Afromontane foragers of the Late Pleistocene: Site formation, chronology and occupational pulsing at Melikane Rockshelter, Lesotho

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A B S T R A C T

This paper provides a preliminary chronostratigraphic and palaeoenvironmental framework for the Late Pleistocene archaeological sequence at Melikane Rockshelter in mountainous eastern Lesotho. Renewed excavations at Melikane form part of a larger project investigating marginal landscape use by Late Pleistocene foragers in southern Africa. Geoarchaeological work undertaken at the site supports in-field observations that Melikane experienced regular, often intensive, input of groundwater via fissures in the shelter’s rear wall. This strong hydrogeological connection resulted in episodic disturbances of the sedimentary sequence, exacerbated by other processes such as bioturbation. Despite this taphonomic complexity, a robust chronology for Melikane has been developed, based on tightly cross-correlated accelerator mass spectrometry (AMS) 14C with acid-base-wet oxidation stepped-combustion (ABOx-SC) pretreatment and single-grain optically stimulated luminescence (OSL) dating. The results show that human occupation of Melikane was strongly pulsed, with episodes of Late Pleistocene occupation at ~80, ~60, ~50, ~46–38 and ~24 ka. At least three additional occupational pulses occurred in the Holocene at ~9 ka, ~3 ka and in the second millennium AD, but these are dealt with only briefly in this paper. Implications of the Late Pleistocene pulsing for the colonisation of high elevations by early modern humans in Africa ahead of dispersals into challenging landscapes beyond the continent are discussed.

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1. Introduction

Research on Late Pleistocene Africans is broadening in scope from an emphasis on modern human cognitive origins to more comprehensive reconstructions of human lifeways. Recent calls to abandon behavioural modernity as an unhelpful concept emphasise its analytical imprecision and the mounting evidence that even the ‘smoking gun’ of modern human behaviour — extrasomatic symbolic storage — can transcend biological boundaries (e.g. McBrearty and Brooks, 2000; Deacon and Wurz, 2001; Barham, 2002, 2007; Gamble, 2007; McBrearty, 2007; Zilhão, 2007; Zilhão et al., 2010; Shea, 2011). The search is made more elusive by the global rarity of artefacts with unambiguous symbolic content before the burst of decoration and artwork in cold Upper Palaeolithic Eurasia (Wobst, 1990; Henshilwood and Marean, 2003). As a more productive alternative, Shea (2011) promotes investigating human behavioural variability and the adaptive strategies that underpinned it.

In Late Pleistocene Africa, as elsewhere in the Palaeolithic world, one of the most prominent sources of human variability was the continent’s great ecological diversity (Barham and Mitchell, 2008). This is particularly high in southern Africa, a region that has produced some of the most intriguing glimpses of Middle Stone Age (MSA) symbolic expression and technological complexity (d’Errico et al., 2001, 2005, 2008; Henshilwood et al., 2001a, 2002, 2009; Parkington et al., 2005; Lombard, 2005a, 2009, 2011; Marean et al., 2007; Backwell et al., 2008; Jacobs et al., 2008a; Mackay and Welz, 2008; Brown et al., 2009; Jacobs and Roberts, 2009; Villa et al., 2009, 2010; Wadley et al., 2009; Jerardino and Marean, 2010; Lombard and Phillipson, 2010; Lombard et al., 2010; Texier et al., 2010). Partitioned by eleven terrestrial biomes

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that fluctuated dramatically through the Late Pleistocene, the subcontinent’s complex biogeography would have demanded a great deal of adaptive flexibility from MSA and early Later Stone Age (LSA) populations.

However, despite this variability, most research on Late Pleistocene lifeways in southern Africa has focused on a single ecozone: the Fynbos Biome of the southern and western Cape coasts. One of only two biomes endemic to South Africa, this highly idiosyncratic environment is characterised by tremendous biodiversity (Cowling, 1992; Cowling and Proches, 2005). Further, a combination of ocean current upwelling and coastal geomorphology make southern Africa’s shorelines some of the most productive in the world (Branch et al., 1992), and there is abundant evidence that MSA populations made good use of them (e.g. Inskeep, 1972; Volman, 1978; Schweitzer, 1979; Brink and Deacon, 1982; Singer and Wymer, 1982; Thackeray, 1988; Deacon, 1989, 1995; Klein et al., 1999, 2004; Henshwood et al., 2001b; Parkington, 2003, 2006, 2010; von den Driesch, 2004; Marean et al., 2007; Avery et al., 2008; Jerardino and Marean, 2010; Marean, 2010, 2011; Sealy and Galimberti, 2011). The resource productivity and stability provided by Cape ecology almost certainly influenced Pleistocene forager groups who exploited them, from demographic processes to diet. Melitonic organisation (Deacon, 1989; Parkington, 2010; Marean, 2011). Models of MSA lifeways derived from sites in the Cape are, therefore, unlikely to be appropriate for reconstructing Pleistocene human adaptations in other locales (Mitchell, 2008).

Fortunately, intensified research at a number of deep sequences outside the Cape is beginning to fill out the picture (e.g. Wadley, 1996, 1997, 2001, 2004a, 2006, 2007; Clark, 1997a,b, 1999; Robbins et al., 2000a,b; Grün and Beaumont, 2001; Bird et al., 2003; Mohapi, 2007; Soriano et al., 2007; Backwell et al., 2008; Jacobs and Roberts, 2008; Wadley and Mohapi, 2008; Jacobs et al., 2008a,b; Lombard and Phillipson, 2010; Lombard et al., 2010; Vogelsang et al., 2010). This paper continues in this vein by exploring Late Pleistocene human adaptations to southern African environments with substantially lower ecological productivity and predictability than that afforded in the Cape coastal forelands, or what Gamble (1993) has termed ‘hard habitats’. These efforts form the core of a project entitled, Adaptations to Marginal Environments in the Middle Stone Age (or AMEMSA), which targets two regions with very different ecological resource structures: the inland, high-altitude grasslands of eastern Lesotho and the coastal desert of Namaqualand in South Africa’s Northern Cape Province. In both regions, research involves performing targeted excavations of rockshelters with deep Upper Pleistocene archaeological sequences. Attempts are underway to reconstruct landscape use by Late Pleistocene foragers by integrating archaeological and palaeoenvironmental data from these excavated sequences with data from the open-air lithic scatters (Lesotho and Namaqualand) and shell middens (Namaqualand) that abound in the surrounding areas. This paper deals exclusively with the Lesotho component of the project; preliminary results from Namaqualand are presented in Dewar and Stewart (this volume).

The Lesotho component centres on re-excavations at the large sandstone rockshelters of Melikane and Sehonghong. Both sites were initially excavated in the early 1970s by Patrick Carter (1976, 1978; Carter and Vogel, 1974; Carter et al., 1988) as part of his pioneering archaeological reconnaissance of Lesotho. Sehonghong’s LSA levels were revisited by Peter Mitchell (1993, 1994, 1995, 1996a,b,c; Mitchell and Vogel, 1994; Mitchell and Plug, 2008; Plug and Mitchell 2008). Melikane, by contrast, received only cursory treatment in Carter’s (1978) doctoral work and in few publications since. These sites are particularly valuable because substantial portions of their MSA sequences sit stratigraphically above the Howiesons Poort (HP) and include rare MSA/LSA transitional industries. They thus offer excellent opportunities to explore the trajectory of change from the widespread burst of innovation seen in the HP, through the heterogeneous assemblages of Marine Isotope Stage (MIS) 3, to the first full-blown microlithic industries of early MIS 2. Their inland, high-altitude setting offers much scope for drawing interesting comparisons with sites in more equitable environments to explore MSA adaptive diversity. This has important implications both for southern African and global prehistory because these sequences span the period when modern humans dispersed from Africa to successfully colonise a range of similarly difficult environments, from Papua New Guinea’s highlands (Fairbairn et al., 2006; Summerhayes et al., 2010) to Borneo’s rainforests (Barker et al., 2007) to Australia’s deserts (O’Connell and Allen, 2004). Investigations in highland Lesotho may thus help resolve when and how our species developed the adaptive plasticity (cf. Barker et al., 2007) necessary to inhabit such ecosystems.

