

On a timescale for the past million years of human history in central South Africa

Peter B. Beaumont^{a*} and John C. Vogel^b

Located between Daniëlskuil and Kuruman in the Northern Cape province of South Africa is Wonderwerk Cave, where excavations from 1978 to 1996 revealed a ~6-m depth of deposits made up of nine Major Units (MUs), of which some have been dated by radiocarbon, the U-series method and palaeomagnetism. The lithic succession in those sediments was found to be Later Stone Age in MU1 at 1.0–12.5 kyr ago, Middle Stone Age in MU2 at ~70 to >220 kyr ago, Fauresmith in MUs 3–4 at ~270–c. 500 kyr ago, and very sparse biface assemblages before then to >0.78 Myr BP. Associated behaviours are represented by collected exotic river pebbles and quartz crystals in MUs 2–4, incised lines on portable stones in MUs 1–4, a grass bedding area in MU4, red pigment pieces in MUs 1–7, and traces of the use of fire in MUs 1–9. These findings, as a whole, are taken to support a scenario that sees the upland savannas at the southern end of Africa as a focal region of biocultural evolution over a period extending back to before the onset of the Middle Pleistocene.

Introduction

Open site collections in the 1920s–30s led to the identification of the Fauresmith Industry over a large portion of South Africa,^{1–6} and to its culture–stratigraphic location below the Middle Stone Age (MSA) at Sites I, III and VI on Riverview Estates near Windsorton^{4,5} (Fig. 1). Assemblages are recorded as being typified by the regular association of small handaxes and rare cleavers^{1–6} with blades,^{5,6} Levallois and retouched points,^{1–3,5,6} convex edged scrapers,^{1–6} burins/gravers,^{5,6} polyhedral stones^{5,6} and prepared cores indicating full Levallois technology.^{5–7} Such material has been variously referred to a terminal grouping within the Earlier Stone Age (ESA),^{1,2,5} to a final phase of the Acheulean,^{8–10} to a since-abandoned First Intermediate^{6,11} or to a subcontinental equivalent of the Middle Palaeolithic,^{12,13} with F. Bordes¹³ commenting that it was ‘clearly of the Mousterian stage’. To investigate these discordant interpretations further, one of us (P.B.) began fieldwork in 1978 at Wonderwerk, the only known cave context with stratified Fauresmith, that could conceivably also be dated,¹⁴ by applying the U-series method to associated stalagmites. In this contribution we provide an overview of the Wonderwerk results that can, if taken together with evidence from various other localities, produce a tentative timescale for the industrial succession in South Africa since ~1.1 Myr ago.

Site and setting

Wonderwerk Cave (27°50′46″S, 23°33′19″E) is a large (~2400 m²) solution cavity, exposed at its north end by erosion, that runs horizontally for 141 m into the base of a koppie on the eastern flank of the Kuruman Hills, some 45 km south of Kuruman, in the Northern Cape province¹⁵ (Fig. 1). Its geological context is a

stratified dolomitic limestone that is overlain further upslope by banded ironstones belonging, respectively, to the ~2.3–2.6-Gyr-old Ghaap Plateau and Asbestos Hills formations of the Griqualand West Sequence.^{16,17} Permanent water sources in the area are at present confined to a seep ~5 km to the south, on the eastern side of Gakorosa Hill, and a pool, marking the mouth of the c. 290-m-deep Boesmansgat sinkhole, ~15 km away on the farm Mount Carmel.¹⁵

Historical background

The first certain description of the cave is that of Methuen,¹⁸ who visited it on 15 July 1844, when he recorded that a ‘massive stalagmite arrested our eye on first entering’ and that many ‘drawings representing game animals garnished the walls’. P.E. Bosman, the original farm owner,¹⁵ lived in the cave with his family from 1909–11, while building the present farmhouse,¹⁹ and later used it as a cart-house, and a sheep shelter in winter, until the early 1930s¹⁵. Between c.1940 and 1944, the cave was exploited commercially for supposed ‘bat guano’ by his brother, N.J. Bosman, and associates,^{20,21} at which time much of the floor backwards of 34 yd (31 m) in was dug over to depths of up to about 2.5 m¹⁵ (Fig. 2).

Investigation record

A parcel of digger finds sent to the then Bureau of Archaeology in early 1940 led to an inspection by B.D. Malan in May of that year,²⁰ followed by excavations with L.H. Wells in January 1943, and an unpublished continuation of that work in November 1944²² (Fig. 2). Malan and members of the University of California African Expedition finally reached bedrock at ~3.5 m down in May 1948²³ (Fig. 2), after which C.K. Butzer undertook a study of the earlier collections and extant exposures on occasions between 1974 and 1977.^{24–28} Soon afterwards, in November–

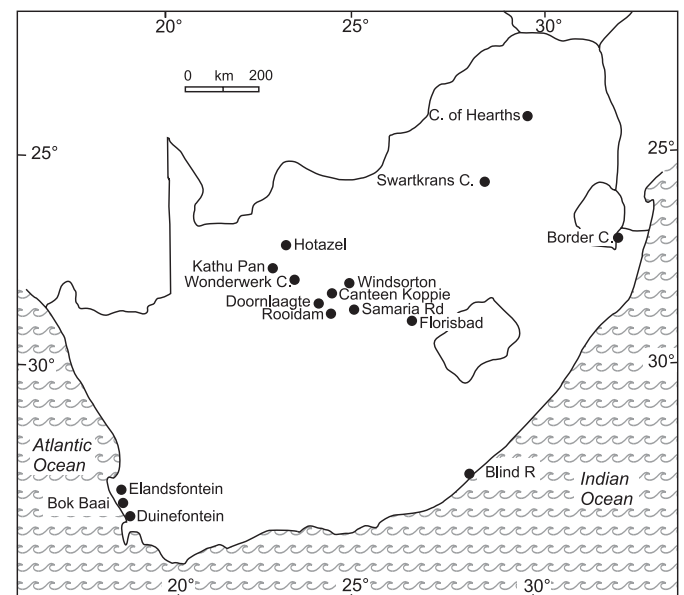


Fig. 1. The approximate location in South Africa of the sites cited in the text.

^ac/o Archaeology Department, McGregor Museum, P.O. Box 316, Kimberley 8300, South Africa.

^bc/o Quaternary Dating Research Unit, CSIR, P.O. Box 395, Pretoria 0001, South Africa.

*Author for correspondence. E-mail: se@museumsnc.co.za

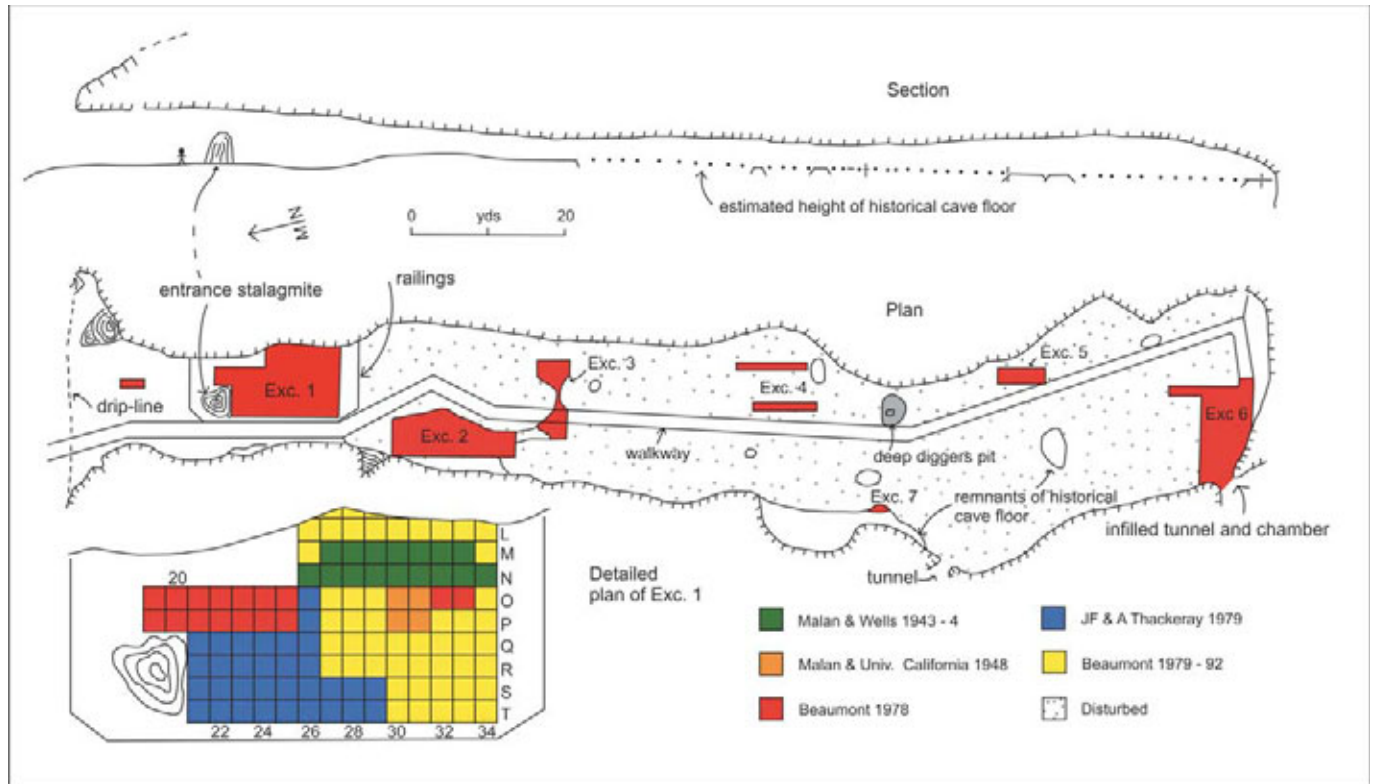


Fig. 2. A plan and section of Wonderwerk Cave, with details for Excavation 1.

December 1978, one of us (P.B.) re-surveyed the site and carried out two small excavations by way of natural strata, in order to establish a composite lithostratigraphic succession for the front section of the site¹⁵ (Fig. 2). One trench clarified the LSA sequence there but, as the recovered sample sizes per stratum were rather small, it was arranged for J.F. and A.I. Thackeray to extend that excavation, which they did between July and October 1979²⁹⁻³² (Fig. 2).

Later, in the 1980s–early 1993,^{14,15} P.B. spent over a fieldwork year consolidating previous digs forward of Strip 34 into a single large Excavation (Exc.) 1, which was necessitated by very low lithic densities in most handaxe levels, as initially shown by the 1978 samples¹⁵ (Fig. 2). It was also established then that additional strata occurred further in, and, in order to determine how those related to the Exc. 1 sequence, all (~500 m³) digger debris was removed from the cave, bar areas below the present pathway and on the south side of Exc. 1 (Fig. 2). That operation permitted a distinctive reddish sand unit (Stratum 6 of Exc. 1) to be traced to the rear wall of the cave by way of digger sections and six smaller excavations, all of which took a further fieldwork year, until the end of 1996, to accomplish (Fig. 2).

