either a remarkably constant environment in which the same tool is always exactly what was needed or else the use of an unchanging technology in changing circumstances so that it was rarely a tool optimal for the tasks at hand. If tools played a critical role in human adaptations to changing physical or social environments, we might well anticipate ongoing alterations to a technological system as an ongoing response to evolving selective contexts. Hence the claim that microliths played a critical adaptive role and yet were constant and unchanging over time and space is challenging and warrants testing. In this paper we present an initial test of the claim that there was temporal uniformity in Sri Lankan microliths by examining the sequence from Batadomba-lena.

Excavations at Batadomba-lena proved fundamental in building a prehistory of Sri Lanka. The site is located at c. 450 m above sea level in equatorial rainforest habitat. This 15 m wide, northeast-facing rockshelter was first excavated by P.E.P. Deraniyagala in 1940 who noted the presence of microliths (Kennedy and Deraniyagala 1989). In the late 1970s Siran Deraniyagala undertook intensive excavations, with Nimal Perera as chief field supervisor (Deraniyagala 1988, 1992, and 2007). Perera (2007, 2010 and Perera et al., 2011) later undertook further excavations aimed at clarifying chronology and associations. Their investigations revealed very early microliths and a long sequence of microlith production. A deposit over 2.5 m deep has been interpreted as having eight layers, with microliths recovered from Layers 3-7. The great depth and archaeological richness of the site made it a key chronological sequence describing the terminal Pleistocene human settlement of the southwest of the country. The site contains a high density of lithic artifacts and was extensively excavated and studied in detail by both Siran Deraniyagala (1992) and Nimal Perera (2010; Perera et al., 2011). In particular this site has been well-dated and contains samples of microliths covering more than 20,000 years of occupational history. As a result of these qualities this site has been employed as a key sequence in recent studies of the Sri Lankan microlithic (e.g., Lewis et al., 2014; Perera et al., 2011; Roberts et al., 2015). Details of the stratigraphy and dating are provided elsewhere (Deraniyagala 1992; Perera 2010; Perera et al., 2011), and here we focus only on the distribution of microliths within the sequence.

Materials and Methods

Our investigation into whether the character of Sri Lankan Microliths varied over time is focussed on an analysis of whether the plan shape of specimens was much the same between phases or measurably different. Since conventional implement classifications of shape are generally both unquantified and subjective, they typically do not provide either sufficient sensitivity or quantification that allows assessments of whether shapes are significantly different. For that reason, we have used Geometric Morphometrics (GM), a method that allows us to not only quantify shape change but also to isolate shape from other factors. Here we have employed 2D images of the microliths from Batadomba-lena to calculate shape differences between three phases. We start with a consideration of sample selection and then describe the GM techniques employed.

Sample selection

We were focussed exclusively on morphology and manufacturing technique when identifying the microliths in this sample. We define 'microliths' as stone flakes that had steep, blunting, marginal retouch (backing) on one or more margins opposite or adjacent to an unretouched margin. This retouch was typically made by sandwiching the flake between an anvil and a hammer and in many instances that flaking involves employing a bipolar technique. We excluded from our sample other small retouched flakes that have often been thought of as 'microlithic' but which do not have the combinations of characteristics with which we define microliths themselves. For example, we have excluded bifacial points ('Balangoda' points) and small notched, shouldered and tanged specimens if they do not have the backed retouched margin and the unretouched margin.

Microliths have conventionally been characterized in terms of both size and shape, but here we use neither trait in defining specimens for analysis. Our analysis investigates the shape of microliths, and any reference to shape in defining that category would pre-empt and constrain an understanding of shape variation. Similarly imposing arbitrary size thresholds on the identification of microliths would predetermine the sample, and in all likelihood would affect the recognition of shape diversity since there may be allometry present. Hence, we have used only those technical properties of the retouching to define the sample. Nevertheless, the Batadomba-lena specimens were uniformly small as has been previously noted, with specimens typically being less than 30 mm across the chord, and some specimens are much smaller in that dimension.