This paper establishes a chronostratigraphic framework for Melikane by presenting the preliminary results of radiometric dating programmes and a suite of geochronological analyses. The radiometric results include cross-correlated accelerator mass spectrometry (AMS) $^{14}C$ and single-grain optically stimulated luminescence (OSL) ages. By employing rigorous laboratory protocols, including OSL measurements of individual quartz grains (Jacobs et al., 2006a,b) and acid-base-wet oxidation stepped-combustion (ABOX-SC) pretreatment for $^{14}C$ samples in excess of ~25 ka (Bird et al., 1999; Brock et al., 2010), a robust preliminary chronology for Melikane is constructed despite taphonomic obstacles. A multi-parameter geoarchaeological approach is employed using sedimentological, geochemical, mineral magnetic and micromorphological analyses. The use of such an approach affords a deeper understanding of the often complex, polygenetic syn- and post-depositional processes that have acted to form the site stratigraphy. Integrating these geoarchaeological techniques provides a powerful tool with which to interrogate the Melikane sequence and reconstruct Late Pleistocene environmental and behavioural processes, well illustrated with recent work at other southern African rockshelters (Goldberg, 2000; Goldberg et al., 2009; Karkanas and Goldberg, 2010).

2. Geographic, climatic and ecological context

Melikane Rockshelter (29° 57’S; 28° 44’ E) is located in the Qacha’s Nek District of eastern Lesotho (Fig. 1). The shelter faces northeast and is situated on the south side of the east-west flowing Melikane River, ~70 m above the valley floor at an elevation of 1860 m a.s.l. (Fig. 2). The Melikane River is a tributary of the Senqu (Orange), which drains the western side of the uKhahlamba-Drakensberg escarpment, and the rockshelter is situated ~4.5 km upstream from the Senqu/Melikane confluence. Highland Lesotho is a mountainous plateau bounded on all sides by prominent scarpas except for an opening to the southwest through which flows the Senqu River (Moore and Blenkinsop, 2006). The highest peaks (>3000 m) are concentrated along the plateau immediately behind the uKhahlamba-Drakensberg escarpment, which forms the border with KwaZulu-Natal, South Africa. At 3482 m, Thabana Ntlenyana near the Sani Pass is Africa’s highest summit south of Mount Kilimanjaro (Tanzania). The mountain ranges to the west of the uKhahlamba-Drakensberg escarpment (i.e. entirely within Lesotho) are termed the Maloti.

The Drakensberg-Maloti mountain complex is composed of massive (~1400 m thick) amygdaoidal flood basalts of Lower Jurassic age above ~1800 m a.s.l. capping a series of Karoo sediments — the Beaufort and Stormberg Groups (Duncan and Marsh, 2006; Schlüter, 2006). The latter consists of three stratigraphic strata: the Molteno, Elliot and Clarens Formations (Schlüter, 2006). The Clarens Formation (or Cave Sandstones) directly underlies the

(Rutherford and Westfall, 1994)
Fig. 1. Map of Lesotho with locations of Melikane and Sehonghong Rockshelters.

Fig. 2. Melikane: a north-facing rockshelter situated ~70 m above the Melikane River.
basalts and outcrop as cliffs up to 150 m high within which hundreds of rockshelters and overhangs, including Melikane and Sehonghong, have formed due to the differential erosion of inter-stratified sandstone and marl beds (Visser, 1989; Donahue and Adovasio, 1990). Intense fluvial erosion and cryo-clastic processes have created the rugged, heavily dissected and deeply incised topography so characteristic of the Lesotho Highlands.

Lesotho lies in southern Africa's summer rainfall zone, receiving over 75% of its rainfall between October and March. The highlands experience cool to warm summers with daily thunderstorms and cold, dry winters often with frost. Rainfall and temperatures vary tremendously with altitude and locality. In general, precipitation in Lesotho decreases from north to south and from east to west because of the pronounced orographic rain-shadow cast by the uKhahlamba-Drakensberg escarpment. Thus while estimates of mean annual precipitation for the escarpment typically exceed 1500 mm (Killick, 1963; Schulze, 1979; but see Nel and Sumner, 2008), a mean of only 578 mm has been recorded for Sehonghong, which is 24 km north of Melikane and at a similar altitude (~1870 m) (Bawden and Carroll, 1968). Rainfall in the highlands can also vary substantially year to year (Jacot Guerrinom, 1971). Snow can fall anytime of year, but especially between May and September after which it may persist on southern slopes for up to six months. Frost occurs ~150 days a year (Harper, 1969; Grab, 1997).

Temperature data are less precise, but again there are strong correlations with altitude. The Senqu River Valley and its tributaries are substantially warmer than the alpine zone, with mean annual temperatures of ~13 °C (Mucina and Rutherford, 2006) in contrast to ~6 °C for the latter (Grab, 1997). The valleys can have marked temperature inversions (Puggle, 1971; Mitchell, 1992), however, and diurnal temperature fluctuations are acute (van Zinderen Bakker and Werger, 1974). Vegetation in highland Lesotho is also strongly differentiated by altitude. Mucina and Rutherford (2006) distinguish three main units: Senqu Montane Shrubland (~1600 to 1900 m), Lesotho Highland Basalt Grassland (~1900 to 2900 m) and Drakensberg Afroalpine Heathland (~2900 m).

3. Melikane Rockshelter: previous research, geomorphological setting and archaeological context

3.1. Previous research

Carter (1976, 1978; Carter and Vogel, 1974) originally excavated Melikane in 1974, extracting a total of 36 m³ of deposit from a trench 12 m² in area. Bedrock was reached at a depth of ~2.6 m. He excavated in arbitrary 10 cm spits, crosscutting the site's natural stratigraphy and amalgamating distinct depositional events. Seven broad stratigraphic units were distinguished, which Carter designated, from surface to bedrock, Layers 1–7. Although never fully analysed, Melikane's rich MSA lithic assemblage was drawn upon by Carter (1978) to augment his interpretations of assemblages from other sites, with particular importance given to the conspicuous HP industry encountered in his Layer 6. A suite of 12 charcoal samples used for conventional 14C dating from Carter's 1974 excavation resulted in ages ranging from the late Holocene (1440 ± 40 BP) to mid-MIS 3 (~42.3 ka) (Carter, 1978; Vogel et al., 1986), though the earliest ages were recognised as infinite. Carter's ages demonstrated that the bulk of Melikane's deposits date to the Late Pleistocene, with ages of ~20 ka obtained only 60 cm from the surface.

3.2. Introduction to the sedimentary sequence

The layers comprising Melikane's ~2.6 m stratigraphic sequence exhibit striking contrasts in colour and composition. This heterogeneity appears to be chiefly governed by marked variations in both the geomorphological mechanisms that delivered sediment to the rockshelter and the intensity of human activity within it. Of particular note is the contrast between very coarse units containing tabular sandstone, and fine-grained, charcoal-rich silt and clay layers. Many of the physical characteristics of the sedimentary sequence are diagnostic of chemical and physical modification. The sediments are commonly mottled with diffuse interfaces often recorded between adjacent lithological units. This is consistent with the presence of two fissures in the rear shelter wall that currently allow water ingress during peak precipitation events (Fig. 3). Melikane Rockshelter is thus connected to a very active hydrogeological system. Groundwater percolating through the sediments can dissolve highly mobile minerals such as calcium carbonate (CaCO₃). These diagenetic processes can often dominate in cave or rockshelter environments, causing the blurring of interfaces and the loss, or partial loss, of elements of the stratigraphy (e.g. dissolution of CaCO₃-rich ash). Also consistent with the periodic ingress of water is the presence in the stratigraphic sequence of rounded to sub-rounded gravels. The plateau area immediately above the shelter may have served as a source of much of this coarse, allogenic material, which was sporadically delivered to the site through the larger of the two fissures at the rear of the shelter (Fig. 3).

Individual stratigraphic contexts observed at Melikane can be differentiated into 30 layers (Fig. 4). All of these layers contain cultural material, analyses of which are in progress. The lowermost layers (30–27) contain very large blade and flake industries made predominantly on hornfels and dolerite. These earliest assemblages appear broadly similar to MSA 2a (Volman, 1984) forms at Klasies River (Singer and Wymer, 1982; Wurz, 2002) and other sites. Layer 26 witnesses a major shift in lithic raw materials from coarse- to fine-grained cryptocrystalline silicates (CCS, locally known as opalines), which dominate all overlying (MSA and LSA) assemblages. Layers 25–22 contain HP industries in which, unlike many other HP occurrences in southern Africa, bladelets overwhelmingly dominate and backed segments are rare. Unretouched and unifacial points increase markedly in Layers 21 and 20, probably signalling a late MSA-like industry broadly similar to that at Shibudu Cave in KwaZulu-Natal (Wadley and Jacobs, 2004, 2006). Blades and bladelets again dominate in Layers 19–11, with rarer occurrences of Levvallois flakes and points and various scrapers. In the upper MSA levels (Layers 10–6) the lithics are extremely informal; flakes, chunky debris (shatter) and irregular cores dominate over other forms, with rare blades and bladelets also present. Layers 5–3 contain extremely informal lithic industries with abundant bipolar cores and pièces esquillées that are likely transitional between the MSA and LSA. The lower spits of Layer 2 contain abundant micro-liths that may represent a terminal Pleistocene Robberg occurrence. Finally, the uppermost layers (upper 2, and 1) contain an informal post-Classic Wilton stone tool industry consisting of a variety of scraper forms and notched pieces, well-preserved bone food remains, ostrich eggshell beads, pottery, ochre fragments, rare grindstones and, in Layer 1, historic artefacts.

