



## Fire and grass-bedding construction 200 thousand years ago at Border Cave, South Africa

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Lyn Wadley, Irene Esteban, Paloma de La Peña, Marine Wojcieszak, Dominic Stratford, et al.. Fire and grass-bedding construction 200 thousand years ago at Border Cave, South Africa. PLoS ONE, 2020, 15 (10), pp.e0239359. 10.1126/science.abc7239 . hal-02998410

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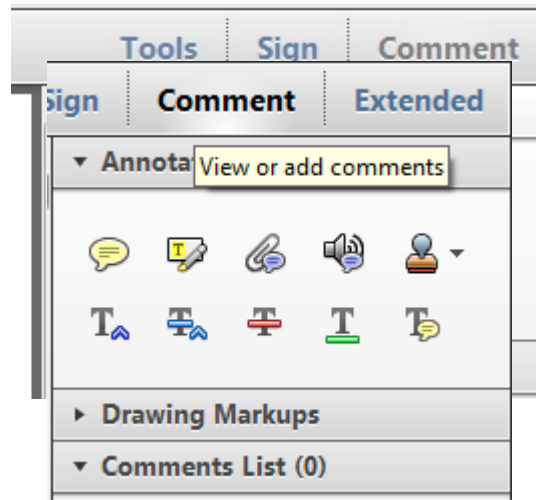
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
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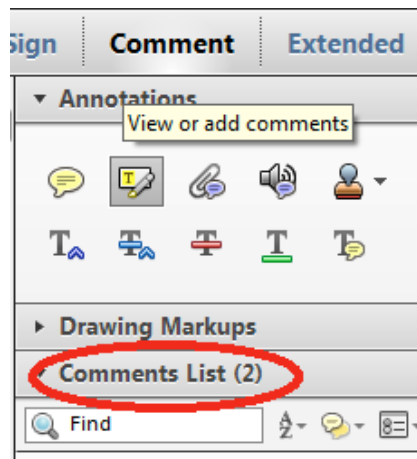
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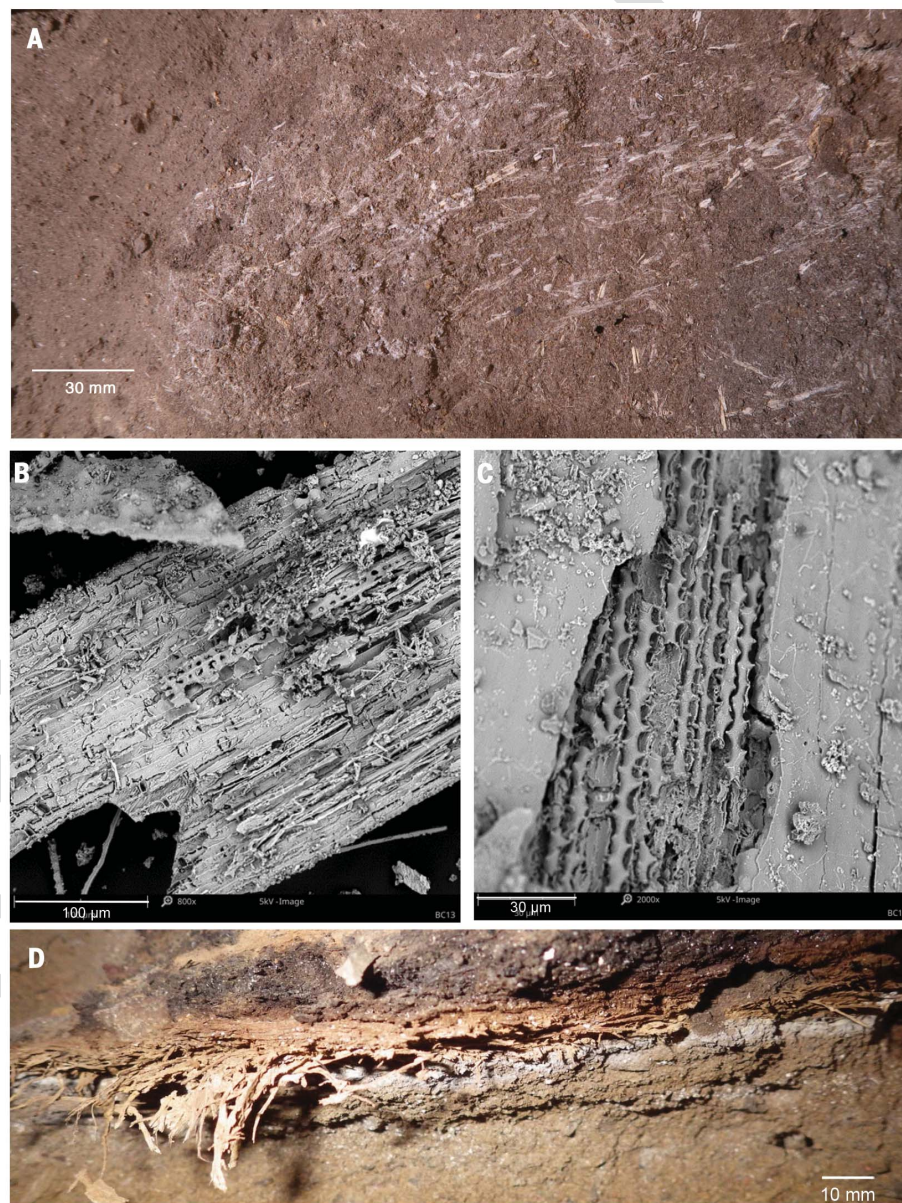
In large-scale, rapid excavations of the last century, this material was largely removed but not recorded; therefore, site-wide spatial inferences must be made cautiously. Organic material degrades over time (19, 20), so 5WA-DBK bedding survives as visually ephemeral fragments of silicified plant (Fig. 2, A, B, and C, and fig. S3). Its original appearance is exemplified by younger bedding features that are better preserved (Fig. 2D).

