Science AAAS

Ages for the Middle Stone Age of Southern Africa: Implications for Human Behavior and Dispersal

Zenobia Jacobs, *et al.*

Science **322**, 733 (2008);
DOI: 10.1126/science.1162219

Ages for the Middle Stone Age of Southern Africa: Implications for Human Behavior and Dispersal

Zenobia Jacobs,[1]* Richard G. Roberts,[1] Rex F. Galbraith,[2] Hilary J. Deacon,[3] Rainer Grün,[4] Alex Mackay,[5] Peter Mitchell,[6] Ralf Vogelsang,[7] Lyn Wadley[8]

The expansion of modern human populations in Africa 80,000 to 60,000 years ago and their initial exodus out of Africa have been tentatively linked to two phases of technological and behavioral innovation within the Middle Stone Age of southern Africa—the Still Bay and Howieson's Poort industries—that are associated with early evidence for symbols and personal ornaments. Establishing the correct sequence of events, however, has been hampered by inadequate chronologies. We report ages for nine sites from varied climatic and ecological zones across southern Africa that show that both industries were short-lived (5000 years or less), separated by about 7000 years, and coeval with genetic estimates of population expansion and exit times. Comparison with climatic records shows that these bursts of innovative behavior cannot be explained by environmental factors alone.

Anatomical and genetic evidence suggests that modern humans (*Homo sapiens*) originated in Africa during the Middle Stone Age (MSA), which lasted from about 280 to 30 thousand years ago (ka) (*1*). The later part of the MSA in southern Africa includes two distinct industries notable for their technological and behavioral innovation, the Still Bay (SB) and the Howieson's Poort (HP), which are found in diverse climatic and biogeographic contexts (Fig. 1). SB flake-based technology includes finely shaped, bifacially worked, lanceolate points that were probably parts of spearheads (*2*), whereas the blade-rich HP is associated with backed (blunted) tools (*3*) that most likely served as composite weapons, made of multiple stone artifacts, and with tools that differ from those in the SB. Evidence from use-wear and residue analysis demonstrates that the SB and HP weapons were hafted (*4*, *5*). Recent discoveries of associated bone points and tools (*6*, *7*), engraved ochres and ostrich eggshells (*8*–*10*), and shell beads (*11*, *12*) validate the interpretation of the SB and HP as innovative (*1*). Increasingly complex technological and social organization, accompanied by expansion in human populations and densities, is implied by the use of bone tools, symbols, and personal ornaments (*13*). No consensus exists, however, on the possible causes or consequences of these innovative technologies.

Genetic studies of expansions, migrations, and isolations of modern human populations within Africa (*14*, *15*) and their initial exodus out of Africa (*16*, *17*) have been temporally associated with the SB and HP (*13*). The establishment of evidence for these hypothesized connections, any link to the origins of click languages (*18*), and putative technological responses to environmental pressures (*13*) has been hindered by a lack of reliable chronological control for the SB and HP. Until now, it was not known whether these industries fell into two discrete periods of relatively short duration or formed a continuum of longer duration. These uncertainties persisted partly because of the chronological "haze" resulting from different sites being dated by means of different methods. Even for a single method, experimental factors typically vary between dating laboratories, owing to the use of different instruments, calibration standards, and procedures for sample preparation, measurement, and data analysis. Here we report the results of a systematic dating study, subcontinental in scope, of the timing of the SB and HP.

We used single-grain optical dating (*19*), combined with statistical modeling, to determine the time of deposition of the artifact-bearing deposits at nine geographically widespread sites across southern Africa (Fig. 1) (*20*). Optical ages indicate the burial times of artifacts in primary context. We have minimized the extent of interfactorial variance by holding the main experimental parameters constant and by having one operator (Z.J.) make all measurements on a single instrument and analyze the data using a common set of procedures. Dating of individual sand-sized grains of quartz allows a direct assessment of stratigraphic integrity and of any evidence for sediment mixing, so that both the accuracy and precision of the ages are optimized (*19*).