Fieldwork procedures

The yard (0.92 m) square grid set up by Malan in 1943 was retained, but all depths were in metrical measurements, with one datum being the historical surface, or the estimated original position of this, in those areas that were partly or largely destroyed by diggers in the early 1940s. Excavations from 1978 onwards were all according to natural strata, with further subdivision, when called for, into 5-cm or occasional 10-cm spits parallel to unit surface, which are taken to have some stratigraphic validity at a site where deposition was preponderantly subhorizontal. Trowelled sediments were taken by bucket to outside the cave and there passed through 1-mm mesh or finer screens, with all residues being then bagged for later study, except for unmodi-

fied roof-derived spalls — slabs which were discarded there and then. The sorting of this retrieved material at the McGregor Museum, Kimberley, took P.B. and one or two assistants from 1997 until December 2002 to complete, during which time it was grouped into various floral, faunal and lithic categories, followed by washing, marking and packaging.

Lithostratigraphic data

Reddish sand up to 1.0 m thick in Exc. 1 was originally separated into Strata 6 and 7 on the basis of differing roof debris content, but this distinction was later found to disappear backwards, in Excs 2 and 6, and those strata are therefore here regarded as subunits of a single unit, namely MU4. This revision results in the Wonderwerk deposits, with a cumulative depth of about 6 m, now being taken to be made up of only nine widespread MUs that are numbered from the modern surface downwards, and that correspond to the strata identified in specific excavations as listed in Table 1. The inwards (north–south) disposition of those MUs in Excs 1 and 2 are shown in Fig. 3, from which it can be seen that the lowermost three follow bedrock slope, whereas the subsequent five tend to lens in ever farther backwards, resulting in MU2 being confined to areas 37 yd (33.6 m) and more in. Lower cave width (east–west) sections have concave MU surfaces that slope upwards slightly (~5°) towards the side-walls, with extant profiles and observations during excavation indicating a total absence of erosional features that could be construed as channelways which furrowed water further in.

A geochemical and sedimentological study by Butzer²⁶⁻²⁸ of deposit samples spanning the entire sequence in Excs 1–3 identified three consistent MU constituents, of which the main one in all levels is a fine, well-sorted sand, made up of subrounded iron oxide-coated quartz grains of extraneous origin.²⁶ Roof debris forms a far smaller component of most excavated strata, with the exception of MU3, which, in Exc. 2, includes a roof spall rubble

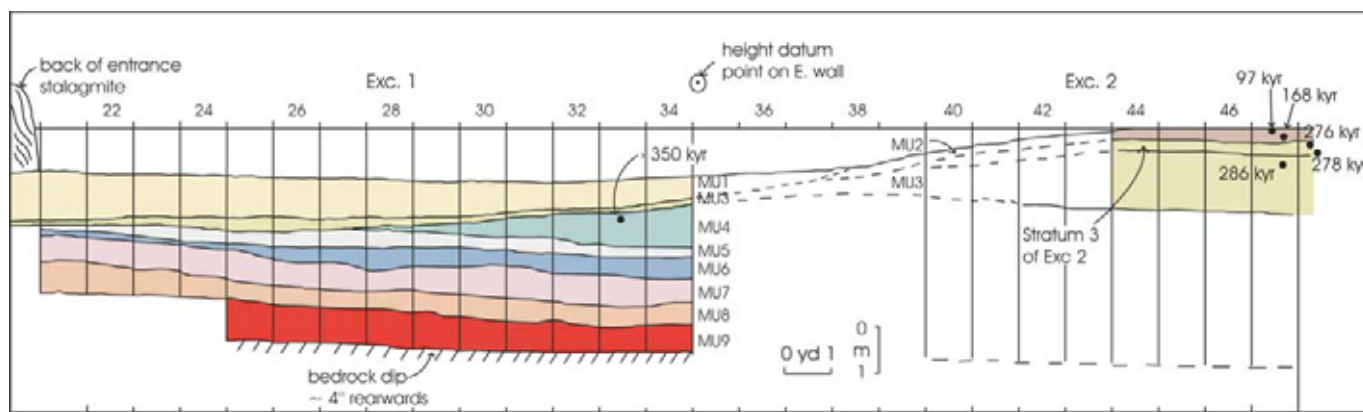


Fig. 3. Composite section showing Major Unit dispositions along Q strip in Excavation 1 and Y strip in Excavation 2.

Table 1. Correlation between excavation-specific strata and site-wide Major Units at Wonderwerk Cave.

Major Unit	Exc. 1	Exc. 2	Exc. 3	Exc. 4	Exc. 5	Exc. 6	Exc. 7
1	1-4d	1	1	-	1	-	-
2	-	2a	2 & 3	-	2	-	Spits
2	-	2b	-	-	-	3UP	Spits
3	5a & b	3,4a-e	4-6	4	-	3LR, 4	-
4	6,7a & b	5	-	-	-	5	-
5	8a-e	-	-	-	-	-	-
6	9a-f	-	-	-	-	-	-
7	10a & b	-	-	-	-	-	-
8	11	-	-	-	-	-	-
9	12a-c	-	-	-	-	-	-

(Stratum 3) and two underlying zones of large roof slabs, namely minor Rockfall 1 (Stratum 4b) and major Rockfall 2 (Stratum 4d). Rockfall 1 does not extend back beyond Exc. 3, but Rockfall 2, consistently underlain by the reddish sands of MU4, was traceable to the back wall in Exc. 6, with the close fit of contiguous slabs in Exc. 4 suggesting that it formed during a single brief cave-roof collapse. The third sediment fraction is in the form of minor organic residues that were largely introduced by humans, porcupines and birds. Of particular note is the finding of wood ash and/or fire-baking in all of the lower samples (MUs 4-9) from Exc. 1.²⁸

It has been suggested^{27,28} that the extraneous sands which dominate the Wonderwerk deposits were introduced by water transport from the cave entrance, and by subordinate aeolian action, but it remains to be established if this is a valid assessment. Concerning aeolian transport, observations show that current outside wind directions and intensities result in no perceptible air movement rearward of Exc. 1,²⁸ but it may be that back-pressure was lower before sediment build-up blocked a tunnel leading in from Exc. 6 (Fig. 2) during MU4 times. As regards water entry, four north-south zones can be identified, beginning with drip-line activity after heavy rains, when water sinks into underlying deposits and then starts flowing down the steepish (~20°) hillslope below, rather than into the cave, where surface gradients have always been flatter (Fig. 3). Just inside the cave mouth there are some substantial and now inactive side-wall speleothems that can be linked to transverse cracks which span the roof, and that seem to have been sealed subsequently by carbonates in the water that used to seep through them.

Further in, and approximating to the northern limit of the impervious upslope banded ironstones, is a localized roof weakness, from which a thin stream of water dribbles in summer months onto the entrance stalagmite, before seeping into the flat

sediments surrounding it (Fig. 2). Above-surface coring of that speleothem by G. Brook revealed a thin (<0.1 m) compact Holocene skin covering poorly calcified sands of presumed Last Glacial age, which suggests that its still lower levels preserve a record of glacial-interglacial fluctuations ranging back to MU9 times. Finally, the April 1994 measurement of the 14 active drips in the ~2000 m² area backwards of Exc. 1 yielded a mere 0.4 litres of water over a week, which implies, given regional glacial aridity,³³ that the roof-derived water influx per unit area there was usually far less than a millimetre per annum. As a consequence of this extreme deposit dryness, the preservation of organic materials in the inner cave is often superlative, as evidenced by ~10-kyr-old porcupine droppings from Exc. 5 (ref. 34) that still smell, and c. ~0.8-Myr-old *Damaliscus niro* horn fragments that have retained their keratin sheaths.³⁵

Chronometric findings

The timespan covered by MU1 was established by over 20 radiocarbon readings, which show that sedimentation over the past 9 kyr was largely confined to the cave front, and that earlier accumulations, both there and further in, nowhere extended back to beyond 12.5 kyr BP.^{15,34} Items of calcite, mainly in the form of small (~5-20 cm high) stalagmites, were found sporadically in many strata, and, as this material is ideal for U-series dating, some have been processed over the years at the QUADRU laboratory in Pretoria.^{36,37} Samples were dissolved in acid and the U and Th isotopes co-precipitated from the solution, together with a ²³²U/²²⁸Th spike and iron carrier, after which the U and Th were separated from each other, and from other metal ions, by ion exchange, and electroplated onto steel discs. These were then subjected to alpha-particle analysis in a multi-channel analyser, with the amount of detrital ²³²Th being found to be small, in most cases. The correction for initial ²³⁰Th consequently had a minimal effect on the calculated ages, as listed in Table 2.

Table 2. Alpha-spectrometric U-series dates for Major Units 1–4 at Wonderwerk Cave.

Industrial grouping	Lab. no.	Material	MU	Exc. & Str.	Square & spit	U-conc. (ppm)	Activity ratios			Corr. age (kyr)
							$^{230}\text{Th}/^{234}\text{U}$	$^{238}\text{U}/^{234}\text{U}$	$^{230}\text{Th}/^{232}\text{Th}$	
LSA	U-420	sm	1	1	S20	0.52	0.04	3.76	126	4.1 ± 1.2
MSA	U-677	sm	2	2, 2	Y47, 0–5	0.7	0.66	7.01	55	97 ± 3
"	U-678	sm-t	2	2, 2	Y55	0.34	0.65	5.17	64	95 ± 7
"	U-679	sm-b	2	2, 2	Y55	0.43	0.8	5.14	46	132 ± 5
"	U-675	sm-t	2	2, 2	Y53, 5–10	0.56	0.84	6.34	97	141 ± 5
"	U-676	sm-b	2	2, 2	Y53, 5–10	0.51	1.06	6.48	118	220 ± 14
"	U-436	sm	2	2, 2	X47, 15–20	0.74	0.91	3.76	57	168 ± 14
"	U-441	st	2	3, 3	O60, 30–40	0.76	0.87	6.22	193	152 ± 9
"	U-577	sm	2	5, 2	P123, 10–15	0.19	0.53	7.58	173	73 ± 5
"	U-680	sm	2	5, 2	O123, 15–20	0.53	0.77	7.26	156	123 ± 5
"	U-681	sm	2	5, 2	O123, 25–30	0.33	0.89	8.49	101	155 ± 4
"	U-576	sm	2	6, 3	CC148, 40–45	0.5	0.99	8.88	110	187 ± 8
"	U-683	sm	2	7, –	FF104, 0–15	0.17	0.56	5.95	177	78 ± 4
Fauresmith	U-437	st	3	2, 3	X48, 35–40	0.64	1.13	4.47	105	276 ± 29
"	U-499	st	3	2, 3	X48, 50–69	0.64	1.13	4.37	90	278 ± 26
"	U-583	sm	3	2, 4	W47, 20–30	0.95	1.15	4.7	58	286 ± 29
"	U-427	sm	4	1, 6	O32/33	0.24	1.24	2.33	18.6	>349
"	U-407	sm	4	1, 6	S33, 5–10	0.18	1.18	1.62	13	>350

Legend: sm, stalagmite; st, stalagmite; t, tip; b, base; MU, Major Unit; Exc. & Str., excavation and stratum. U-576 is a minimum age; U441 is a maximum age.