4. Materials and methods

4.1. Excavation

Carter's trench at Melikane was re-opened in 2007, and a suite of OSL samples was taken to improve and extend the site's chronology (Jacobs and Roberts, 2008; Jacobs et al., 2008a). Encouraged by the results (discussed below), re-excavation at Melikane was initiated the following year using a single context recording system and a multi-disciplinary approach. The new 2 × 3 m excavation was positioned 1 m east of Carter's trench (Fig. 5) in order to use his exposed sections as reference guides. Aligning the grid to Carter's,
Fig. 3. Position of AMEMSA and Carter trenches relative to large fissures in Melikane Rockshelter’s rear wall. Note: Carter backfill only partially removed.

Fig. 4. West section wall of AMEMSA trench. Facies refers to sedimentary characteristics and not to temporal classification.
his coordinate system was adopted. A second excavation season in April 2009 reached bedrock.

Excavation proceeded stratigraphically, separating contexts according to colour, texture and inclusions. If a stratigraphic unit exceeded 5 cm in thickness, which occurred frequently at Melikane, arbitrary 5 cm spits were used until encountering a new stratum. Sediments from the upper levels were sieved using 1.5 mm mesh, until the high moisture content necessitated a switch to 3 mm mesh. All materials recovered were sorted on-site, with bucket flotation used for targeted recovery of botanical remains from deposits with substantial organic components.

4.2. Geoarchaeology

4.2.1. Field logging and sampling

A vertical column (Fig. 4) of bulk sediment samples (n = 22) was taken at 10 cm intervals through the sequence for preliminary sedimentological analyses. A series of 13 intact sediment blocks for micromorphological analyses were also removed, 11 from Carter’s eastern and northern profiles (squares Q5 and Q6) and two from AMEMSA’s western profile (square T5). The blocks were removed in modified 150 × 50 × 80 mm aluminium foil tins, wrapped in plastic film and sealed for transport.

4.2.2. Particle size analysis, loss-on-ignition and magnetic susceptibility

Particle size data were ascertained on bulk samples of the <2 mm (0.04–2000 μm) sediment fraction using a Malvern Mastersizer 2000 laser diffraction analyser fitted with a hydro-dispersal unit. Samples were soaked in a solution of 5% sodium hexametaphosphate dissolved in de-ionised water for 8 h to defloculate any very fine-grained aggregates. Samples were measured three times, and data averaged before analysis.

Loss-on-ignition analyses were carried out in accordance with Heiri et al. (2001). Samples of <2 mm were first oven dried at 105 °C, followed by a first combustion at 550 °C to remove organic carbon then a second burn at 950 °C to drive off carbonates. Final calculations were undertaken as a percent of the dry weight.

Mass specific magnetic susceptibility (χlf) measurements were carried out using a Bartington MS2 system, after procedures outlined in Dearing (1999). Measurements were taken at low frequency (0.46 kHz) — the standard measure of the concentration of magnetic minerals in a sample. To calculate the dimensionless magnetic susceptibility value (χ), the average reading of two control measurements was subtracted from the averaged measurement of the sample. In order to calculate mass specific magnetic susceptibility (χl) the value (χ) was divided by the mass of the sample (g).

4.2.3. Micromorphological analysis

Samples were taken from three of the four main facies types at Melikane – Facies A, C and D — to allow their preliminary characterisation. Facies describe sediments with similar modes of deposition (see below). It was not possible to sample Facies B since this consists of large angular roof-fall within an extremely loose sediment matrix. Three intact blocks (samples <101>, <117> and <136>) covering layers considered representative of Facies A and D in the field were removed from the eastern and northern profiles of Carter’s trench. A fourth sample (<121>) was removed from Facies C (Layer 8) in the AMEMSA trench.

The blocks were air-dried before impregnation with crysyt polymer resin under vacuum, and four 7 × 13 mm slides prepared to a thickness of ~30 μm by J. Boreham at Earthslides. Preliminary micromorphological analysis was undertaken using a Leica Wild M40 wide-view microscope at magnifications of x4 to x35, and a Leitz Laborlux 12 Pol microscope for magnifications of between x40 and x400, under plane polarised light (PPL), crossed polarised light (XPL) and oblique incident light (OIL). Standard micromorphological description was undertaken following Courty et al. (1989) and Stoops (2003).

4.3. Dating

4.3.1. AMS 14C dating

Six charcoal samples were carefully collected from Layers 1–5 and 45 samples from Layers 6–20 of the AMEMSA trench. Layer 20 was the deepest level sampled because an OSL sample obtained by Jacobs et al. (2008a) from the equivalent level in Carter’s trench (Carter’s upper Layer 6) produced an age of ~50 ka, indicating that Layer 20 and the underlying strata are beyond the range of 14C dating. It is well known that standard chemical pretreatment of charcoal samples may not remove all contaminants and, in
particular, younger contaminants in older samples with low $^{14}$C activity ratios may give rise to artificially young $^{14}$C ages (Aitken, 1990). A systematic study by Wheeler (2010) showed that contamination of charcoal samples from Melikane is problematic and that rigorous chemical pretreatment is required to obtain accurate ages, especially for older samples. Only 14 of the 45 samples from Layers 6–20 survived the standard acid-base-acid (ABA) pretreatment chemistry, indicating that the charcoal contained little elemental carbon. Even fewer samples would likely survive the more aggressive ABOx-SC pretreatment (Bird et al., 2010).

As a result, standard ABA pretreatment was used for samples thought to be younger than ~25 ka, and ABOx-SC pretreatment for the remaining, older samples. All sample pretreatments and analyses were conducted at the Oxford Radiocarbon Accelerator Unit (ORAU), using the protocols described by Brock et al. (2010). Bayesian modelling was applied to the ABOx-SC $^{14}$C ages, which were calibrated using the IntCal09 data set and OxCal 4.1 (Bronk Ramsey, 2009; Reimer et al., 2009). A correction of 56 ± 24 years was applied to account for the $^{14}$C reservoir offset between the northern and southern hemispheres (McCormac et al., 2004), and four OSL ages (samples MLK4, MLK5, MLK6 and MLK8) were included in the Bayesian model to further constrain the $^{14}$C chronology. The $^{14}$C ages reported previously by Carter (1978) and Vogel et al. (1986) were calibrated to facilitate comparison with the new chronology, but they were not included in the Bayesian model.

4.3.2. Single-grain OSL dating

Ages obtained by OSL dating represent estimates of the time elapsed since the dated mineral grains were last exposed to sunlight. By measuring grains individually, those with aberrant OSL properties can be identified and discarded from the data set, and grains with bright and well-behaved signals can be selected for determination of the burial dose (the so-called ‘equivalent dose’, $D_e$). The latter is divided by the environmental dose rate to calculate the OSL age (Jacobs and Roberts, 2007). With single-grain analysis, it is also possible to assess the adequacy of pre-depositional exposure of sediment grains to sunlight and to directly check the stratigraphic integrity of archaeological deposits for possible effects of post-depositional disturbance (e.g. mixing by anthropogenic or other processes) (Roberts et al., 1998; Jacobs et al., 2006a, 2008a; David et al., 2007; Jacobs and Roberts, 2007; Jacobs, 2010; Lombard et al., 2010). Owing to the inherent benefits of single-grain analysis, this approach was used to construct an OSL-based chronology for the archaeological sequence at Melikane.

