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Sub-surface movement of stone artefacts at White Paintings Shelter, Tsodilo Hills, Botswana: Implications for the Middle Stone Age chronology of central southern Africa

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ABSTRACT

White Paintings Shelter, Tsodilo Hills, Botswana plays a pivotal role in the archaeological chronology of the Middle Stone Age in the Kalahari. Results of refitting and the application of the chaîne opératoire on the Middle Stone Age lithic assemblage from this site suggest that the previously reported relatively undisturbed nature of the lower deposits should be refuted. Potential causes for this admixture include sloping deposits and post-depositional processes. The significant consequences for the Middle Stone Age occupation, dating and transition to the Later Stone Age at White Paintings Shelter are explored.

Introduction

Chronology has a fundamental role in archaeological research, underlying our understanding of relative timing, comparative dating, and developments through time. Chronological sequences link environmental and archaeological records. As deposits from caves and rock shelters tend to produce well-stratified assemblages, they are favoured for revealing these sequences. One such site is White Paintings Shelter (WPS), in the Tsodilo Hills, northwest Botswana, where 7 m deep excavations gave rise to a chronological sequence serving as a mainstay for the wider Kalahari (Robbins et al., 2000; Ivester et al., 2010). This sequence also figures in numerous other, more extensive chronological overviews for sub-Saharan and southern Africa (e.g., Mitchell, 2002a,b, 2008; Phillipson, 2005; Willoughby, 2006; Lombard, 2012). The important findings, including evidence for early bone points, a gradual transition from the Middle Stone Age (MSA) to Later Stone Age (LSA), and fishing in the MSA, have made WPS a commonly referenced site. Central to these points of reference is the stratigraphic integrity of the excavated remains. This is a vital prerequisite at any archaeological site, particularly if it is proposed as a chronological framework.

This paper documents artefact movement in the lower 4 m of deposits of WPS, following a recently completed chaîne opératoire analysis of these levels. These deposits include the c. 3 m assigned to the MSA and the c. 110–120 cm level reported as a transitional layer from the MSA to the early LSA (Robbins et al., 2000). These two archaeological periods were separated by an unbroken rock fall horizon capping the MSA deposits, believed to prevent post-depositional mobility. It will be demonstrated through refitting that there is extensive movement of artefacts within and between the layers in question. A range of potential causes will be explored. These include: (i) excavation procedure, (ii) the slope of the lowest deposits, and (iii) post-depositional disturbance including various pedoturbative processes. The impact of the refitting results on the dating and interpretation of the site, including a recent provenancing study on lithic raw material, will be discussed. It will be proposed that the apparent gradual LSA/MSA transition at WPS is likely a product of depositional mixing and that the site was used less frequently and for briefer periods during the MSA.

White Paintings Shelter, Tsodilo Hills – a brief summary

As the most prominent and accessible natural shelter in Tsodilo Hills, WPS (Fig. 1) has been the subject of excavation and analyses since the early 1990s (Feathers, 1997; Murphy, 1999; Robbins, 1999; Robbins et al., 2000, 2010, 2012; Ivester et al., 2010). From 1989 to 1993, a total of 31 1 m^2 squares were excavated in 10 cm levels to

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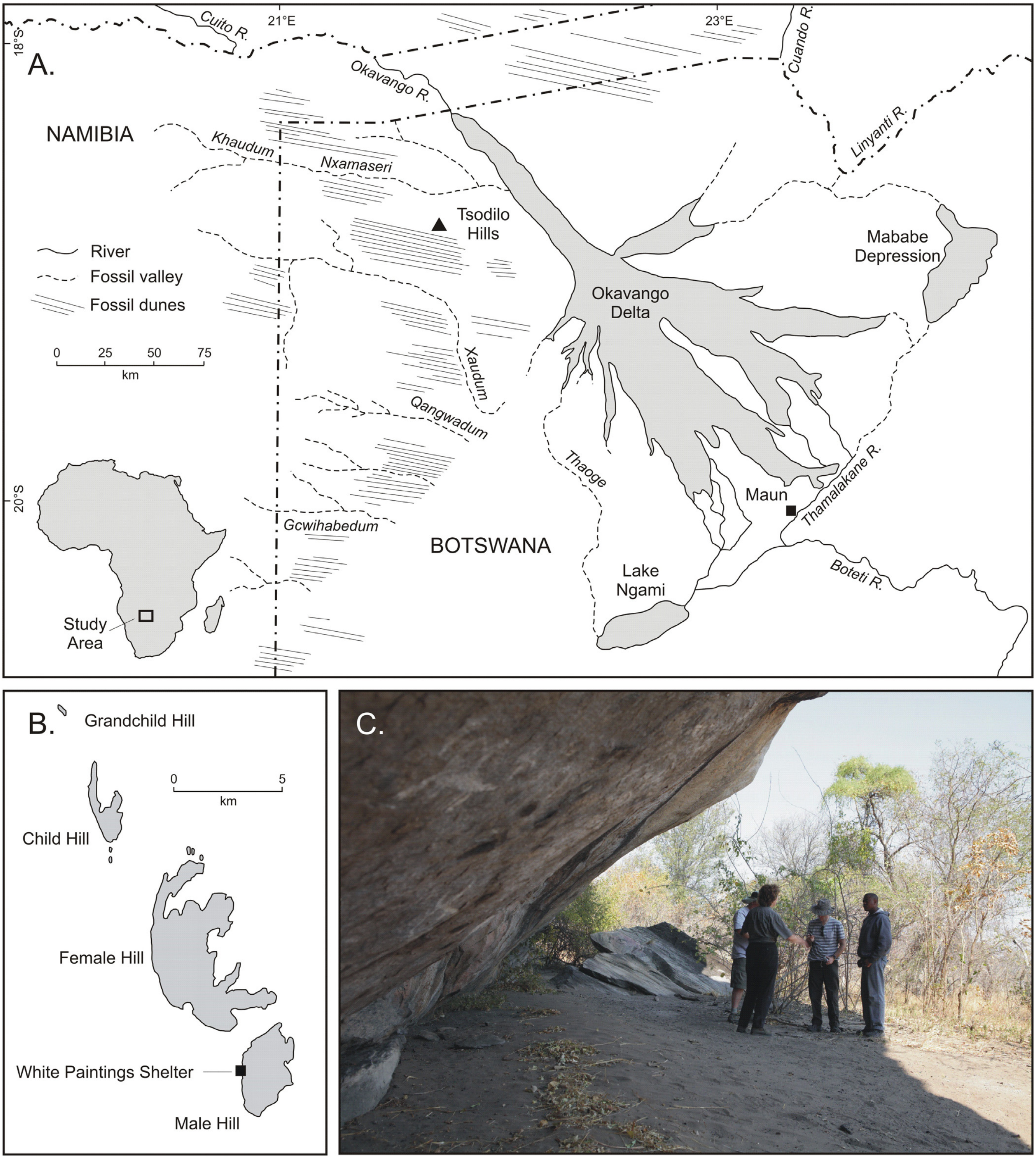

Figure 1. A. Map of north-western Botswana and Tsodilo Hills. B. Tsodilo Hills and site location. C. White Paintings Rock Shelter. Maps complied by David Nash. Photograph by Trevor Thomas.

