Quaternary International 495 (2018) 87–101

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

The first bone tools from Kromdraai and stone tools from Drimolen, and the place of bone tools in the South African Earlier Stone Age

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ARTICLE INFO

Keywords:
Paranthropus robustus
Early Stone Age
Karst
Bone tools
Acheulian
Oldowan
Palaeocave
Stone tools

ABSTRACT

An apparently unique part of the Earlier Stone Age record of Africa are a series of bone tools dated to between ~2 and ~1 Ma from the sites of Olduvai in East Africa, and Swartkrans, Drimolen and Sterkfontein in South Africa. The South and East African bone tools are quite different, with the South African tools having a number of distinct characters formed through utilisation, whereas the East African tools are flaked tools that in some cases mirror stone tool production. The South African bone tools currently consists of 108 specimens from the three sites above. They have been interpreted as being used for digging into homogenous grained soil to access high quality food resources, or as a multi-purpose tools. It has generally been assumed that they were made by *Paranthropus robustus*, as this species is most often associated with bone tool bearing deposits, especially when high numbers occur. However, early *Homo* is also found at these sites. Here we report on two fossils from the *Paranthopus robustus* site of Kromdraai B, which has only yielded one stone tool to date, that have the same characteristic wear patterns as the bone tools identified at other sites. We also describe a small collection (N = 6) of the first stone tools recovered from the bone tool and *Paranthropus* and early *Homo* bearing site of Drimolen Main Quarry. These discoveries further increase the association between bone and stone tool technologies in the South African Earlier Stone Age. However, there remains no direct correlation between the occurrence of bone or stone tools and a particular species being found at the different sites. We then review the place of these bone tools within the South African archaeological record. They appear to be a consistent part of the South African record for around a million years or so between < ~2.3 and > ~0.8 Ma. While they change little over this time, they occur with both Oldowan and Acheulian assemblages.

1. Introduction

Bone tool, or osseous tool, is a generic term used to identify artefacts produced from bone, tooth, antler, and ivory (Backwell and d'Errico, 2014). Such items regularly occur within the late Middle to Later Stone Age record of Africa (Backwell and d'Errico, 2014), but the nature of their origin is difficult to determine. Since the announcement of the Osteodontokeratic Culture from the ~3.0–2.6 Ma, *Australopithecus africanus*-bearing Makapansgat Limeworks Member 3 in South Africa in the 1950s (ODK) (Dart, 1957; Herries and Adams, 2013), speculation has existed over the occurrence of osseous technologies associated with *Australopithecus,* and in general within the Pliocene to early Pleistocene African record (see Wolberg, 1970 for review; Brain, 1981). The recent discovery of both stone tools (Lomekwe, Kenya) and cut marked bone (Dikika, Ethiopia) from ~3.4 to 3.3 Ma deposits that are contemporary with *Australopithecus* have further fuelled the debate around which hominin species maybe tool makers (McPherron et al., 2010; Harmand et al., 2015). However, not all researchers are convinced by the early cut mark or stone tool evidence (Domínguez-Rodrigo et al., 2013; Domínguez-Rodrigo and Alcalá, 2016).

Mary Leakey (1971) reported 125 potential bone tools with evidence of intentional flaking, battering and abrasion from a variety of sites throughout Olduvai Bed I and II in Tanzania; dating from between ~1.9 and ~1.3 Ma (Deino, 2012; Domínguez-Rodrigo et al., 2013); although the majority appear to come from levels dated to between ~1.5 and 1.3 Ma (Deino, 2012). These bone tools are generally associated with Oldowan and Developed Oldowan assemblages, although the presence of a flaked bone handaxe at one such site may also suggest an association to the Acheulian (Leakey, 1971). These bone tools are mainly associated with *Paranthropus bosei* and *Homo habilis*, although in the youngest layers they are also associated with *Homo erectus*. The BK site, where the youngest bone tools at Olduvai have been discovered,

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https://doi.org/10.1016/j.quaint.2018.04.026
Received 15 September 2017; Received in revised form 12 April 2018; Accepted 13 April 2018
Available online 17 April 2018
1040-6182/

has also yieled the youngest occurrence (~1.34 Ma) of *P. bosei* in direct association with Oldowan technology (Domínguez-Rodrigo et al., 2013). Reanalysis of these bone tools led Shipman (1989) to identify only 40 as definitive tools, whereas Backwell and d'Errico (2004b) identified 36 as bone tools. However, they still occur throughout the Olduvai sequence and suggest that bone tools were potentially part of the repetoire of multiple hominin species making a variety of bone tool industries. The fact that such bone tools have only been found locally within the Olduvai sequence may suggest a distinct regional adaptation.

While the ODK from South Africa has been conclusively discounted as a cultural tradition (Washburn, 1957; Brain, 1968, 1969; 1981; also see Wolberg, 1970), there are a number of occurrences of purported bone tools associated with younger (post 2.3 Ma) Earlier Stone Age (ESA) technology from South African palaeocave deposits from the Fossil Hominid Sites of South Africa; UNESCO World Heritage Area near Johannesburg (Robinson, 1959; Backwell and d'Errico, 2001, 2003); commonly referred to as the 'Cradle of Humankind' (COH). Robinson (1959) was the first to identify a potential early Pleistocene bone tool in South Africa, with the discovery of a single bone tool in association with stone tools from what is now termed the Sterkfontein Member 5 West (M5W) deposits. These deposits are now dated to between 1.4 and 0.8 Ma and are associated with Acheulian technology and early *Homo* (Kuman and Clarke, 2000; Herries and Shaw, 2011). Later work by C. K. Brain and colleagues (1988, 1989, 1993) at the South African site of Swartkrans, recovered a further 84 bone tools similar to the one found by Robinson (1959), and work by Andre Keyser at Drimolen Main Quarry (DMQ) identified another 23 (Backwell and d'Errico, 2008). In both of these cases, the bone tools are associated with *Paranthropus robustus* and early *Homo* (see discussion; Keyser et al., 2000; Kuman, 2007; Moggi-Cecchi et al., 2010). In Swartkrans Member 1 Lower Bank (M1LB), dated to < 2.33 and > 1.64 Ma (Pickering et al., 2011; Gibbon et al., 2014), the bone tools are found in associated with Oldowan stone tools (Caruana, 2017). Whereas in Member 2 (M2; < 1.65- > 1.07 Ma; Balter et al., 2008) and Member 3 (M3; between ~1.3 and ~0.6 Ma or 1.05–0.87 Ma) (Blackwell, 1994; Herries and Adams, 2013; Gibbon et al., 2014) bone tools are associated with Acheulian technology; although the bifaces suggested to come from these deposits were in fact recovered from limeminers dumps (Kuman, 2007). Subsequently, in South Africa, as with those from Olduvai, bone tools occur over a significant period of time (~1 Ma) and are associated with more than one stone tool industry. Moreover, they are also from a very geographically restricted area, only being found at sites within about a 10 km radius of each other.

The South African bone tools from Sterkfontein M5W, Swartkrans M1-3, and DMQ fall into the category of tools formed through use, although the exact nature of their use and hominin association (early *Homo* or *Paranthropus robustus*) has been a matter of debate (Brain and Shipman, 1993; Backwell and d'Errico, 2001, 2003). They are thus distinct from the East African flaked bone tools where it has been suggested that some may have been deliberately flaked according to a template, rather than being formed through utilisation (Backwell and d'Errico, 2004b; Deino, 2012).

Here we report the first discovery of bone tools from the *P. robustus* bearing palaeocave of Kromdraai B, that have the same published character as those from DMQ and Swartkrans (Fig. 1). We also provide the first description of stone tools associated with bone tools from the 2.0–1.4 Ma Drimolen Main Quarry. The paper then provides a discussion and review of how these bone tools may fit into the archaeological and hominin landscape of South Africa and the South African ESA.

2. Sites and samples

2.1. Drimolen Main Quarry (DMQ)

Drimolen is a fossil bearing palaeocave situated around 6 km to the north-east of the sites of Sterkfontein and Swartkrans, in the COH, South Africa (Figs. 1 and 2). Today the site is divided into two deposits, the much older ~2.61 Ma Drimolen Makondo (Rovinsky et al., 2015; Herries et al., 2018), which contains no archaeology or hominins to date, and the younger (2.0–1.4 Ma) hominin bearing Drimolen Main Quarry (DMQ) deposits that have been the main focus of excavations since the 1990s (Keyser et al., 2000; Adams et al., 2016; Herries et al., 2018). DMQ is well known for finds of *P. robustus*, including the most complete skull of this species ever discovered, DNH 7 (Keyser et al., 2000), as well as around 140 hominin fossils, that also include early *Homo* (Moggi-Cecchi et al., 2010). DMQ has also yielded a diverse fauna (Adams et al., 2016), and has a small published collection of 14 confirmed bone tools (Fig. 3) (Backwell and d'Errico, 2008). Originally 22 fossils were identified as having a general character of bone tools, however, only 14 (Fig. 3) (Backwell and d'Errico, 2008) were identified as definitively anthropogenically worked and the remaining eight were defined as pseudo-tools (Fig. 3D and E) (Backwell and d'Errico, 2008). Since this original announcement of the DMQ bone tools a series of 121 potential bone tools have been identified at DMQ based on overall gross morphology (currently under study by RCS). Moreover, excavations since 2013 have yielded several bone tools in close proximity to each other at the very basal limits of the known DMQ sequence. This makes the Drimolen collection comparable in size to that from Swartkrans (Brain and Shipman, 1993).