Ten samples were collected from the eastern wall of square Q6 in Carter’s trench for single-grain OSL dating (the sample locations and associations with Carter’s and the AMEMSA Layers are shown in Fig. 10). Together, the OSL samples span the entire archaeological sequence. The section wall was cleaned to remove any grains partially exposed to sunlight. By measuring grains individually, those with aberrant OSL properties can be identified and discarded from the data set, and grains with bright and well-behaved signals can be selected for determination of the burial dose (the so-called ‘equivalent dose’, $D_e$). The latter is divided by the environmental dose rate to calculate the OSL age (Jacobs and Roberts, 2007). With single-grain analysis, it is also possible to assess the adequacy of pre-depositional exposure of sediment grains to sunlight and to directly check the stratigraphic integrity of archaeological deposits for possible effects of post-depositional disturbance (e.g. mixing by anthropogenic or other processes) (Roberts et al., 1998; Jacobs et al., 2006a, 2008a; David et al., 2007; Jacobs and Roberts, 2007; Jacobs, 2010; Lombard et al., 2010). Owing to the inherent benefits of single-grain analysis, this approach was used to construct an OSL-based chronology for the archaeological sequence at Melikane.

5. Results

5.1. Geoarchaeology of the Melikane sedimentary sequence

Detailed sediment logging in the field showed that the sequence, though highly variable, could be divided into four main facies describing sediments with similar modes of deposition. The division of the sequence into facies facilitates interpretation and allows for broad-scale changes in sediment history to be traced throughout the profile. These facies may relate to both natural environmental change (i.e. climate-driven) and anthropogenic environmental change (i.e. relating to human activity at the site). The results of the sedimentology are presented in Fig. 6.

5.1.1. Facies A

This facies is represented by four samples from Layers 4 and 10. Matrix colour (Munsell notation) varies from 10YR 6/6 brownish yellow to 10YR 5/4 yellowish brown. Coarse material dominates the facies, with rounded to sub-rounded, medium to large sandstone clasts (and occasional cobble-sized material) held in a silty sand matrix. The clasts are commonly imbricated in a northerly direction, towards the mouth of the shelter and away from the rear wall. The grain size peaks are the highest recorded in the profile. Although the coarse component exhibits a wide size range, there is a tendency towards moderate sorting in the medium gravel range. The organic carbon and carbonate content is consistently low, with three samples generating the lowest values for these two parameters. Magnetic susceptibility ($\chi$) values for this facies are also low.

Micromorphological analyses (samples <101> and <117>) reveal that the sediment matrix consists of very fine to medium quartz sand (60–300 $\mu$m) and yellow fine silt. The quartz sand is very similar in size and shape (roundness) to the sand that forms the gravel sandstone clasts (2–40 mm) and the host bedrock from which they derive (Fig. 7a). The rare, sand-sized rounded dolerite clasts are also potential products of bedrock weathering as dolerite dykes outcrop locally within the sandstones. Anthropogenic inclusions, such as sub-rounded fragments of burnt bone (Fig. 7b) and blocky charcoal (some with preserved cell structure), are found in variable abundance.

5.1.2. Facies B

Facies B (Layers 9 and 12) is a coarse, gravel-dominated unit of horizontally-aligned, tabular sandstone slabs and gravel clasts. The colour varies from 10YR 2/2 very dark brown to 7.5YR 5/6 strong brown. The organic carbon content is relatively high, probably through contamination from the overlying charcoal-rich layers (Layers 8 and 11). A subtle peak in $\chi$ may reflect reworking of burnt material washed down into the interstitial spaces between the coarse fraction.

Facies B was not sampled for micromorphological analysis owing to the coarse nature of the material.

5.1.3. Facies C

Facies C is divided into two sub-facies: C1 and C2. The former is characterised by dark (occasionally humic), charcoal-rich, sandy silts ranging in colour from 7.5YR 2.5/1 black to 10YR 4/2 dark greyish brown. Layers 15 and 16 are very mottled with a strong brown (7.5YR 5/6) colouration. Tabular sandstone cobbles, fine to medium sandstone clasts, and anthropogenic inclusions

previously and described by Jacobs et al. (2008a). The same procedures were used in this study to obtain OSL ages for nine of the ten samples, but not enough quartz grains were extracted from sample MLK7 for measurement and analysis.
Fig. 6. Results of the particle size, loss-on-ignition and magnetic susceptibility analyses of the vertical sediment column taken from AMEMSA trench square S6.

Fig. 7. Microphotos from Facies A and D. a) Sub-rounded limestone clasts (Ss) typical of Facies A showing similarity between quartz in clasts and in fine matrix. Note bone fragment (B). Sample <117> (XPL). b) Fragments of bone and lithics in Facies A. <117> (PPL). c) Clay coating in Facies D, showing shift between dusty clay (D) and limpid clay (L). <101> (PPL). d) Calcite hypocoatings to voids (H) overlying limpid clay coatings (L). <101> (XPL).
(e.g. lithics) are commonly encountered. Grain size data reveal significant intra-facies variation. Layer 19, for example, has a high sand content (>70%), whilst Layer 15 has one of the lowest frequencies of sand-sized material (~46%). There is a strong tendency towards high values of organic carbon, exceeded only by Facies D at the top of the profile. Similarly, carbonate values are the highest obtained throughout the sampled section. Magnetic susceptibility values for the facies range from moderate to high.

C2 is a thick layer of burnt material (Layer 8) within and above roof-fall (Layer 9). The colour is 7.5YR 6/8 reddish yellow to 7.5YR 2.5/1 black, and the unit consists primarily of charcoal and ash-rich silt with occasional to moderate medium to large sandstone clasts. Grain size data show that the layer is relatively fine, with high concentrations of silt and comparatively low quantities of sand and clay. This sub-facies is extremely rich in charcoal and organic material. Analysis of this layer generated moderate magnetic values, but marks the midway point in an up-profile trend of increasing magnetic values. Organic carbon and carbonate values are moderate to high.

The thin section from Layer 8 (<121>) contains micro-strata diagnostic of well-stratified combustion material (Fig. 8a). There are two main groups of organic remains: charred organic material (Fig. 8b), and ash containing articulated phytoliths and extensive silica plant structures preserving entire structures of leaves and stems (Fig. 8c). The intact nature of these structures indicates a primary depositional context; mechanical disturbance during
re-deposition would have fragmented these structures. Wood charcoal is present in the form of small blocks and cross sections of twigs, along with charred parenchymous tissue and numerous silicified stem fragments (J. Morales pers. comm., 2011). Also present are phosphatic infillings to void spaces, irregular calcitic nodules (Fig. 8d) and partially-dissolved bone fragments (Fig. 8e).

5.1.4. Facies D

Facies D has also been divided into two sub-facies: D1 and D2. These sub-facies are combinations of anthropogenetic material mixed with either colluvial sediments (D1) or host bedrock attrition material (D2). D1 is represented by two samples from Layer 5 forming a variable unit of 10YR 3/4 dark yellowish brown to 7.5YR 4/6 strong brown, fine to medium, rounded to sub-rounded clasts in a sandy silt matrix, with occasional lenses of organic-rich material. Particle size data reveal a fining-up sequence, with an increase in silt and concomitant decrease in sand. At the base of Layer 5 organic carbon values are high, declining to a lower, but still relatively high, level at the top. Carbonate levels are moderate to high and uniform between the two samples. Magnetic susceptibility values are moderate and decrease upwards.

D2 comprises coarse, sub-angular to sub-rounded sandstone fragments intermixed with dark, charcoal- and lithic-rich material. Colour ranges from 7.5YR 5/6 strong brown to 10YR 2/1 black. Sediments of this facies often possess a mottled colouration and commonly fine upwards (e.g. Layer 14). Grain size data indicate a wide size-range trending towards moderate to high levels of either silt or sand. Loss-on-ignition data reveal moderate values of both organic carbon and carbonates, and moderate magnetic susceptibility values with the exception of one notable peak in Layer 7.

Micromorphologically, the layers of Facies D (samples <101> and <136>) primarily comprise organic sandy silt with a minor clay component, common sub-rounded sandstone clasts and angular CCS lithics (2 mm–3 cm). The sediment has a spongy structure, with frequent channels with clay coatings. These coatings are dusty at the edges of the void, becoming laminated towards

Table 1

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Table 2

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the centre (Fig. 7c). Blocky charcoal fragments are common throughout, with pore spaces frequently infilled with silty clay. The sandstone clasts and CCS fragments are stained with amorphous iron. There are rare sparitic calcite coatings to voids in areas overlying limpid clay coatings (Fig. 7d).

5.2. Dating the Melikane sedimentary sequence

5.2.1. AMS 14C dating results

This section presents the results for the ~25 ka ABA pretreated 14C samples (68.2% probability) from the uppermost levels, and the six samples from Layers 6–9 and 14 that survived ABOx-SC pretreatment and were modelled using Bayesian statistics. The 14C ages for the uppermost levels (Layers 1–6) suffer from chronological inversions (Table 1). This suggests that these levels were subjected to intensive post-depositional disturbance, probably at least in part by bioturbation. Four of these dates fall within the last few centuries, further hindering the development of a robust chronology due to difficulties in calibrating such recent ages (Tans et al., 1979). Despite these uncertainties, the uppermost ages do appear to cluster into three phases: recent, ~3.2 ka cal BP and ~23 ka cal BP. These may be representative of the broad chronology of these layers prior to post-depositional modification.