Our survey includes "classic" MSA sites, which we have redated (such as Klasies River), and SB and HP deposits not dated previously. The coastline of South Africa is represented in our survey (Fig. 1), as are near-coastal areas and the continental interior of Lesotho and Namibia to altitudes of up to 1850 m. Most major present-day climatic ranges and ecological zones are encompassed in our survey, but we recognize that the position and extent of these biomes will have varied during the late Pleistocene because of changes in ocean/atmosphere circulation patterns (*21*). Fifty-four sediment samples were dated from stratigraphic units containing unambiguous evidence for the HP ($n = 22$) and SB ($n = 4$), and from units immediately before ($n = 10$) and after ($n = 18$) these industries. Details of sites, samples,

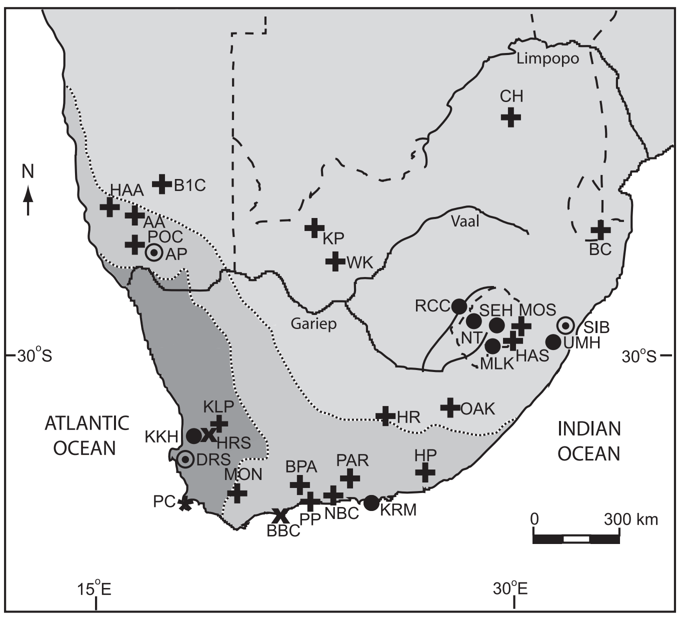

Fig. 1. Locations of sites at which SB and HP artifacts have been found. Solid circles indicate those sites where HP deposits, have been dated in this study, whereas open circles with a central dot denote study sites that contain both dated SB and HB industries. The symbols **x** and **+** indicate other known (or claimed) occurrences of SB and HP, respectively; these sites may have associated independent age estimates. Also shown are the modern rainfall zones: winter (dark gray), all year (medium gray), and summer (light gray). Site acronyms are defined in (*20*).

[1]GeoQuEST Research Centre, School of Earth and Environmental Sciences, University of Wollongong, Wollongong, New South Wales 2522, Australia. [2]Department of Statistical Science, University College London, London WC1E 6BT, UK. [3]Iziko Museums of Cape Town, Cape Town 8000, South Africa. [4]Research School of Earth Sciences, Australian National University, Canberra, Australian Capital Territory (ACT) 0200, Australia. [5]School of Archaeology and Anthropology, Australian National University, Canberra, ACT 0200, Australia. [6]School of Archaeology, University of Oxford, Oxford OX1 2PG, UK. [7]Institute of Prehistoric Archaeology, African Archaeology Unit, University of Cologne, Köln 50823, Germany. [8]School of Geography, Archaeology and Environmental Sciences, and Institute for Human Evolution, University of the Witwatersrand, WITS 2050, South Africa.

*To whom correspondence should be addressed. E-mail: zenobia@uow.edu.au

and dating procedures are given in (*20*). It is unlikely that each site will cover the entire age range of each industry, but we consider that sufficient samples have been dated to recognize chronological patterns for each industry. In particular, we have obtained reliable estimates of the timing and duration of the HP.