varying depths, with two squares reaching 7 m below surface (Robbins, 1990; Robbins and Murphy, 1998; Murphy, 1999; Robbins et al., 2000, 2010). This is the longest archaeological sequence yet documented for a single locality in the Kalahari (see Fig. 2 for an overview), spanning from 60 to 70 years ago to the MSA, where the base of the deposits were estimated to 100–120 ka (thousands of years ago) (Ivester et al., 2010). Eleven stratigraphic units were identified on the basis of palaeoenvironmental conditions inferred from sediments and other data (for details see Ivester et al., 2010). These units contained over 100,000 archaeological specimens and

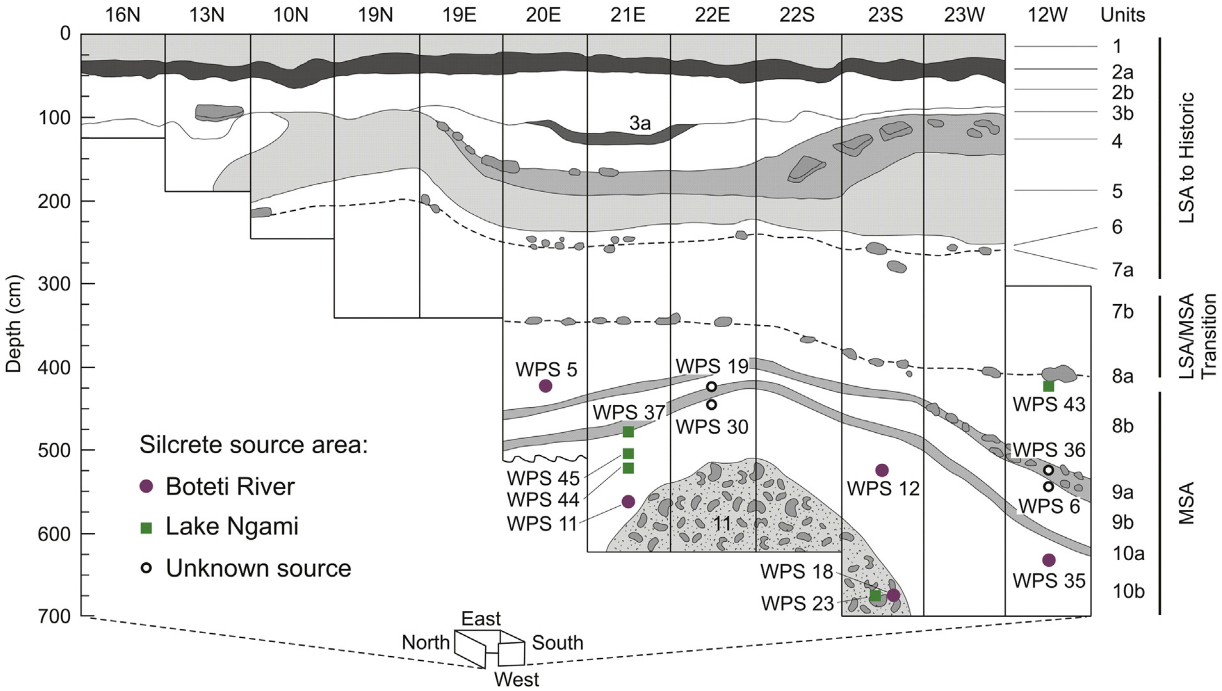

Figure 2. Wraparound stratigraphic cross-section of the archaeological sequence at White Paintings Shelter, Tsodilo Hills. The stratigraphy is dominated by units of aeolian sediment, while unit 11 is a carbonate-indurated breccia. Shading is used to differentiate layers per the original figure and does not necessarily imply sedimentological differences. The right hand axis indicates archaeological periods: Middle Stone Age (MSA), transitional layer between the MSA and Later Stone Age (LSA), LSA to Historical. The approximate stratigraphic position of silcrete manufacturing waste flakes analysed for a raw material provenancing study discussed later in this paper is also shown (From Nash et al., 2013: Figure 2, adapted from Robbins et al. 2000, with permission from Elsevier).

incorporated seven major divisions in a chronological cultural sequence (Murphy, 1999; Robbins et al., 2000). The findings have commonly been used as points of reference for the wider region (Table 1).

The strata under discussion here are the MSA layers and the transitional LSA/MSA assemblage, termed ‘The Large Blade, Early LSA/Transitional MSA’. The latter occurs between 300 and 410/420 cm below surface (see Supplementary Online Information [SOM] Table S1 for an overview). Here the microlithic industry prevalent in the upper LSA levels is supplemented by large blades made on prepared cores. This was interpreted as being in continuity with the MSA layers, which occur from 410/420–700 cm below surface (Robbins and Murphy, 1998; Robbins et al., 2000; also see SOM Table S1). The MSA assemblage was characterized by 77 unifacial and bifacial points, and by a substantial increase in debitage, particularly in non-locally acquired raw materials such as silcrete and chert (Robbins et al., 2000). In addition, some fish bones were recovered from the upper levels of the MSA, thus marking the oldest known use of fish in the interior of southern Africa (Robbins et al., 2000).

The lower levels of the 7 m deep aeolian sediments at WPS were believed to be relatively undisturbed and therefore a suitable document of the cultural, chronological and palaeoenvironmental record (Robbins et al., 2000; Ivester et al., 2010). This was due to three main factors: (i) a general correlation between the lithic assemblages and the sedimentary characteristics of the stratigraphic units; (ii) intact capping layers encountered during excavation; and (iii) new optically stimulated luminescence (OSL) datings (Ivester et al., 2010) resolving initial chronological irregularities.

In the upper, LSA/Iron Age strata of the site, rejoined bone artefacts, pottery and ostrich egg shell fragments indicated vertical movement in the range of 0–30 cm and horizontal separation of normally less than 1 m (Robbins et al., 2000; Ivester et al., 2010). Based on two conjoined articulated fish bones found between 240 and 250 cm below surface, it was believed that some areas of these upper deposits had seen very little movement (Robbins et al., 2000; but compare; Kokis et al., 1998). Further down, the early LSA/transitional MSA deposits were separated from the MSA levels by a substantial schist rock fall (unit 9a), which first occurred 4.2 m beneath the surface. An additional schist rock fall (unit 10a) separates two of the MSA layers. These capped the underlying deposits and thus were believed to have prevented post-depositional mobility (Robbins and Murphy, 1998; Robbins et al., 2000, 2010; Ivester et al., 2010). The deepest unit (11) consisted of a rock breccia talus cone. As can be seen in Fig. 2, the solidity of this cone significantly influenced the formation and slope of the overlaying aeolian deposits. Based on these factors, the general chronology of the site was considered intact (Murphy, 1999; Robbins et al., 2000).

A wide variety of materials and methods were employed in dating WPS, some resulting in inconsistencies (see SOM Table S2). Regarding the strata under discussion here, these initial irregularities were attributed to the limited number of thermoluminescence (TL) and OSL dates at WPS (see Robbins et al., 2000; Ivester et al., 2010 for summary). The recent addition of nine new OSL dates, four of which were from these lower layers, was believed to resolve these ambiguities (Table 2). These were made on samples from a single vertical profile of the south face of square 23, and their consistency suggested that this sediment column represented an intact sequence (Ivester et al., 2010).