The ages obtained for the MSA levels, from the base of Layer 6 downwards to Layer 14, are stratigraphically more coherent (Table 1). With the exception of the uppermost ABOx-SC age from Layer 6 (OxA-23039), all unmodelled ages are statistically similar at ~42 ka cal BP. This gives rise to a shallow gradient of age versus depth when Bayesian modelling is applied (Table 2, Fig. 9). An age of 38.6–37.5 ka cal BP (OxA-23039) was obtained for Layer 6 and ages of 41.4–40.0 ka cal BP (OxA-23041) to 43.2–42.3 ka cal BP (OxA-23036) for Layers 7–14. The span of modelled ABOx-SC 14C ages at Melikane suggests one pulse of occupation in the later part of the MSA ~43 to 38 ka, during which time a large proportion (~80 cm) of the MSA sequence was deposited.

5.2.2. OSL dating results

The $D_e$ values and dose rate information are presented in Table 3, together with the OSL ages for the nine samples from which sufficient quartz grains could be extracted for analysis. Several features of the OSL data are noteworthy.

For each sample, the $D_e$ values are spread more widely than can be explained solely on the basis of their measurement uncertainties. Such ‘overdispersion’ is typical for quartz, and overdispersion estimates of less than 20% are generally considered representative of well-bleached quartz grains that have remained undisturbed since burial (Olley et al., 2004; Galbraith et al., 2005; Jacobs et al., 2008a). The $D_e$ overdispersion values for the Melikane samples range between 9 ± 3% and 70 ± 5% (Table 3). Three of the samples (MLK1, MLK3 and MLK4) collected from the lowest part of the sedimentary sequence (Layers 19–30) have overdispersion values smaller than, or consistent with, 20%. The lack of evidence for post-depositional disturbance is consistent with the macro and micro-sedimentological observations of these layers. For these three samples, therefore, the central age model (Galbraith et al., 1999) was used to calculate the weighted mean burial doses for purposes of age determination.

The $D_e$ distributions of the other six samples could be mathematically-fitted by either two or three discrete components using the finite mixture model (Roberts et al., 2000; David et al., 2007; Jacobs et al., 2008b). One of these samples (MLK2) was collected from the lowest part of the sedimentary sequence, and showed evidence for only a small degree of post-depositional mixing: ~3% of the grains have intruded from younger levels. By contrast, the remaining five samples (MLK5–10), all of which were collected from above the lowest discrete roof-fall layer (Layer 18), show evidence for more extensive mixing, with the intrusion of younger and/or older grains sometime after initial sediment deposition. For these samples, large-scale and continuous turnover of sediments can be discounted, because almost no $D_e$ values close to zero were obtained, and because the $D_e$ distributions consist of discrete components, whereas a continuum of $D_e$ values would have resulted from extensive and ongoing mixing. The majority (56–66%) of $D_e$ values in these samples are captured by a single component (Table 3) that most likely represents the depositional age of the associated artefacts. The weighted mean $D_e$ values of the main components were used to calculate the ages of these six samples.

The minor $D_e$ components in samples MLK5–10 include younger and/older grains. In the middle part of the sequence (Layers 18–7), most of the intrusive grains (~30%) are derived from the older, underlying layers, whereas younger intrusive grains are relatively more important in the upper part of the sequence (Layers 6–1). It is
important to recognise that the post-depositional movement of sand-sized mineral grains does not necessarily imply that the artefacts have also been displaced. For such samples, the time of deposition of the majority of grains (determined from the main Ds component) is considered to closely approximate the depositional age of the artefacts. The ages so obtained (Table 3) are in correct agreement with the previously derived 14C chronology for the site (see Section 6.1.2 below). For samples fitted by more than one Ds component, the ages of the minor components are often similar to those obtained from the major components of the overlying and/or underlying samples, and with some of the 14C ages. The age clusters at ~80, ~60, ~50, ~ 46–41, ~27–23, ~9 and ~3 ka may correspond to pulses of human occupation of the site.

6. Interpreting the Melikane sedimentary sequence

6.1. Depositional environments of Melikane

The results of the geochronological analyses support the field-based observations of the four primary facies. The facies are discussed below in terms of reconstructing the depositional and post-depositional environments represented in the Melikane sequence.

6.1.1. Facies A: moderately-sorted, rounded to sub-rounded medium to large sandstone clasts – colluvial sedimentation

Facies A represents a unique depositional environment at Melikane. Occurrences of this facies – Layers 3, 4, 6 and 10 – occur exclusively in the upper half of the profile. The partially rolled and abraded, rounded to sub-rounded sandstone gravel is consistent with colluvial deposition, as allometric material is transferred to the site via the large fissure at the rear from sources immediately above the shelter. As observed in thin section, the similarity in grain size between the fine material and the constituents of the host bedrock appears to indicate an autogenic origin for the former, perhaps through a combination of dissolution of the carbonate bonds in the sandstone and physical weathering of the shelter walls. An aeolian component to the fine material cannot be ruled out, however, with sediment blown into the shelter from a sparsely vegetated landscape.

It is possible that occasional high-intensity precipitation events occurring within otherwise semi-arid phases introduced this coarse material to the site, resulting in extensive scoring of the underlying units. Clarke et al. (2003, p. 199) note that “widespread colluviation occurred [in southern Africa] during a semi-arid phase associated with the Last Glacial Maximum” and this “colluvium is formed when the climate in southern Africa is most arid” (Clarke et al., 2003, p. 211). The peaks in mean particle size (Layers 10 and 4) support the presence of this dynamic environment as large volumes of sand, as well as the coarse, imbricated gravel, washed into the site through the fissure. Low organic carbon values could be corroborated by the low magnetic susceptibility values reflecting a dynamic, unstable landscape. Inclusions of sub-rounded burnt bone and charcoal observed in the thin sections, along with macroscopic faunal material and rolled lithics, reveal intermixing of anthropogenic material with natural sediments, consistent with the scouring of underlying sediments.
6.12. Facies B: tabular sandstone blocks and coarse angular to sub-angular gravel — roof-fall, bedrock attrition

The coarse angular material that dominates Facies B is indicative of a highly dynamic environment wherein host bedrock breaks down onto the rockshelter floor to become incorporated as auto- genic fill. Unlike Facies A, this material shows no signs of significant rolling or abrasion reflecting the proximal source from inside the site. A minor peak in \( \gamma f \) (Layer 12) may reflect the reworking of older, anthropogenic material. Alternatively, this may result from the translocation of burnt fines (e.g. charcoal powder) from overlying sediments down into the pore spaces between clasts, particularly as hominin activity often resumed on the irregular upper surface of this coarse debris following these roof-fall events (e.g. Layers 8/9).

6.13. Facies C: charcoal-rich fine-grained sediments — occupation layers with intermixed combustion material (C\(^1\)) and an in-situ combustion feature (C\(^2\))

Facies C\(^1\) is characterised by distinct dark bands occurring sporadically throughout the profile. These bands are conspicuously abundant in charcoal and organic matter related to repeated burning events within the rockshelter. The moderate to high carbonate levels could signal the presence of highly mobile CaCO\(_3\) — the primary constituent of ash (Canti, 2003). Alternatively, these peaks could relate to the liberation of CaCO\(_3\) from the carbonate-cemented sandstone precipitated into the sediment matrix (Goldberg and Arpin, 1999).

The mottled appearance of C\(^1\) most likely relates to post-depositional changes in sediment chemistry (diagenesis). In caves and rockshelters these transformations “are driven by . . . water passing through the cave sediments, and the dissolved organic and inorganic constituents” (Karkanas et al., 2000, p. 916). Water episodically flushes through Melikane, confirming a strong link with the groundwater hydrological system. This motting, therefore, results from percolating water dissolving, remobilising and precipitating minerals vertically through the sediment sequence (e.g. Karkanas et al., 1999, 2000; Weiner et al., 2002). This throughput of water may have partially dissolved the ash normally associated with such charcoal-rich layers (Schiegl et al., 1996).