We did not make any interpretation of function in selecting the sample. Our sample is constructed using a definition that references only morphological features visible on the specimen, so that the specimens were congruent with the morphometric analysis we have undertaken. Only retouched specimens fitting those morphological criteria were selected for study. We excluded specimens that had similar features, but which were not retouched, such as flakes with relic core platforms on their dorsal ridges. Those retouching features are essential to the measuring system we describe below, and they provide the critical distinction of chord and backed edge. Chord is the largest unretouched edge, while the backed edge is the other flake margins that have either continuous or discontinuous retouch scars. In our illustrations and in measuring shape we positioned specimens with their dorsal face up and the chord at the base of the image.

The sample so constructed consists of 33 microliths that were recovered from Batadomba-lena by Perera (2010). Note that all specimens are made of quartz, and therefore we treat material and engineering constraints as uniform throughout the sequences. These specimens were distributed through the Pleistocene strata, from 35,820 BP to 15,575 BP (Perera, 2010; Lewis et al., 2014). To study chronological change, we divided the sequence into three broad phases. Phase 1 was those strata dated older than 30,000 BP, and we had a sample of 13 specimens from that antiquity. Phase 2 are the strata dating to between 30,000 BP and 20,000 BP, and we have a sample of 5 specimens from this period. Phase 3 consists of those strata dated to 20,000 BP to 10,000 BP, and we have a sample of 14 microliths from that period. We have one specimen that was recovered in section clean-up and which we have excluded from discussions of chronological change. Our analysis concentrates on comparisons of Phase 1 and 3, because the sample from Phase 2 is currently too small to employ. We also note that even the samples from Phases 1 and 3 are minimal ones for the analysis that follows. While we may expand the samples in the future and/or decimate landmarks we contend as a first order analysis to use the total 33 artifacts for an analysis of 18 landmarks, while acknowledging a larger sample would be preferable in future studies.

Data Acquisition

Our analysis employed photographs of the dorsal face of each specimen. Specimens were positioned so that the camera focal plane was parallel to the plane of the ventral face. Photographs were taken with a DSLR camera to give images between approximately 3,800 x 2,800 pixels, at 300 dpi. This provided considerable details when landmarking. A scale was placed in each image so that size could be input.

Definition and digitizing of Landmarks

This analysis involves using Geometric Morphometrics (GM) to study chronological changes in the shape of microliths at Batadomba-lena. This analysis statistically measures the location of key points of the specimens shown in the photographs. Those key points are called landmarks. One important principle in conceptualizing and selecting landmarks is usually expressed as a requirement for landmarks to be ‘homologous’, because the mathematical propositions of GM presume and demand the correspondence of every landmark with conceptually equivalent landmarks on other specimens (Lele & Richtsmeier, 2001). The key characteristic of landmarking is simply that each landmark should represent the same point on each specimen in the analysis. With that requirement in mind, we defined 18 corresponding landmarks on each specimen (Figure 2).

The most critical landmarks are LM1 and LM2, which define the left-hand and right-hand ends of the chord. Those points are a junction between two edges, usually the unretouched chord and the retouch of the backed edge, although some microliths have the platform intact and in those cases the chord at one end may terminate at the platform edge. Those two points give each specimen an orientation that helps determine the location of other landmarks. We conceptualise a line joining LM1 and LM2, which we name the ‘chord length’ (see Figure 2). LM 3 and 4 designate the maximum size of each specimen parallel to the chord length. When no portions of the specimen protrude beyond LM1 and 2, then LM1 co-occurs with LM 3 and LM2 co-occurs with LM4. But in a number of specimens mass protrudes beyond LM1 and LM2 and in such specimens LM3 may be located away from LM1 and/or LM4 away from LM2 to reveal the maximum extension of the specimen. LM5-11 are located on the chord, at points that are equally spaced along the chord length (at equal distances representing 12.5% of the chord length). LM12-18 are located on the backed edge (the non-chord edge), at points that are equally spaced along the chord length (at equal distances representing 12.5% of the chord length). Landmarks 5-18 are arbitrarily located, but provide an expression of edge shape at the same relative location on every specimen in our sample to provide the correspondence required for geometric morphometrics. Given the adequacy of this landmarking system and the low sample sizes we are employing, high dimensional morphometric approaches are neither warranted nor necessary.