Grass in 5WA-DBK bedding was identified further by Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), and phytolith analysis (16) (Fig. 3, figs. S4 to S14, and tables S3 to S6). Silicified plant fragments viewed at high magnification using SEM (16) reveal grass anatomy (Fig. 3, A and C). Phytolith analysis confirms the presence of prickles, stomata, and epidermal long and short cell bilobates that characterize the Panicoideae subfamily of grasses (Poaceae), especially *Melinis repens* (Willd.) Zizka, *Setaria pallide-fusca* (Schumacher) Stapf & C.E. Hubb., *Panicum maximum* Jacq., *Panicum deustum* Thunb., and *Themeda triandra* Forssk. (16) (Fig. 3, B and D, and fig. S14). The Border Cave phytolith concentration exceeds that from other archaeological sites (12, 16) (tables S5 and S7), and we infer intentional, intensive grass accumulation. Moreover, dicotyledonous epidermal leaf fragments, mostly lying on grass as articulated phytoliths, comprise at least three cell shapes, which implies the presence of several unidentifiable species. Charcoal in bedding (table S8) includes *Tarchonanthus trilobus* DC (broad-leaved camphor-bush) that has aromatic leaves like those from *T. camphoratus*, which is used as insect repellent in modern plant bedding in Africa (21). The identified grass and woody species still grow in woodland near the cave (supplementary text).

Thin sections made from 5WA-DBK sediment reveal details of the layered ash and plant material at millimeter scale (Fig. 4, C, D, E, and F, and fig. S15), which implies multiple

phases of hearth and bed construction. Charred grass, charcoal, ash, and calcined bone fragments in some 5WA-DBK bedding phases (16) (Fig. 4, fig. S15, and supplementary text) imply that these beds were occasionally burned for site maintenance before being refreshed [as described in (22, 23)]. 5WA-DBK sediments are compressed against underlying ashy layer 5WA-VPBK (Member 5 WA, layer Very Pale Brown Kim). Both layers, especially 5WA-VPBK, are silicate- and apatite-rich (this includes carbonated hydroxyapatite) (figs. S5 to S7). The ash of *Panicum maximum*, one likely bedding grass at Border Cave, contains apatite