The ages are summarized in Fig. 2. They are plotted according to site location (west, or east and south) to illuminate any tendencies for spatial variation across geographic and climatic boundaries. No spatial patterns could be discerned, so both data sets were combined for all subsequent statistical analyses (*20*). We determined, by maximum likelihood estimation, that the composite data set is not consistent with a continuum of ages between the SB and HP (P = 0.008) but rather with a gap of 6.7 thousand years (ky) [95% confidence interval (CI): 2.7 to 9.3 ky]. We then estimated that the HP started 64.8 ka (95% CI: 68.2 to 61.6 ka) and ended 59.5 ka (95% CI: 62.7 to 56.5 ka), with a duration of 5.3 ky (95% CI: 2.0 to 8.3 ky). The start and end ages for SB were calculated as 71.9 and 71.0 ka, respectively, but there are too few data to reliably constrain their 95% CIs to better than 4 to 5 ky. The current ages are consistent with it being of short duration (<1 ky), but additional ages for the SB would help refine this estimate. The 10 earliest post-HP ages agree with a common value (56.5 ka; 95% CI: 59.0 to 54.0 ka); assuming that this marks the start of this period, we estimated a gap (P = 0.02) of about 4.2 ky (95% CI: 1.9 to 6.6 ky) between the end of the HP and the start of the post-HP period (*20*). The CIs for all of the start and end ages include a calibration uncertainty of 2% (associated with the laboratory beta source), but this uncertainty does not apply to estimates of duration (which are differences of ages).

Our SB and HP ages are plotted in Fig. 3 with other chronological estimates obtained previously (table S1). For these comparisons, the total uncertainty on the optical ages includes the calibration uncertainty of 2%. Nearly all of the previous HP ages are consistent with being inside our estimated HP period, and all of the SB estimates are consistent with a single common age (*20*). But our optical ages are more precise, being compatible with the most accurate and precise estimates available [from uranium-series dating of speleothems (Fig. 3) and acid-base-wet oxidation pretreatment with stepped combustion (ABOX-SC) radiocarbon dating of charcoal from post-HP levels at Border Cave (*22*)].

Southern Africa lacks continuous and well-dated paleoenvironmental records for the time interval of interest across the full range of biomes (*21*). But we argue against a substantial influence of local- to regional-scale climatic variations on the archaeological record because HP and SB sites cross-cut climatic and ecological zones. At a subcontinental scale, the climatic records identified in ice cores from West and East Antarctica (*23*, *24*) (Fig. 4) can be used for comparison, bearing in mind the detailed differences in timing and amplitude of changes in the Antarctic records and the additional uncertainties associated with extrapolating climatic changes in Antarctica to southern Africa. Although the HP occurred during a period of climatic warming, this was also the case for the late and final MSA occupations at Sibudu (*25*, *26*). The SB and post-HP periods cannot be reliably associated with either warm or cool intervals (Fig. 4). Accordingly, we cannot identify any particular climatic attribute that is consistently and uniquely associated with any MSA industry. Other differences also occur; for example, the SB coincided (within error) with the Toba volcanic super-eruption (*27*) and with the end of megadroughts in tropical Africa (*28*), whereas the HP is not associated with any such known events. Environmental factors may have been responsible for episodic occupation and abandonment of rock shelters (*26*), but they were not necessarily the driving force behind technological change.