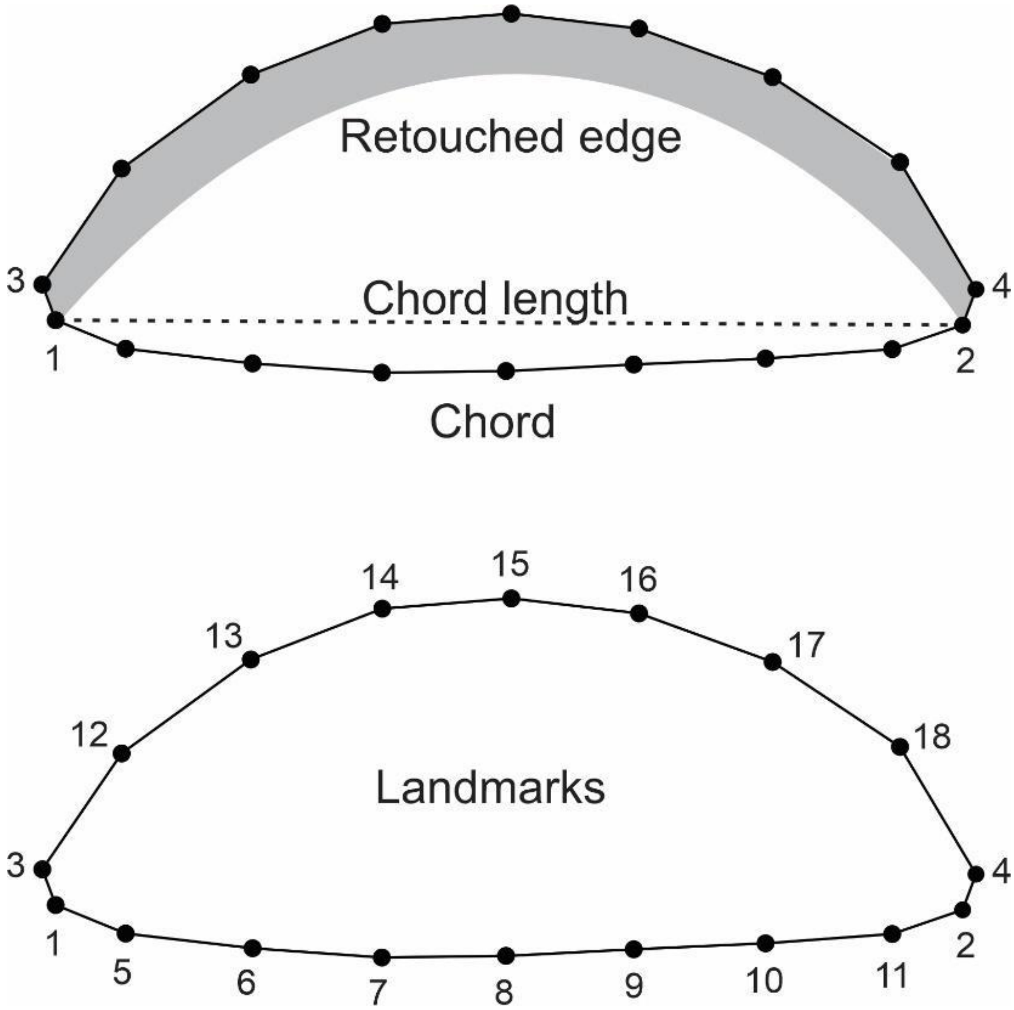

Figure 2. Examples of Landmarking on microliths at Batadomba-lena. The images shown here are wire-frame graphs of the average microlith shape for the site, based on the GM analysis presented in the paper. The upper image shows the orientation of the specimens, with the chord length between LM1 and 2 being a reference for the other landmarks. Shading represents the typical region of retouch. The lower image numbers each of the landmarks described in the text.

Computation of shape differences

We carried out this GM analysis with Klingenberg's MorphoJ program (2011, 2013), and proceeded through the standard statistical manipulations: Generalised Procrustes Analysis (GPA), followed by the compilation of a covariance matrix, then a regression analysis to remove allometric effects, followed by Principal Component Analysis (PCA). Each of these steps plays a critical role in isolating shape and understanding the structure of shape variation. Briefly, the Procrustes superimposition removed size, orientation and position information to transform raw landmark coordinates to Procrustes coordinates that depict shape variation. Creating the covariation matrix yields a dataset describing the relationship of all coordinates with each other and formats these data to allow us to employ PCA as a data reduction procedure. However, these data may still retain allometry and so we regressed shape data (Procrustes coordinates) against size data (centroid size) to determine the effect of allometry. We then removed allometry by employing regression residuals as data for subsequent PCA calculations. With those PCA we are able to characterise the magnitude and dimensionality of shape variation observable within the sample.