Materials and methods

Refitting analysis and investigation procedure

Refitting, as a part of a chaîne opératoire investigation, is ideally suited for identifying potential vertical displacement of artefacts. Refitted artefacts are part of the same technological process and

Table 1
List of key archaeological features and their references attributed to White Paintings Shelter, Tsodilo Hills.

Prominent archaeological features	Main sources
Early worked bone points	Yellen et al., 1995; Yellen, 1998; McBrearty and Brooks, 2000; Henshilwood et al., 2001; d'Errico et al., 2003; Backwell et al., 2008; Robbins et al., 2012; Beaumont and Bednarik, 2013; Bednarik, 2013
A gradual transition between the MSA and the early LSA	McBrearty and Brooks, 2000; Ambrose, 2002; Wadley, 2005; Prendergast et al., 2007; Backwell et al., 2008; Mitchell, 2008; Beaumont and Bednarik, 2013
Early evidence of fishing	Stewart et al., 1991; Stewart, 1994; Yellen et al., 1995; Yellen, 1998; McBrearty and Brooks, 2000; Mitchell, 2002b; d'Errico et al., 2003
Comparative dating using components of the MSA assemblage	Tribolo, 2003; Phillipson, 2007a; Wadley, 2010; Coulson et al., 2011; McCall et al., 2011
Early ostrich egg shell beads	McBrearty and Brooks, 2000; Wadley, 2001; Beaumont and Bednarik, 2013; Bednarik, 2013; Miller and Willoughby, 2014
Use of ostrich egg shell for dating	Kokis et al., 1998; Robbins et al., 2010
MSA points functioning as spearheads	Donahue et al., 2004; Phillipson, 2007a, b
Early bone arrow points – use of poison and intentional marking of arrows	Robbins et al., 2012
Notable change in the use of non-locally acquired lithic raw material between the MSA and the LSA	Ambrose, 2002
Source provenancing of non-locally acquired lithic raw materials from the MSA assemblage	Nash et al., 2013
A benchmark for the beginning of the LSA	Klein, 2001

therefore contemporaneous (Cahen and Moeyersons, 1977). It then follows that if, for example, the vertical replotting of elements of reconstructed cores does not follow the order in which they were originally detached, the site stratigraphy has been disturbed. Likewise, widely vertically separated single refits herald potential disturbance. A few refits within a single excavation unit should not automatically be considered evidence of the undisturbed nature of a deposit.

A comprehensive study of the transitional LSA/MSA and MSA assemblages from WPS was conducted using the chaîne opératoire approach (by contributor SS). The study comprised lithic finds between 300 and 700 cm below surface, the designated depths for these periods (Robbins et al., 2000). An obvious starting point for the refitting phase of this investigation was the artefacts produced in silcrete and chert (see Coulson et al., 2011). These are very distinct, non-locally acquired raw materials. In the MSA deposits they account for approximately 4300 artefacts or 55% of the assemblage (Robbins et al., 2000), while comprising a smaller portion in the transitional LSA/MSA layer. In contrast to the remainder of the assemblage, which is primarily composed of locally available quartz and quartzite, the silcretes and cherts have distinctive hand specimen characteristics, which can be used to establish raw material groupings (e.g., grain size, degree of cementation, level of translucence, type of cortex, colour, and presence of rinds, patches or specks in other colours).

The non-quartz collection from these lower deposits was initially separated, cleaned, and labelled. All artefacts were further analysed irrespective of their placement in the stratigraphic sequence. This included all lithic specimens from the MSA and transitional LSA/MSA layers: manufacturing waste flakes, blanks, cores and tools. The artefacts were divided into raw material groups based on hand specimen characteristics. Colour was found to be a potentially misleading characteristic, as a number of artefacts displayed colour changes and/or patches of different colours. However, the variety and distinctiveness of the other characteristics of the silcretes and cherts meant that separating different cores and their associated debitage was relatively straightforward. The resultant groups and classification were first independently separated using archaeological characteristics (by contributor SS and confirmed by contributor SC), and then cross-checked by David Nash, a geomorphologist and silcrete expert (Nash et al., 2004; Nash and Ullyott, 2007; Nash, 2012).

The various raw materials could be divided into 11 groups. The majority of these could be further subdivided, based on like characteristics (see SOM Table S3). Two such subgroups consisted of silcrete with a matrix comprising patches of glassy, translucent cement, bridging two lithic raw materials but forming very distinct material groups. This made a simple distinction between cherts and silcretes, based on hand specimen characteristics alone, impractical. During the next stage of the archaeological chaîne opératoire analysis, the assemblage was submitted to a technological and refitting study. This confirmed and refined the type groups, by refits and by detailed technological similarities, such as distinct point production debris, and variations within discoid and Levallois core reduction strategies. This also indicated that artefacts classed in the various subgroups belonged to the same or closely related chaînes opératoires (see details for silcrete groupings Nash et al., 2013: Table 1).

It is beyond the scope of this paper to present the entire chaîne opératoire study of this site (see forthcoming Ph.D. by contributor SS). The present discussion is restricted to the results of a limited refitting study, in part initiated to determine the level of integrity of these deposits. For this purpose refitting efforts were specifically concentrated on two of the raw material sub-groups (SOM Table S3, groups 5 and 6a). These groups had readily recognizable diagnostic hand specimen characteristics, did not overlap or refit with other groups and were widespread throughout the examined deposits. The refitting study was not exhaustive, and was terminated when it became apparent substantial artefact admixture had occurred.

Results

Refitting analysis

The refitting demonstrates that there was substantial artefact movement throughout and between the early LSA/transitional MSA level and the MSA deposits. A total of 34 groups of refitted artefacts, comprising 88 pieces, provide evidence of vertical separation, the longest in excess of 1 m with corresponding horizontal disturbance

Table 2
Overview of dates from early LSA/transitional MSA and MSA deposits, White Paintings Shelter, Tsodilo Hills.

Lab number	Depth (cm)	Age (ka)	Reference
UGA03OSL-89	360	45.2 ± 12.6	Ivester et al., 2010
UCR 3364	390–400	33.9 ± 0.3	Robbins et al., 2000
UGA03OSL-95	415	54.2 ± 9.5	Ivester et al., 2010
WP91-450/U. Washington	450	55.43 ± 4.7	Feathers, 1997; Robbins et al., 2000
UGA03OSL-96	450	58.5 ± 12.2	Ivester et al., 2010
U. Botswana	500	66.4 ± 6.5	Robbins et al., 2000
UGA03OSL-98	510	61.2 ± 12.4	Ivester et al., 2010
U. Botswana	605	94.3 ± 9.4	Robbins et al., 2000

Table 3
Refits between separate excavation units at White Paintings Shelter, Tsodilo Hills. Vertical distances are given as a minimum–maximum extent as the site was excavated in 10 cm mechanical levels.