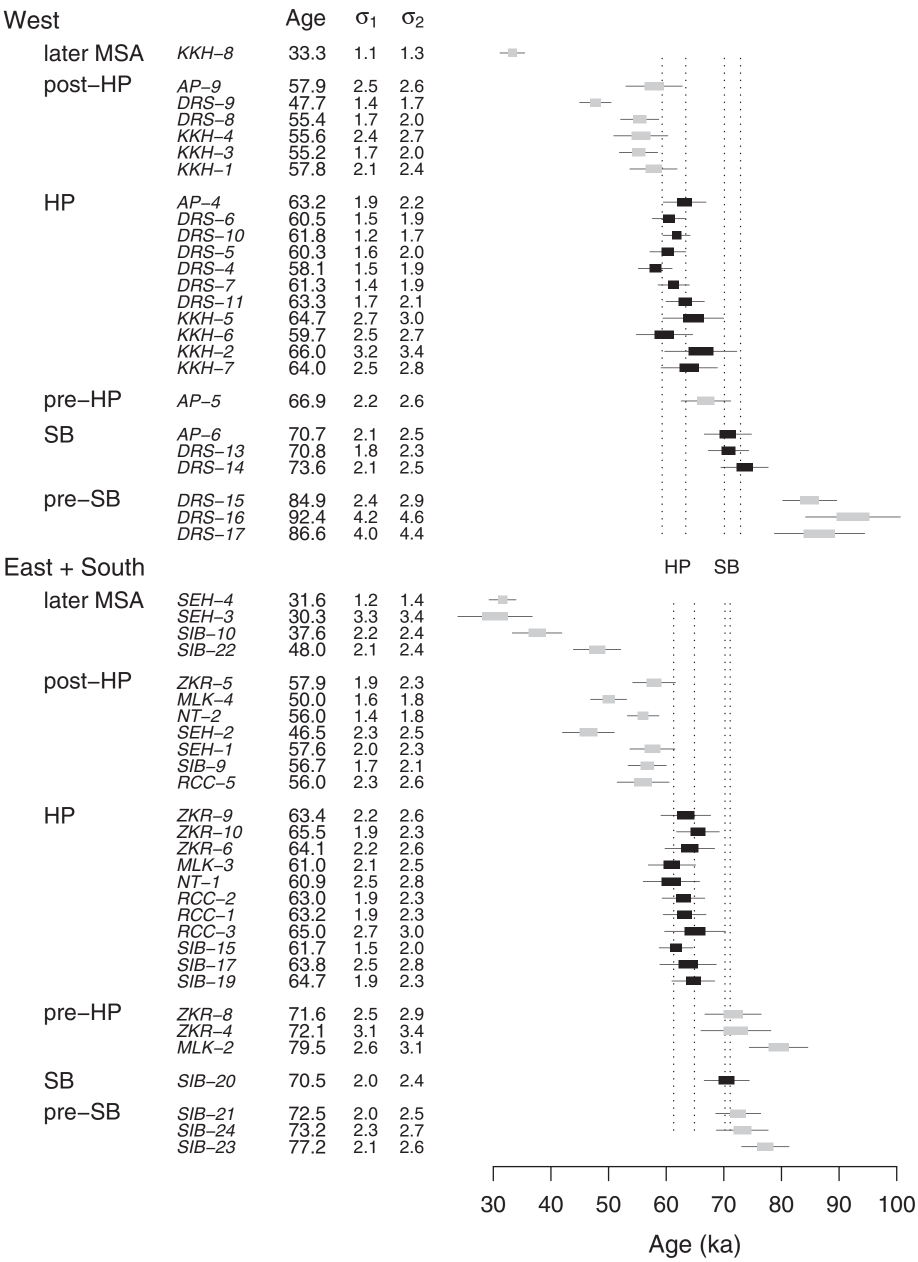

Fig. 2. Optical age estimates (ka) classified by region, archaeological association, and site. Samples are listed in stratigraphic order within each site. Samples with the association "pre-HP" have been identified as being before the start of the HP but not necessarily after the end of the SB. Standard errors σ_1 and σ_2 exclude and include, respectively, possible systematic error (any systematic error is the same for each estimate and does not affect comparisons between estimates). Shaded boxes and error bars denote 50 and 95% CIs, respectively, calculated using σ_1. Intervals for samples from the HP and SB are highlighted in black. Dotted lines indicate the start and end ages of the HP and SB, estimated separately for each region. ZKR denotes samples from Klasies River; other site acronyms are defined in (*20*).

The age and duration of the HP have been long-standing topics of dispute (*29*). We have resolved, with useful precision and over a broad geographical range, start and end ages for the HP (which is of sufficiently short duration that it represents a marker horizon of about 62 ka for southern Africa), the probable brief duration of the SB, and the existence of an age gap of several millennia between the SB and HP. The cause of these two bursts of technological innovation, closely spaced yet separated in time, remains an enigma, as does the reason for their disappearance. But, intriguingly, both fall within the genetic bottleneck that occurred 80 to 60 ka and the subsequent expansions of modern human populations within (*14*, *15*) and out of (*16*, *17*) Africa. Determining whether the emergence of innovative technology in southern Africa was a precursor to the latter exodus (*13*), or whether population expansions were the stimulus for the SB and HP (*15*, *28*), requires that similar chronological data sets be compiled and evaluated for comparable lithic technologies in East and North Africa (*30*).