The DMQ bone tools recovered to date have all come from the central talus cone in the centre of the palaeocavern (Fig. 1). As Keyser et al. (2000) note, the stratigraphy of the DMQ is not very complex, and consists of a single unit of clast supported breccia in the centre of a large cavern, transitioning to matrix supported breccia and then laminated siltstone and sandstone at the edge of the cavern. While such different sedimentological deposits have been defined as different Members at other sites (e.g. the red siltstone and pink breccia of Makapansgat Limeworks Member 2 and Member 4 respectively; Partridge, 1979), recent work has shown that such deposits are often contemporary because the siltstone and sandstone deposits represent fine-grained material winnowed from the talus cones and deposited at the edge of caverns during flooding (Latham et al., 1999, 2003; Herries and Adams, 2013; Herries et al., 2018). Such processes are seen in nearby modern caves (i.e Wonder Cave) and this is certainly the case at DMQ. As such, all the bone tools from DMQ are considered to be from a single deposit and thus of a relatively similar age. This paper describes the first stone tools from DMQ.

2.2. Kromdraai B

The Kromdraai Locality (Figs. 1 and 4) has been of interest to palaeoanthropology since Broom's identification of the type specimen of *P. robustus* (TM 1517) at the site in 1938 (Broom, 1938a). The Kromdraai B sample includes 31 hominin specimens, with a minimum number of 17 individuals (Braga et al., 2013, 2016; Thackeray et al., 2001). Previously, the hominin remains have all been assigned to *P. robustus* (Broom, 1938a, 1938b; Vbra, 1981; Thackeray et al., 2001), although one, KB 5223, has been suggested to be more akin to early *Homo* (Braga and Thackeray, 2003). However; others have debated this assignment. KB 5223, was initially classified as *P. robustus* by Grine (1982) and additional assessment by Lacruz (2007) does not provide unambiguous evidence of the presence of *Homo* at Kromdraai B.

Kromdraai B has yielded only 2 stone tools, although the nearby site of Kromdraai A has yielded 100 artefacts and 'manuports' from decalcified and hard breccia deposits (N = 71), and miners dumps (N = 29) (Kuman et al., 1997). During our study of unaccessioned fossil martial housed at the Ditsong Museum of Natural History in Pretoria, and excavated at Kromdraai B by C.K. Brain between 1955 and 1956 (Brain, 1958, 1975, 1978, 1981), we discovered a number of fossils that had the gross morphology of bone tools as published at Swartkrans M1-3, DMQ and Sterkfontein M5W (Backwell, 2000). They represent the first potential bone tools from either site (A and B) at Kromdraai. The

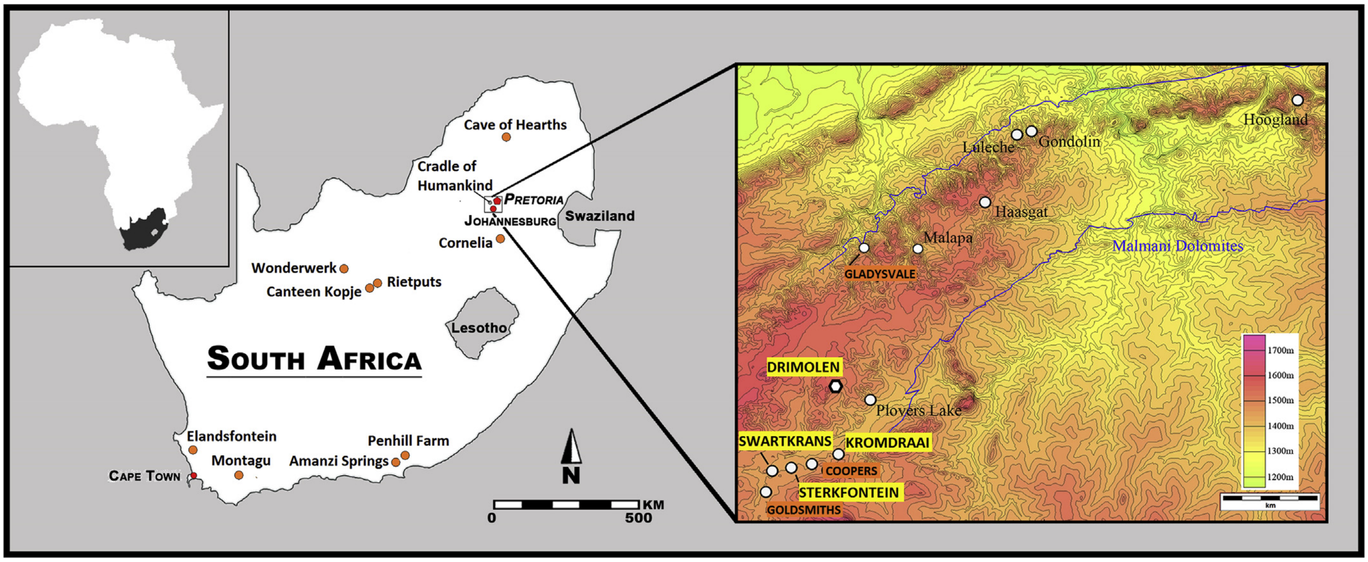

Fig. 1. Location of Kromdraai and Drimolen in comparison to other sites mentioned in the text. Orange: ESA stone tools sites; Yellow: bone and stone tool sites. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

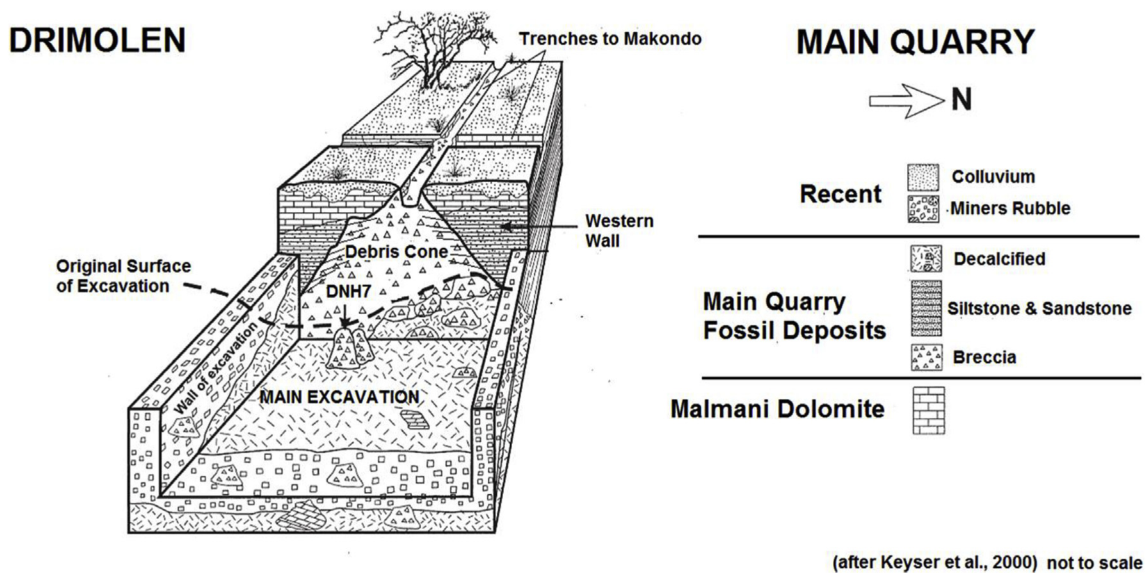

Fig. 2. The Drimolen Main Quarry deposits (after Adams et al., 2016). The archaeology and hominin remains have almost all come from the central debris cone area, or from miners rubble.

unaccessioned material excavated by Brain in the 1950s represents the largest collection of fossil material recovered from Kromdraai B to date, and has been subject to minimal analysis; however, they are included in bulk specimen counts by Vbra (1981) and Brain (1981). Despite its large size, the assemblage has only yielded eight hominin fossils. Brain's excavations focused on mainly decalcified deposits of the Kromdraai B East Formation. While Partridge (2000) considered the majority of the fossil remains excavated by Brain (1981), including the hominins, to have come from what he defined as Member 3 (Partridge, 1982), Braga et al. (2016, 2017) and Bruxelles et al. (2016) have recently redefined the stratigraphy and split Member 3 into more than one deposit (Table 1).

Kromdraai has in the past been divided into three separate sites, A-C, although Kromdraai B and C have now been shown to be contiguous and are generally referred to as just Kromdraai B (KB) (Partridge, 2000) (Fig. 4). KB has itself been split into the KB East and KB West deposits (Vbra, 1981) with the association between Partridge's (1982) five Members in KB East and the three in KB West not known (Vbra, 1981; Braga et al., 2016). These same deposits are referred to by Partridge (2000) as the KB Formation and KB West Formation. Recent excavations by Braga et al. (2016) have opened an extensive area (KE) north of the original KB excavations. They suggest that equivalent sediments occur at KA and KB and thus that the Kromdraai locality should be considered a single cave site with different aged infills; similar to Swartkrans or Sterkfontein (Braga et al., 2016). An extensive re-evaluation of the stratigraphy by Bruxelles et al. (2016) now defines seven Members, with Member 4 subdivided into 4.1–4.3. The relationship of these new Members to old Member sequences is shown in Table 1 and Fig. 4.