Refit group number	Type of refit	Number of pieces	Excavated square and depth (cm)	Vertical distance (cm) (min.–max.)	Raw material type	Raw material groups (see SOM Table S3)
1	Burning	2	W21 400–410 + W12 500–510	90–110	Chert	9a
2	Refit with core	9	W22 370–380 + W22 380–390 + W22 390–400 + W21 390–400 + W21 400–410 (×2) + W11/12 440–450 + W11/12 460–470 (×2)	80–100	Silcrete	6a
3	Refit and snap	3	W22 400–410 + W22 420–430 + W22 480–490	70–90	Silcrete	7g
4	Refit	2	W21 530–540 + W12 600–610	60–80	Silcrete	5
5	Burning	3	W21 510–520 (×2) + W23 570–580	50–70	Chert	6c
6	Snap	2	W22 410–420 + W23 460–470	40–60	Silcrete	7a
7	Refit with core	2	W21 370–380 + W20 410–420	30–50	Chert	3c
8	Refit	2	W21 400–410 + W11/12 440–450	30–50	Chert	6b
9	Snap	2	W21 480–490 + W12 520–530	30–50	Silcrete	7d
10	Snap	2	W21 420–430 + W11/12 460–470	30–50	Silcrete	7c
11	Refit	2	W12 570–580 + W12 600–610	20–40	Silcrete	8d
12	Snap	2	W21 440–450 + W22 470–480	20–40	Silcrete	1a
13	Snap	2	W23 440–450 + W11/12 470–480	20–40	Silcrete	1e
14	Burning MSA point	3	W23 440–450 (×2) + W23 470–480	20–40	Silcrete	9a
15	Refit	2	W21 510–520 + 'WPS 490+ Back Dirt'	20–30	Silcrete	1e
16	Burning	2	W11/12 460–470 + W12 480–490	10–30	Silcrete	9a
17	Burning	2	W12 520–530 + W12 540–550	10–30	Silcrete	8b
18	Refit with core	4	W12 530–540 (×2) + W12 550–560 (×2)	10–30	Chert	6b
19	Refit	3	W12 540–550 + W12 560–570 + W21 560–570	10–30	Silcrete	5
20	Snap	2	W12 540–550 + W23 560–570	10–30	Silcrete	7d
21	Lateral break	2	W12 550–560 + W12 570–580	10–30	Chert	6b
22	Refit	3	W12 560–570 + W12 570–580 + W12 580–590	10–30	Silcrete	5
23	Snap	2	W20 390–400 + W21 410–420	10–30	Chert	6b
24	Refit and breaks	4	W22 510–520 (×2) + W21 530–540 + 'WPS 490+ Back Dirt'	10–30	Silcrete	5
25	Burning	2	W23 480–490 + W21 500–510	10–30	Chert	9a
26	Snap	2	W11/12 410–420 + W23 420–430	10–20	Chert/Silcrete	1d
27	Recent break	2		0–20	Silcrete	1e
28	Refit MSA point	2	W21 510–520 + W23 510–520	0–20	Silcrete	5
29	Lateral break	2	W12 560–570 + W12 570–580	0–20	Quartzite	10
30	Snap	2	W12 560–570 + W21 570–580	0–20	Chert	3a
31	Snap	2	W22 380–390 + W22 390–400	0–20	Silcrete	1a
32	Centre break	4	W22 410–420 + W22 420–430 (×3)	0–20	Silcrete	7d
33	Centre break	4	W23 400–410 + W23 410–420 (×3)	0–20	Silcrete	1e
34	Recent break	2	W23 670–680 + W23 680–690	0–20	Silcrete	4b

Excavated squares designate a 1 m^2 area, and are prefaced by 'W' for the site name. 'W490+ Back Dirt' is presumed to refer to the back dirt of several squares from 490 cm below surface downwards.

between all six excavation units containing these deposits (Table 3). This movement was not restricted to some levels but was apparent throughout the lower 4 m of the site (Fig. 3). The refit groups and the further analysis also document a previously unreported high level of breakage and a surprising number of burnt fragments redistributed within this assemblage. The refits were not limited to separate excavation units: an additional 75 refit groups were found on lithic artefacts recovered from within single units. These refits reaffirm that the occurrence of this type of rejoining does not guarantee the undisturbed nature of a deposit.

The largest and most illustrative refit example is group #2 (Figs. 3 and 4 and Table 3). This light brown silcrete group (subgroup 6a in SOM Table S3) comprises an amorphous core and eight flakes and flake fragments. These artefacts form a knapping sequence and are therefore contemporaneous. Yet the vertical displacement of these artefacts is a minimum of 80 cm and a maximum of 100 cm with a horizontal spread over three separate 1 m^2 excavated squares. To determine whether only some of the artefacts or excavation units in this group were responsible for this widespread range of vertical displacement, the removals were re-plotted in two ways: (i) following the order of flake detachment from the core, and (ii) plotting the distance of the individual removals back to the core (see Table 4). Both of these re-plotted sequences illustrate the substantial amount of random upward and downward vertical movement of these artefacts.

The other 33 refit groups displaying vertical separation between excavation units contain two to four artefacts each (Table 3). Re-plotting these groups provides evidence that supports and expands the level and range of movement documented by group #2. It is important to note that a difficulty was encountered in replotting some of the refit sequences in Fig. 3. This is due to an apparent discrepancy in Robbins et al. (2000) regarding the first occurrence of the schist fall horizon (unit 9a). In the text this is reported to occur at 420 cm (Robbins et al., 2000, 2010). However, in the WPS stratigraphic cross-section illustration (Robbins et al., 2000: Fig. 5; and more recently Ivester et al., 2010: Fig. 6) this horizon is reported 20–30 cm higher up in square 22. Rather than alter the original diagram, the refits from this square were replotted strictly according to depth measurements (see Table 3).

Three refit sequences, groups #3, #6 and #14, cross the substantial schist rock fall (unit 9a) previously believed to prevent post-depositional mobility. Group #3 is made up of three pieces all recovered from excavation square 22 but separated vertically by 70–90 cm. Following the published depth measurements for these units (Robbins et al., 2000), one piece was retrieved in the transitional LSA/MSA deposit (unit 8b), the second from the upper MSA deposit under the first schist fall horizon (unit 9b), and the final fragment from within the lower MSA deposit (unit 10b). Group #6 is made up of two fragments separated by 40–60 cm. Depth measurements from the original publication (Robbins et al., 2000) place one piece in the transitional LSA/MSA deposits (unit 8b) and the other well within the upper MSA deposit (unit 9b). However, a recent re-analysis of the south profile of square 23 reported new depth measurements for those stratigraphic units (Ivester et al., 2010). According to this study, the initial fragment from group #6 remains unchanged but the second fragment from W23 460–470 is now well within or near the base of unit 9a. The third refit group, #14, is also from square 23. According to measurements by Robbins et al. (2000), these three refitted burnt fragments were located at the base of unit 9a (two pieces) and well into unit 9b (one piece). Based on the more recent results of Ivester et al. (2010) this group also transects the schist fall horizon of unit 9a. Two of the three refits would now be from unit 8b and the final fragment from unit 9b. In summary, regardless of which of the published depth measurements are used, these refit groups transect unit 9a, the divide between the MSA and the early LSA/transitional MSA periods at this site. The similar, lower schist fall horizon (unit 10a), believed to divide two MSA layers, was also penetrated by artefact movement (see Fig. 3).