The Stratum 3 rubble in Exc. 2 contained only 'soda straw' stalactites, with U-series dating in this case being applied to two specimens from its surface reaches, that must have formed after underlying rock debris in that layer had spalled off the roof above. The stratigraphically consistent U-series results (Fig. 3) show that MU2, bar its base, dates from ~70–220 kyr ago, and that upper MU3 in Exc. 2 extends back from ~276–286 kyr ago, which may indicate that Strata 3 and 4a there relate to the marine isotope stage (MIS) 8.5 interstadial.³⁸ Base and tip readings on two ~0.1-m-high stalagmites from MU2 in Exc. 2 show that those grew over 36- and 79-kyr intervals (Table 2), thereby indicating slow accretions that are consistent with the mean rate at which locally ~0.3-m-thick MU2 accumulated, namely about 2 mm per millennium. As MU2 is predominantly composed of sand, and is situated over a metre above the modern surface at the drip-line (Fig. 2), a further inference is that it must have been built up mainly by aeolian processes and that most of the underlying levels there may have accumulated in the same way.

Palaeomagnetic samples, collected by K.L. Verosub from the lower levels of Exc. 1 in 2001, produced results indicating normal polarity in MU5, no reliable directions for MU6, and a polarity boundary in upper MU7, 1.0 m above an arbitrary datum (Table 3). Reversed polarity continued to the base of MU7, reliable directions were lacking in MU8, while MU9 yielded normal polarity for its top subunit (Table 1), followed, at just above bedrock, by another normal, bounded by reversed polari-

ties (Table 3). Re-sampling of the same sediments by H. Ron³⁹ in 2004 resulted in further readings indicating normal polarity throughout MU6, reversed polarity in upper MU7, normal polarity further down in MU7, reversed polarity for MU8, and only normal polarity in MU9. From these two studies we conclude that the Brunhes–Matuyama boundary probably lies in upper MU7, but that more work is called for to establish a sound magnetostratigraphy for the underlying sequence, beginning with the discordant data for lower MU7 and lower MU9. However, it does seem that MU9 may reach back to Olduvai times, and that its accumulation was slow, given that the cave mouth may have opened only then, and that reduced regional dust levels accompanied lower rainfall seasonality before 1.0 Myr BP.⁴⁰ Overall, the U-series and magnetozone results leave mid MU3–MU6, at ~286–<780 kyr ago,⁴¹ as a major undated portion of the Wonderwerk sequence, with further resolution within that timespan being possible by way of the available small-mammal data.

A preliminary study by D.M. Avery⁴² of such samples from MUs 4–9 of Exc. 1 produced proxy evidence indicating that these all represent interglacial accumulations, which show an upward trend towards more open and arid conditions, culminating in >350-kyr-old MU4 (Table 2). The youngest possible interglacial to which MU4 could therefore correspond is MIS 11 at 362–420 kyr ago,⁴³ but this was a time when peak warmth and wetness would have prevailed within the subcontinental

Table 3. K.L. Verosub's palaeomagnetic results for MUs 5–9 of Excavation 1 at Wonderwerk Cave.

Major Unit	Exc. stratum	Sample no.	Vert. position	Data quality	Declination	Inclination	Assessment*	Correlation
5	8	42	+1.75	Excellent	North	Up	N	Brunhes
5	8	41	+1.66	Excellent	North	Up	N	Brunhes
5	8	40	+1.59	Excellent	North	Up	N	Brunhes
5	8	37	+1.54	Excellent	North	Up	N	Brunhes
7	10	35A	+1.00	Excellent	North	Up	N	Brunhes
7	10	35	+1.00	Very good	South	Down	R	Matuyama
7	10	34	+0.91	Good	South	Down	R	Matuyama
7	10	33	+0.68	Excellent	South	Down	R	Matuyama
7	10	32	+0.57	Excellent	South	Down	R	Matuyama
7	10	30	+0.44	Excellent	South	Down	R	Matuyama
9	12	9	-0.03	Very good	North	Up	N	Jaramillo?
9	12	3	-0.20	Very good	South	Down	R	Matuyama
9	12	2	-0.23	Very good	North	Up	N	Olduvai?
9	12	1	-0.26	Good	South	Down	R	Matuyama

*N, normal; R, reversed.

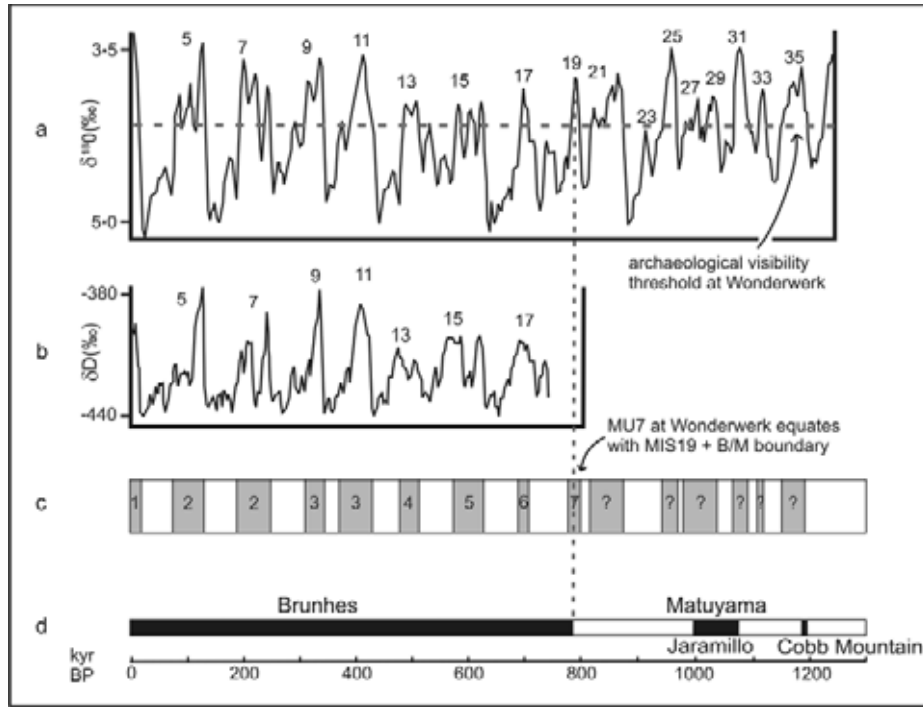


Fig. 4. Correlation of (a) the marine isotope record for the SPECMAP stack and ODP site 677,⁴¹ (b) the δD variations for the EPICA Dome C ice core,⁴⁷ (c) the sedimentary succession at Wonderwerk Cave and (d) the magnetic polarity timescale back to the Cobb Mountain subchron.^{41,41}

interior,⁴⁴⁻⁴⁶ whereas the MU4 micromammals register the very reverse.⁴² Given this clear mismatch, MU4 is rather referred to prior MIS 13 at ~478–513 kyr ago,⁴³ which was indeed an interglacial of markedly low amplitude, as shown by the standard SPECMAP $\delta^{18}O$ stack^{41,43} and the EPICA Dome C ice core δD record (Fig. 4).⁴⁷ Consistent with this deduction is then the palaeomagnetic evidence, which equates the MU7 interglacial with MIS 19, in which the Brunhes–Matuyama boundary also occurs,⁴¹ from which it follows that MU6 represents MIS 17, that MU5 represents MIS 15, and that MU4 represents MIS 13 (Fig. 4). Digger debris derived from just forward of Exc. 5 produced an abundance of large mammal teeth, including two that were identified by V. Eisenmann (pers. comm. to P.B.) as *Hipparion* sp., which has a last East African appearance in Olorgesailie Member 7 at >746 to <974 kyr ago.⁴⁸⁻⁵⁰ These most likely came from a deep nearby pit at ~106 yd (96.4 m) in (Fig. 2) with basal red sand that seems, on stratigraphic grounds, to represent MU7. If so, this indicates that the sediments in the cave interior also extend back to at least 780 kyr ago.⁴¹

Cultural succession

The lithic sequence at Wonderwerk, from the modern surface downwards, was found to be as follows:

LSA: MU1 in Exc. 1 contained Ceramic LSA in Stratum 3 Upper at 0.9–2.0 kyr ago, Wilton in Stratum 3 Lower–4c at 2.0–8.0 kyr ago, Oakhurst in Stratum 4d at 8.0–10.5 kyr ago and intrusive Robberg? in Stratum 5 Upper, with ostrich eggshell-based ages of 11.0–12.5 kyr BP.¹⁵ The deposition of Stratum 5, as a whole, was initially referred to the LSA on the basis of Robberg? in its upper spits, but this ascription was later invalidated by the finding that artefacts of earlier type were also present, and that the level rose rearwards to link up with MU3 in Exc. 2 (Fig. 3).

MSA: MU2 lithic samples, dating from ~70–>220 kyr ago, include prepared cores, blades, and Levallois, unifacial and bifacial points, that compare closest in typological and metrical terms with Middle–Late Pietersburg assemblages, like those from Beds 5–8 at the Cave of Hearths^{8,51} (Fig. 1). Also recovered

from it were two handaxes that are deemed to be intrusive, namely a lightly weathered specimen from Stratum 3 UP in Exc. 6, that was probably collected from outside, and another from basal Stratum 2 of Exc. 2, which is taken to have been displaced from the surface of MU3.

Late Fauresmith: MU3 artefact samples, largely from the 276–286-kyr-old Stratum 3 of Exc. 2, include prepared cores, blades, Levallois points, and bifaces, of which the handaxes are sometimes rather coarsely flaked (Fig. 5), often resulting in patches of cortex remaining, particularly at butt ends. Also present are convergent or nosed scrapers that, together with the crude largish bifaces, are taken to be sufficiently distinctive to warrant the identification of a late stage of the Fauresmith, which, a recently found sample suggests, also occurs in >8 m beach deposits⁵² at the Blind River site^{53,54} in East London (Fig. 1).

Middle Fauresmith: MU4 artefact samples, with an inferred age of ~480–510 kyr ago,⁴³ include prepared cores, blades, Levallois points, convex ‘scrapers’, and small handaxes that are much more refined than those in MU3, despite being based on

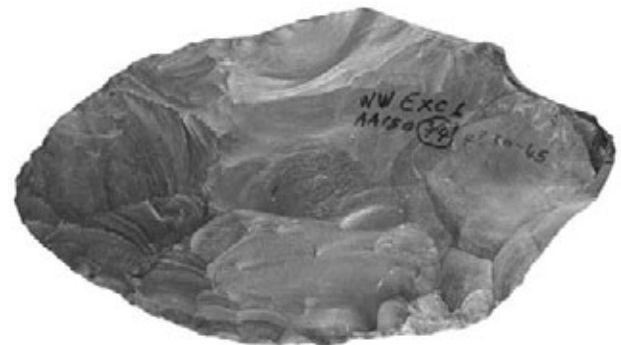


Fig. 5. This 155-mm-long handaxe, with scant shaping of its butt end, is one of the last bifaces made in central South Africa. It came from MU3 in Excavation 6, with an estimated age of ~276–286 kyr, on the basis of U-series readings from Excavation 2 (Table 2).