Like many Bloubank Stream Valley palaeocave sites, the dating of the Kromdraai locality is complex. Based on the proposed stratigraphy of Partridge (2000), biochronology and palaeomagnetism (Thackeray et al., 2002), the five Members of KB were suggested to date as follows by Thackeray et al. (2002): Member 1: > 1.95 Ma (Older than the Olduvai SubChron), Member 2: 1.95–1.78 Ma (Olduvai SubChron age). In a review of the age of *Paranthropus* sites Herries et al. (2009)

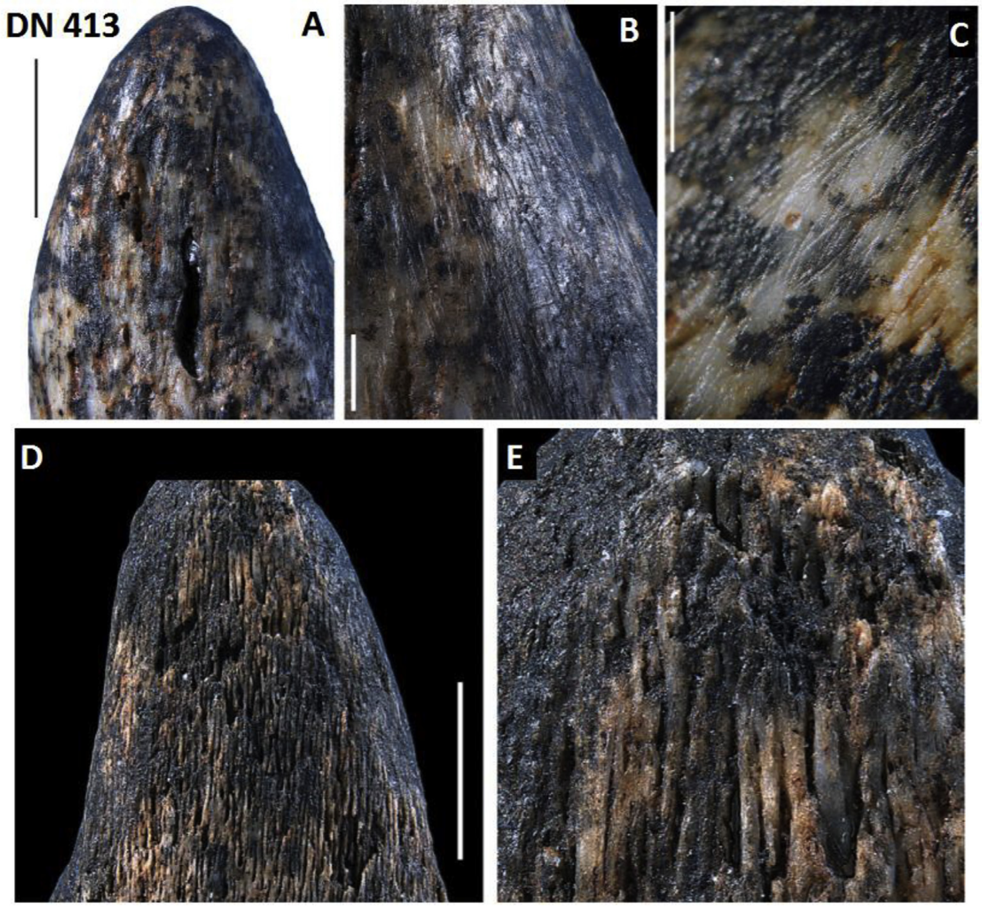

Fig. 3. A definitive bone tool (A-C; DNH 413) and pseudo-tool (D-E; DNH 1038) from DMQ based on the analysis of Backwell and d'Errico (2008).

suggested an age estimate of 1.78–1.65 Ma for the Member 3 deposits that Partridge (2000) stated all the hominins came from. Braga et al. (2016, 2017) have subsequently stated that "Herries et al. (2009) miscorrelated Thackeray et al.'s (2002) palaeomagnetic data and ignored the KB stratigraphy". They say that Thackeray et al. (2002) analysed a capping flowstone stratigraphically younger than Member 3 and obtained an interval of reversed polarity that they interpreted as older than the Olduvai Event (between 1.95 and 1.78 Ma). This interpretation was well in line with biostratigraphic data". This is actually not what Thackeray et al. (2002) state. In their concluding paragraph they clearly state that "Most, if not all, of the samples that we have analysed relate to Member 1 and 2 on the Eastern Side of Kromdraai B, but that the distinction between these two Members is not clear". As such, there is no suggestion in Thackeray et al. (2002) that they sampled anything younger than Member 2 (or Member 3 itself) as stated by Braga et al. (2016). Thackeray et al. (2002) interpret the reversed polarity to represent an age greater than the Olduvai SubChron at 1.95 Ma and the normal polarity to represent the Olduvai SubChron between 1.95 and 1.78 Ma. These are exactly the ages Herries et al. (2009) report for Members 1 and 2 of Kromdraai B, with the assumption that this polarity reversal occurs across the two Members Thackeray et al. (2002) suggested they sampled.

The identification of reversed polarity in the flowstone that Braga et al. (2016) state is younger than Member 3 does in no way specifically relate it to > 1.95 Ma, as it could equally represent ages < 1.78–1.65 Ma as suggested by Herries et al. (2009) as a good age estimate for Member 3. In defining an age for Member 3, Herries et al. (2009) simply took the reversed-normal-reversed polarity sequence that Thackeray et al. (2002) state is from Member 1 and 2 deposits to suggest an age of younger than the Olduvai SubChron, which ends at ~1.78 Ma, for Member 3 as interpreted by Partridge (2000); as Partridge's (1982, 2000) Member sequence moves from oldest to youngest from Member 1–5. At the time (2009), no other stratigraphic interpretation existed for the site. Thus there was no misinterpretation of the stratigraphic sequence as it was then currently understood and Bruxelles et al. (2016) have only very recently re-evaluated the Kromdraai stratigraphy (Table 4). Due to this, the Member 3 deposit of Partridge (1982, 2000), from which the majority of hominins are meant to have been recovered, is now divided into two separate units (Member 3 and Member 4.1). As such, the dating of the deposits as suggested by Herries et al. (2009) can thus no longer be applied, especially given the fact that Braga et al. (2016) seem to suggest the palaeomagnetic samples taken by Thackeray et al. (2002) were from deposits younger than Member 3. If the flowstone that Braga et al. (2016) refer to as being younger than Member 3 is the one in Fig. 5 from Thackeray et al. (2002), then reversed polarity also occurs in the red breccia shown capping it (sample KRM6). This would either make Members 1–3 older than 1.95 Ma or may suggest that an entirely different, post 1.78 Ma younger reversal is recorded. Recent work (Pickering et al., 2011) has shown that short reversals can occur in these palaeocave deposits and that they are much more numerous than once thought (Singer, 2014). Due to this it is increasingly difficult to correlate normal and reversed polarities to specific Chrons or SubChrons without some supportive chronometric ages (e.g uranium-lead, electron spin resonance, cosmogenics). Moreover, the reanalysis by Bruxelles et al. (2016) clearly highlights the complex interaction and reworking of various stages of breccia formation, especially around what they call the Holotype Block, which also seems to be what Thackeray et al. (2002) sampled. Thackeray et al. (2002) suggest based on the matrix of the TM1517 type specimen of *Paranthropus robustus* that it may have come from Member 1. However,