Within the upper section of the deposits attributed to the MSA, the range of displacement previously demonstrated by group #2 is reflected by group #1 at 90–110 cm (Fig. 5) and group #3 and to a slightly lesser extent by groups #6, #7 (Fig. 5), #8 (Fig. 5) and #10 (Fig. 8). However, significant vertical displacement is not restricted to the upper limits of the MSA deposits, as is demonstrated by re-plotting groups #4 and #11 (Fig. 5). These are dorsal/ventral refits separated by 60–80 cm and 20–40 cm, respectively, and were recovered from deep within the MSA deposits (see Table 3). As these groups comprise only two to four pieces, many of which are snaps or burnt fragments, it is not possible to determine the direction of movement.

Evidence further demonstrating the amount of movement in the lower MSA deposits is offered by silcrete group 5 (SOM Table S3 and Fig. 6). This is one of the non-locally acquired raw material groups selected for concentrated refitting attention (Figs. 6 and 7 and SOM Table S4). There are only 81 artefacts in this group, including seven from units not in situ. The technological features of this group are consistent with MSA exploitation of a single imported block of raw material. This was cleaned, flakes were removed and an MSA point produced before the remaining core was removed elsewhere. This interpretation is supported by the five refit sequences from this group, which are spread over a maximum range of 100–110 cm and connect the excavation squares of the lower deposits (Figs. 3 and 7).

The distribution of this material forms a distinctive pattern (Fig. 7 and SOM Table S4). Squares 12 and 21 contain the largest number of artefacts, with 29 and 21 pieces, respectively. Both have concentrated areas with a vertical spread of 20–30 cm (Fig. 7, units in darker green). The high likelihood that these artefacts all belong to one knapping sequence indicate the contemporaneity of these concentrated areas. Both squares 12 and 21 have one to two pieces per 1 m^2 extending 20–30 cm deeper into the deposits. Above these areas there are also one to two pieces per 1 m^2 extending upwards for 40–70 cm (see Fig. 7). The battleship-shaped seriation curves formed by the distribution of this raw material group indicate gradual artefact dispersal upwards and downwards from an original concentration (SOM Table S4) (also see Rowlett and Robbins, 1982: Fig. 3 for a similar redistribution pattern). This raw material type is also represented in adjacent squares 22 and 23 (one piece refits to group #28). In square 22, eleven pieces are scattered between 130 and 140 cm and in square 23 eight specimens are spread between 340 and 350 cm, although the majority range only 130–140 cm.

During the refitting study, extensive artefact breakage was observed throughout the lower 4 m of deposits (see examples in Table 3). The breakage generally occurred on the weakest points of flakes, resulting in transverse or longitudinal snaps, but there were also numerous examples of fire-induced fractures. Refits on breaks and snaps also provided evidence of vertical movement of up to 70–90 cm (Table 3, group #3). Conversely, almost all 75 refits on artefacts from within the same excavation unit and level were made on breaks (see examples in Fig. 8). This phenomenon made the original size of all artefact types (e.g., blanks, cores and tools) difficult to determine. It also would have affected the artefact counts, and led to inaccurate artefact classifications. For example, after refitting many fragments previously classed as blades were determined to be sections of elongated flakes. All artefacts in Fig. 8, save the distal end of the flake on the far right, top row, were previously classed as separate ‘blades’.

A further surprising discovery was the level of burning and the number of refits possible within this category. Of the limited sample incorporated in the 34 refit groups, 17% (6) are burnt silcrete or chert (Table 3), based on characteristics such as heat fractures, crazing, incipient cracking, deterioration and colour change (e.g., Domański and Webb, 1992; Rowney and White, 1997; and more recently; Schmidt et al., 2013). However, due to the highly fractured nature of these artefacts, these percentages inflate the occurrence of burning in the assemblage. The only previous indication of burning in these levels at WPS was made by Murphy (1999), who reported evidence of fire-cracking (potlids) on the artefacts in the upper MSA deposits to be ‘very rare’ (>1%). The widespread distribution of these friable fragments reinforces the overall pattern of breakage within this assemblage.

In summary, the 34 groups of refits from the lower 4 m of the deposits of WPS indicate random patterns of vertical and horizontal artefact movement in all six excavation units. The longest vertical movement documented is 90–110 cm. The apparent clustering of refits found between depths of 370–600 cm corresponds to the larger numbers of artefacts retrieved from these levels (Fig. 3). Similarly, there are fewer refits in the uppermost and deepest units, where the overall artefact count is considerably lower (for detailed counts see Murphy, 1999; Robbins et al., 2000; Ivester et al., 2010). Regarding differences in types of refits (such as breakage or burning), no distribution pattern could be established.

Discussion

Possible causes of artefact movement

Several factors, acting independently or in conjunction, may be suggested as causes of artefact movement at WPS. These include: (i) excavation procedure, (ii) the slope of the lowest deposits, and (iii) post-depositional disturbance including various pedoturbative processes.

One factor that could account for apparent artefact ‘movement’ is a consequence of deep excavations. The use of excavation shoring was not reported at WPS, and some artefacts could therefore potentially have fallen from the exposed profiles. For example, a single diagnostic LSA microblade core was found in square 22 at 430–440 cm (SOM, Figure S1). This is well within the upper MSA deposit and below the schist rock fall horizon (unit 9a). Although this core is made from non-locally acquired raw material, it does not match any of the MSA material groups. Both of these features indicate the piece was dislodged from the upper deposits and accidentally included in the MSA assemblage. Furthermore, the chances of refitting such displaced pieces are small. If they occurred, finds resulting from this scenario would only account for a limited number of the refits composed of two artefacts; it cannot account for all 34 groups, particularly those with three or more artefacts.

Second, some vertically separate refits are attributable to the slope of the deposits draped over the talus cone in the lower levels

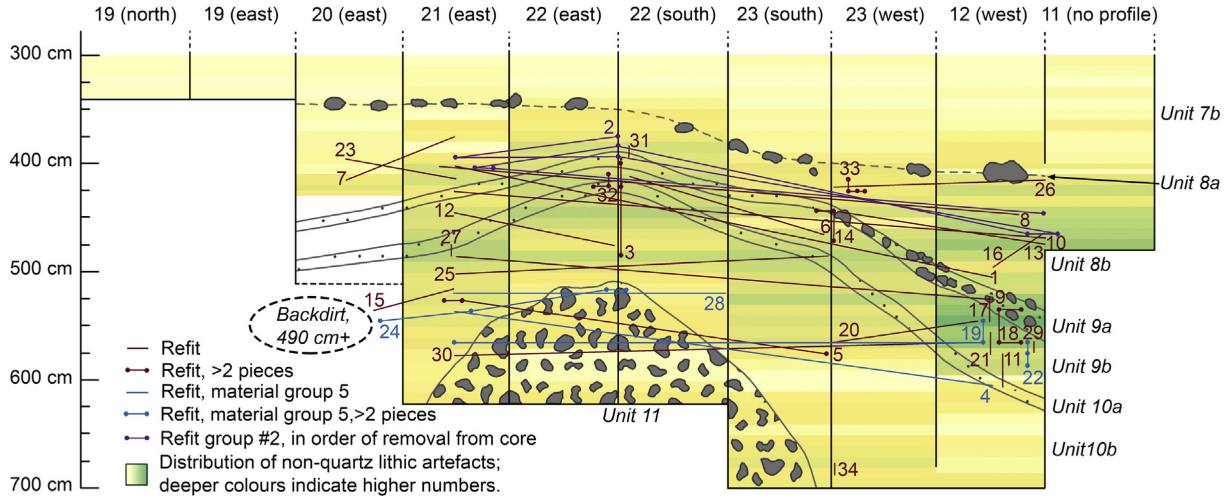

Figure 3. The 34 groups of the refits containing elements connecting separate excavation units at White Paintings Shelter, Tsodilo Hills. Note that the wraparound effect of this cross-section, adapted from Robbins et al. (2000: Figure 5, with permission from Elsevier), in some cases exaggerates the horizontal distance between refits. In compliance with standard conventions, refits were replotted in the centre of squares as much as possible while leaving separate lines distinguishable. Discrepancies regarding the placement of the archaeological layers in square 22 are discussed in the text. No finds were reported from the blank area of the profile below 420 cm in square 20 (Robbins et al., 2000).