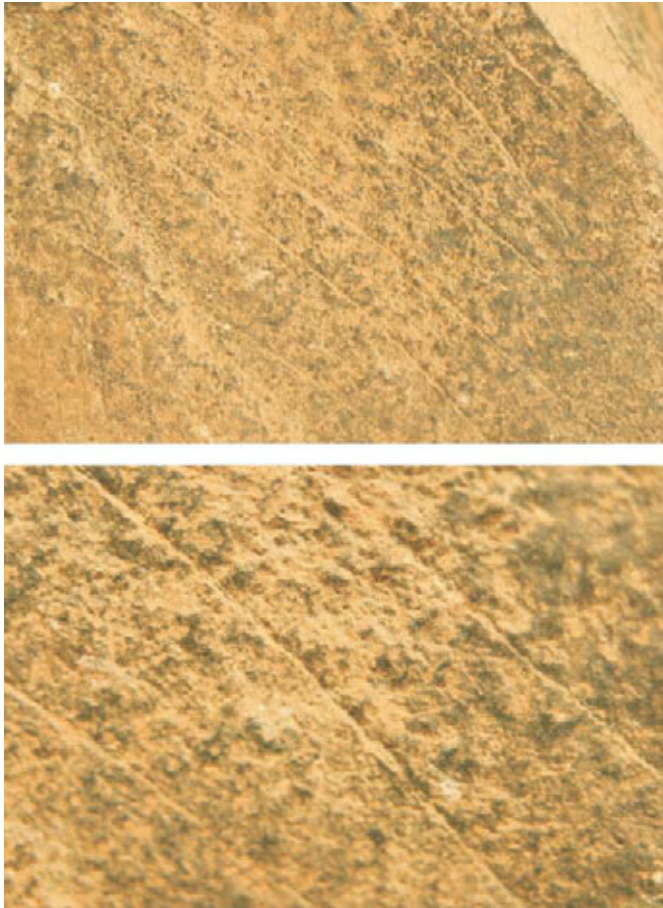


Fig. 6. Nomalinde Msuthu spotted these sub-parallel curved lines on one 80-mm-wide face of a banded ironstone slab, found close to and a spit below the Late Fauresmith handaxe shown in Fig. 5.

the same raw material, namely banded ironstone. This assemblage, here referred to the Middle Fauresmith, corresponds to widespread occurrences in the eastern Northern Cape and western Free State,⁶ that are often found below red aeolian Hutton Sands,⁵⁵ as at the Roseberry Plain (Samaria Road) site⁵¹ near Kimberley (Fig. 1).

Early Fauresmith?–Acheulean: MU5–8 artefact samples are all too small for close industrial ascription, but the ~780-kyr-old MU7 has a small prepared core, a bifacial cleaver, and a refined handaxe similar to those in MU4, all of which suggests, typologically, an Acheulean stage postdating Younger Gravel assemblages.⁵ MU9 is sterile, except for a few small irregular cores and flakes in spits ranging down to just above bedrock, of which the earliest could be of Oldowan age, if further palaeomagnetic work confirms its ascription to the Olduvai subchron, at ~1.77–1.95 Myr BP.⁴¹

Wonderwerk Cave has also produced evidence for a number of additional human behaviours, namely:

Mobiliary art: MU1 yielded approximately 20 fine-line engraved slabs, dominated by schematic motifs, and often deliberately broken afterwards,⁵⁶ whereas MUs 2–4 contained, relative to associated assemblage size, a similar number of incised slabs that often feature well-spaced parallel curved lines (Fig. 6). Those finds, from stratified cave contexts extending back to ~0.5 Myr ago, imply that engraved lines at subcontinental open sites, where used surfaces are sufficiently resistant, may not always be confined to the LSA or MSA, particularly if the markings show significant signs of weathering.

Exotic minerals: It was found that MUs 2–4 contained thin



Fig. 7. Two isolated exotic finds from Excavation 1, namely a reddish, rounded 15-mm-wide chalcedony pebble from MU3 at ≥ 276 kyr ago and a rounded 21-mm-long chert pebble with natural markings from MU4 at c. 478–513 kyr.⁴³

scatters — clusters of unmodified stones that tend to vary in Exc. 1 from small quartz pebbles in MU2 to small chalcedony pebbles in MU4 (Fig. 7), whereas those same MUs in Exc. 6 yielded mainly small quartz crystals in single or rosette form.⁵⁷ It appears, therefore, that this patterned and possibly non-utilitarian collecting practice was sustained for ~400 kyr, despite the effort that must have been involved in retrieving those items from their nearest known occurrences, which, in the case of chalcedony pebbles, is along the Kuruman River, over 45 km away.

Pigment finds: Specularite fragments in MUs 1–2 are likely to be from Blinkklip Breccia sources up to 50 km to the west,^{58,59} whereas haematite pieces in MUs 1–7 are probably, in the main, from interbeds that are common upslope of the cave, in the surface reaches of the Ghaap Plateau Dolomite Formation.¹⁶ Present evidence from open sites in the region suggests that the deliberate retrieval of both specularite and red ochre began fairly late in the Acheulean proper, as evidenced by *in situ* finds at Kathu Townlands 1¹⁵ and in Stratum 4b at Kathu Pan 1¹⁵ (Fig. 1).

Bedding material: Fieldwork at Exc. 4, some 90 m in (Fig. 2), involved removing Rockfall 2, and then sinking a trench through basal MU3, that was there found to consist of a 0.4-m thickness of completely humified vegetation with interdigitating ash lenses, indicating its accretion by additions. C-13 analysis showed shifts from -21‰ to -16‰ ,³⁶ with the latter reading indicating a composition of pure C₄ grasses that were brought in c. 400 kyr ago (Fig. 4) to build a >50-m² bedding area, thereby providing direct evidence for home base organization by that time, regionally.

Fire usage: Pervasive signs of this practice are present throughout the sequence and site, with manifestations mainly in the form of heat fractures on artefact surfaces, and phytolith-rich (A. Powers-Jones, pers. comm. to P.B.) ash lenses^{15,28} that show minimal diagenesis, due to the near-absence of sediment moisture.⁶¹ The earliest traces of this behaviour are from Jaramillo-aged (or earlier) MU9 of Exc. 1, in the form of an extensive ash sheet containing hundreds of charred–calcined large-mammal

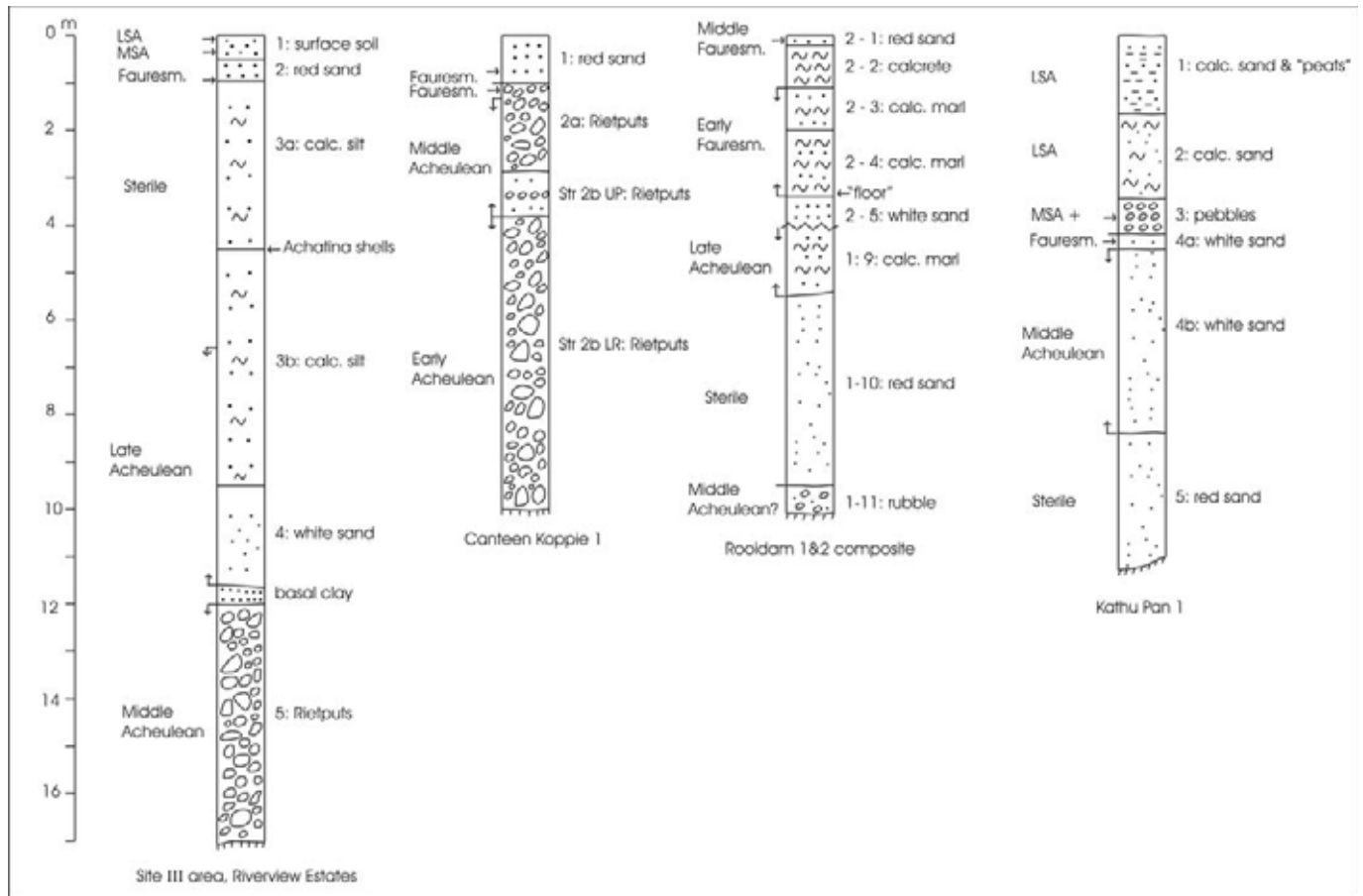


Fig. 8. Composite section for the Site III vicinity near Windsorton,^{5,36,87} section for the north face of Exc. 1 at Canteen Koppie,^{64,86} composite section for Sites 1 & 2 at Rooidam⁶²⁻⁶⁴, and section based on squares Q23 and Z23 at Kathu Pan 1.^{15,64} H.B.S. Cooke's study of an *Elephas* sample from Cornelian-aged Stratum 4b at Kathu Pan 1^{131,132} suggests (pers. comm. to P.B.) an *E. recki recki* ascription at the Olduvai Bed IV level,^{48-50,133} whereas suids link the Cornelian fauna at Rietputs localities^{87,88,91} to a longer Olduvai Beds upper II-IV timespan.^{134,135}

bone fragments, thereby demonstrating that one use of early man-made fire was to roast meat.