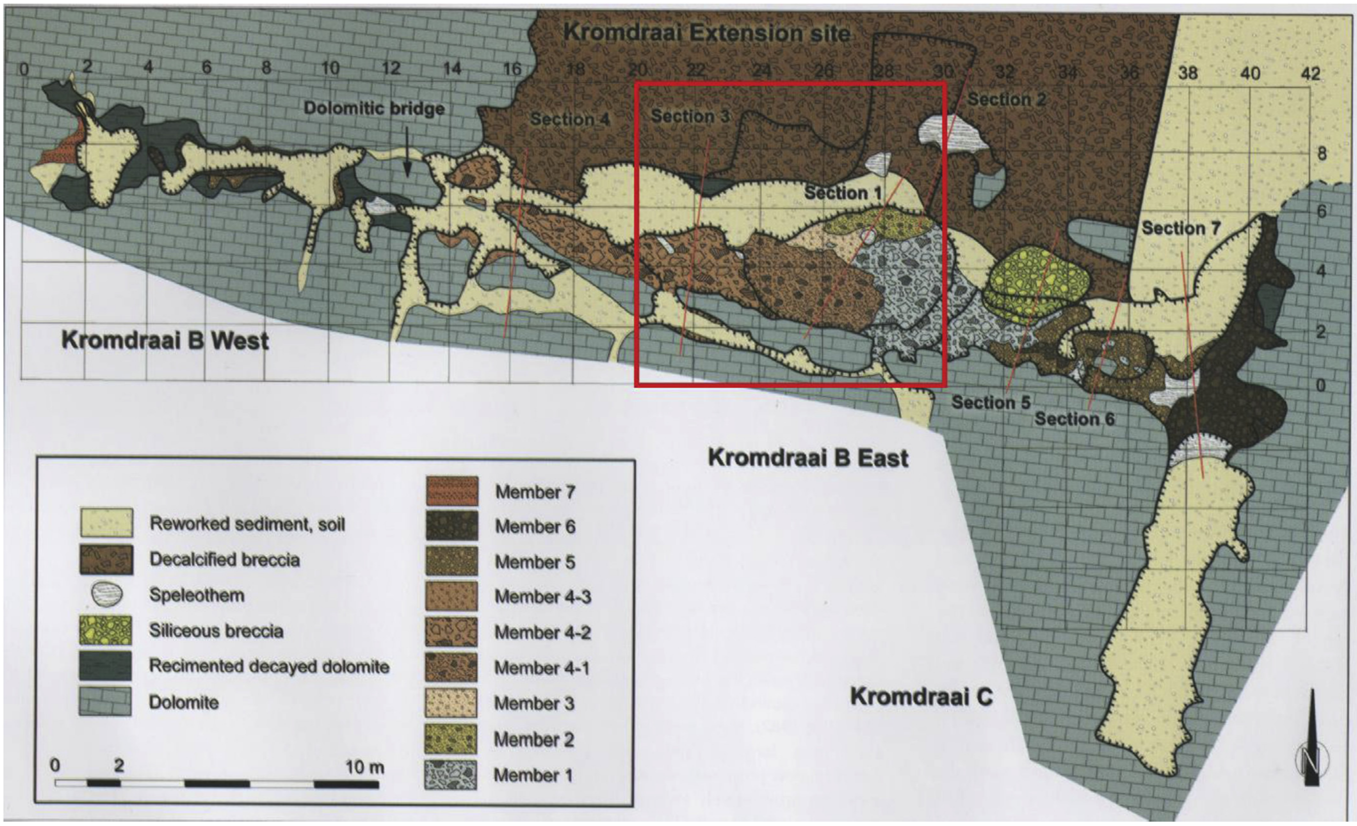

Fig. 4. Bruxelles et al. (2016) reinterpretation of the stratigraphy and Member sequence of Kromdraai B. Brain's 1955 and 1956 excavations, and the source of the bone tools, were decalcified deposits between E-W grids 20–30 (red square). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 1
Comparisons of the stratigraphic divisions of Brain (1958), Partridge (1982, 2000), Bruxelles et al. (2016).

Brain, 1958	Partridge, 1982, 2000	Bruxelles et al., 2016	Description
Stony breccia	Member 1	Member 1	Grey dark stony breccia
Pink breccia	Member 2	Member 2	Bedded Orange breccia, fine grains and blocks
Pink breccia	Member 3	Member 3	Pink Sandstone with no sedimentary structure.
Pink breccia	Member 3	Member 4.1	Pink Bedded breccia and sandstone becoming stonier towards distal part
Pink breccia	Member 4	Memner 4.2	Massive pink sandstone becoming stonier towards distal part
Pink breccia	Member 5	Member 4.3	Breccia with more abundant sandy breccia
Pink breccia	Member 1 (KB West)	Member 5	Orange sandstone including little pieces of weathered breccia and ferruginous fragments.
Pink breccia	Member 2 (KB West)	Member 6	Orange to brown breccia with only weathered chert and ferruginous fragments
Pink breccia	Member 3 (KB West)	Member 7	Bedded orange sandstone including gravel layers

Bruxelles et al. (2016) suggest that the Member 1 Grey Dark Stony Breccia formed prior to an entrance having formed in the cave. It appears that small blocks of this Member 1 breccia occur within Member 5 and 6 deposits in this location and thus it seems that either this type specimen came from these deposits, or from within blocks worked into this conglomerate of different breccias when the centre of the cavity may already have been deroofed (Bruxelles et al., 2016).

Despite the re-evaluation of the stratigraphy by Bruxelles et al. (2016) into 7 Members, with 3 sub-Members for Member 4, they still consider these Members to represent packages of sediments, with Member 1 being a distinct early phase formation mostly derived from material inside the cave. In contrast Members 2–4 represent the influx of externally derived material in the central portion of the cavity. Members 5 and 6 represent formation at either end of the cavity, perhaps when the central roof had been eroded away. This is not dissimilar to the way that Partridge (1982, 2000) divided the site, with Bruxelles et al. (2016) Members 5–7 representing Partridge's (1982, 2000) Members 1–3 of the KB West Formation, and Member 1 being separate and Members 2–4 being represented by Partridge's Members 2–5. The major change is in splitting Member 3 into a separate Member 3 and a subunit of Member 4 (4.1). Bruxelles et al. (2016) also identify deposits representing Members 5–6 in the area where Kromdraai B East and Kromdraai C meet, whereas in Partridge's (1982, 2000) scheme these are only found in KB West. This change in interpretation is particularly highlighted in the area of the Holotype Block and palaeomagnetic sampling.

Despite a very comprehensive series of papers in Braga and Thackeray (2003), including a review of the stratigraphy by Bruxelles et al. (2016), there are no age estimates for the site beyond vague statements suggesting an age of between 2.6 and 2.0 Ma (Braga et al., 2016). This appears to be based on the palaeomagnetic interpretation of the magnetic reversal identified at the site representing the base of the Olduvai Chron at 1.95 Ma. However, given the uncertainty in what was sampled at the site for palaeomagnetism versus the biochronology from the fauna, this seems a somewhat premature assessment.

The KB fauna has been recovered during five phases of study

Table 2
Characters of bone tools as previously defined.

	Rounding	Smoothing/Polish	Striations	Element
Bone tool (after Backwell and d'Errico, 2001)	Single rounded end	Confined to between 5 and 50 mm from the tip	Covering worn tip, including recessed areas, 5–40 μm wide, running parallel or subparallel to the long axis of the bone. Not on other areas of bone	Any, but particularly bone flakes and horn cores.
Pseudo-tool (after Brain, 1968; Backwell and d'Errico, 2001)	Not restricted, predominantly on more than one area	Not restricted, predominantly on more than one area	If any (not common), perpendicular to the main axis of the bone. > 50 μm wide, discontinuous	Any

(Fourvel et al., 2016): Broom's initial collections between 1938 and 1944, Brains excavations in 1955 and 1956 which recovered the bulk of the fossil material to date, Vbra's excavations between 1977 and 1980, Thackeray's work from 1993 until 2002 and Braga's excavations since 2002). The earliest excavated fossils are accessioned with the prefix TM and are held at Ditsong National Museum of Natural History. Others are accessioned with KA or KB, depending on which deposit they derive. More recent fossils from the Braga et al. (2016) post-2014 excavations have the prefix KW and are held at the Evolutionary Studies Institute of the University of the Witwatersrand in Johannesburg. An extensive number of fossils from Brain's excavations at Kromdraai B have not been accessioned. This includes the potential bone tools that are reported here, which have been assigned vacant numbers in the KB number series. It should be noted that the magnitude of the KB number does not necessarily designate the time period in which it was excavated.

Brain's excavations occurred prior to any formal definition of stratigraphy at the site and consisted primarily of excavations into decalcified material along what Brain thought was the northern wall of the KB eastern exposures. Brain (1958) states that this material all came from a single unit and Partridge (2000) considered this to represent Member 3 in his stratigraphic scheme. Similarly, the majority of Vbra's material was thought to have come from Member 3, with Member 2 considered sterile (Vbra, 1981). However, Braga et al. (2016) note that the association of all the fossils to Member 3 is not certain in the majority of cases. Brain's excavations of mostly decalcified material between E-W coordinates 20–30 m of Vbra (1981) grid. This area includes Members 1–4 and thus the material excavated from the decalcified deposits could come from any of these Members, except presumably Member 1. This is the package of sediments filling the central part of the cavity. Brain additionally excavated into a ‘Stony Breccia’ at the Eastern end of KB that Bruxelles et al. (2016) interpret as being their Member 6 and a stratified fine breccia. Braga et al. (2016) also consider that the large collection recovered by Brain from decalcified deposits may come from Members 1–4, that exists in the central area of the site, and that, as noted by Partridge (1982), major hiatuses and thus large time periods may occur between the deposition of different Members. As such, the exact association to Member of Brain's material, and thus the bone tools described here, is questionable. Bruxelles et al. (2016) suggest it is impossible to relate Brain's material to a single Member. Moreover, due to the non-accessioned nature of the material within the museum the material has no detailed spatial information or provenience beyond coming from Brain's 1955–56 excavations. Assigning an age to these bone tools is thus difficult. To date, our study has analysed 499 bone flakes of various sizes from the Kromdraai B fossil collections.

3. Methods

3.1. Stone tool methods

All stone tools from the DMQ were analysed according to their typologies, raw material types, cortex ratios and weathering pattern, as well as measured with digital calipers (mm). Core exploitation patterns were assessed through a diacritical analysis, which examines flake scar patterns to reconstruct reduction methods (Forestier, 1999; Domínguez-Rodrigo et al., 2002; Baena and Cuartero, 2006; de la Torre et al., 2008; Baena et al., 2010; de la Torre, 2011; Carmignani et al., 2017; Sánchez-Yustos et al., 2017). This includes the number of flaking surface, flake scar orientation, core rotation and the angle of flake detachments (Baena and Cuartero, 2006; Natron et al., 2014; Baena et al., 2017, 2010; Sánchez-Yustos et al., 2017). Flakes were analysed by dorsal scar count and cutting edge measurement. This information is used to assess technological organisation of flaking systems, although the small sample size from the DMQ only provides a preliminary insight such behavioural capacities of the Drimolen tool-makers.