Geometric Morphometric Results

Allometry was strong in these microliths. Regression revealed a positive but not strongly linear increase in coordinate values as centroid size increased. The regression indicated that about 34.5% of shape variation changed in response to size change, and a permutation test indicated this was highly significant ($p<0.0001$). We will consider the specific effect of size on microlith shapes in a later paper, and here we focus on measuring shape by removing allometric effects. All results reported here are based on 'size-corrected' data, meaning that we are describing 'pure' shape change with the effect of size removed through the analysis of regression residuals rather than original values.

A PCA of those size-corrected data yielded thirty components, most of which explain trivial amounts of shape variation. We consider only the three largest components: PC1 = 49.0%, PC2 = 22.1%, and PC3 = 9.1%. Together these three components explain 80.2% of shape variation in the Batadomba-lena microliths. We explore only these three principal components to examine the shape differences over time at this key site.

Shape differences represented by each of those three components is shown in Figure 3. Note that by definition each component represents different and independent shape traits. PC1 primarily expresses shifts in the symmetry of the specimens, and particularly of the backed margin (positioned at the top of each wireframe in Figure 3). Values at or close to zero represent shapes that are bilaterally symmetrical, in which there is roughly equivalent mass on either side of the centre line, the widest part of the specimen (chord to backed edge) is close to that centre line, and for which the curvature of the backed edge is very similar on either half. Strongly negative values of PC1 are distinctly asymmetrical with the widest portion of the specimen, and much of the mass, located to the left of the shape, giving an acute convergence of backed edge and chord on the right. Strongly positive values of PC1 are distinctly asymmetrical with the widest portion of the specimen, and much of the mass, located to the right of the shape, giving an acute convergence of backed edge and chord on the left.

Shape variation on PC2 can be primarily described in terms of the curvature of the chord. Values close to zero represent specimens with relatively straight chord edges. Strongly negative PC2 values come from specimens with concave chords, in which the chord edge curves in the same direction as the backed edge. Strongly positive PC2 values come from specimens with convex chords, in which the edge bulges outwards from the centre of the specimens, in the opposite direction to the backed edge. While on some specimens there are small sections of chord edge that are damaged or even have light marginal retouching, chords are for the most part unretouched and hence their curvature is not a product of microlith manufacture. Rather the shape of the chord in PC2 reflects the kinds of flakes produced during core reduction, and more specifically the selection of flakes for backing and the selection of which margin would be retouched and which would be selected as the chord.