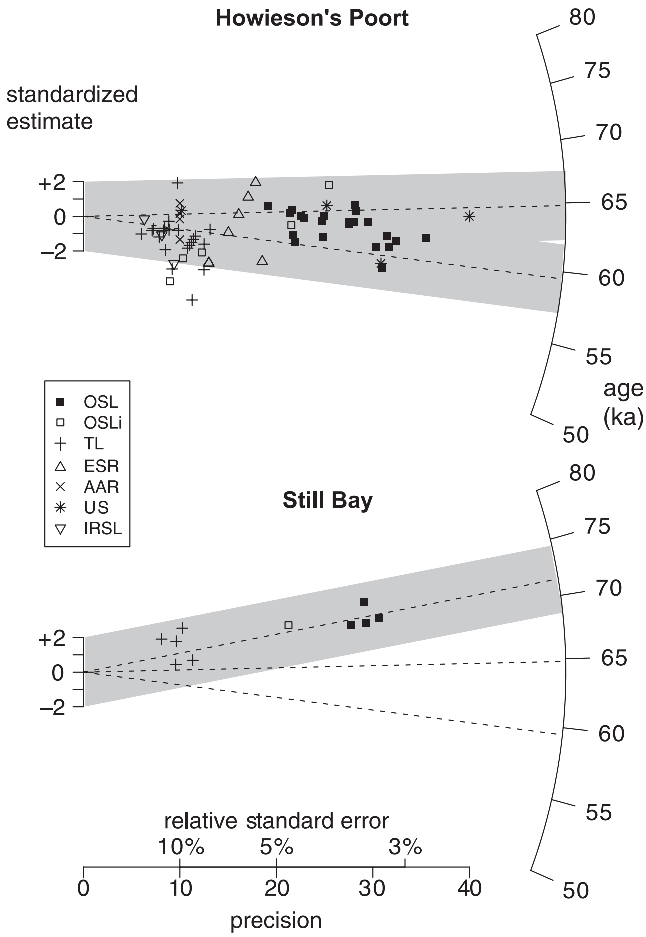

Fig. 3. Radial plots comparing age estimates of samples from the HP and SB obtained in different studies. Solid squares denote estimates from this study presented in Fig. 2, with precisions obtained using σ_2 (that is, including possible systematic error). Other symbols denote estimates obtained independently by various researchers using different dating methods (table S1). Dashed lines show the estimated start and end ages of the HP period and the midpoint of the SB. Shaded bands indicate ±2 SE (for any age estimate) about each of these lines. Estimates consistent with a common age should scatter mostly within such a band.

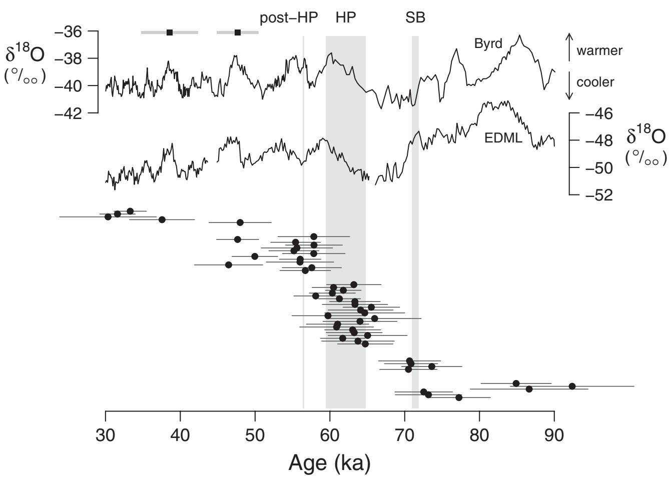

Fig. 4. Age estimates (with 95% CIs) from Fig. 2 plotted alongside oxygen isotope data (‰, per mil) from the Byrd and European Project for Ice Coring in Antarctica (EPICA) Dronning Maud Land (EDML) ice cores from Antarctica (*23*, *24*). Both records are plotted on a common time scale, achieved by synchronization with Greenland ice core data (*24*), and the EDML data are lowess-smoothed to 100-year resolution. Ages labeled "pre-HP" in Fig. 2 are omitted here, as they cannot be identified with a specific period. Vertical gray bands show our estimates of the HP and SB periods as well as the pulse immediately post-HP. The gray horizontal bars show mean age estimates and 95% CIs for the late and final MSA periods obtained in (*26*).