Regional comparisons

The following localities in South Africa have produced data bearing on the Wonderwerk succession:

Rooidam: The 1964-5 excavation by G.J. Fock⁶² at Rooidam 1, near Kimberley (Fig. 1), cut through 5 m of stratified pan sediments⁶⁵ (Fig. 8), from which came, mainly from Stratum 9,⁶⁴ over 18 000 artefacts that were assigned to the Fauresmith on the tenuous basis of handaxe length-to-breadth ratios.⁶³ However, a re-examination by P.B. of the collection showed that, while prepared cores and blades are present, there were no convincing Levallois points, with the assemblage being consequently best referred to the Late Acheulean,⁶⁴ distinguished by the first regional appearance of true blades.⁶⁵⁻⁶⁷ Subsequent research showed that Stratum 1, the reddish surface sand, contains Middle Fauresmith rather than Fauresmith⁶⁴, and that, at nearby Rooidam 2,⁶⁴ this is underlain by lacustrine levels with Early Fauresmith (Fig. 8), that is typified by a much reduced range of scraper and other retouched forms. It is therefore likely that the Fauresmith extends back at least one interglacial before MIS 13, and that the single U-series date of ~174 kyr,⁶⁸ on a limestone sample between Late Acheulean and Early Fauresmith at Rooidam 1, is far too young, relative to the more reliable Wonderwerk data.⁶⁴

Florisbad: The 1981-4 investigation by R.J. Clarke⁶⁹ at this site near Bloemfontein (Fig. 1) resulted in a firm lithostratigraphic

succession that subsequently yielded luminescence ages of ~121-135 kyr for Unit F, ~157 kyr for Unit M, ~181 kyr for Unit O (Peat 1), and ~279 kyr ago for the 'spring fauna' in Unit P.⁷⁰ A small core and flake sample from Unit P⁷¹ is undiagnostic, and, in fact, the only formal items from it are a cleaver that Dreyer⁷² reports from the *H. helmei* eye, and a long 'Hagenstad' point,^{2,3} which is a rare but characteristic component of Middle-Early Fauresmith assemblages.¹⁵ Supporting this lithic evidence are palaeoenvironmental investigations,⁷³⁻⁷⁷ which suggest that the build-up of the Florisbad deposits is best interpreted in terms of an interaction with climatically controlled high and low water levels in the nearby Soutpan lake complex. According to this scheme, the two youngest high stands, with ages of ~5.5 and ~121-135 kyr ago,^{69,70} would represent the Holocene Hypsithermal and MIS 5.5,⁴⁴⁻⁴⁶ but, below this, the relationship breaks down, with the Unit M and Unit P high stands being improbably paired with arid MIS 6 and MIS 8.³⁸ However, given saturation problems with the earlier dates,^{70,78} it is more likely that Unit M relates to MIS 7 or 9, and inferred peak primary production in Unit P (refs 69, 74, 79) to MIS 11 at ~400 kyr ago,⁴³ which is the age that some new ESR estimates (J. Brink, pers. comm. to P.B.) provide for the 'spring fauna'.³⁵

Cave of Hearths: The 1953-4 excavation by R.J. Mason^{8,51} in this dolomitic cave remnant near Makopane (Fig. 1) revealed a succession of 11 beds, defined (bar the top one) by basal ash lenses, from which came Iron Age in Bed 11, Oakhurst? in Bed 10, Pietersburg in Beds 4-9 and Acheulean in Beds 1-3. The MSA assemblages were later grouped into three stages,⁸ of

which the Early Pietersburg sample from Bed 4 is problematical, in that Mason⁵¹ mentions a handaxe from it, whereas Sampson⁹ records another probable specimen in the collection, which suggests, as does flake size,^{8,51} that this material is a Fauresmith variant. Supporting that interpretation is the closer correspondence of early (MIS 7) MSA at Border Cave⁸⁰ with the Middle Pietersburg in Bed 5, and the finding that handaxes are also present in a McGregor Museum collection from the only other claimed Early Pietersburg occurrence, at Koedoesrand, south of Windsorton.^{8,81} Concerning the Late Acheulean with blades from ~5-m-thick Beds 1–3,^{8,51} these may well represent a succession of interglacial occupations,⁸² which the Wonderwerk timescale would position before Early Fauresmith at ~600 kyr ago, and after Middle Acheulean at c. 0.99 Myr (see below).

Doornlaagte: 1963 fieldwork by G.J. Fock, H.J. & J. Deacon and R.J. Mason^{51,83} at this open site west of Kimberley (Fig. 1) exposed the surface of a calcified greenish silt stratum over a ~100-m² area, from which 1920 artefacts were recovered from an inferred near-primary pan margin context.^{51,63} The lithic sample⁵¹ includes a few Victoria West 2-type cores, which are a diagnostic form of the regional Middle Acheulean^{9,51} that also occurs in the upper reaches of the Rietputs Formation⁸⁴ (or Younger Gravels), as in Stratum 2a of Exc. 1 at Canteen Koppie^{64,85,86} (Fig. 1). The fauna from such deposits^{87,88} has a Pliocene component in the Waldeck Gravel Splay,^{84,87,89,90} but the preponderant younger fraction, there and elsewhere along the lower Vaal River, falls into the c. >800-kyr-old Cornelian Land Mammal Age^{35,88,91} and compares with those in Beds upper II–IV at Olduvai^{87,92} at ~1.52–0.78 Myr ago.^{92,93} Palaeomagnetic analysis of samples spanning the middle–lower levels of the greenish silts at Doornlaagte all produced normal polarities (K.L. Verosub, pers. comm. to P.B.), which suggests, given the constraints imposed by its faunal age, that the Middle Acheulean falls, at least partly, in Jaramillo times, at ~0.99–1.07 Myr BP.⁴¹

Duinefontein 2: Excavations since 1973 at this site near Cape Town^{94,95} (Fig. 1) show that superficial white drift sands there are underlain by a ~10-m-deep ferruginized dune plume, in the upper reaches of which are two bone and artefact-rich palaeo-surfaces, namely Horizons 2 and 3. Dates reported so far are U-series assays that centre on 160 kyr ago^{94,95} for the remnants of a calcrete crust capping the red sands, and luminescence values,⁹⁶ by the subtraction method,⁹⁷ that place the accumulation of sediments immediately above and below Horizon 2 at ~270 kyr BP. Incompatible with that MIS 8³⁸ estimate is the palaeoenvironmental evidence provided by associated bird and large mammal remains,^{94,95} which suggest a high nearby sea and a southward displacement of more productive savanna mosaics⁴⁶ during a major interglacial^{94,95,98} that Butzer⁹⁹ refers to MIS 9 (or MIS 9 & 11). The retrieved artefacts include a refined handaxe of Fauresmith aspect, similar to those found overlying the 6–8 m beach not far north at Bok Baai¹⁰⁰ (Fig. 1), but the flake component appears to lack blades or Levallois points, which could be due to the smallish sample size.

Comments and conclusion

The following remarks summarize or expand on aspects of the evidence that has been presented:

- Wonderwerk Cave originally contained some 12 000 m³ of deposits, on the assumption of a mean sediment depth of 5 m over its established extent, of which c. 20% was destroyed by guano digging in the early 1940s and a further <4% by excavations between 1943 and 1996. Still remaining, in terms of MU volumes, is roughly 25% of MU 1 with LSA, less than 5% of MU 2 with MSA, 75% of MUs 3–4 with Fauresmith, and at least

95% of MUs 5–9 with earlier assemblages that largely or entirely refer to the Acheulean. During clearance operations, it was noted that large mammal teeth and smallish handaxes were present in disturbed deposits throughout the inner cave, but, whereas the bifaces show no clear concentrations, the teeth appear to be more abundant at ~100–120 yd (91–109 m) in than in any level of Excs 1 & 2.²⁰

- Similar timespans for the abandonment of Wonderwerk Cave from ~70–12.5 kyr ago, and Kalahari sand sheet formation near Hotazel (Fig. 1) from 60–12/6 kyr ago,¹⁰¹ are taken to reflect inferred regional rainfall declines of up to ~60% below present values³³ during the cold MIS 4–2 intervals at 73–12 kyr BP.³⁸ Those correlations therefore endorse archaeological visibility observations,¹⁰² which suggest that Griqualand West was uninhabited at times when temperatures fell below those prevailing during MIS 5.1 (Fig. 4), except for sparse settlements at places where water persisted, like the Kathu Pan 5 doline^{15,103} (Fig. 1). More generally, present evidence supports the hypothesis⁸² that human populations in the summer rainfall region of the subcontinent tracked major shifts of the ice volume $\delta^{18}\text{O}$ record closely, with numbers being high when the climate was warm and wet, but low and localized during protracted glacial pulses.
- Extreme aridity within Wonderwerk Cave has led to organic preservation that is often exceptional, as exemplified by the recovery of many horn fragments with keratinous sheaths from the guano digger debris at ~100–120 yd (91–109 m) in, of which three are attributable to the extinct alcelaphine *Damaliscus niro*.³⁵ A preliminary study of one of those (WH 1)¹⁰⁴ indicated the presence of DNA, albeit in degraded form, despite morphological considerations that place the specimen near the onset of the Florisian Land Mammal Age at ~0.8 Myr ago.³⁵ This would, in turn, suggest its derivation from the deep digger pit (Fig. 2). One implication of this finding is that keratin preservation should be even better in the ~400-kyr-old grass bedding level of Exc. 4, which may therefore preserve human hair with the potential to produce DNA information¹⁰⁵ bearing on the immediate ancestor of *Homo sapiens*.
- A particularly reliable molecular clock age for modern human origins is provided by the complete mitochondrial DNA genome estimate (without gamma rates) of 167 ± 18 kyr for the most recent common ancestor, based on an assumed divergence of the hominid and chimpanzee lineages at 5.0 Myr ago.^{106,107} However, the subsequent discovery of *Sahelanthropus*,¹⁰⁸ a primal Upper Miocene member of the hominid clade,¹⁰⁹ now suggests that this split took place earlier, by c. 7.0 Myr ago, in which case the mtDNA age of the most recent common ancestor of modern humans shifts back commensurately, to ~230 kyr BP. The close correspondence between that figure and one of c. 250 ± 10 kyr ago for the regional onset of the MSA, based on bracketing estimates of ~240 kyr at Border Cave⁸⁰ (Fig. 1) and ~270 kyr at Wonderwerk (Table 2), could mean that the subcontinental emergence of modern humans and the MSA took place simultaneously, in terminal MIS 8 times.⁸⁰
- Excavated artefact samples from MUs 3 & 4 at Wonderwerk, and sealed open sites like Kathu Pan 1¹⁵ (Fig. 8), confirm the presence in central South Africa of the Fauresmith,^{1–6} a culture–stratigraphic entity typified by the co-occurrence of Levallois points and bifaces, which our age estimates place between ~250 and >500/c. 600 kyr BP. The subcontinental distribution of this complex remains to be defined, but recent findings suggest that it is replaced to the north, along the Limpopo River, by a differing lithic tradition¹¹⁰ and that it is largely coeval with the 266–>400-kyr-old Lupenban in A Block