Facies C\(^2\) (Layer 8) is distinguished from C\(^1\) by its substantial thickness and lateral extent across the entire excavation area, representing a zone of intensive combustion. Why this combustion zone is so extensive in comparison with those in Facies C\(^1\) is unclear, but it may relate to a reconfiguration of the internal functional space of the site or to an increase in occupational intensity. The high carbonate value is in accordance with the frequent ash observed in the field, which could also account for the increase in silt-sized material in this layer. The internal stratification of this combustion zone represents the overprinting and perhaps raking out of successive burning features. Diagenetic processes, including the dissolution of ash and consequent reduction in sediment volume (see Schiegl et al., 1996; Karkanas et al., 2000), may explain the distorted nature of some of these micro-strata. The silicified plant structures and articulated phytoliths represent the insoluble residue, with calcite leached from the ash re-precipitated as nodules. The partial dissolution of bone fragments and the presence of phosphatic infillings also confirm the presence of water moving through the sediment sequence. Although Layer 8 appears to have undergone significant diagenesis by percolating groundwater, the exceptional preservation of plant structures affords great potential for further micromorphological, phytolith and plant-macro analyses.

6.14. Facies D: heterogeneous layers of anthropogenic material mixed with gravel (D\(^1\)), and coarse tabular sandstone slabs (D\(^2\))

The mixed composition of this facies signifies the reworking of cultural horizons through natural geomorphological processes. Facies D\(^1\) (Layer 5) results from the reworking of the surface of occupation horizons (Facies C) by inwash colluvial gravel (Facies A) associated with episodic high precipitation events, and as such combines elements of both Facies A and C. Enhanced organic carbon levels at the base of Layer 5 indicate a buried occupation horizon exists, which has been scoured and reworked by the erosive action of the overlying colluvium deposition.

Facies D\(^2\) comprises a reworking of elements of Facies B and C. Layer 7 represents a roof-fall event with a matrix of anthropogenic material reworked from the underlying ash layer (Layer 8), and infiltrated from overlying levels. The peak in \( \gamma f \) indicates either the reworking of burnt material down into the coarse roof-fall below, or the inwashing of pedogenic material from outside the shelter. This roof-fall event occurred when hominin activity increased, resulting in the intermixing of cultural material with natural sediments.

Micromorphological observations of a lower layer of Facies D (sample <136>) fit well with the mixed origin of the sediments. The organic-rich matrix appears bioturbated — a process which has severely disturbed the microstratigraphy of this facies. There are also micromorphological features consistent with the movement of water through the sediment matrix. The abundant clay-coated channels and shift from dusty clay to limpid clay coatings indicate a potential stabilisation of the surface, punctuating a prolonged and intensive period of illuviation in the shelter (Courty et al., 1989). Amorphous iron staining of lithics also indicates the strong influence of water, and sparitic calcitic coatings may reflect the dissolution and re-precipitation of calcium carbonate from ash. Facies D results from a range of complex taphonomic pathways at both the micro- and macroscale, but the fine material appears primarily anthropogenic in origin.

6.2. A revised chronological framework for Melikane

The original \(^{14}\)C chronology reported by Carter (1978) and Vogel et al. (1986) suggested three broad phases of occupation at Melikane: late Holocene LSA in the equivalent of AMEMSA Layer 1, early LSA (MIS 2) in the equivalent of AMEMSA Layer 5, and late MSA (MIS 3) in the equivalent of AMEMSA Layers 8, 13 and 15–21. Table 4 presents details of the \(^{14}\)C age estimates, uncalibrated and calibrated (using IntCal09; Reimer et al., 2009), generated by Carter (1976) and Vogel et al. (1986). The new \(^{14}\)C and OSL ages for Melikane correspond closely to the calibrated ages of Carter (1978) and Vogel et al. (1986) in some parts of the sequence, but not in others. The new chronology, presented in Fig. 10, is thought to be superior for three main reasons.

First, the large quantities of sample material required for conventional \(^{14}\)C dating (e.g. Vogel et al., 1986) typically make it necessary to combine several individual pieces of charcoal to produce a single sample. If post-depositional mixing of differently aged pieces has occurred, this approach may generate an average age of ambiguous accuracy. By contrast, the new \(^{14}\)C ages were all measured by AMS, which requires much smaller amounts of material, so individual pieces of charcoal, rather than aggregates, can be measured.

Second, Wheeler (2010) has shown that AB/ABA pretreatment procedures (e.g. Vogel et al., 1986) do not adequately remove all contaminants from the Melikane charcoal samples. For Melikane samples older than ~25 ka cal BP, application of the more rigorous ABOx-SC pretreatment protocol was required to deal effectively with contamination by younger carbon (Aitken, 1990). Contamination of the original samples is manifested by the non-linear age-depth relationship for Carter’s Layer 5 and below (AMEMSA Layer 15 downwards) (Table 4).
Third, when the Melikane artefact assemblage was first analysed in the 1970s, conventional 14C dating was the only means of constructing a site chronology. As the technique has an upper technical limit of ~50 ka or less, a different method is required to date the older MSA levels (Layers 20–30). OSL dating of sediments provides this means and was employed at Melikane. The application of the single-grain OSL technique has extended the Melikane chronology by a further 40 kya, back to ~83 ka, generating a robust geochronological framework for the entire archaeological sequence.

Taking these advantages into consideration, the following revised chronology for Melikane is proposed (see Fig. 10). Initial human occupation of the site is dated by statistically consistent OSL ages of 83 ± 6 ka (MLK1) and 80 ± 3 ka (MLK2) for Layers 30 and 29. An OSL age of 61 ± 3 ka (MLK3) was obtained for Layers 25–23, ~20 cm above MLK2, and is associated with the HP. This age (Jacobs

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<tr>
<td>Melikane 6</td>
<td>3 (upper)/R9</td>
<td>5</td>
<td>Pta-1367</td>
<td>19700 ± 150</td>
<td>23.3–23.8</td>
</tr>
<tr>
<td>Melikane 2</td>
<td>3 (upper)/Q8</td>
<td>5</td>
<td>Pta-1407</td>
<td>20200 ± 150</td>
<td>24.3–24.8</td>
</tr>
<tr>
<td>Melikane 3</td>
<td>3 (upper)/Q9</td>
<td>5</td>
<td>Pta-1406</td>
<td>20000 ± 170</td>
<td>24.2–24.6</td>
</tr>
<tr>
<td>Melikane 9</td>
<td>4a (upper)/R8</td>
<td>8</td>
<td>Pta-1408</td>
<td>33100 ± 600</td>
<td>38.5–37.0</td>
</tr>
<tr>
<td>Melikane 19</td>
<td>4a (upper)/Q7</td>
<td>8</td>
<td>Pta-1331</td>
<td>35800 ± 920</td>
<td>41.8–39.9</td>
</tr>
<tr>
<td>Melikane 24</td>
<td>4b (lower)/Q5</td>
<td>13</td>
<td>Pta-1534</td>
<td>42000 ± 1700</td>
<td>47.3–44.1</td>
</tr>
<tr>
<td>Melikane 25</td>
<td>5 (upper)/Q6</td>
<td>15</td>
<td>Pta-1330</td>
<td>42300 ± 2100</td>
<td>48.0–44.2</td>
</tr>
<tr>
<td>Melikane 10</td>
<td>5 (upper)/R9</td>
<td>15</td>
<td>Pta-1369</td>
<td>33800 ± 960</td>
<td>39.9–37.3</td>
</tr>
<tr>
<td>Melikane 29</td>
<td>6 (upper)/Q7</td>
<td>19 or below</td>
<td>Pta-1370</td>
<td>40200 ± 1650</td>
<td>45.5–42.8</td>
</tr>
<tr>
<td>Melikane 33</td>
<td>6/P6</td>
<td>21 or below</td>
<td>Pta-1372</td>
<td>37000 ± 1050</td>
<td>42.7–41.0</td>
</tr>
<tr>
<td>Melikane 36</td>
<td>6/P5</td>
<td>21 or below</td>
<td>Pta-1371</td>
<td>30400 ± 560</td>
<td>36.2–34.5</td>
</tr>
</tbody>
</table>

Table 4
Carter’s original 14C ages (uncalibrated and calibrated) (Vogel et al., 1986: 1143–1145; Bronk Ramsey, 2009; Reimer et al., 2009).

Fig. 10. Stratigraphic correlation between AMEMSA layers (square S6) and Carter layers (square Q6) with the results of 14C (left) and OSL dating programmes (right).
indicative of recent contamination was also found within this layer. A single ABOx-SC14C age of 38.6 ka for Layer 5 (Table 4) accords with the mixing observed in the uppermost two layers of the Melikane sequence. The uppermost levels (Layers 14–7) are acute. This is especially true of rockshelter environments, where issues of taphonomy are pervasive. In this paper, key aspects of site formation at Melikane are tackled head-on, thus establishing a reliable framework for future analyses of other aspects of the site.