References and Notes

1. S. McBrearty, A. S. Brooks, *J. Hum. Evol.* **39**, 453 (2000).
2. L. Wadley, *J. Hum. Evol.* **52**, 681 (2007).
3. S. Wurz, *S. Afr. Archaeol. Bull.* **54**, 38 (1999).
4. M. Lombard, *S. Afr. Archaeol. Bull.* **62**, 62 (2007).
5. M. Lombard, *J. Archaeol. Sci.* **35**, 26 (2008).
6. C. S. Henshilwood, F. d'Errico, C. W. Marean, R. G. Milo, R. Yates, *J. Hum. Evol.* **41**, 631 (2001).
7. L. Backwell, F. d'Errico, L. Wadley, *J. Archaeol. Sci.* **35**, 1566 (2008).
8. C. S. Henshilwood *et al.*, *Science* **295**, 1278 (2002).
9. A. Mackay, A. Welz, *J. Archaeol. Sci.* **35**, 1521 (2008).
10. J.-P. Rigaud, P.-J. Texier, J. E. Parkington, C. Poggenpoel, *C. R. Palevol.* **5**, 839 (2006).
11. C. S. Henshilwood, F. d'Errico, M. Vanhaeren, K. van Niekerk, Z. Jacobs, *Science* **304**, 404 (2004).
12. F. d'Errico, M. Vanhaeren, L. Wadley, *J. Archaeol. Sci.* **35**, 2675 (2008).
13. P. Mellars, *Proc. Natl. Acad. Sci. U.S.A.* **103**, 9381 (2006).
14. P. Forster, *Philos. Trans. R. Soc. London Ser. B* **359**, 255 (2004).
15. D. M. Behar *et al.*, *Am. J. Hum. Genet.* **82**, 1130 (2008).
16. V. Macaulay *et al.*, *Science* **308**, 1034 (2005).
17. H. Liu, F. Prugnolle, A. Manica, F. Balloux, *Am. J. Hum. Genet.* **79**, 230 (2006).
18. S. A. Tishkoff *et al.*, *Mol. Biol. Evol.* **24**, 2180 (2007).
19. Z. Jacobs, R. G. Roberts, *Evol. Anthropol.* **16**, 210 (2007).
20. Materials and methods are available as supporting material on *Science* Online.
21. B. M. Chase, M. E. Meadows, *Earth-Sci. Rev.* **84**, 103 (2007).
22. M. I. Bird *et al.*, *Quat. Sci. Rev.* **22**, 943 (2003).
23. T. Blunier, E. J. Brook, *Science* **291**, 109 (2001).
24. EPICA Community Members, *Nature* **444**, 195 (2006).
25. S. Soriano, P. Villa, L. Wadley, *J. Archaeol. Sci.* **34**, 681 (2007).
26. Z. Jacobs, A. G. Wintle, G. A. T. Duller, R. G. Roberts, L. Wadley, *J. Archaeol. Sci.* **35**, 1790 (2008).
27. S. H. Ambrose, *J. Hum. Evol.* **34**, 623 (1998).
28. C. A. Scholz *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **104**, 16416 (2007).
29. Z. Jacobs, R. G. Roberts, *S. Afr. Archaeol. Soc. Goodwin Ser.* **10**, 8 (2008).
30. A. Bouzouggar *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **104**, 9964 (2007).

31. We acknowledge support from the Australian Research Council (R.G.R., R.G., and Z.J.), Deutsche Forschungsgemeinschaft, and National Museum of Namibia (R.V.). The South African Heritage Resource Agency, Amafa, the Namibian Heritage Council of Namibia, and the Protection and Preservation Commission of Lesotho (N. Khitsane) issued permits.

Supporting Online Material

www.sciencemag.org/cgi/content/full/322/5902/733/DC1
Materials and Methods
Figs. S1 to S29
Tables S1 to S29
References

24 June 2008; accepted 25 September 2008
10.1126/science.1162219