3.2. Bone tool analysis

Backwell and d'Errico (2001) defined the South African early Pleistocene bone tools based on the use-wear pattern and gross morphology of the fossils (Table 2). The Kromdraai B sample was thus assessed against the published definition (Backwell and d'Errico, 2001) of a bone tool from the early Pleistocene hominin sites from South Africa (Table 2). The Kromdraai B specimens were analysed and imaged using a Dino-lite Edge AM4815ZTZ (AnMo Electronics Corp.) variable field of depth digital microscope. Under white LED cross-illumination, images were taken with the Dino-lite camera at low magnifications between 15× and 80×, according to the visibility of wear patterns and modifications on the materials. All measurements were taken using digital callipers of the maximum width and length of each specimen. Mammal size class of the bone flakes was estimated using the method outlined by Reynard et al. (2014).

The identification of bone surface modifications was based on comparison with reference materials collected by C. K. Brain (1981) during his tenure at the Ditsong Museum of Natural History in Pretoria, South Africa (formally the Transvaal Museum), fossils from the Florisbad spring site (Brink, 1988), reference materials housed at Arizona State University, fossils from the palaeocave site of Gondolin (GD1, Adams et al., 2007, and GD2, Adams and Conroy, 2005) and the published early hominin bone tools from the palaeocave sites of DMQ, Swartkrans M1-3 and Sterkfontein M5W (cast only). These bones were modified by human and nonhuman agents, including hyena, dog, leopard, cheetah, porcupine, river gravel, spring water, flood plain, wind, trampling and digging. Modifications were also compared against taphonomic literature (Maguire et al., 1980; Brain, 1981; Shipman, 1989; Cook, 1986; Smith and Poggenpoel, 1988; Olsen and Shipman, 1988; White, 1992; Lyman, 1994; Fisher, 1995; Buc, 2011; Fernandez-Jalvo and Andrews, 2016), including published modifications on bone tools that were used to treat skin and hide with or without the addition of sand, remove bark from trees, process fruit and dig in various sedimentary environments (Shipman et al., 1984; Shipman and Rose, 1988; Shipman, 1989; Backwell and d'Errico, 2004a, 2004b), that were intentionally shaped using different techniques (Webb and Allen, 1990; LeMoine, 1997; d'Errico and Backwell, 2003) and submitted to treatments mimicking long-term transport in leather bags (d'Errico, 1993).

Additionally, the principles of traceology (use wear analysis) were applied to the specimens to understand the potential anthropogenic nature of surface modifications (after Buc, 2011). Any lineal and deep trait seen in the bone surface is considered a striation. If identified, striations were classified according their distribution and morphology (following Legrand and Sidéra, 2007). Distribution (relative to tool's axis): transversal, longitudinal, random (Averbouh, 2000). Arrangement (among striations): parallel, crossed, irregular (Buc, 2011). Morphology Width: narrow, wide (defined by the observer), variable (the same striation has different widths along its entire length). Depth: deep, shallow. Length: long, short. Length is defined according they are shorter or larger than 1 cm (Legrand and Sidéra, 2007).

Weathering stages were also noted for each fossil, however, weathering stages as defined by Behrensmeyer (1978) for the Amboseli ecosystem are used in a descriptive capacity only, and not to suggest an estimation of exposure on the surface prior to bone burial. The weathering stage schema may not be appropriate for the Gauteng area due to the difference between the Highvelt and Amboseli ecosystems and the uncertainty of the effect of cave deposition on weathering duration and rates (as defined by Lyman and Fox, 1989).

4. Results

4.1. Drimolen Main Quarry (DMQ) stone tools results and discussion

DMQ has yielded a small lithic assemblage of six artefacts, comprised of three flakes and three cores. Quartz (N = 3; 50%), quartzite (N = 2; 33%) and chert (N = 1; 17%) were used as raw materials although the provenance of material sources is unknown (Figs. 5 and 6). On the modern landscape, an exposed quartz vein is located on a hill directly to the southwest of DMQ, although it is not known if this vein was available to the hominin tool-makers or was exposed more recently by erosional forces. Furthermore, quartzite sources are not found locally (> 1 km) suggesting a degree of transport. Chert on the other hand is interbedded within the Malmani dolomitic formation and was likely sourced at or near the site. Most artefacts are in a fresh condition with two cores slightly weathered, suggesting their rapid incorporation into the cave deposits upon discard.

While sample size prevents conclusive interpretations of these materials, they fit within a Mode 1 technological designation. Thus, DMQ likely represents an 'Oldowan-like' assemblage, as found in the Swatkrans M1LB deposits somewhere between 2.33 and 1.64 Ma (Pickering et al., 2011), and Sterkfontein Member 5B (East; Oldowan Infill) (either < 1.6 Ma; Herries and Shaw, 2011 or 2.4–2.0 Ma, Granger et al., 2015); both also bone tool bearing deposits. Core dimensions average 6.30 cm in length, 5.30 cm in width, 3.83 cm in thickness and 139 g in weight and include a bifacial, discoid and single platform core forms (Fig. 5). Cores do not exceed ten percent cortex and exploitation patterns were organized around radial and bifacial strategies that maximized material expenditure (DN 1110 and 2904). The single platform core (DN 5405) is likely made on a quartz chunk suggesting possible recycling of waste materials. Flake dimensions average 6.15 cm in length, 4.92 cm in width, 2.32 cm in thickness, 61.10 g in weight and 26.74 cm in usable cutting edge and bare no cortical surfaces (Fig. 6). These flake proportions are considerably larger than flakes from both Swartkrans M1LB (4.26 cm × 3.56 cm × 1.36 cm × 30.4 g) and Sterkfontein M5B (3.47 cm × 2.74 cm × 1.04 cm × 11.4 g). Also, one large quartz flake (DN 215) has been retouched around its lateral and distal edges.

These patterns imply that material economisation may have played a role in tool-making activities. The lack of cortex on artefacts, recycling and retouch points to the fact that the DMQ hominins extensively reduced toolstone. Furthermore, the large size of flakes suggests that knapping strategies were likely focused on maximizing cutting edge production, and the retouched flake further supports attempts to extend the use-life of flake tools. As such, it is possible that these practices are reminiscent of patterns uncovered in East Africa, particularly the Karari sites in the Koobi Fora formation (Braun et al., 2009). Here, the manufacturing of single platform cores (i.e. 'Karari scrapers') represents economic exploitation patterns of raw materials that may have been scarce during the deposition of the Okote member (~1.6 Ma) (Braun et al., 2009). Thus, as transport costs increase with distances to material sources, extending the use-life of raw materials limited consumption risks. Interestingly, the Karari sites are associated with both geomorphological shifts in the Palaeo-Omo River and the appearance *of Homo erectus/ergaster* (Braun et al., 2009). If a similar model were applied to DMQ, the small assemblage of stone tools and

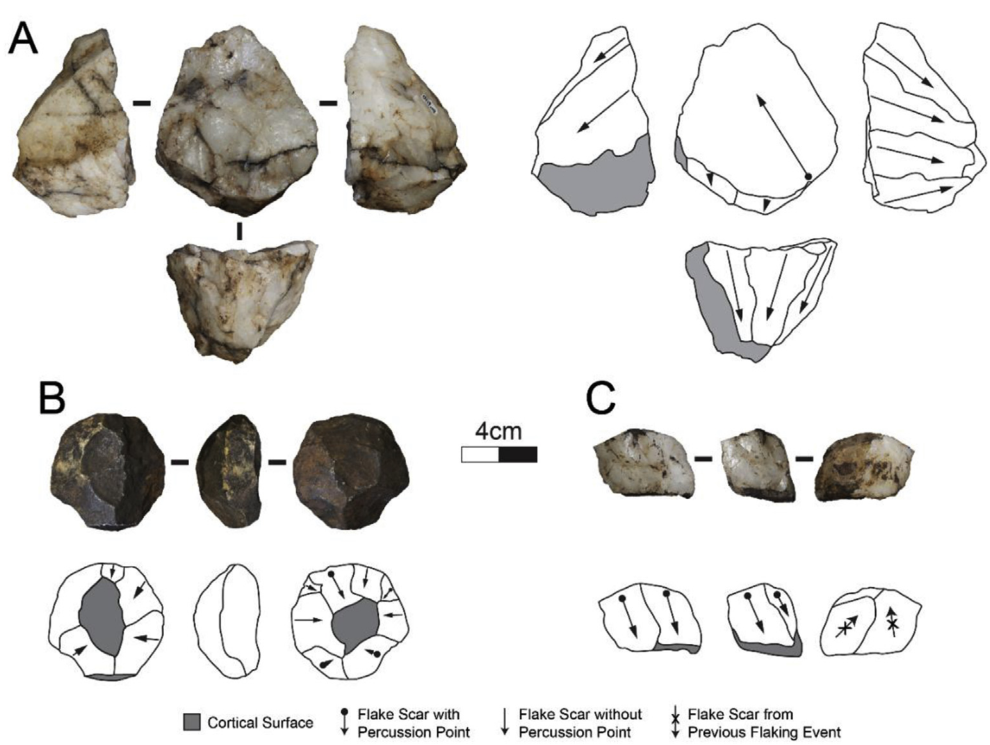

Fig. 5. Cores from DMQ: A. Quartz core showing bifacial, orthogonal reduction strategy (DN 1110); B. A quartzite core showing a radial, alternating reduction strategy (DN 2904); C. A quartz core made on a possible chunk (DN 5405).