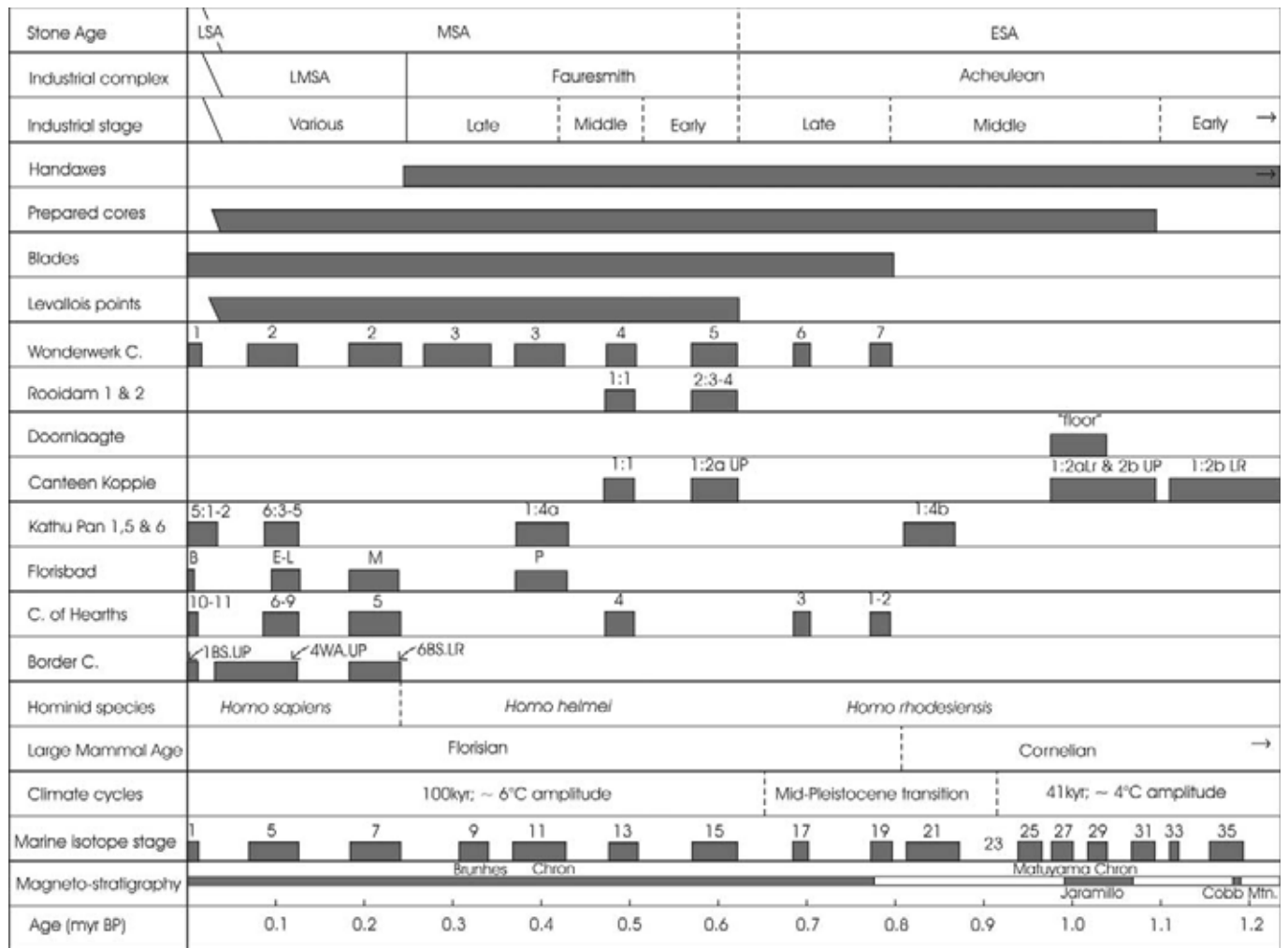


Fig. 9. The most probable relative and absolute ages of the Rooidam 1 & 2,⁶²⁻⁶⁴ Doornlaagte,⁵¹ Kathu Pan 1, 5 & 7,¹⁵ Florisbad⁶⁹⁻⁷¹ and Cave of Hearths^{8,51} lithic assemblages, in terms of stratigraphic, chronometric and typological data, modulated by Large Mammal Age,^{34,136} climate cycle,^{40,137-140} marine isotope stage⁴¹ and magnetic polarity^{41,141} constraints. It should be noted that industrial stage terms, such as 'Late', are purely provisional, in lieu of agreed-upon type sites, with potential candidates in this regard being Wonderwerk for 'Late' Fauresmith, Rooidam for 'Early' Fauresmith, Cave of Hearths for 'Late' Acheulean and Canteen Koppie for 'Middle' Acheulean.

at Twin Rivers in Zambia.^{111,112} Some have argued that the Fauresmith is merely an Acheulean variant induced by the use of hornfels,^{3,6,113,114} but that interpretation is not supported by the subsequent finding that many other raw materials were used to produce precisely the same forms, in areas where hornfels is less accessible, or absent.¹⁵

• The >0.25 Myr overlap between last bifaces and earliest Levallois points necessitates a choice between which of those two forms may best be used to define the MSA, while, at the same time, not compromising the ideal of compatible Stone Age terminologies in the western Old World. Following the axiom, common to all historical disciplines, that periods are best defined by first appearances rather than last lingerings,^{115,116} we advocate adherence to Goodwin's twin criteria,² namely, faceted platforms and convergent flaking,¹¹⁷ which imply full Levallois capability,¹¹⁸ the basis on which the Middle Palaeolithic is defined.^{119,120} Since convergent flaking and faceted platforms are both consistently present in the Fauresmith, this grouping is best referred to the MSA, with final bifaces then serving to subdivide an extended MSA into an Early MSA (EMSA), with handaxes, and a Late MSA (LMSA) that always lacks them.¹⁵ A practical problem in this regard is that the incidence of handaxes in excavated Fauresmith assemblages is often low, at ~0.1-0.01% of total lithics, which means that largish samples are essential to separate EMSA and LMSA

firmly in central South Africa.

- The Acheulean proper in central South Africa is divisible, on lithostratigraphic grounds, into three distinct stages, of which the youngest is typified by the first appearance of blades, as evidenced by assemblages from Beds 1-3 of the Cave of Hearths,^{8,51} and those overlying the Rietputs Formation at Site III on Riverview Estates^{5,66} (Fig. 8). Lithics from the prior Middle stage, distinguished by the introduction of prepared cores, occur at many Rietputs Formation sites on Riverview Estates^{4,5} and in Strata 2a & 2b Upper of Exc. 1 at Canteen Koppie (Fig. 8), where Levallois and Victoria West I & II cores occur in Stratum 2a, but Levallois cores only in underlying Stratum 2b Upper.^{64,86} It was also noted that Victoria West II types predominate in the youngest accumulation of Stratum 2a at Canteen Koppie and, on this basis, the inferred Jaramillo age of the Doornlaagte assemblage, with only Victoria West II specimens, is conservatively taken to suggest that the regional Middle Acheulean ranges from c. 0.8 to 1.1 Myr BP.
- Initial excavations in 1947 at the Cave of Hearths⁵¹ resulted in the recovery of a juvenile human mandible from Bed 3,^{121,122} which subsequently yielded a large mammal fauna of Florisian sort and a blade-rich Late Acheulean assemblage that our age estimates for Early Fauresmith and Middle Acheulean constrain to c. 0.7 Myr BP. Later (1953 and 1955) came the discovery at Elandsfontein (Fig. 1) of a human skullcap and a

mandibular fragment^{123,124} associated with a Cornelian fauna^{91,125} like that from ~1.33–0.78-Myr-old Beds III–IV at Olduvai^{92,93,126} and Middle Acheulean lithics¹⁰ with flakes that analysis (by P.B.) shows to be mainly side-struck, which suggests a lower end age of ≥ 0.9 Myr BP. All of these remains are ascribable to *Homo rhodesiensis*,^{122,127} whose occupation of the subcontinent during the Middle–Late Acheulean may therefore be linked to early use of fire, as shown by the Cave of Hearths⁵¹ and Wonderwerk evidence and, perhaps, that at Swartkrans (Fig. 1), where a prepared core-derived flake came from the surface of Member 3.^{128,129}

- Figure 9 provides a best fit for various subcontinental sites according to the proposed timescale, which points to a precocious biocultural trajectory extending back to well within the Lower Pleistocene, a finding that, we hope, will rekindle an interest in the more remote prehistory of central South Africa.¹³⁰

Some artefacts from Late Fauresmith–Middle Acheulean assemblages are illustrated in the supplementary material online.

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Supplementary material to:

Beaumont P.B. and Vogel J.C. (2006). On a timescale for the past million years of human history in central South Africa *S. Afr. J. Sci.* **102**, 217–228.

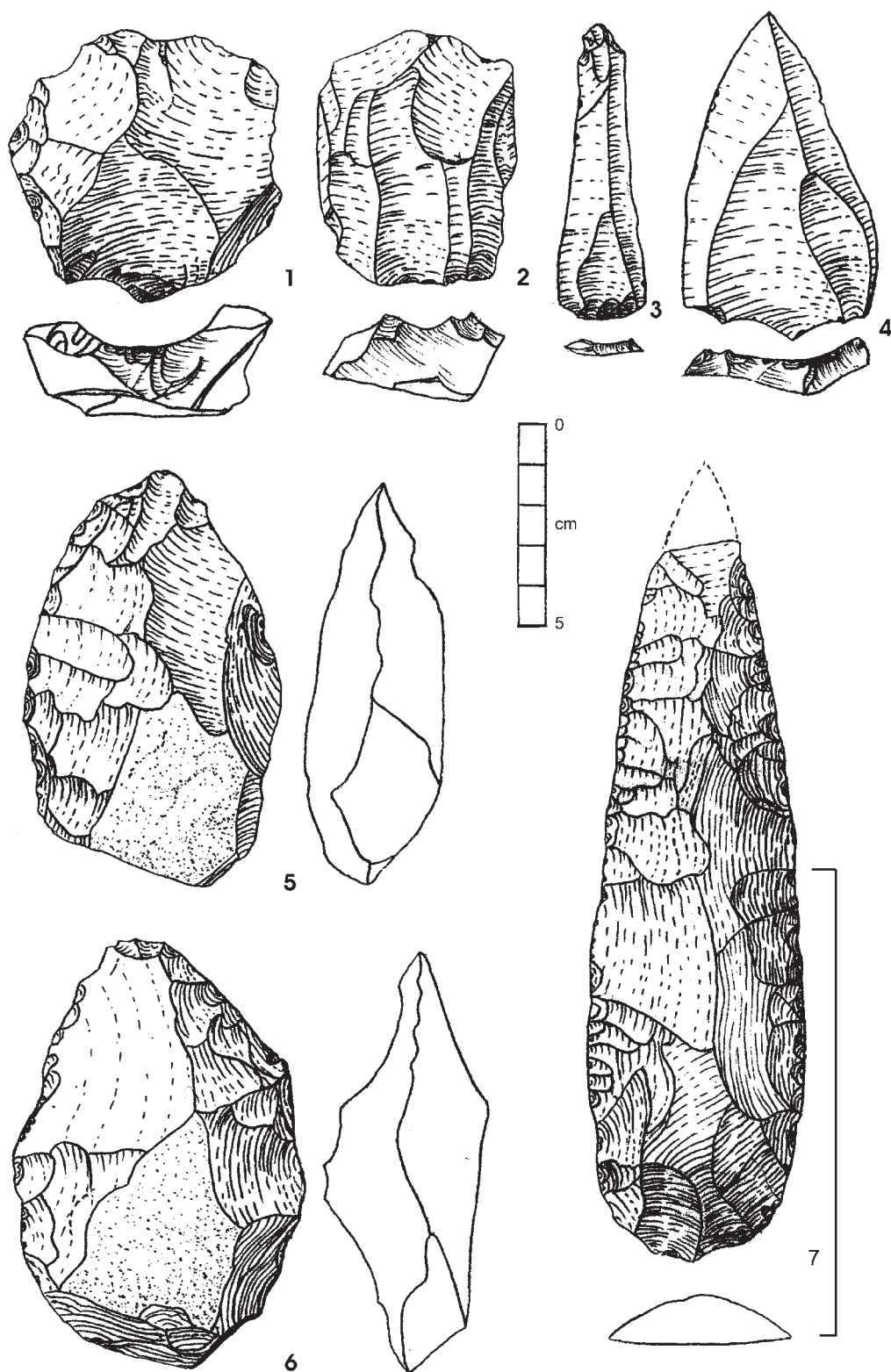


Fig. 10. Late Fauresmith artefacts from MU3 of Wonderwerk Cave at ~270–400 kyr BP. **1**, Prepared core, banded ironstone; **2**, prepared core, cryptocrystalline silica (ccs), chert variety; **3**, blade, ccs (chert); **4**, Levallois/convergent point, ccs (brown jasper); **5 & 6**, coarse final ~270-kyr-old handaxes, banded ironstone; **7**, flake-based, large unifacial point, ccs (brown jasper), perhaps a late refinement of the Hagenstad form (see Fig. 13). Note: Bracketed ccs varieties are provisional identifications.