of the excavation (see Fig. 3). However, attempts to determine the impact of the slope are, in part, limited by the site excavation strategy. Briefly, as noted, WPS was excavated in 1 m^2 and 10 cm horizontal spits. Artefacts were not individually piece-plotted, nor were they assigned to a host layer in the cases where one horizontal unit transected one or more archaeological layers. Archaeological layers were also consistently referred to and analysed as horizontal units: the early LSA/transitional MSA between 300 and 410/420 cm (units 7b and 8), and the MSA as between 410/420–700 cm (units 9–11) (Robbins et al., 2000). These measurements do not correspond to the profiles in the stratigraphic section drawing (Robbins et al., 2000; replicated without modification by Ivester et al., 2010). Consequently, the impact of the slope can only be discussed on a general level.

Sloping deposits normally result in downward artefact movement with slumping along the decline or in conjunction with clustering at the base of the slope (e.g., Rick, 1976). Unit 8b, containing the early LSA/transitional MSA, is a steeply sloping deposit reported to be 'draped over' unit 11 (Robbins et al., 2000). The largest refit group, #2, is confined to the lower half of unit 8b (see Fig. 3). This knapping sequence of a core and eight flakes has been replotted according to the reduction sequence and alternatively by tracing individual removals back to the core (see Table 4). All but one of these removals shows *upward* movement through the deposits to a maximum extent of 60–80 cm. As seen in Fig. 3, a number of refits also indicate movement against the slope, others traverse the different layers affected by it.

A third potential cause of artefact movement at WPS is post-depositional disturbance. The impact of post-depositional disturbance and redistribution of artefacts buried in Kalahari sands was documented by Cahen and Moeyersons (1977), when refitting demonstrated that in these deposits there was a distinct likelihood of post-sedimentary differential movement of artefacts in a sediment sequence. Consequently, dates obtained from these deposits would have no direct relation to the archaeological material. A study of the typological and quantitative distribution of artefacts according to depth within these deposits may appear to suggest different prehistoric industries, and occupation layers could become mixed, making it difficult to determine if one or more industries were present (Cahen and Moeyersons, 1977). Numerous studies have since increased our knowledge of sub-surface redistribution processes (e.g., Moeyersons, 1978; Wood and Johnson, 1978; Rowlett and Robbins, 1982; Schiffer, 1983; Villa and Courtin, 1983; Erlandson, 1984; Gifford-Gonzalez et al., 1985; Hofman, 1986; Bocek, 1986, 1992; McBrearty, 1990; Johnson, 2002; Araujo and Marcelino, 2003; Araujo, 2013; Bueno et al., 2013), specifically with regard to the role refitting can play in determining disturbance (to name but a few: Hofman, 1981, 1992; Villa, 1982; Cahen, 1987; Bergman et al., 1990; Bollong, 1994; Morrow, 1996; Roebroeks et al., 1997; Close, 2000; Hovers, 2003).

Both biogenic activity (e.g., termites or burrowing fauna) and differential stresses in the aeolian soil column due to consolidation can lead to upward and downward movement of artefacts. According to Cahen and Moeyersons (1977), alternate wetting and drying of sediments will cause vertical descent of artefacts into the soil (see Robbins et al., 2000; Ivester et al., 2010 on increased wet and dry episodes during the MSA at WPS). Trampling and 'settlement traffic' in sandy deposits also warrants consideration. These processes contribute to differential movement, and, of particular relevance to the present study, are common causes of artefact fragmentation (e.g., Stockton, 1973; Tringham et al., 1974; Villa, 1982; Villa and Courtin, 1983; Pryor, 1988; Nielsen, 1991; McBrearty et al., 1998; Eren et al., 2010; Pargeter, 2011). In addition to trampling, other human actions such as the digging of holes in later periods could potentially affect artefact movement. This would presumably result in severe displacement in some areas of the site, while others remained intact. The distribution of refits and of raw material group 5 (see above) is, however, more symptomatic of generalized vertical artefact movement. Admittedly, the low resolution in documentation of artefact placement could prevent the identification of such highly disturbed areas. Experiments also indicate that stone artefacts in reconsolidating deposits do not necessarily accompany the movement of the sediment (e.g., Moeyersons, 1978; Rowlett and Robbins, 1982; Hofman, 1986; Bueno et al., 2013); they undergo differential movement during this process that can occur without leaving detectable traces in the soil (Harris, 1979). As stated by Villa (1982: 287) "layers and soil should be considered as fluid, deformable bodies … through which archaeological items float, sink, or glide".

Several factors may have caused artefact movement in the lower levels of WPS. The combination of wetting and drying of the deposits and trampling could account for the extensive artefact

Figure 4. Three views of the refitted core and eight flakes and flake fragments from White Paintings Shelter, Tsodilo Hills (see Table 3, group 2). The vertical displacement of these artefacts is a minimum of 80 cm and a maximum of 100 cm with a horizontal spread of over three separate 1 m^2 excavated squares. Photograph by Sigrid Staurset.

breakage. The sloped deposits potentially explain vertical distribution within archaeological layers. The impact of this feature could have been better understood given higher resolution documentation of artefact distribution during excavation. However, the slope does not explain refits between layers, nor refits indicating movement opposite to the slope. These features are likely caused by post-depositional factors such as biogenic activity or other pedoturbative processes.

Implications for the dating of White Paintings Shelter

A number of the refit groups contain artefacts from host deposits overlapping two or more dates (see Tables 2 and 3 and Fig. 3). For example, refit group #3 is composed of three flake fragments that were recovered in square 22 from depths of 400–410 cm, 420–430 cm and 480–490 cm below surface. The distribution of this group alone encompasses the sediments for three of the new OSL dates: 54.2 ± 9.5, 58.5 ± 12.2 and 61.2 ± 12.4 ka (Table 2). Refit groups #6 and #14 are also composed of elements retrieved from sediments dated to both 54.2 ± 9.5 and 58.5 ± 12.2 ka. Other examples from deeper in the deposits are refit groups #9, #12, #20 and #25. These are composed of elements retrieved from sediments dated to both 58.5 ± 12.2 and 61.2 ± 12.4 ka. A final example, group #4 (Table 3 and Figs. 5 and 6), comprises two artefacts. One is from a depth of 530–540 cm where the closest date is 61.2 ± 12.4 ka taken at 510 cm. However, the piece refits to an artefact from 600 to 610 cm recovered from the range of date 94.3 ± 9.4 ka taken at 605 cm.