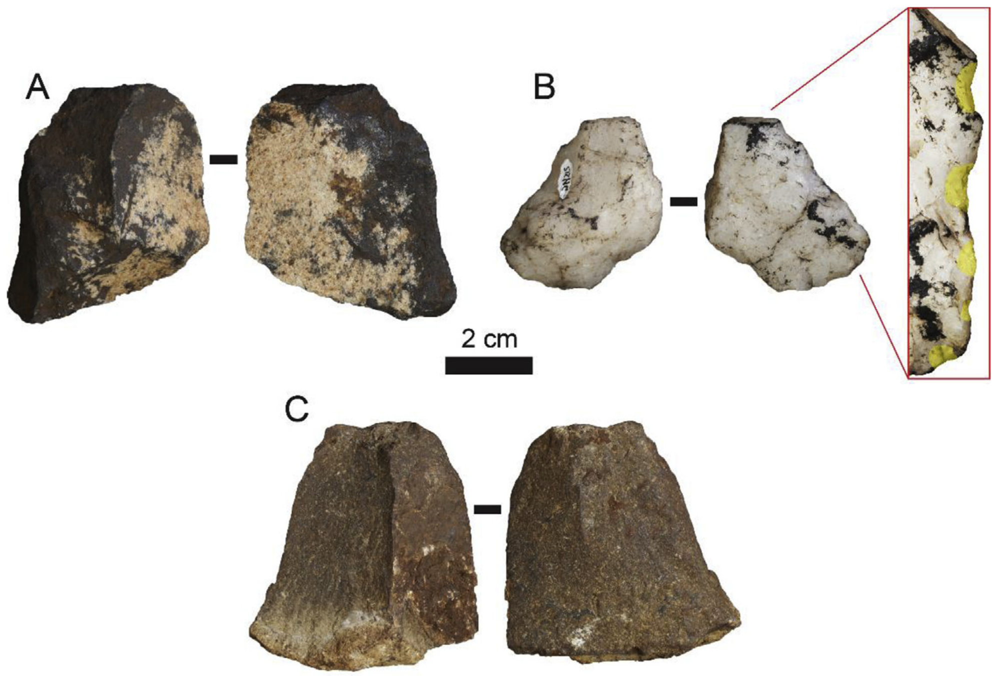

Fig. 6. Flakes from DMQ: A & C. Quartzite flakes; B. A quartz flake with discontinuous retouch.

the suggested patterns of material economy may stem from transport cost issues. In this sense, the lack of immediate raw material sources near DMQ (particularly quartzite) required increased transport costs for hominin tool-makers, which were managed through extensive reduction sequences, including recycling and flake retouch. Interestingly, DMQ is positioned relatively high in elevation within the Malmani dolomites when compared to Sterkfontein and Swartkrans, which contain larger assemblage sizes of Oldowan materials. Therefore, DMQ may have been farther from reliable toolstone sources when compared to the Bloubank Stream Valley sites, which are in close proximity to the palaeo-Bloubank stream gravels (Kuman, 2007).

4.2. Kromdraai B bone tool results and discussion

Based on visual characterisation and comparison of 3D and z-stacked images of use-wear, of the 499 specimens analysed from the Kromdraai B faunal assemblage sample, only two fossils (KB1585 and KB6012) (Figs. 7 and 8) conform to the published definition of bone tools from the South African ESA. They display a single rounded tip, with a localised lateral to sub-lateral striation pattern, which radiates from, and is restricted to, within 40 mm of the rounded tip, and is oriented sub-parallel to the main axis of the tool. Both artefacts (Fig. 7; Table 3) were formed on straight diaphyseal bone flakes from medium-to large-sized mammals. The good cortical preservation of KB6012, allows for a well-preserved striation pattern (Figs. 7 and 8). However, the striations on KB1585 are faint, due to the poor preservation of the bone cortex (Fig. 7). Additionally, 11 pseudo-tools were identified (Fig. 9). These specimens present a single rounded and polished tip, with no associated striations. Several other surface modifications were noted on the sampled assemblage. These include edge rounding from water movement, carnivore bite marks, root etching, beetle boring holes and rodent gnawing.

Several bone tools from the ESA have been published from three cave sites in South Africa. Eighty four bone tools have been recovered from Swartkrans Members 1–3 (M1-3; < 2.3- > 0.8 Ma) (Brain et al., 1988; Brain, 1989; Backwell and d'Errico, 2004b; Herries and Adams, 2013), 14 from DMQ (although there are 121 potential bone tools under study (2.0–1.4 Ma)) (Keyser et al., 2000; Backwell and d'Errico, 2008; Herries and Adams, 2013), and a single specimen from Sterkfontein Member 5 West (M5W, Oldowan infill) (M5B, Robinson, 1959).

At Kromdraai B, DMQ, Swartkrans M1-3 and Sterkfontein M5W, raw material selection, the type of bone selected for tool production, focused primarily on straight diaphyseal bone flakes, predominantly from medium-to large-sized mammals. However, since size class III–IV mammals are comparatively under-represented at DMQ, bone with a thinner cortex was selected, predominantly from class II to III. At Kromdraai B, artefacts fall within the mammal size classes III to IV (Table 3). The exceptions to bone flake selection are two mandible fragments, a rib, and a horn core from DMQ (Backwell and d'Errico, 2008), and one mandible, seven ribs, and fourteen horn cores from Swartkrans (Backwell and d'Errico, 2001).

Both Kromdraai B specimens displays post-depositional/utilisation breakage (Fig. 6). Both have pre-depositional breakage visible on the opposite end to the rounded tip; KB6012 has a transverse, right angle break and KB1585 a transverse, oblique/right angle break. This type of ‘right angle break’ is evident in many of the specimens from Swartkrans and DMQ. At these sites, most of the tools are represented only by their tips (Backwell and d'Errico, 2008). This breakage pattern may be a consequence of the digging action that has been suggested by Backwell and d’Errico, a penetrative and levering action (d'Errico and Backwell, 2009), coupled with the selection of dry bone (Backwell and d'Errico, 2001) that does not have high elastic qualities and thus is easily fractured. However, the Kromdraai B tools do not appear to have been produced on bone that was heavily weathered before use. However; KB1585 may have weathered on the surface after use, before being incorporated into the cave based on the weathered state of the striation marks on the specimen (Fig. 7). This would support the selection of unweathered raw material. Additionally, KB6012 does not display any long weathering cracks, as is the case for the majority of the tools at the other sites, and is relatively unweathered, displaying a weathering stage I-II.

Pseudo-tools have been noted at both Drimolen and Swartkrans (Backwell and d'Errico, 2001, 2008, Fig. 9) The Kromdraai B assemblage also contains similar abraded materials. Abrasion is defined as the erosion of a bone's surface, by any agent, through physical force (Bromage, 1984). It is characterised by smoothness, and a glossy polish through the removal of external lamellar bone (Behrensmeyer, 1982).

Fig. 7. Newly identified bone tools, left, KB1585 and, right, KB6012, from Kromdraai B.

Many of the bone flakes analysed in the Kromdraai B assemblage display abrasion (this analysis; Brain, 1981). This rounding has also been noted within the Swartkrans and DMQ assemblages. These flakes are rounded and shiny; however, this polish is not localised, and the majority of the specimens lack any form of striation pattern. Water movement through the cave (Brain, 1981) or inwash from the surrounding landscape, may account for this modification, as Kromdraai B has been suggested to have had a vertical entrance (Brain, 1958; Vbra, 1981), at some stage in its history.

Two hypothesises exist for the accumulation of the faunal assemblage. 1) it was collected by either mixed carnivores (Brain, 1981) or exclusively by hyenas (Braga et al., 2016) or 2) it was a death trap situation for bovids and the vast collection of primates that have been recovered, which were then opportunistically scavenged by carnivores (Vbra, 1981). It is also possible that given the large number of primate fossils from the site that it was at some stage a sleeping site for primates (Val et al., 2014). Given the extensive number of deposits suggested by Braga et al. (2013, 2016), it seems highly likely that all these different depositional mechanisms may be responsible for deposition at different times. Such a depositional mechanism may suggest why there is such a small archaeological assemblage from the site.

Research into South African ESA bone tool assemblages, since their initial announcements, has further refined the characteristic of these bone tools (Backwell, 2000; Backwell and d'Errico, 2001, 2003, 2004a; d'Errico and Backwell, 2005; d'Errico et al., 2001; d'Errico and Backwell, 2003, 2009). The light weight nature of the South African ESA bone tools makes them portable yet highly useful for a variety of tasks. Brain and Shipman (1993) originally proposed tuber procurement and hide working, based on scanning electron micrograph images of the rounded ends of the specimens, as the primary task undertaken with the bone tools. Other studies, while not disputing the artefactual nature of the specimens, propose other tasks such as processing fruits (Brain and Shipman, 1993; d'Errico and Backwell, 2009). Backwell and d'Errico (2001, 2003, 2005) propose the excavation of termite mounds,

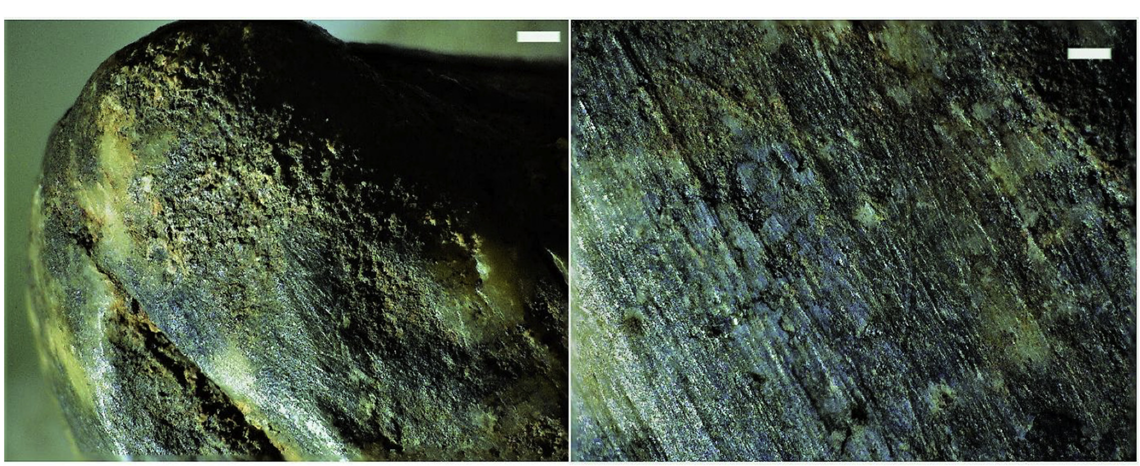

Fig. 8. Striation patterns present on KB6012, 40× magnification (scale 1 mm).