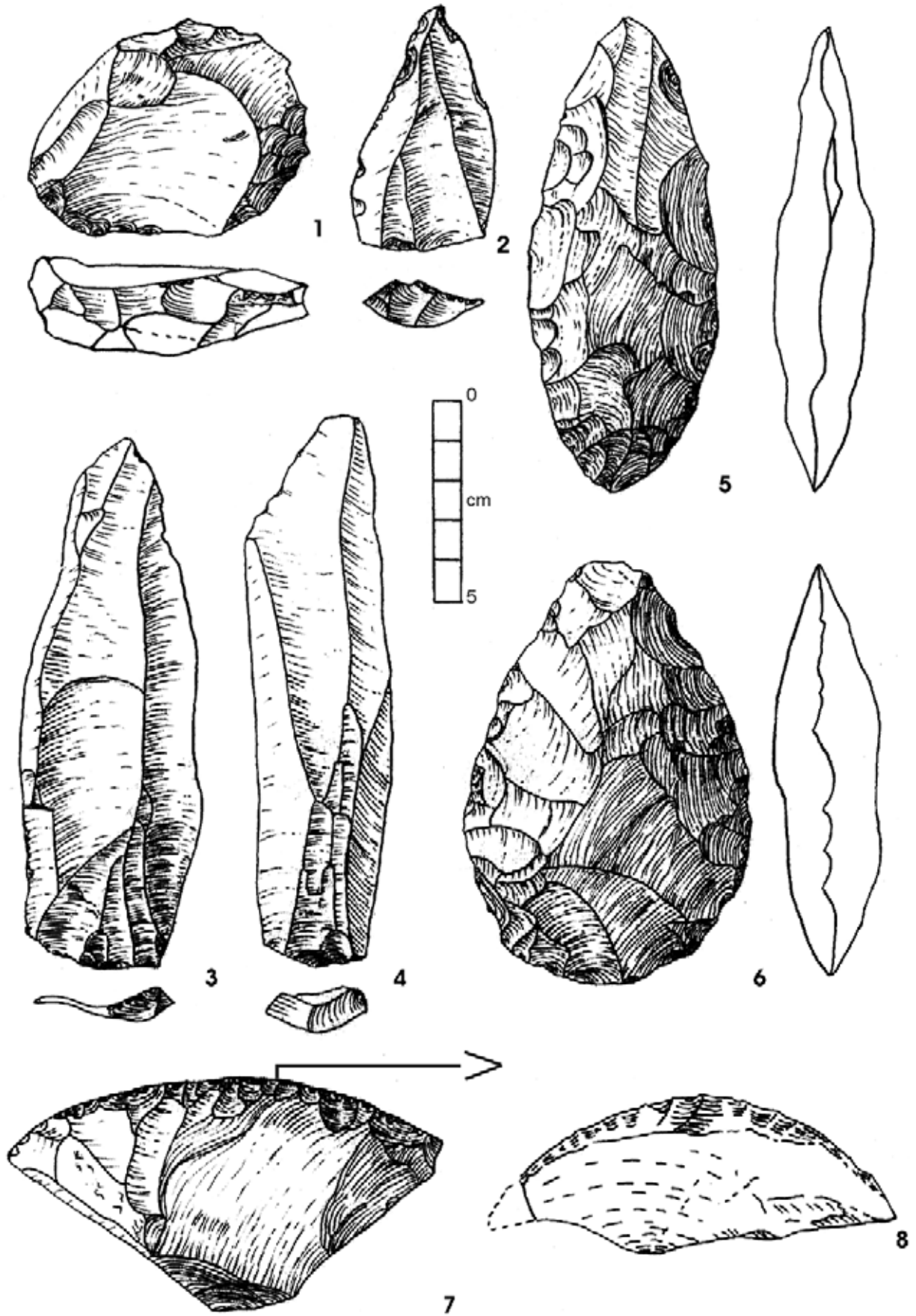


Fig. 11. Middle Fauresmith artefacts from MU4 of Wonderwerk Cave with an inferred age of ~500 kyr BP. 1, Prepared core, banded ironstone; 2, convergent point, ccs (chert); 3 & 4, blades, ccs (brown jasper); 5 & 6, handaxes, ccs (brown jasper), typically more refined than those in later MU3; 7, flake with convex retouched edge, ccs (brown jasper); 8, a similar specimen on hornfels, described as a scraper, from the Fauresmith type site at Brakfontein, Free State (after illustration on p. 77 of ref. 3).

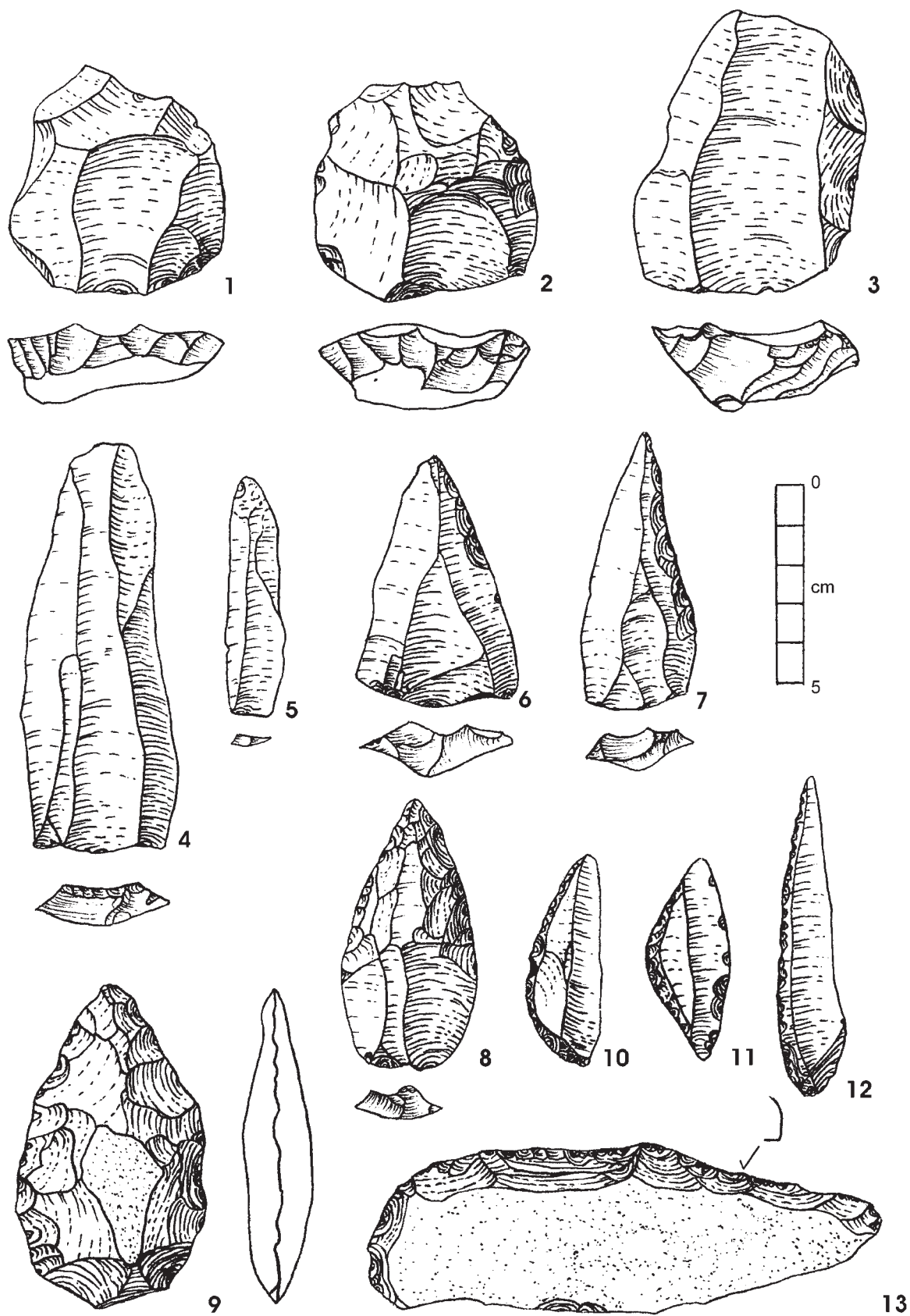


Fig. 12. Middle Fauresmith sealed open sites at c. >400 but <500 kyr BP. Stratum 4a at Kathu Pan 1 (ref. 15): **1 & 2**, Prepared cores, ccs (brown jasper); **3**, prepared core, ccs (chert); **4 & 5**, blades, ccs (chert); **6 & 7**, convergent points with minor lateral retouch, ccs (brown jasper); **8**, flake with steep distal unifacial retouch, ccs (chert); **9**, handaxe, banded ironstone. Stratum 3 at Pniel 6 (ref. 15): The same range of forms but including: **10 & 11**, rare segments, on hornfels, confirming like-aged finds in the 266–>400-kyr-old Lupemban in A Block at Twin Rivers in Zambia;^{111,112} **12**, backed point, hornfels; **13**, scraper, similar to one from the Fauresmith type site at Brakfontein, Free State (after illustration on p. 87 of ref. 3).