The refitting study demonstrates that artefacts have undergone substantial differential movement within and between the lower deposits of WPS. Subsequently, the dated chronological sequence of the sediment column can have no direct relation to the archaeological material. Likewise, the palaeoenvironmental links to the wider region established by Ivester et al. (2010) cannot be directly connected to the archaeological assemblage or occupational periods. The generally consistent datings of the lower WPS deposits and their clear correspondence to the palaeoclimate sequence of the Kalahari (Ivester et al., 2010) indicate that the sediment column may be less disturbed than the artefact assemblage recovered from it. Regarding the upper levels, a similar scenario could potentially explain the previously documented post-depositional movement of artefacts and the earlier anomalous dates (also see suggestion by Kokis et al., 1998 of stratigraphic mixing in these levels). As the current study did not include materials from these strata, no conclusions can be drawn here.

Implications for the provenancing of silcrete at White Paintings Shelter

Silcrete, a non-locally acquired raw material central to this study, was also the focus of a recent geochemical fingerprinting investigation to determine possible sources of its origin (Nash et al., 2013). The silcretes from the 3 m of MSA deposits at WPS were used as a case study for a new trace element provenancing approach, where analysis was conducted on a sample of 14 archaeological flakes and flake fragments (Nash et al., 2013). To ensure

Table 4
Refit group #2: a core, flakes and flake fragments recovered from various excavation units and levels at White Paintings Shelter, Tsodilo Hills. Two alternative re-plotted distribution patterns are presented.

Refit order	Artefact description	Excavation unit	Vertical distance (cm) between refits in order of removal	Vertical distance (cm) between refits from the core
1	Amorphous core	W11/12 440–450	Core	Core
2	Flake	W21 400–410	30–50 (upward)	30–50 (upward)
3	Hinged flake	W21 400–410	30–50 (upward)	30–50 (upward)
4	Flake fragment	W22 380–390	10–30 (upward)	50–70 (upward)
5	Hinged flake	W11/12 460–470	70–90 (downward)	10–30 (downward)
6	Hinged flake	W11/12 460–470	As listed for #5	
7	Flake (proximal end of #6)	W22 390–400	60–80 (upward)	40–60 (upward)
8	Flake (distal end of #5)	W21 390–400	As listed for #7	
9	Hinged flake	W22 370–380	10–30 (upward)	60–80 (upward)

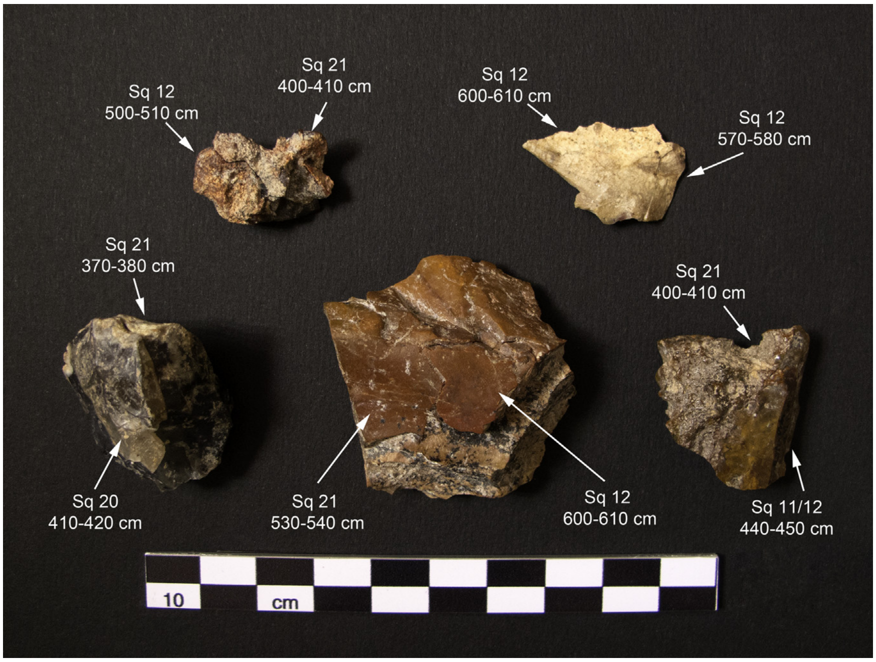

Figure 5. Selection of refit groups in a range of silcretes and cherts illustrating artefact movement at White Paintings Shelter, Tsodilo Hills. Additional information for each group can be found in Table 3. Upper row, from left: groups 1 and 11; bottom row: groups 7, 4 and 8. Photograph by Sigrid Staurset.

representativity while sampling, two factors were considered: (i) the full range of types of silcrete present in the archaeological materials (Nash et al., 2013: Table 1, also see expanded version, this article SOM Table S3), and (ii) their horizontal and vertical distribution in the MSA layers (Nash et al., 2013: Fig. 2, reproduced in this article as Fig. 2). The surprising outcome of the analysis was that these raw materials were transported from distant sources. Five of the waste flakes were found to match statistically the geochemical signature of silcretes from Lake Ngami and five with samples from the Boteti River (see Fig. 1). The Lake Ngami localities are a

Figure 6. Selection of refits from raw material group 5, a non-locally acquired silcrete, White Paintings Shelter, Tsodilo Hills (also see SOM Tables S3 and S4). Top row from left: refit group #22; refitted break, both pieces from W21 520–530. Bottom row: refit group #28 (Middle Stone Age point); refit group #19; refit group # 4 (also illustrated in Fig. 5). Photograph by Sigrid Staurset.

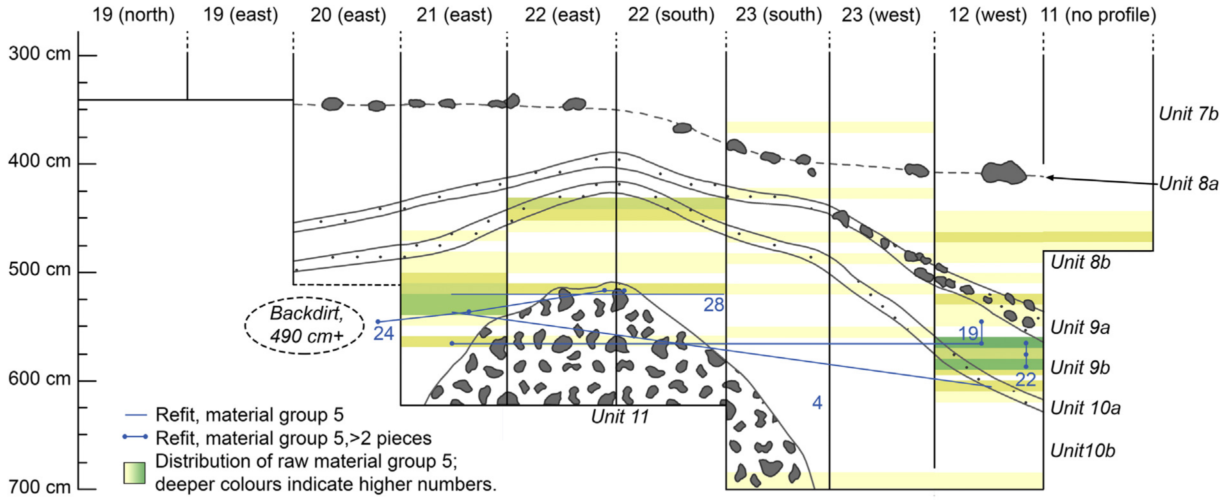

Figure 7. Distribution of, and refits within, raw material group 5, a non-locally acquired silcrete, White Paintings Shelter, Tsodilo Hills (also see SOM Tables S3 and S4). Adapted from Robbins et al. (2000: Figure 5), with permission from Elsevier. Note the corresponding artefact concentrations in Fig. 3.

