# Emergence of Modern Human Behavior: Middle Stone Age Engravings from South Africa

**Christopher S. Henshilwood,[1,2,3]* Francesco d'Errico,[4] Royden Yates,[1] Zenobia Jacobs,[5] Chantal Tribolo,[6] Geoff A. T. Duller,[5] Norbert Mercier,[6] Judith C. Sealy,[7] Helene Valladas,[6] Ian Watts,[1,7] Ann G. Wintle[5]**

**In the Eurasian Upper Paleolithic after about 35,000 years ago, abstract or depictional images provide evidence for cognitive abilities considered integral to modern human behavior. Here we report on two abstract representations engraved on pieces of red ochre recovered from the Middle Stone Age layers at Blombos Cave in South Africa. A mean date of 77,000 years was obtained for the layers containing the engraved ochres by thermoluminescence dating of burnt lithics, and the stratigraphic integrity was confirmed by an optically stimulated luminescence age of 70,000 years on an overlying dune. These engravings support the emergence of modern human behavior in Africa at least 35,000 years before the start of the Upper Paleolithic.**

Archaeological evidence associated with modern cognitive abilities provides important insights into when and where modern human behavior emerged (*1*). Two models for the origins of modern human behavior are current: (i) a late and rapid appearance at ~ 40 to 50 thousand years ago (ka) associated with the European Upper Paleolithic and the Later Stone Age (LSA) of sub-Saharan Africa (*2*, *3*) or (ii) an earlier and more gradual evolution rooted in the African Middle Stone Age (MSA; ~250 to 40 ka) (*4*, *5*). Evidence for modern behavior before 40 ka is relatively rare and often ambiguous (*2*, *6*). However, in sub-Saharan Africa, archaeological evidence for changes in technology, economy, and social organization and the emergence of symbolism in the MSA may support the second model (*4*, *5*, *7–9*). Examples of these changes include standardized formal lithic tools (*5*, *8*, *10*), shaped bone implements (*5*, *7*, *9*, *11*), innovative subsistence strategies such as fishing and shellfishing (*10–12*), and the systematic use of red ochre (*10*, *13*).

[1]Iziko Museums of Cape Town, South African Museum, Post Office Box 61, Cape Town, 8000, South Africa. [2]Department of Anthropology, State University of New York at Stony Brook, NY, 11794, USA. [3]Centre for Development Studies, University of Bergen, Strømgaten, 54, 5007 Bergen, Norway. [4]Institut de Préhistoire et de Géologie du Quaternaire, UMR 5808 du CNRS, Avenue des Facultés, 33405, Talence, France. [5]Luminescence Dating Laboratory, Institute of Geography and Earth Sciences, University of Wales, Aberystwyth, SY23 3DB, UK. [6]Laboratoire des Sciences du Climat et de l'Environnement, UMR CEA-CNRS, Avenue de la Terrasse, 91198 Gif-sur-Yvette cedex, France. [7]Department of Archaeology, University of Cape Town, Private Bag, Rondebosch, 7701, Cape Town, South Africa.

*To whom correspondence should be addressed. E-mail: chenshilwood@iziko.org.za

Utilized ochre is found in almost all Stone Age occupations in southern Africa that are younger than 100 ka (*13*). The ochre may have served only utilitarian functions (e.g., skin protection or hide tanning) (*3*) or may have been used symbolically as pigment (*4*, *10*, *13*). Evidence for the latter is a persistent use of ochre with saturated red hues to produce finely honed crayon or pencil forms (*10*, *13*). However, no ochre pieces or other artifacts older than ~40 ka provide evidence for abstract or depictional images, which would indicate modern human behavior (*2*, *14*, *15*).

We have recovered two pieces of engraved ochre from the MSA layers at Blombos Cave, South Africa. Situated on the southern Cape shore of the Indian Ocean, the cave is 35 m above sea level. A 5- to 60-cm layer of aeolian sand containing no archaeological artifacts (BBC Hiatus; Fig. 1) separates the LSA from the MSA occupation layers. The MSA is divided into three substages (*9*, *10*) (Fig. 1): (i) an upper series of occupational deposits, BBC M1, typified by abundant bifacially flaked, lanceolate-shaped stone points (Still Bay points) (*10*); (ii) a middle series, BBC M2, containing fewer Still Bay points but relatively abundant in deliberately shaped bone awls and points that were probably hafted (*9*, *11*); and (iii) a lower BBC M3 series with few retouched pieces but with blades and flakes typical of the Mossel Bay/MSA 2b subphase (*10*). Associated, well-preserved faunal remains from all layers indicate that subsistence strategies were wide ranging and include terrestrial and marine mammals, shellfish, fish, and reptiles (*10*, *11*).