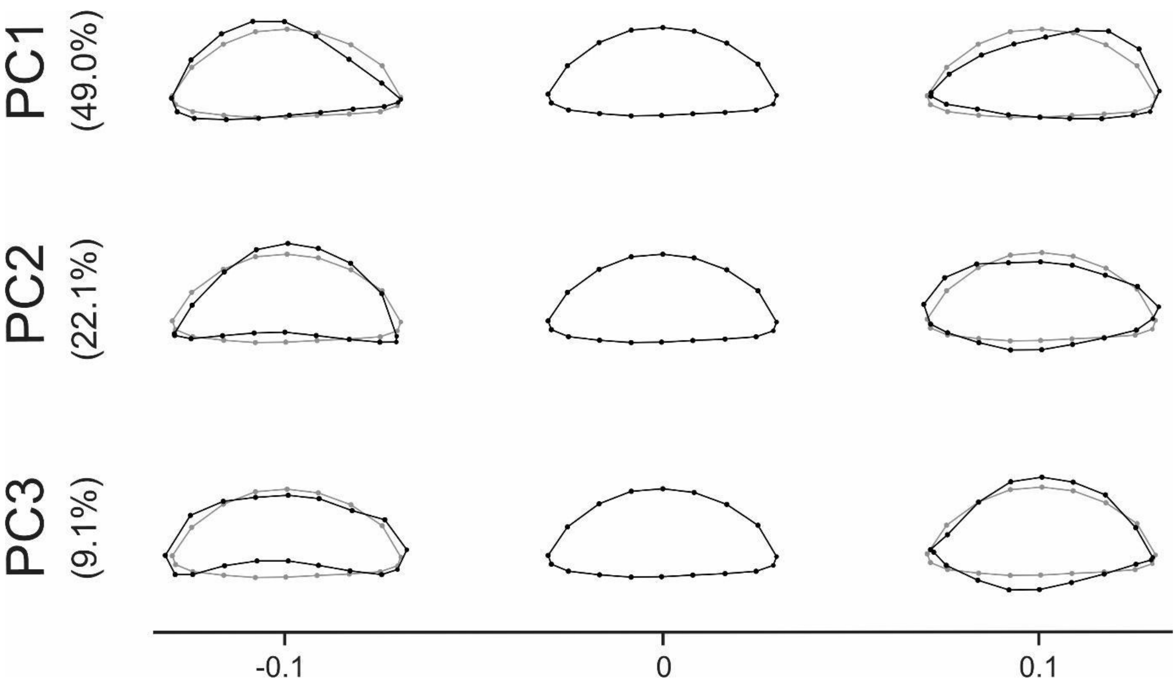

Figure 3. Shape differences in PC1-3 for microliths at Batadomba-lena using wireframes (black wireframes show shapes at different values of the axis, whereas grey wireframes show centroid values, i.e., 0, for comparison).

Shape variation expressed in PC3 represents the configurations of landmarks 3 and 4 involving the extent to which the specimens extend beyond the end of the chord length. Values at or near zero are shapes with landmarks 1 and 3, and 2 and 4, being at nearly the same location but not quite so that landmarks 3 and 4 are slightly offset Such configurations often have a relatively straight chord and curved backed edge, creating a somewhat hemispherical shape with moderate angles between chord and non-chord edges. Strongly negative PC3 values are found on specimens with ends that are squared or even angled outwards, as landmarks 3 and 4 are further apart than landmarks 1 and 2, creating mass that protrudes beyond the chord length.

In such specimens, landmarks 3 and 4 are also further from the chord. That pattern typically produces a flatter backed edge and concave chord, so the overall shape is rather reniform. Strongly positive PC3 values are found on specimens with ends that are bi-pointed, as landmarks 3 and 4 are co-occur with landmarks 1 and 2, creating a shape in which mass is concentrated in the centre of the plane and both chord and backed edge are distinctly convex, to give a shape that is narrow at the ends but broad in the centre.

In combination these three principal components depict most of the shape differences that are present in the Batadomba-lena microliths and recognised in previous studies of the site. However, the PC values now provide us with quantitative descriptions of independent elements of shape differences that we can use to evaluate whether microliths were a uniform class that remained constant over time or alternatively a variable class that evolved over time.

Our analysis begins with an examination of the inter-relationship between PC1 and PC2, shown as in the bivariate plot in Figure 4A. Data points representing specimens are coded by phase and to a large extent the microliths in all three phases display a similar range of shapes. Specimens in phases 1 and 3 are encompassed by lines that depict convex hulls, defining the area of shape-space occupied at those different time periods. (This was not done for phase 2 because that sample is small). Since the convex hulls of microliths in phases 1 and 3 are roughly the same area we can conclude there is little difference in the level of standardisation over time. However, the pattern in that bivariate plot shows that for each phase a different portion of the shape space was emphasised. Specimens from Phase 1 are found reasonably frequently in the central parts of both PC1 and PC2, shown as the grey strips in Figure 4A, while no specimens from phase 3 have those shapes. That pattern can be presented more clearly by looking at the frequency of specimens in each PC independently (Figures 4B and 4C).