The Melikane sequence has been influenced to varying degrees by the active hydrogeological system to which the shelter is linked via fissures in the bedrock, presenting both opportunities and challenges. The sandstone setting of Melikane offers scope for interrogating hydrological connections in a non-karstic geological setting, a great opportunity given the paucity of research in such systems. Of particular importance is the potential for establishing the provenance of the fine, allargenic component of the sequence, opening up the possibility of linking Melikane’s stratigraphic sequence to the climatically-controlled dynamics of the late Quaternary landscape in which it is situated. These two aspects of research are ongoing and will be published elsewhere.

The most challenging taphonomic issue at Melikane concerns the percolation of groundwater through the stratigraphic sequence. This has resulted in post-depositional diagenesis of the sediments to variable degrees, evidence for which has been observed in many stratigraphic contexts. Much of the fine component of Facies A is likely to be the product of the chemical and mechanical breakdown of the parent sandstone through colluvial (primarily sheetwash) and infiltration processes, according with observations of water channelling and clast sorting. Also present are diagnostic features of groundwater infiltration, including the intermixing of scoured natural and anthropogenic material (Facies D). Percolating water has also affected the anthropogenic, charcoal-rich layers of Facies C by dissolving mobile minerals such as calcite and phosphate (hydroxyapatite), which accounts for the low concentrations of ash and virtual absence of faunal material below Layer 2. The same process accounts for the degraded condition of charcoal, which, although structurally intact, is often depleted of elemental carbon. The five OSL ages that exhibit multiple-component mixtures of differently aged quartz grains also suggest the translocation of fine sediments through the sequence. Efforts have been actively made to isolate and thus control for these dynamic hydrological processes in order to minimise the constraints they may place on the resolution of the cultural and palaeoenvironmental data.

It is important to note that chemical transformations of the Melikane sequence decrease down-profile. This suggests that the opening of the fissure at the rear of the site occurred during the occupancy of the rockshelter. If groundwater flux to the site suddenly increased when the fissures opened at the rear of the shelter, this percolating water could only have penetrated to a certain depth below the ground surface contemporary with that event. Karkanas et al. (2000, p. 917) state that sediment diagenesis in caves and rockshelters “tends to occur at or near the surface, and then slows down significantly after deeper burial”. Consequently, Layers 30–19 are more clearly stratified and less chemically altered than those of the overlying Layers 18–1. This could show that the opening of the fissures, and concomitant increase in percolating groundwater, occurred sometime after the burial of Layers 30–19. The integrity of the lower levels is supported by four OSL dates from these layers, which show little (MLK2) or no (MLK1, MLK3 and MLK4) evidence of sediment mixing. The vertical movement of archaeological materials is thus unlikely in these earliest MSA deposits, and would have been minimal in Layers 18–4 since these phases contain thick, often cemented layers. The potential for intermixing of archaeological material is, therefore, confined to Melikane’s uppermost levels (Layers 3–1). Particularly encouraging is the generally excellent agreement achieved in Layers 14–5.

7. Discussion

7.1. Taphonomic issues and diagenetic processes

Without a deep understanding of the syn- and post-depositional histories of sedimentary sequences, the challenges of interpreting the archaeological and palaeoenvironmental...
between the cross-correlated ABOx-SC-pretreated $^{14}$C ages and the ages calculated for the majority of quartz grains in each multi-component OSL sample. Despite the taphonomic complexities, therefore, Melikane’s sequence has substantial archaeological and palaeoenvironmental research potential.

7.2. Depositional history, occupation pulses and palaeoenvironmental context

Melikane is the oldest radiometrically dated archaeological site in Lesotho with a sedimentary sequence spanning the last ~83 kyr. The geochronology suggests that Melikane experienced marked pulsing of human occupation throughout the Late Pleistocene. These occupational pulses occurred at ~80 ka (MIS 5a), ~60 ka (late MIS 4), ~50 ka (early MIS 3), ~46–38 ka (mid-MIS 3), and ~24 ka (early MIS 2). Punctuating these pulses were hiatuses in sediment deposition that appear to have been of longer duration than the pulses themselves. Although not all layers have been dated at Melikane, there is a strong connection between human occupation and sediment deposition as indicated by the minor $D_3$ components of each multi-component OSL sample. Rather than showing a continuum of ages, as would be expected were sediments reworked through a sequence that formed continuously, these samples recurrently register ages that correlate to the majority $D_3$ components of other OSL ages in the sequence – that is, to other occupational pulses. The pulses seem to coincide, therefore, with increased sedimentation at the site, suggesting that human activity accelerated deposition, that their visits corresponded with particular climatic conditions favouring deposition, or both. As at other Late Pleistocene rockshelter sites, the timing and intensity of occupational bursts at Melikane were most likely linked to palaeoclimatic/environmental change.

Palaeoenvironmental reconstruction at Melikane is ongoing. However, the occupational pulses can be correlated with external environmental data to explore broader southern African palaeoenvironmental conditions prevailing when Melikane was inhabited. As a corollary, potential reasons for the use of afromontane woodlands at Late Pleistocene foragers can also be examined. The expectation is that human exploitation of eastern Lesotho would uplands by Late Pleistocene foragers can also be examined. The latter expectation relies on knowledge of the hydrology of highland Lesotho. As the primary headwater catchment for the Orange (Senqu) River – the continent’s largest south of the Zambezi – Lesotho contributes nearly half of the river’s streamflow from only five percent of its total basin area (Earle et al., 2005). Unlike other parts of the catchment area, high annual precipitation in the highlands (>2000 mm) comfortably exceeds annual evaporation (~1200 mm) (Earle et al., 2005). With lower glacial temperatures further suppressing evaporation and prolonging snowmelt, highland Lesotho, and the Senqu corridor in particular, would have offered Late Pleistocene foragers stable sources of fresh water during arid episodes. The diversity of resources over short distances afforded by the highly dissected terrain would have also been attractive when conditions were arid (Mitchell, 1990).

The earliest sedimentation at Melikane (Layers 30–19) took place ~83–50 ka. Thin, horizontal bands and abrupt bounding surfaces, with limited input of spalled material, reveal sporadic, pulsed occupation in a relatively stable rockshelter environment. The fissure at the rear of the shelter had probably not yet fully developed and so Melikane provided a comparatively drier environment than it would later. This isolation from the hydrogeological system enhanced the preservation of this lower part of the archaeological sequence owing to relatively low throughput of groundwater. Frequent combustion zones testify to the habitual use of fire at the site.

The first pulse of human occupation at Melikane occurred ~80 ka in MIS 5a. Lithic industries in these levels (Layers 30–27) are dominated by large to very large MSA 2a-type (Volman, 1984; or Klasies River sub-stage sensu Wurz, 2002) blades on coarse-grained raw materials (hornfels and dolerite), and rarer small blades on CCS. There is some evidence that conditions in southern Africa ~80 ka were cold and/or arid. In northeastern South Africa, Brook et al. (1997) record a hiatus in speleothem growth ~83–77 ka, indicating drier conditions. Likewise, although the sediment sequence at Tswaing Crater (near Pretoria) is poorly dated, a drop in total organic content ~80 ka suggests decreased precipitation (Partridge et al., 1997; Kristen et al., 2007). In the high resolution speleothem record from Crevuce Cave on the southern Cape coast, a dip in winter rainfall and C3 grasses at ~80 coincides with cold southern hemisphere sea surface temperatures (Bar-Matthews et al., 2010). At present the nearest palaeoenvironmental records to Lesotho thus seem to suggest that conditions at ~80 ka were cooler and drier than today. If correct – and provided strategies (seasonal occupation?) and/or technologies (sewn clothing?) to cope with reduced temperatures were in place – this meets one of the two expectations, discussed above, of the palaeoenvironmental conditions under which highland Lesotho would have been attractive to Late Pleistocene populations.