minimum of 220 km from Tsodilo Hills and those along the Boteti River are up to 295 km away (Nash et al., 2013). The flakes from these localities represent six of the seven main silcrete type groups used in tool manufacture at WPS. The remaining four flakes come from as yet unidentified sources (Nash et al., 2013). MSA artefacts were recovered in silcrete quarry localities much closer to the Tsodilo Hills, indicating that these locations were being used during this period. This suggests that the acquisition of silcrete from south of the Okavango Delta rather than from closer sources was a deliberate choice.

As illustrated in Fig. 2, the samples sourced to Lake Ngami and the Boteti River are interspersed throughout the 3 m of MSA deposit. This could indicate that the transport of raw materials from such distant sites represents a *repeated* procurement strategy for resource acquisition during the MSA. It was earlier believed that the MSA deposits reflected a time span of at least 50,000 years

Figure 8. Selection of refits in a range of silcretes and cherts illustrating transverse breakage of elongated flakes at White Paintings Shelter, Tsodilo Hills. These include both refits from the same excavation unit and level and ones that are separated by between 10 and 50 cm. Additional information for refit groups can be found in Table 3. Top row from left: W23 420–430 (both pieces); refit group #31; W11/12 440–450 (both pieces); refit group #26; W22 370–380 (both pieces). Bottom row from left: refit group #23; W12 570–580 (both pieces); W23 440–450 (both pieces); refit group #10. Photograph by Sigrid Staurset.

revealing ‘a very long period of MSA occupation’ (Ivester et al., 2010; Robbins and Murphy, 2011), or long-term re-occupation by small groups of people (Robbins and Murphy, 1998). It has also been suggested that during the MSA Tsodilo Hills were part of an aggregation area for fairly large groups of people, with use occurring on a seasonal basis (Robbins and Murphy, 1998).

The present findings raise no arguments against the long-distance procurement of lithic raw material during the MSA at WPS. The intermixing of the strata does, however, diffuse occupations, which at this stage are not possible to separate clearly. As there are a limited range of raw material groups present (see SOM Table S3) and relatively few chaînes opératoires, it is probable that lithic raw materials were transported to WPS from Lake Ngami and the Boteti River on a limited number of occasions during the MSA. Both these factors indicate that WPS was used less frequently and for briefer periods during the MSA. While the relative and absolute timing of these occurrences is still ambiguous, the previously suggested scenario of 50,000 years of MSA occupation (Ivester et al., 2010; Robbins and Murphy, 2011) appears unlikely.

Archaeological implications

The present results call into question a number of earlier reported observations and interpretations, regarding both the cultural designation, interpretation and dating of the site. The MSA lithic artefacts at WPS have moved substantially within the lower 4 m of deposit. They have moved through layers of schist rock fall believed to separate undisturbed strata, both within the MSA and between the MSA and the ‘transitional’ assemblage to the LSA. The number of refits and artefact distance casts doubt on the separation of these two cultural periods. As observed by Cahen and Moeyersons (1977), post-depositional movement can lead to a mixing of the originally superposed occupation layers and results in the inability to decide if one or more industries are present. The reasons why the ‘Large Blade’ 300–410/420 cm assemblage was considered transitional between the MSA and LSA were largely based on the local sequence. These included: (i) the use of blade technology in both the ‘transitional’ and LSA layers; (ii) the co-occurrence of prepared ‘tortoise’ core and blade technology; (iii) that microblades were recovered in both layers; and (iv) the gradual appearance of MSA points, below the transitional layer (Murphy, 1999; Robbins et al., 2000; Robbins and Murphy, 2011).

Central to all of these points is the co-occurrence of artefacts/technology characteristic of the two periods in question. The refitting indicates that this co-occurrence is caused by gradual displacement of artefacts, not gradual technological change; there is no evidence of an on-site transition from Middle to Later Stone Age cultures (contrary to Robbins et al., 2000; Ivester et al., 2010). More likely, the deepest deposits at White Paintings Shelter are the result of intermingled MSA occupations, topped by a mixed zone containing both MSA and LSA artefacts (also see Ivester et al., 2010 regarding possible mixing of differently aged grains in the upper layers). The admixture may also explain the difficulty in establishing a chronological series of datings (Robbins et al., 2000; Ivester et al., 2010). The relationship between WPS and the MSA in a wider geographic context is similarly rendered ambiguous.

The disturbed deposit also casts doubt on the evidence for early fish consumption (Robbins et al., 2000). Based on the occurrence of some fish bones found in levels below 420 cm, fish were reportedly eaten occasionally during the MSA (Robbins et al., 1994). Fish bones were most frequent in the ‘Upper Fish’ deposits (80/90–130 cm) and between 210 and 280 cm in the ‘Lower Fish’ layers (Robbins et al., 2000). The admixture evident in the lower layers opens the possibility that the fish bones could have percolated down from the LSA levels, well within the established range of vertical disturbance.

Conclusion

The MSA is still poorly documented in large regions; there is a distinct need for reliable chronologies. The nature of the transition to the LSA is a tantalizing area of study where many questions are still left unanswered. The excavations at WPS provided us with invaluable data that will surely be the focus for future investigations into these topics. However, the site can also serve as an example of the value of using refitting to test the stratigraphic integrity of an archaeological sequence before interpretations are made. The presence of apparently undisturbed strata and a chronological dated sequence is no guarantee against artefact movement. If refitting, even at a limited level, is included at an early stage of investigation, later stages of analysis and interpretation may rest on more solid ground. These conclusions should not be surprising, as numerous studies have yielded similar results (e.g., Cahen et al., 1979; Cahen and Keeley, 1980; Hofman, 1981, 1992; Barton and Bergman, 1982; Villa, 1982; Cahen, 1987; Bergman et al., 1990; Richardson, 1992; Bollong, 1994; Kroll, 1994; Morrow, 1996; Audouze and Enloe, 1997; Roebroeks et al., 1997; Close, 2000; Rees, 2000; Bordes, 2003; Enloe, 2004; Henry et al., 2004; Morin et al., 2005; Surovell et al., 2005; Brantingham et al., 2007; López-Ortega et al., 2011) although such investigations have not been common in southern Africa. White Paintings Shelter is not unique: it is one of a great many sub-Saharan sites with deep, aeolian deposits. It is unusual only in the sense that refitting has been used to assess post-depositional movement. Future research will be needed to determine whether the level of disturbance at WPS is also present at other MSA sites.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jhevol.2014.04.006.

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