In Figure 4B a smoothed curve shows the proportion of specimens for different values of PC1. Note that a significant contributor to PC1 is the shape of the backed edge, which is emphasised (bold) in the wireframes in Figure 4B for reference. While phase 1 shows a unimodal distribution peaking almost exactly at 0, and falling away either side of that value, phase 3 shows a bimodal distribution with peaks that are moderately strongly positive and negative values and no specimens at all in the shape zone that was dominant in phase 1. We interpret this as evidence of initial microlith production at the site focussed on making symmetrical specimens and over time a shift to the consistent avoidance of symmetry and the manufacture of distinctly asymmetrical microliths. Perhaps in phase 3 there were two distinct forms being manufactured, but alternatively it may be that the direction of the asymmetry was not particularly important and that norms and/or production habits were simply concerned with producing asymmetry. In any case we see a switch over time from production of symmetrical microliths before 30kya until all microliths in Batadomba-lena were asymmetrical after 20 kya.

In Figure 4C we see a somewhat similar trend in relation to chord shapes measured by PC2. Note that a significant contributor to PC2 is the shape of the chord edge, which is emphasised (bold) in the wireframes in Figure 4C for reference. Here the phase 1 specimens display a broad range of chord shapes, from moderately concave to moderately convex, with slightly concave edges being most frequent but all shapes well represented, as though the knappers making those microliths were not prescriptive about the edge form. However, knappers operating during phase 3 employed noticeably different behaviour, selecting specific flake edge shapes and avoiding others. In phase 3 microliths had concave or convex but not straight chord edges. This may have been a result of selection against straight edges or possibly because altered core reduction was not producing flakes with straight edges. A study of unretouched flakes would test which of those mechanisms was more likely, but we do not present such a study here.

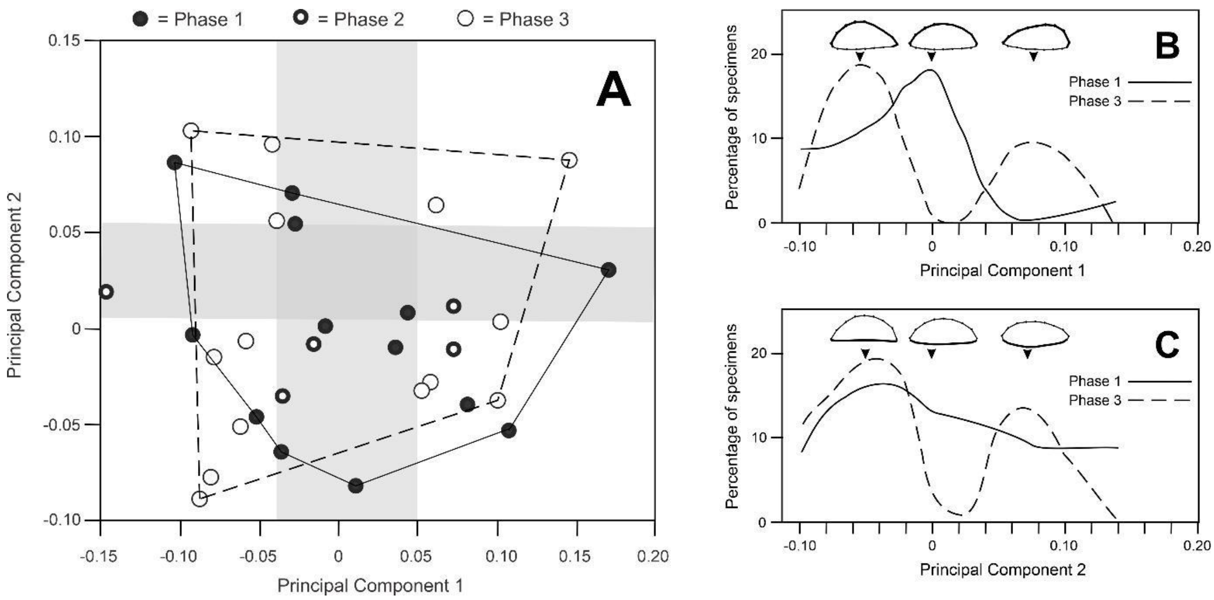

Figure 4. Graphs showing chronological changes in shape expressed in PC1.
Upper plot (A) depicts a bivariate plot of Principal Components 1 and 2 for the shape of microliths at Batadomba-lena, coded by the three phases defined in the text. Vertical and horizontal grey zone represents the region containing no specimens from Phase 3. Middle plot (B) presents smoothed curves of the frequency of data points in PC1 for Phases 1 and 3. Wireframe models show the shapes at each mode, with retouched edge in bold. Lower graph (C) shows smoothed curves of the frequency of data points in PC2 for Phases 1 and 3. Wireframe models show the shapes at each mode, with chord edge in bold.