Table 3
Measurements of the Kromdraai B bone tools.

ID#	Bone type	Length (mm)	Width (mm)	Height (mm)	Cortical thickness (mm)	Class size (after Reynard et al., 2014)
KB6012	Long bone mid shaft	45.4	15.1	9.7	6.9	IV
KB1585	Long bone mid shaft	48.8	14.6	6.7	6	Upper III/IV

whereas Van Ryneveld (2003) concludes that the bone tools were a multi-purpose implement, used for both termite extraction and tuber digging, as well as other tasks, such as bark removal and hide processing. Lesnick and Thackery (2007) concurs with Van Ryneveld (2003) in regard to the multi-purpose nature of the purported bone tools, stating that, although the tools studied by Backwell and d'Errico manifest a characteristic wear pattern that strongly suggests their use on termite mounds, the analysis presented by Backwell and d'Errico does not refute the analysis conducted by Brain and Shipman (1993). Further research utilising complex surface microtopography of a sample of the Swartkrans and DMQ specimens concur that the tools were utilised for digging activities as well as other unidentified activities (d'Errico and Backwell, 2009). It was postulated that this digging activity was conducted in soil rich in loose abrasive particles of different sizes with consistent motions parallel to the tool's main axis and perpendicular to the penetrated matter (d'Errico and Backwell, 2009). However, the complex surface microtopography results were inconclusive to an individual activity beyond simply digging, creating uncertainty as to the exact use of the bone tools.

While termite mounds have been suggested to contain such a dirt profile, they are not the only environments to do so. Therefore, digging within termite mounds cannot be considered the only task carried out with the bone tools. It is more likely that they were utilised for a wide variety of tasks, most likely including foraging for termites. The pattern observed on the Kromdraai B specimens supports the multi-use hypothesis. The pattern, although similar to those on the Swartkrans, Sterkfontein M5W and DMQ tools, does not perfectly replicate the termite foraging striation pattern but does correlate with sedimentary abrasion.

5. The place of bone tools in the ESA of South Africa

This research reports for the first time the occurrence of bone tools from the hominin bearing palaeocave site of Kromdraai B, which has yielded only two definitive stone tools (a core and a flake; Kuman et al., 1997), as well as the first small collection of six stone tools from DMQ that are associated with an ever increasing collection of bone tools. This work expands the number of sites that now contain both ESA stone tool technology and bone tools to include Swartkrans M1-3, Sterkfontein M5W, Kromdraai B and DMQ. DMQ is the only site in the COH outside of the Bloubank Stream Valley to contain both bone and ESA stone tools (Fig. 1; Table 4). A review of the sites that contain bone versus stone tools and hominins indicates that there is no clear pattern (Table 4). While DMQ and Swartkrans, as a whole, contain the largest number of bone tools and are dominated by *Paranthropus*, there are also early *Homo* specimens from these sites. At Kromdraai B only *Paranthropus* has

Fig. 9. Examples of pseudotools from Kromdraai B, top left KB243, 54 × magnification (scale 1 mm); top right KB838 80× magnification (scale 0.5 mm); bottom left KB 1693, 54× magnification (scale 1 mm); bottom right KB1790, 54× magnification (scale 1 mm).

Table 4
Chronology and hominin and archaeological associations of the palaeocave sites in the Gauteng portion of the Hominid Sites of South Africa UNESCO World Heritage Area, South Africa (COH).

SITE	Bone Tools	Stone Tool Industry	LCTs	Artefact No.	Bone Preservation	Hominin	Context	Age Estimate (between)	Dating Method	Reference
Swartkrans M1LB	32	Mode 1		298	x	*Paranthopus*/early *Homo*	palaeocave	< 2.3- > 1.6 Ma	Cosmogenics, ESR, U-Pb	Herries and Adams, 2013; Gibbon et al., 2014
Swartkrans M1HR					x	*Paranthopus*/early *Homo*	palaeocave	< 2.3- > 1.8 Ma	Cosmogenics, ESR, U-Pb	Herries and Adams, 2013
Drimolen MQ	14	Mode 1		6	x	*Paranthopus*/early *Homo*	palaeocave	< 2.0- > 1.4 Ma	ESR	Herries et al., 2018
Rietputs other sites		Acheulian	x	1174			alluvial gravels	< 1.9/1.4- > 1.0 Ma	Cosmogenics	Leader et al., 2018
Swartkrans M2	11	Acheulian	x (ex-situ)	388	x	*Paranthopus*/early *Homo*	palaeocave	< 1.7- > 1.1 Ma	U-Pb(t)	Herries and Adams, 2013
Sterkfontein M5B		Mode 1		3245	x	*Paranthropus*	palaeocave	< 1.62- > 0.83 Ma or 2.4–2.0 Ma	ESR, U-Pb. Or cosmogenics	Herries and Shaw, 2011; Granger et al., 2015
Canteen Kopje		Acheulian	x	15,243			alluvial gravels	< 1.6- > 0.8 Ma,	Cosmogenic data not published	Li et al., 2017
Rietputs Pit 5		Acheulian	x	1174			alluvial gravels	< 1.5- > 1.1 Ma	Cosmogenics	Leader et al., 2018
Coopers D		unknown		50	x	*Paranthopus*	palaeocave	~1.4 Ma	U-Pb	de Ruiter et al., 2009
Sterkfontein M5C	1	Acheulian	x	701	x	early *Homo*	palaeocave	< 1.4- > 0.8 Ma	ESR, Pmag.	Herries and Shaw, 2011
Swartkrans M3	41	Acheulian		299	x	*Paranthopus*	palaeocave	< 1.3- > 0.6 Ma	Cosmogenics, ESR, U-Pb(t)	Herries and Adams, 2013; Gibbon et al., 2014
Goldsmith's		Mode 1/MSA?		13	x		palaeocave	unknown		Kuman, 2007
Kromdraai B	2	unknown		2	x	*Paranthopus*	palaeocave	normal & reversed polarity	Pmag.	Kuman, 2007
Kromdraai A		Acheulian?		100	x		palaeocave	unknown		Kuman, 2007
Cornelia-Uitzoek		Acheulian	x	124	x	early *Homo*	alluvial sediments	< 1.07- > 1.01 Ma	Pmag., fauna	Brink et al., 2012
Wonderwerk L12		Mode 1		65	x		cave sediments	~1.01 Ma or ~1.78 Ma	Cosmogenics., U-Pb, Pmag.	Herries, 2011; Pickering, 2015; Chazan et al., 2012
Wonderwerk L6-11		Acheulian	x	269	x		cave sediments	< 1.01- < 0.78 Ma	U-Pb., Pmag.	Herries, 2011; Pickering, 2015; Chazan, 2015
Elandsfontein		Acheulian	x	1000s	x	*Homo rhodesiensis*	dune deflation	~1.0–0.6 Ma	Fauna	Braun et al., 2013
Gladysvale		Acheulian	x	1	x		palaeocave	> 0.78 Ma	Palaeomag., ESR	Herries, 2011; Hall et al., 2006
Amanzi Springs		Acheulian	x	> 3299			spring deposits	unknown		Deacon, 1970
Cave of Hearths		Acheulian	x	2212		*Homo rhodesiensis*	cave sediments	< 780 ka	Pmag.	Herries and Latham, 2009

been definitively identified, while the one bone tool from Sterkfontein M5 West is associated with fossils attributed to early *Homo* (Kuman and Clarke, 2000).

DMQ is the only site outside the Bloubank Stream Valley group of sites to contain bone tools, which are not found at other *Paranthropus* sites to date, such as Cooper's D and Gondolin. DMQ also contains the only known Mode 1 technology site outside of the Bloubank Stream Valley, other than the potential Mode 1 assemblage from Wonderwerk Cave Layer 12 (either ∼1.78 Ma or perhaps as young as ∼1.01 Ma; Pickering, 2015). However, the small number of artefacts from DMQ, and its age (sometime between 2.0 and 1.4 Ma) make this designation not definitive. DMQ is however only one of two sites, the other being Gladysvale's single Acheulian handaxe (Hall et al., 2006), that have yielded stone tools outside the Bloubank Stream valley in the COH.