More than 8000 pieces of ochre, many bearing signs of utilization, have been recovered from the MSA layers at Blombos Cave (*10*). Seven of nine pieces are potentially engraved and under study. We report here on the two unequivocally engraved pieces recovered in situ from layer CC, square E6a and layer CD, square H6a (Fig. 1) (*10*) during excavations in 1999 and 2000, respectively. The engraved ochre piece from layer CC (SAM-AA 8937) was located adjacent to a small hearth, and that from layer CD (SAM-AA 8938) was surrounded by a number of small, basin-shaped hearths. Both specimens were located in a matrix of undisturbed and consolidated mixed ash and sand. There is no indication of perturbation in either the overlying 15 to 20 cm of MSA deposits or in the blanketing aeolian dune sand and no sign of intrusion of younger LSA materials (*9*, *10*). All lithic artifacts in the ochre-bearing and overlying MSA layers are typologically MSA (*9*, *10*).

On the 8937 piece (Fig. 2, A and B), both the flat surfaces and one edge are modified by scraping and grinding. The edge has two ground facets, and the larger of these bears a cross-hatched engraved design. The cross hatching consists of two sets of six and eight lines partly intercepted by a longer line. The engraving on 8938 (Fig. 2, C and D) consists of a row of cross hatching, bounded top and bottom by parallel lines and divided through the middle by a third parallel line that divides

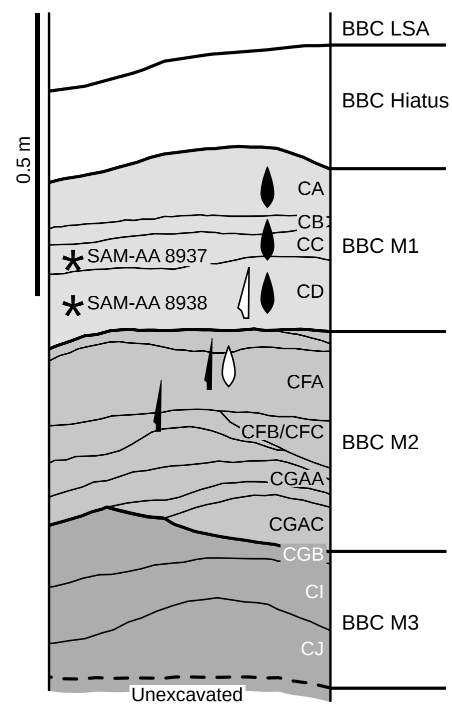


**Fig. 1.** Stratigraphy of Blombos Cave (34°25′S, 21°13′E). Sequence of MSA layers in square H6 showing relative location of engraved ochre pieces SAM-AA 8937 and SAM-AA 8938, bifacial Still Bay points (lanceolate shape), and bone tools. Closed and open symbols for bifacial points and bone tools indicate common and rare occurrences, respectively. The MSA layers consist principally of sands interlayered with consolidated beds, lenses, and stringers of marine shells, organic matter, and wood ash.

the lozenge shapes into triangles. Some of the lines are well-defined single incisions; others have parallel tracks along part or all of their lengths. Much of the parallel tracking may have resulted from a change in position of the engraving tool causing simultaneous scoring from more than one projection. The midline comprises three marking events. Examination of the intersections of the cross-hatched lines indicates that they were not executed as consecutive cross hatchings but that lines were made in first one direction and then another; the horizontal lines overlie the cross hatching. The preparation by grinding of the engraved surface, situation of the engraving on this prepared face, engraving technique, and final design are similar for both pieces, indicating a deliberate sequence of choices. Although the engraving on the 8937 ochre has fewer markings than the 8938 piece, it indicates that 8938 is not unique; the engraving on 8938 can be considered a complex geometric motif as the cross-hatched lines are bisected and framed by horizontals.