These patterns interact and allow us to describe an evolutionary pattern at Batadomba-lena, in which a relatively uniform population of microliths at the start of the sequence evolved into two distinct microlith forms in the last 20,000 years. Figure 5 uses a series of wireframes from each phase to show the range of shapes and how they transformed over time. Phase 1 is typified by microliths with symmetrical, hemispherical-shaped backed edges and straight or gradually curved chords. Some 10,000 years or more later, by phase 3, microliths fall into two discrete groups. Typically, they are either somewhat asymmetrical lunates with concave chords or flattened, near parallel-sided specimens with convex chords. Most significantly in phase 3 there are no microliths with shapes like those in phase 1. This evolutionary trend resulted in microliths that were significantly different in phase 3 than 10-15,000 years earlier in phase 1. Canonical Variate analysis was used to test the level of difference, and permutation tests (permutation 10,000 rounds) show significant differences (Mahalanobis distance: $p<0.0001$; Procrustes distance: $p=0.0269$).

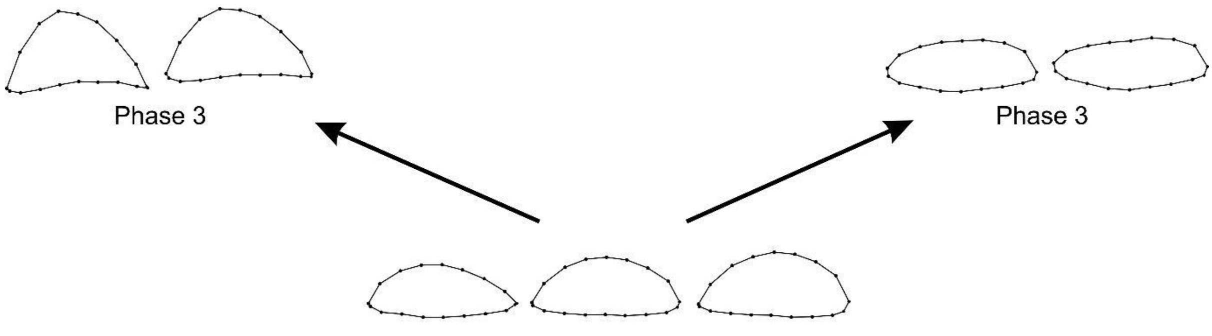

Figure 5. Depiction of the evolution of microliths at Batadomba-lena, from phase 1 (>30ka) to phase 3 (<20ka). These wireframes show the range of shapes present in each phase using PC1.

Discussion

We have documented a distinct change in microlith shape over time at Batadomba-lena. This represents evolution of microlith production systems and challenges views that the Sri Lankan microlithic was a singular and uniform phenomenon. The evolution of different shapes within the Batadomba-lena sequence may not be consistent with functional propositions of microliths being a single kind of tool, used for a specific purpose, and providing adaptive benefit in one specific ecosystem.

A program of broader study and comparison will be needed to develop coherent models of the process of evolution and to understand the contexts that underpin the selection of different forms. At Batadomba-lena itself we have shown that evolution occurred, by demonstrating that the microliths produced at phase 3 were not the same as those made earlier in phase 1. However, sample sizes limited our comparison to those two groups, and hence we have not been able to chart the evolution trajectory in more precision to establish whether the change occurred gradually or very rapidly. And since this initial study examined only the Batadomba-lena site we cannot assess whether the evolutionary changes discussed here are local or whether parallel changes occurred across multiple sites within the rainforest landscape of southwestern Sri Lanka or even beyond that region in other biogeographic contexts. Establishing the uniformity or diversity of evolutionary sequences across Sri Lanka will be critical in testing models about the adaptive role of microliths, as we discussed in our introduction.