After a ~20 kyr hiatus – during which time Still Bay and early HP stone tool-makers do not appear to have exploited the Lesotho Highlands – Melikane was occupied again at ~60 ka (late MIS 4). The occupants now produced a variant of the HP dominated by small blades and bladelets with very rare backed pieces (Layers 25–22). The OSL results suggest the HP occupation at Melikane, like that at the site of Ntosa Tsoana in western Lesotho, falls towards the end of this industry’s temporal span (Jacobs et al., 2008a) and overlaps in time with the end of the longer HP occupation at Sibudu Cave (Wadley and Jacobs, 2006; Jacobs et al., 2008a,b). As recently argued by Chase (2010), a range of proxy data suggest that conditions across southern Africa at this time were cold but relatively humid. In the detailed palaeoenvironmental sequence at Sibudu, charcoal and macrofauna from late MIS 4 levels suggest a moist evergreen forest setting (Allott, 2006; Clark and Plug, 2008; Hall et al., 2008). Cool, if perhaps drier, conditions for MIS 4 are also recorded in the speleothem record from Crevuce Cave (Bar-Matthews et al., 2010). Although records from several other locales on the subcontinent hint that MIS 4 was not uniformly humid (Brook et al., 1996, 1998; Kristen et al., 2007; Bar-Matthews et al., 2010), Sibudu’s proximity to Lesotho makes it a more reliable indicator of the prevailing conditions when HP tool-makers occupied Melikane, which seem to have been cold and humid. This does not match the hypothesised conditions for highland settlement.

After a shorter hiatus of ~10 kyr, Melikane was briefly occupied again at ~50 ka (early MIS 3). Both the duration of this hiatus and the timing of re-occupation are in sync with Sibudu (Wadley and Jacobs, 2006; Jacobs et al., 2008a,b). Similar to the late MSA lithic assemblages at Sibudu (Wadley and Jacobs, 2004, 2006), these levels at Melikane (Layers 21–19) contain unifacial and unretouched Levallois points. A range of palaeoenvironmental proxy data at Sibudu indicate the presence of grasslands and dry open woodlands at ~50 ka, signaling warmer and drier conditions than existed in late MIS 4 (Plug, 2004; Wadley, 2004b; Allott, 2006; Reynolds, 2006; Sievers, 2006). However, conditions at Sibudu ~50 ka were probably not as dry as they were at the start of MIS 3 (~58 ka), when there is evidence for dramatic aridification (Allott, 2006; Chase, 2010). Climate was evidently wet enough for
speleothem growth ~50–43 ka in southern Botswana (Brook et al., 1996) and ~58–46 ka in northeastern South Africa (Holzkämper et al., 2009). Increased humidity ~55–48 ka is also registered at the Ts’wani Crater (Kristen et al., 2007). Thus, conditions during the ~50 ka occupational pulse at Melikane were probably warmer and less humid than the previous pulse in late MIS 4, but were probably not particularly arid. Pending further detailed palaeoenvironmental data from the study area, this may match the first expectation that the highlands were used at times of climatic warming.

Following another hiatus of ~7 ky, the occupational pulse at ~46–38 ka witnessed a major change in site formation processes. From Layer 18, Melikane became a much higher-energy sedimentary environment, with water throughput causing physical and chemical transformations of the sequence. Coarse autogenic material became more prolific in the sedimentary sequence at this time. Roof-fall events increased in frequency as water ingress through fissures in the shelter walls and roof promoted the mechanical weathering of the relatively weak parent bedrock. The driving force behind the generation of this coarse material (e.g. Layer 9) was most likely increased freeze-thaw action relating to climatic deterioration. Palaeoenvironmental records throughout southern Africa suggest that the period ~46–38 witnessed acute aridity and cooling. At Lobatse II Cave in southern Botswana, for example, a hiatus in speleothem deposition 43–27 ka has been ascribed to dry conditions (Brook et al., 1996). The speleothem at Wolkberg Cave also stopped growing at ~46 (Holzkämper et al., 2009). High chlorine intensities ~48–38 ka in the Ts’wani Crater sequence have been linked to increased aridity. Closer to Lesotho, well-dated sequences of alternating colluvium and palaeosols in northern KwaZulu-Natal provide evidence, respectively, for erosive land surfaces at times of aridity and hillslope stability in wetter periods; at various locales, drier periods of colluviation occurred ~47–41 ka (Botha and Partridge, 2000) and ~42–37 ka (Clarke et al., 2003).

Unlike the Melikane occupations at ~60 ka and ~50 ka, the ~46–38 ka pulse does not accord with occupation at Sibudu. Rather, it corresponds broadly to an occupational/depositional hiatus both at Sibudu and at Border Cave (northern KwaZulu-Natal): humans were absent from each site from ~47 ka to at least ~39 ka (Jacobs et al., 2008b). Jacobs et al. (2008b) have linked the occupational hiatuses at Sibudu to the broadly coeval arid episodes in KwaZulu-Natal as evidenced in enhanced colluviation (noted above). They suggest that humans may have abandoned Sibudu when local rivers dried up, relocating to areas with perennial water supplies: “Where these people migrated to remains unresolved, because similar periods of occupation and abandonment are observed at Border Cave. It is possible that the now-submerged continental shelf was host to these populations” (Jacobs et al., 2008b, p. 1804). Another area to which such populations may have migrated to access reliable sources of fresh water could have been the Lesotho Highlands. This is consistent with the second of the two expectations offered above regarding Late Pleistocene upland settlement during particularly arid periods, and may thus explain the ~46–38 ka occupational pulse at Melikane. Some support for this hypothesis may come from the geoarchaeological results presented in this paper, which suggest that conditions at this time were unstable, with frequent roof-fall events (Facies D) and colluvial gravels (Facies A). Whereas the former likely relate to prolonged cold conditions when freeze-thaw action generated large amounts of tabular sandstone heaved from the shelter’s walls and roof, colluvial material may indicate drier conditions (e.g. Clarke et al., 2003) when mechanically weathered coarse sediment entered the site via the larger of the two fissures.

Another long period (~14 ky) of abandonment ensued before Late Pleistocene humans re-occupied Melikane at ~24 ka just prior to the Last Glacial Maximum (LGM). This pulse at Melikane roughly coincides with the onset of very cold and arid conditions in the region, as suggested by a wide range of proxy data in the Drakensberg. Multiple lines of geomorphological evidence suggest the LGM development of permafrost on Lesotho’s high plateau and marginal niche glaciers on south-facing slopes of the high escarpment (Grab, 2002; Mills and Grab, 2005; Mills et al., 2007, 2009a,b), Likewise, a variety of periglacial and glacial landforms of likely LGM age have been recorded in the Eastern Cape Drakensberg (Lewis and Hanvey, 1993; Lewis and Illgner, 2001; Lewis, 2008a,b,c). That these occur at altitudes as low as 1900 m in the Eastern Cape Drakensberg may suggest that mean annual temperatures here during the LGM were ~8–10 °C relative to today, with precipitation reduced by up to 70% and permanent snowlines at ~2100 m (Lewis and Illgner, 2001; Lewis, 2008b). At Strathalan Cave B (Eastern Cape), situated at an altitude of 1800 m, a drastic change occurs in levels postdating 24 ka whereby the pollen spectra become indicative of alpine environments that today occur at ~2900 m; soon thereafter the site is abandoned until the Holocene (Opperman and Heydenrych, 1990; Opperman, 1996; Lewis, 2008c). Similarly, Vogel’s (1983) δ13C study of equid teeth from Carter’s excavation at Melikane itself showed that equids from the ~20 ka levels had much higher proportions of C3 plants in their diets (75–84%) compared to Holocene individuals (35%), suggesting a substantial downward altitudinal shift of alpine vegetation belts in response to LGM climatic cooling. This conforms to expectations of highland exploitation during arid phases, but abandonment of the highlands soon after ~24 ka may suggest LGM conditions deteriorated to the point that the disadvantages of upland living outweighed the benefits.

8. Conclusions

A suite of geoarchaeological analyses was used to reconstruct the depositional history of Melikane Rockshelter and changes in environment have been linked to a tightly constrained site chronology. Melikane experienced a complex depositional and post-depositional history resulting in a highly variable sedimentary sequence. The geomorphological mechanism driving these changes appears to have been variability in the degree of connectivity to the ground-water hydrological system, from which percolating water was introduced via fissures in the rear of the shelter. This connection probably first developed after the deposition of the bottom one-third of the sequence (Layers 30–19). Bioturbation processes were also important, but were only intensive in the uppermost deposits. In general, the integrity of the sediments improves down-profile. The preliminary cross-correlated OSL and AMS 14C chronology for Melikane shows the sequence spans the period from MIS 5a (~83 ka) to the late Holocene, with occupational pulses coinciding with sediment deposition at ~80, ~60, ~50, ~46–38, ~24, ~9, ~3 ka and the second millennium AD. The resulting geochronological framework will anchor future archaeological and palaeoenvironmental work at this and surrounding upland sites. As a deep repository situated in a comparatively challenging habitat, Melikane can be usefully interrogated to probe the limits of early modern human adaptive flexibility in Late Pleistocene Africa and beyond.

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