Bone tools are found in a wide range of deposits between approximately 2 and 1 Ma and in deposits containing both Mode 1 (DMQ; Swartkrans M1LB) and Acheulian technology. Interestingly, neither bone or stone tools have yet to be discovered in Swartkrans Member 1 Hanging Remanent, despite the hominin remains found there. This perhaps further defines the unique nature of the two different Member 1 deposits, despite their suggested similar age. Bone tools are yet to be noted in the Oldowan infill at Sterkfontein, despite it being one of the largest collection of stone tools (3245) recovered from the COH sites. Outside of the COH bone tools are yet to be discovered, suggesting they are perhaps a unique part of that COH record. However, most of the ESA sites outside of the COH do not preserve bone of any sort. The exceptions being the ∼1.1–0.6 Ma Acheulian deposits at Cornelia-Uitzoek, Wonderwerk Cave Layers 6–11 (1.0- < 0.8 Ma; Pickering, 2015), and Elandsfontein. As such, bone tools may either represent their own unique part of the South African archaeological record associated with *P. robustus*, or a species of early *Homo*, or they may be associated with Mode 1 stone tool use. While bone tools have been discovered with supposed Acheulian at Swartkrans and Sterkfontein, the nature of those assemblages (small and generally not containing large cutting tools [LCTs]), means that they may represent a mixture of Mode 1 and Acheulian technology made by different species of hominins, perhaps including different species of early *Homo*. It's hard to define whether most stone tool assemblages in the region belong to the Mode 1 or Acheulian tradition, but both do occur.

The stone technology from Swartkrans M1LB is Mode 1 in general character (Caruana, 2017). Swartkrans Member 2 and 3 have both been defined as Acheulian, despite no in-situ LCTs, and this is a common theme at most sites, including Kromdraai A. This character may relate to these younger assemblages being Acheulian, or they may represent a local variety of Mode 1 technology, distinct from either. This may explain the apparent late occurrence of Mode 1 technology in the region as in Sterkfontein M5B Oldowan Infill (< 1.6 and > 0.8 Ma). The overlap of Mode 1 and Mode 2 technology may also indicate, along with the bone tools, that these were made by different hominins, although the secondary context of most assemblages makes this difficult to determine.

There are important differences between lithic and osseous technologies in terms of their manufacturing and associated behavioural implications. In comparing these implements, stone tools are produced prior to utilisation and involves operational sequences of material procurement and production that provide insight into behavioural and cognitive aspects these activities (Wynn, 1979; Andrefsky, 1994, 2008; McPherron, 2000). Breaking lithic production sequences into relevant behavioural events, procurement involved excursions (either planned or spontaneous) to raw material sources, material collection was driven by preferences for specific material compositions (i.e. fine-grained) and materials were sometimes transported to specific locations for production (Braun and Harris, 2003; Stout et al., 2005, Stout, 2010; Braun et al., 2009, 2010). Production phases involved flaking and/or shaping and degrees of rotation, either guided by expedient tool production (flaking) or guided by a mental representation (shaping). Analysing the structure and relationship of these operational sequences provides insight into their cognitive demands including fore-sight, planning and intentionality (Wynn, 1979; Wynn and Mcgrew, 1989; Stout, 2010; Delagnes and Roche, 2005).

Bone tools on the other hand do not involve such extensive technological sequences. Procurement did not likely require a similar depth of planning as bone elements were presumably available near or within cave systems as a result of carnivore activities. In this sense, material collection was based more on immediate availability. Further, osseous technologies were not shaped before use, rather their characteristic polish and abrasion patterns only result from utilisation. As such, the cognitive and behavioural demands inherent in bone tool use are perhaps not as informative when comparing production processes with lithic production. Interpretations based on comparing these technologies have thus concluded that the more immediate nature of bone tool use implied less cognitive demands and emulative social learning strategies (Caruana et al., 2013).

However, when considering the finds presented above, there are some points of commonality between early Pleistocene lithic and osseous technologies in southern Africa. The results of this analysis highlight aspects of material selectivity in bone prior to their use. At Kromdraai B, DMQ, and Swartkrans M1-3, straight, diaphyseal bone flakes from medium to large animals seemed to be preferred. Further, the Kromdraai B sample suggests selection for relative fresh bone, albeit Backwell and d'Errico (2001) argue that weathered bone was selected for, these results imply a degree of preference, similar to the selection of specific lithologies in lithic production. In terms of tool use, while bone tools have been argued as digging tools, striations patterns are also not unlike fruit defleshing (Backwell and d'Errico, 2008). The exact purpose of digging activities have been recently been narrowed to exploiting termite mounds (Backwell and d'Errico, 2001, 2008), although Brain and Shipman (1993) originally suggested that they were likely used for digging up tubers. This implies that they might have been used in a number of different subsistence activities although preferred for specific tasks in the same manner that stone tools are thought to relate to carcass defleshing and meat-eating (Plummer, 2004).

If bone tools use is directly related to *P. robustus* at Kromdraai B, Drimolen, and Swartkrans, the commonalities been osseous and lithic technologies imply that this species was clearly selective in terms of raw materials. While it has been argued that stone tools in the early Pleistocene of South Africa were likely produced by early *Homo*, the inherent preference for specific bone element types observed at these sites demonstrates that *P. robustus* was capable of similar cognitive demands involved in stone tool procurement. As such, this provides some support that *P. robustus* possessed some minimum cognitive and behavioural competencies, as well as the physical capabilities and dexterity for tool manufacturing that could have extended to lithic technologies (Susman, 1988).

6. Conclusion

The striation pattern and localised nature of the wear on the polished tips of the two Kromdraai B fossils is consistent with other bone tools from Swartkran M1-3, DMQ and Sterkfontein M5W. Other processes active in caves would cause a wear pattern over the entirety of the fossils and thus it is ultimately the very localised wear that confirms these fossils as being bone tools formed through anthropogenic utilisation. However, these studies also highlight the need to further explore the nature of cave specific taphonomy and weathering, rather than using methods developed for the East African, open record. The discovery of bone tools at a fourth site in South Africa suggests they were a common part of a suite of archaeological materials utilised by hominins during the early Pleistocene. The use of bone tools and related activities seem relatively common and well established within the region, spanning from sometime after 2.3–1.6 Ma (Swartkrans Member 1 Lower Bank) (Pickering et al., 2011) till as late as 1.3–0.6 Ma (last occurrence, Swartkrans Member 3) (Balter et al., 2008; Herries and Adams, 2013), with seemingly unchanged morphology. Due to the apparent correlation in deposits between minimal stone tools/abundance of bone tools and the association of hominin remains, it has been suggested that *P. robustus* is responsible for utilising the bone tools (Brain and Shipman, 1993; Backwell and d'Errico, 2001). The identification of bone tools from Kromdraai B potentially strengthens the argument that *P. robustus* was the tool user. Although, again this is not definitive, as it has been suggested that both early *Homo* and *P. robustus* exist at the site (Braga and Thackeray, 2003). Without a clear consensus on the presence of early *Homo* at Kromdraai B (Lacruz, 2007), it can be assumed that there is a correlation between the bone tools, as part of an archaeological suite, and *P. robustus*. Stone tools have also been recovered from KB, although only two in total (Kuman et al., 1997). Given the complexity of the deposit as suggested by Bruxelles et al. (2016), and perhaps age difference of these deposits as suggested by the occurrence of different species of *Dinofelis* in different units (Fourvel et al., 2016), whether the stone and bone tools come from the same deposit or time period is highly questionable. Moreover, it appears impossible to be certain which Members the bone tools came from, and thus their age. Stone tools seem to be much more prevalent in the younger Kromdraai A time period. Again, at Drimolen bone tools and *P. robustus* are both far more common than stone tools and early *Homo* fossils. The association of artefacts and fossil remains may suggest *P. robustus* was utilising both stone and bone, or the correlation could be considered a coincidence.

Future research should engage in expanding the sample size of the Kromdraai B assemblage, focusing on bone flakes recovered from the site, as well as exploring the other sites within the Gauteng dolomite that preserve hominin fossils for potential bone tools. These analyses will allow for greater intra-site comparisons and potentially address which species utilised the tools.

Acknowledgements

This work was undertaken as part of Australian Research Council Future Fellowship Grant FT120100399 and ARC Discovery Grant DP170100056 to AIRH and with funds from the IRGS program to RCS from the College of Arts, Social Science and Commerce at La Trobe University. MVC is funded by the Center of Excellence for Palaeosciences at the University of the Witwatersrand (South Africa). Thanks to Stephanie Potze of the Ditsong National Museum of Natural History for access to the Kromdraai collections and to Justin Adams for discussion during analysis. Thanks to Colin Menter for initial access to study the Drimolen stone tools and to Stephanie Baker, the current permit holder at Drimolen along with AIRH. This paper is written as part of a special issue in honour of James Brink. I (AIRH) first published with James in 2002 about Gladysvale Cave, but only met him for the first time in 2005 when excavating sites along the Ghaap Plateau Escarpment in Northern Cape. Since that time I have been lucky enough to work with him at Cornelia in Free state, as well as a number of other sites in South Africa and Kenya. His passion for fossils has always been inspirational and I learnt so much about the palaeontology of South Africa from him. I always love spending time with him wild camping at Cornelia or at the rondavels at Florisbad. I was once lucky enough for him to take me on a walk through the hills of his childhood home of Stellenbosch to look at the numerous scatters of handaxes that inspired him into archaeology as a young man. It was amazing to visit the type site for the Stellenboshian, as well as sample the local fruit. He has been both a great mentor and friend.

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