What mechanisms might be involved in the evolution of microliths at Batadomba-lena? Well, there are multiple possibilities that will need to be evaluated, and we discuss a number here to suggest some of the tests we will be pursuing in future studies. The most conventional explanation would be that over time microliths used in the areas around Batadomba-lena were employed for different functions, and that shape changes were an adjustment to create better tool performance for the altered functions. Several predictions would be made if that was a primary mechanism, including a coincidence of microlith shape change with altered faunal suites in the sequence, and perhaps altered residues/wear on the microliths themselves. Spatial comparisons will also give us a significant insight into the functional effect on specificity of microlith shape because if this mechanism is in play microlith shapes should be different between the varied environments of Sri Lanka.

Another plausible mechanism is that microlith shape is articulated to hafting design rather than to specific tool use. In this case the evolution of microlith shape would be a consequence of evolution in the form of the composite tools into which they were embedded. Evaluating this possibility directly may rely largely on residue and wear evidence to establish hafting methods, although even with such evidence the specifics of composite tools may be hard to establish (e.g., how many microliths were in a single tool, and with what spacing and relationship on that tool). A different line of evidence would be to examine the rate of change over time. Gradual microlith shape change over long periods is not likely to be consistent with coevolution of composite tools unless there is specific reason to think that composite tools are scalable along a large continuum of configurations in the way that microlith shapes might be continuously transformed. That issue of scalability might be evaluated experimentally.

It is also worth noting that the changes we have documented are a complex set that involved a number of distinct technological practices. Specifically, we have differentiated the alteration in core reduction and/or flake selection that was responsible for shifts in chord shape from alterations of retouching patterns that were responsible for shifts in the shape of the backed edge(s). Although we have yet to investigate the relationship between those technological components, we predict they are largely independent, and in that case the evolutionary pattern in Batadomba-lena is not explicable as the consequence of a single modification of knapping practices. If independent shifts arose by chance drift over time, then we would see an uncoordinated pattern occurring between different sites and ecosystems.

However, there are other mechanisms to be explored, ones that are not random and yet do not principally involve tool use or technology. Distinctive and standardised lithic implements have the capacity to be, or be part of, equipment used to send signals within the social system. Archaeologists are aware of materials, such as rock art or sculptures that are typically understood in these terms, and other kinds of artifacts may be used to send information in the same way.

The application of signalling theory to geographic and temporal patterns of microlith shape provides a way of tracking past information flow and the geographic configurations of those signalling systems (see Hiscock 2021). Several predictions would be made if public signalling was the key mechanism responsible for microlith shape and its evolution. There would be relative uniformity in microlith shape geographically, as contemporary people were coordinated in the shapes to objects they used to transmit information. Those systems of coordination would have been spatially bounded at any time, but within the landscapes in which the same signalling system operated there would have been similar microlith forms being made. If similar-shaped microliths are found across environmentally quite different locations that pattern would not be predicted in similar functional models but would be congruent with mechanisms such as signalling. Similarly, if use-wear and residues studies reveal that microliths did not have a uniform use this would complicate functional explanations but be compatible with public signalling.

Conclusion

Excavations at Batadomba-lena proved fundamental in building a prehistory of Sri Lanka. One of its many contributions has been to establish a chronology for microliths and now to document an evolutionary change in the shape of microliths. On the basis of that evolutionary trajectory, we conclude that there is significant diversity within Sri Lankan microliths, and that treating this class of artifacts as an invariant unit hides variation in its spatial and temporal patterning. Our discussion of the evolutionary diversification of microlith shapes at Batadomba-lena suggests that there is significant analytical gain to be had by studying the variability of microlith shape as a way of testing models about the Pleistocene occupation of different environments across Sri Lanka. We have demonstrated morphological diversification of microliths within Batadomba-lena and we now ask whether early microlith shapes were relatively standardised and whether comparable diversification trends occurred in different parts of the country or whether we see niche-specific evolutionary trends. Answers to those questions would inform us of the evolutionarily history of microlith production within Sri Lanka but would additionally shed light on models of the relationship of the Sri Lankan microlithic to the dispersion of technological systems and human populations across Asia. Hence a more extended consideration of evolutionary and geographic variation in microlith shape and technology within Sri Lanka should be a topic of future research.

Authors' contributions:
NP excavated the site, formulated the sample, identified and photographed specimens. PH conceived of the analysis, landmarked the points and carried out the Geometric Morphometrics analysis. Both NP and PH contributed to writing the paper.

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