Assessing the significance of these engravings demands an accurate determination of their age (*16*). The engraved ochres were found within layers containing bifacially flaked stone points; in the South African MSA, these stone point types occur only within or below Howiesons Poort horizons (*10*) dated to ~65 to 70 ka (*17*). This association suggests that the engravings are older than 65 ka. To independently confirm and refine this time frame, we applied two luminescence-based dating methods to the Blombos Cave layers. Thermoluminescence (TL) dates were obtained for five burnt lithic samples from the MSA phase BBC M1 (Fig. 1) (*18*, *19*). The mean age for the lithic samples is 77 ± 6 ka (*20*). To confirm the stratigraphic integrity, we applied optically stimulated luminescence (OSL) dating to the aeolian dune (BBC Hiatus) separating the LSA and MSA layers (Fig. 1). Multiple grain measurements with a single aliquot regenerative (SAR) procedure (*21*) yielded a depositional age of 69 ± 5 ka (*22*). Single-grain SAR measurements (*23*) yielded consistent ages (*24*), indicating that the aggregate samples were not contaminated by grains of different ages (*25*). Because only 1.8% of the 1892 grains analyzed yielded reproducible growth curves, a more representative approach was also used (*26*), combining OSL signals from grains to generate synthetic aliquots. These provide a depositional age of 70 ± 5 ka (*20*) and confirm the antiquity of the engraved ochres.

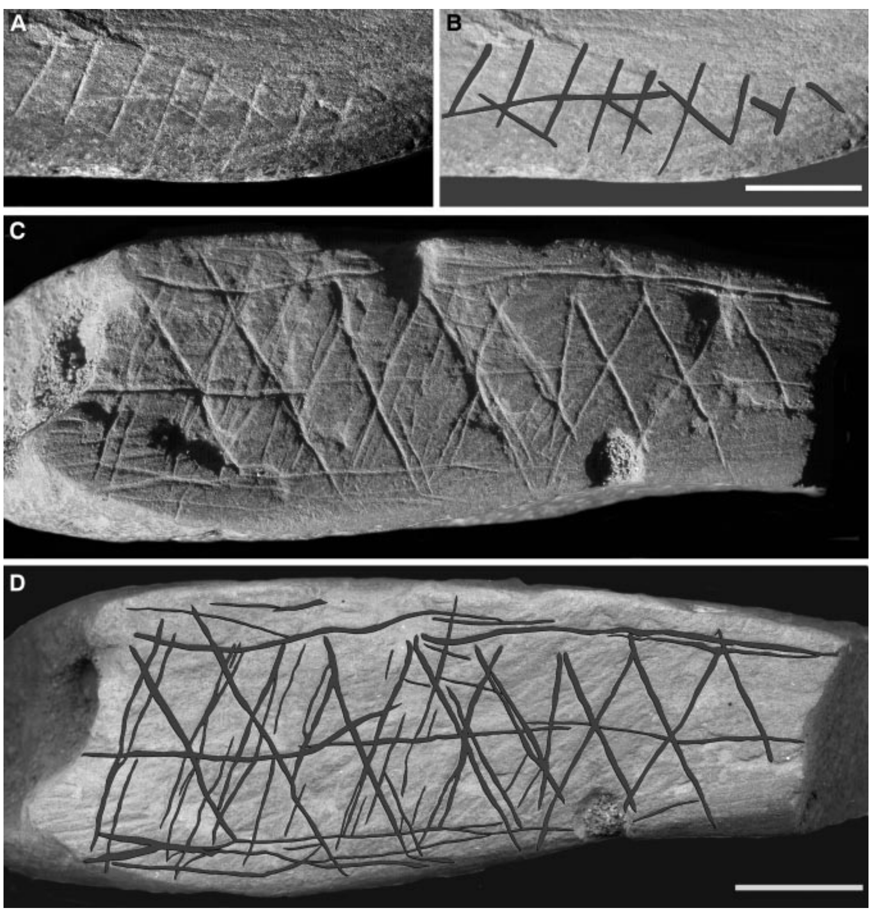

**Fig. 2.** Engraved ochres from Blombos Cave. (**A**) SAM-AA 8937 is a flat piece of shale-like ochre that grades into silt on the reverse side: weight = 39.2 g; maximum length = 53.6 mm; breadth = 42.6 mm, depth = 11.7 mm; streak color notation 3060 Y65R (*33*). (**B**) Tracing of lines verified as engraved by study under magnification (scale bar, 5 mm). (**C**) SAM-AA 8938 is a rectangular slab of ochreous shale: weight = 116.6 g; maximum length = 75.8 mm; breadth = 34.8 mm; depth = 24.7 mm; streak color notation 4050 Y60R (*30*). Oblique lighting of specimen accentuates both engraved lines and irregularities of the surface, some created by grinding before the engraving and others by the process of engraving. (**D**) Tracing of lines verified as engraved by study under magnification, superimposed on flat-bed scan of engraved surface (scale bar, 10 mm).