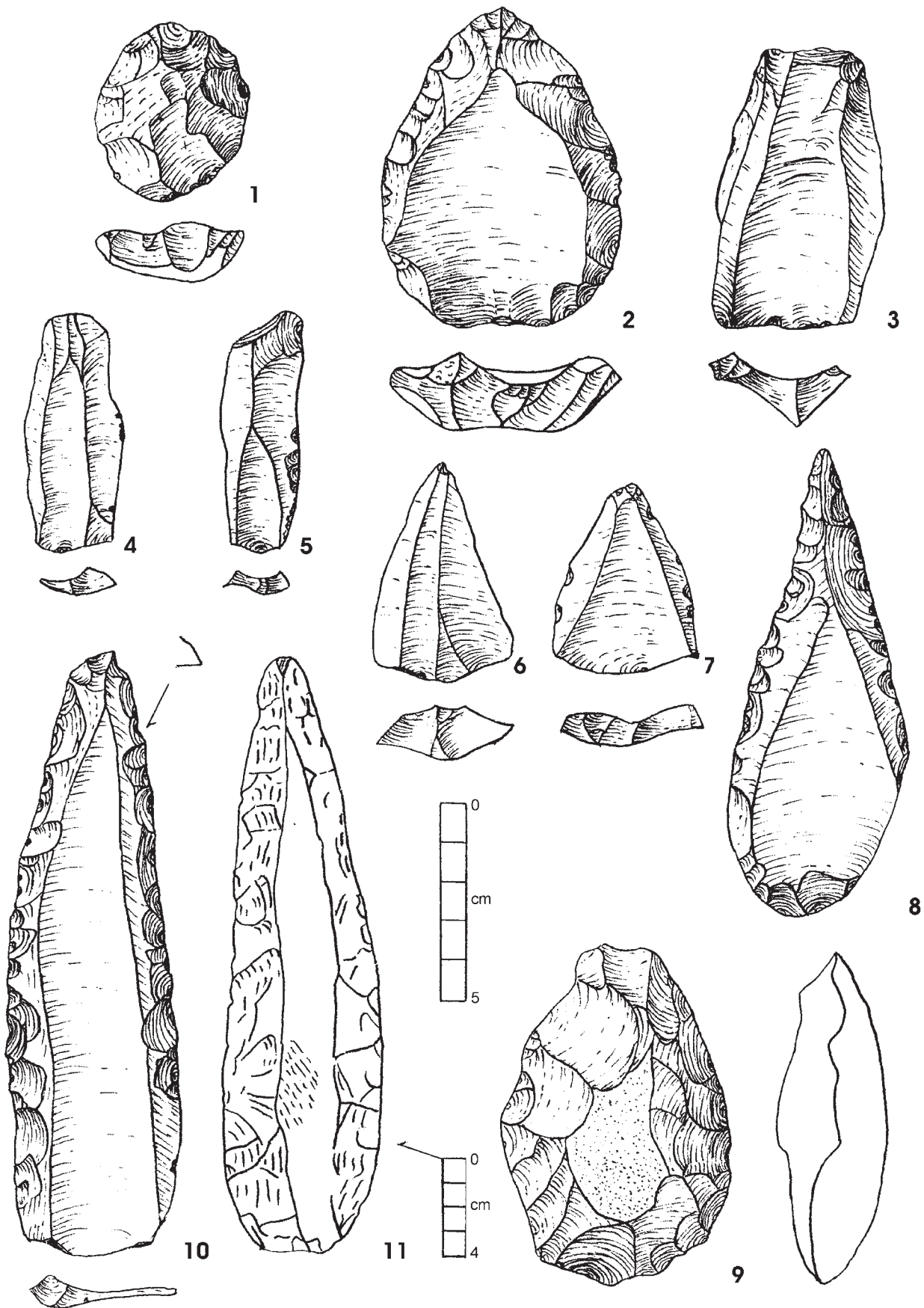


Fig. 13. Early Fauresmith artefacts from Strata 2 & 3 at Biesiesput near Rooidam⁶⁴ at c. 600 kyr BP: **1, 2 & 3**, Prepared cores; **4 & 5**, blades; **6 & 7**, convergent points; **8**, flake with some lateral retouch; **9**, handaxe, perhaps with a broken tip; **10**, Hagenstad point, with steep lateral retouch; **11**, the typologically identical, but larger, specimen found in association with the 'spring fauna' at Florisbad, after illustration in ref. 2. 1–11 all hornfels.

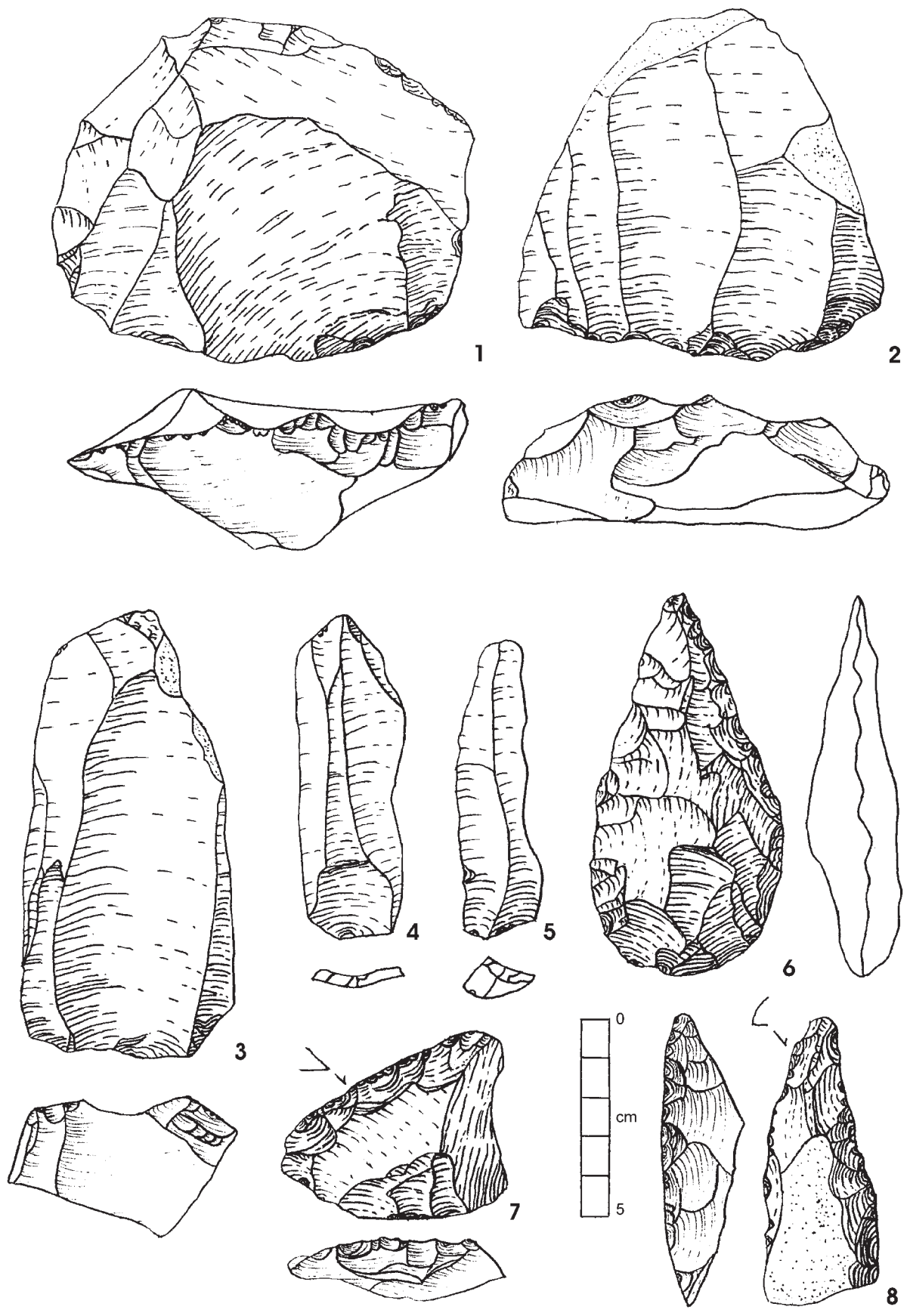


Fig. 14. Late Acheulean sealed open sites at c. 700 kyr BP. Stratum 2 at Kathu Townlands 1 (ref. 15), a ~180 m x 640 m quarry-cum-workshop site with over ~700 million artefacts: 1, 2 & 3, Prepared cores; 4 & 5, blades; 6, a handaxe. All ccs (brown jasper). Rooidam 1 (refs 15, 64): 7 & 8, scrapers, both hornfels.

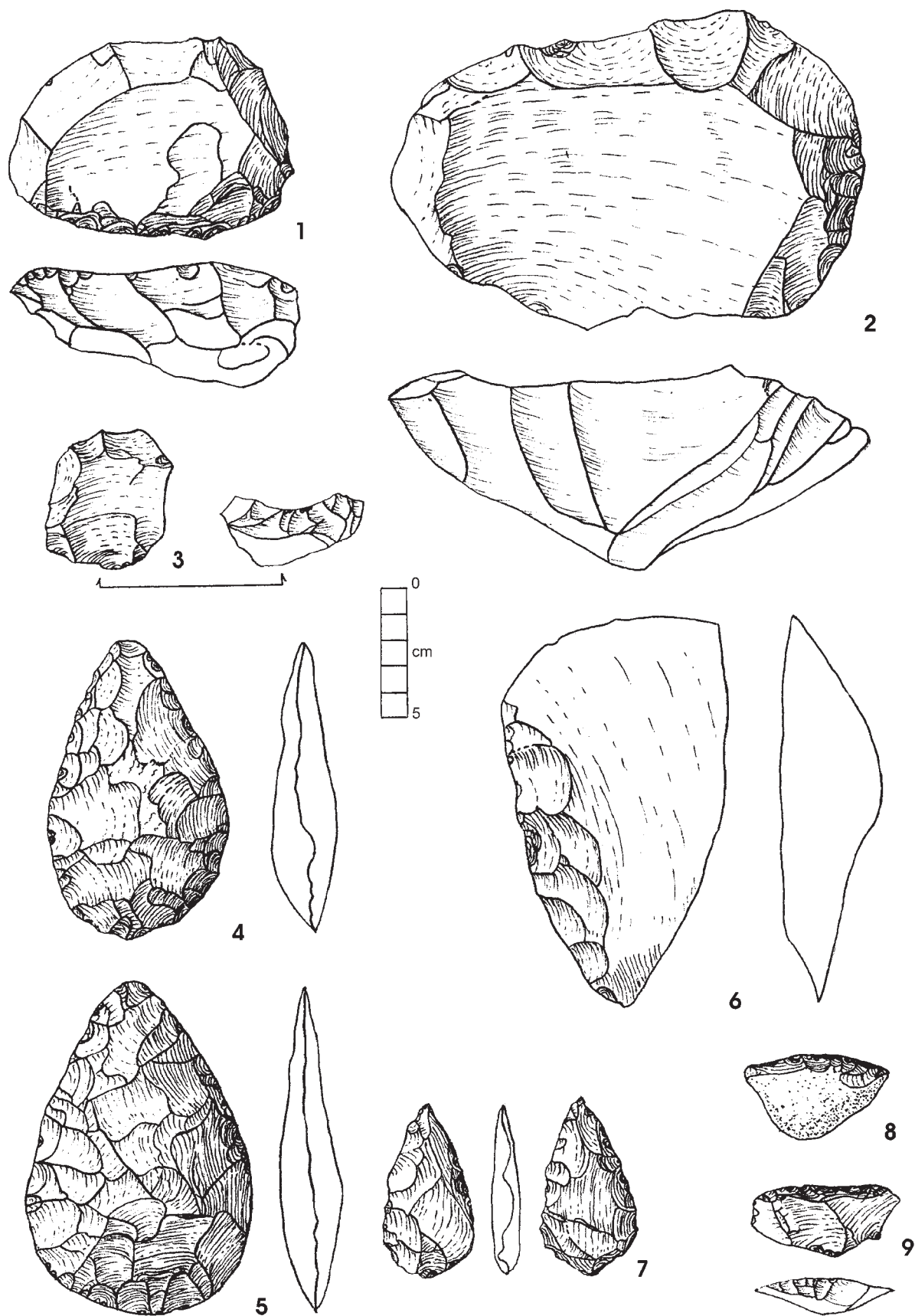


Fig. 15. Middle Acheulean artefacts at >0.78 or >0.99 —c. 1.1 Myr BP. Lower MU7 at Wonderwerk Cave: **1**, prepared core, ccs (brown jasper); **4**, handaxe, ccs (brown jasper). Stratum 2a at Canteen Koppie:^{15,64} **2**, prepared (Victoria West 1) core, andesite. Stratum 4b at Kathu Pan 1:¹⁵ **3**, prepared core, quartzite; **5**, handaxe, ccs (brown jasper), reflecting maximum regional refinement of this form by ~800–900 kyr ago; **7**, bifaced point on slab, ccs (chert); **8 & 9**, scrapers, ccs (chert). The 'living floor' at Doornlaagte:^{51,83} **6**, cleaver, typical of earlier assemblages within this stage, on a Kombewa flake of andesite.

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