Abstract images similar to the Blombos Cave engravings occur at Upper Paleolithic sites in Eurasia (*15*). The Blombos Cave motifs suggest arbitrary conventions unrelated to reality-based cognition, as is the case in the Upper Paleolithic (*15*), and they may have been constructed with symbolic intent, the meaning of which is now unknown. These finds demonstrate that ochre use in the MSA was not exclusively utilitarian and, arguably, the transmission and sharing of the meaning of the engravings relied on fully syntactical language (*5*, *27*).

Genetic and fossil evidence suggests that humans were anatomically near modern in Africa before 100 ka (*5*, *28*, *29*). Key questions are whether anatomical and behavioral modernity developed in tandem (*5*) and what criteria archaeologists should use to identify modern behavior (*2*, *4*, *5*). For the latter, there is agreement on one criterion—archaeological evidence of abstract or depictional images indicates modern human behavior (*2*, *14*, *15*). The Blombos Cave engravings are intentional images. In the light of this evidence, it seems that, at least in southern Africa, *Homo sapiens* was behaviorally modern about 77,000 years ago.

### References and Notes


1. The term "modern human behavior" as used here has no chronological implication and means the thoughts and actions underwritten by minds equivalent to those of *Homo sapiens* today. Key among these is the use of symbols.
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16. A sediment sample from Blombos was included in an earlier study of coastal sediments, in which it was found to date to oxygen isotope stage 5 (*30*). However, the dates obtained for unetched quartz and feldspar grains with TL and infrared stimulated luminescence, respectively, were inconsistent.
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18. The five lithic specimens (a few cm in size and weighing between 6 and 35 g) came from the upper phase of occupational deposits BBC M1: Samples BBC24 and BBC23 are from CA/CB and BBC15, BBC20, and BBC22 are from CC. Examination of thin sections revealed the presence of quartz grains embedded in a siliceous matrix. The time since they were burnt was computed from TL analysis of 100- to 160-μm grains obtained by crushing after the samples' outer surfaces had been removed with a diamond saw (*31*). The equivalent dose ($D_e$) was determined with a combined additive and regenerative dose protocol (*19*). U, Th, and K concentrations of the lithic samples were measured by neutron activation analysis (*32*). The total dose rates (*20*) were calculated assuming that the quartz grains were free of radioactive impurities and that all radioisotopes were confined to and uniformly distributed within the surrounding siliceous matrix. In computing the alpha and beta dose rates received by the grains, attenuation factors appropriate for the mean grain size in each specimen were taken into account. To determine the gamma dose rates, we buried 24 dosimeters in the cave deposits for 1 year at points no farther than 1 m from each previously excavated lithic. The ages combine to provide a mean age of 77 ± 6 ka, which is consistent with the OSL age for the overlying dune layer.
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20. Supplementary data including a table containing dose rate, $D_e$, and age information for TL and OSL analyses and a supplementary figure showing a radial plot of OSL $D_e$ values for the "synthetic" aliquot data are available on *Science* Online at www.sciencemag.org/cgi/content/full/1067575/DC1.
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22. The depositional age of the dune layer was determined by OSL dating. OSL analyses on Aber/52-ZB-15 were undertaken on quartz grains to measure the radiation dose that they had received since their last exposure to daylight. Their equivalent dose ($D_e$) was determined with the SAR procedure. The total radiation dose rate to the grains (*20*) was measured with a combination of thick-source alpha counting, beta counting, and atomic absorption spectroscopy for potassium determination, and a water content of 10 ± 5% (weight water / weight dry sediment) was used, based on current moisture contents in the cave. The calculated gamma dose rate was consistent with that measured in the field, and the cosmic ray dose rate of 45 μGy/year was based on the thickness of the overlying rock. Quartz grains were extracted after treatment with 10% hydrochloric acid to remove carbonates and 30 vol of $H_2O_2$ to remove organics. The sample was sieved to obtain grains from 212 to 250 μm in diameter. Feldspars and heavy minerals were removed by density separation at 2.62 and 2.70 g/cm$^3$. The alpha-irradiated outer layer of the grains was removed by etching in 48% hydrofluoric acid for 45 min. The initial set of luminescence measurements (stimulation at 470 nm with blue diodes) used 48 aliquots, each containing about 500 grains. A range of thermal pretreatments (preheats) from 160° to 300°C for 10 s was used. From 200° to 280°C, the $D_e$ values from 30 replicate aliquots were reproducible and showed no systematic trend with temperature. A weighted mean was calculated, with the individual $D_e$ values weighted according to their uncertainty. The uncertainty in the mean was divided by $\sqrt{N}$, where $N$ is the number of independent estimates of $D_e$—in this case 30. $D_e$ values were calculated with the package Analyst, which combines uncertainties due to the counting statistics of each OSL measurement and the error associated with the mathematical fitting of the growth curve to the luminescence data. The 30 aliquots gave a value of 47.9 ± 1.7 Gy, resulting in an age of 69 ± 5 ka.
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24. The single-grain SAR measurements were made in an automated reader based around a 10-mW, 532-nm Nd: $YVO_4$ laser, whose beam can be directed at individual grains (*23*). A single preheat at 220°C for 10 s was used, with the main OSL measurement ($L$) being followed by measurement of the OSL response ($T$) to a test dose as observed after a 160°C cut heat (*21*). Grains whose natural signal ratio ($L_N/T_N$) does not intersect the regeneration growth curve were not used in subsequent analyses. In addition, grains thought to contain some feldspar were also rejected. The presence of feldspar was identified by making additional measurements of a given regeneration dose on each grain. The first measurement is undertaken within the SAR procedure and yields the ratio $L_1/T_1$ used in the growth curve. For each grain, two additional measurements of $L/T$ were made at the end of the SAR procedure. The first duplicates the previous measurement, as a test of the sensitivity correction. The second uses the same regeneration dose, but, before preheating, the grains are exposed to infrared (830 nm) radiation from a 500-mW laser diode for 100 s. If the grains contain feldspar, then the infrared exposure will have reduced the magnitude of $L$, and hence the ratio of these last two measurements of $L/T$ will be substantially less than unity; for a quartz grain, the ratio will be consistent with unity. Of the 1892 grains that were measured, 22 were rejected on the basis of these criteria. The OSL signal from many of the remaining 1870 grains was close to instrumental background, and only 34 yielded reproducible growth curves.
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26. Single-grain OSL measurements were made with 19 aluminum discs, with up to 100 grains on each disc. For each disc, the OSL signals from the unrejected grains were combined to generate "synthetic" aliquots consisting of between 93 and 100 grains. The $D_e$ values for 18 "synthetic" aliquots were combined to give a weighted mean of 48.5 ± 1.2 Gy, giving a depositional age of 70 ± 5 ka (*20*).
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34. This work was supported by grants to C.H. from the Anglo American Chairman's Fund, Centre National de la Recherche Scientifique OHLL, the Leakey Foundation, the National Geographic Society, NSF, the South African National Research Foundation, and the Wenner-Gren Foundation; to F.D. from CNRS Origine de l'Homme, du Langage et des Langues (OHLL) and the Service Culturel of the French Embassy in South Africa; to Z.J. from the Sir Henry Strakosch Memorial Trust and an Overseas Research Student award; to C.T. from CNRS OHLL; to G.D. from the Natural Environment Research Council; to J.S. from the South African National Research Foundation and the University of Cape Town; and to I.W. from the British Academy. We thank G. Avery at Iziko Museums of Cape Town, the South African Museum, and K. van Niekerk.

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# Marine Biodiversity Hotspots and Conservation Priorities for Tropical Reefs

**Callum M. Roberts,[1,2*] Colin J. McClean,[2] John E. N. Veron,[3] Julie P. Hawkins,[2] Gerald R. Allen,[4,8] Don E. McAllister,[5†] Cristina G. Mittermeier,[4] Frederick W. Schueler,[6] Mark Spalding,[7] Fred Wells,[8] Carly Vynne,[4] Timothy B. Werner[4]**

**Coral reefs are the most biologically diverse of shallow water marine ecosystems but are being degraded worldwide by human activities and climate warming. Analyses of the geographic ranges of 3235 species of reef fish, corals, snails, and lobsters revealed that between 7.2% and 53.6% of each taxon have highly restricted ranges, rendering them vulnerable to extinction. Restricted-range species are clustered into centers of endemism, like those described for terrestrial taxa. The 10 richest centers of endemism cover 15.8% of the world's coral reefs (0.012% of the oceans) but include between 44.8 and 54.2% of the restricted-range species. Many occur in regions where reefs are being severely affected by people, potentially leading to numerous extinctions. Threatened centers of endemism are major biodiversity hotspots, and conservation efforts targeted toward them could help avert the loss of tropical reef biodiversity.**

Coral reefs fringe one-sixth of the world's coastlines (*1*) and support hundreds of thousands of animal and plant species (*2*). Fifty-eight percent of the world's reefs are reported to be threatened by human activities (*3*). Terrestrial agriculture, deforestation, and development are introducing large quantities of sediment, nutrients, and other pollutants into coastal