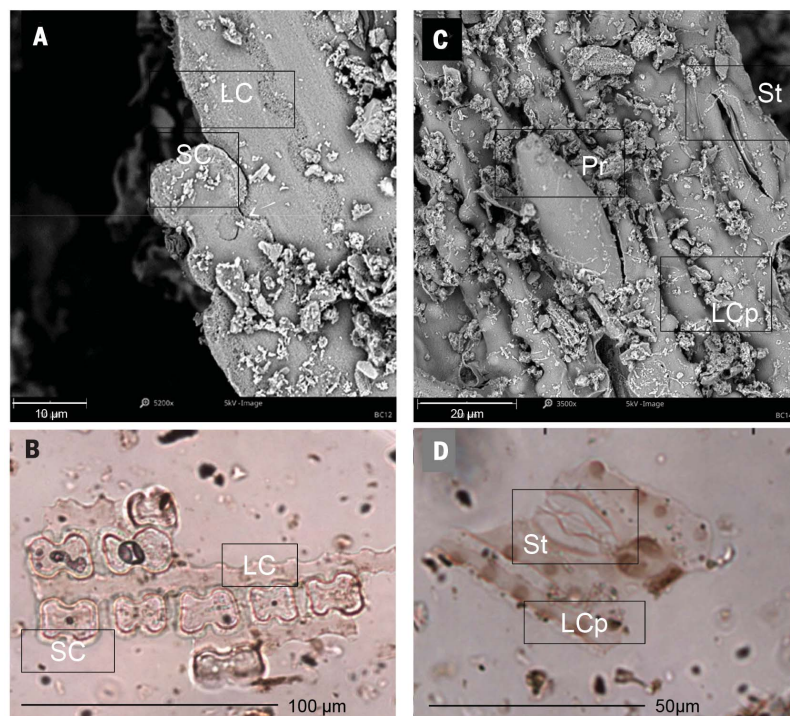
amongst other minerals (16, 24) (fig. S9). The chemical content and high phytolith concentration in 5WA-VPBK (tables S3 to S5) imply burning of grass bedding there too (16). The chemistry might also signal the presence of bone, guano, or diagenetically altered calcite (16, 25, 26). Calcite is a better-known component of ash than apatite, and in bedding younger than that found in 5WA-DBK, layers of calcitic ash underlie desiccated grass bedding (16) (fig. S8). Although this is probably wood ash, we must be circumspect because ash studied from 35 European plant species revealed diverse chemical compositions (27). Ash was possibly



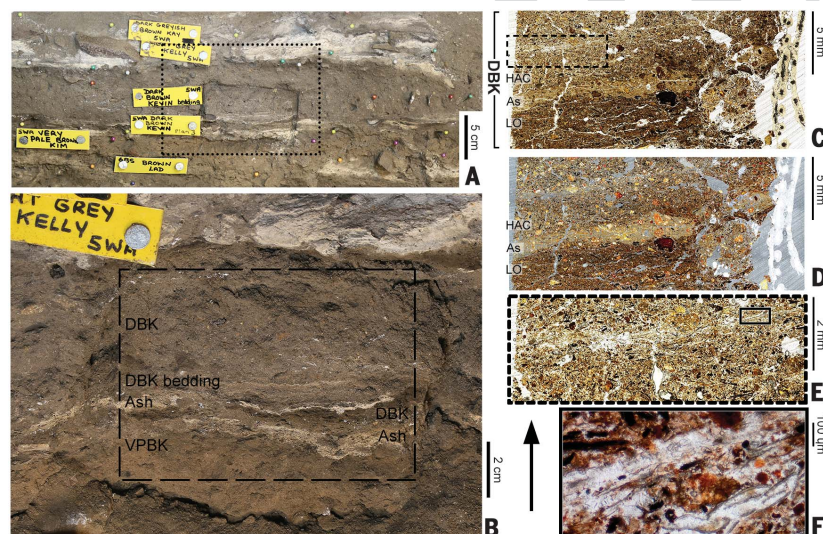
**Fig. 2. Border Cave plant bedding from 5WA-DBK and 1 WA.** (A) Horizontal field view of silicified bedding in 5WA-DBK. Scale bar, 30 mm. (B and C) SEM images of grass fragments from (A). Scale bar in (B), 100 μm. Scale bar in (C), 30 μm. (D) Vertical field section of desiccated bedding grass on Member 1 WA ash (~43 ky old). 5WA-DBK bedding may have looked like this 200 ky ago. Scale bar, 10 mm.

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**Fig. 3. Silicified Panicoidae grass remains from plant bedding in 5WA-DBK.** (A) SEM image of silicified grass epidermis showing articulated short cell bilobate and epidermal long cells. Scale bar, 10 µm. (B) Microphotograph of silicified grass epidermis showing articulated short cell bilobate and epidermal long cells. Scale bar, 100 µm. (C) SEM image of silicified grass epidermis showing articulated epidermal long cells with papillate ornamentation, prickle, and stomata. Scale bar, 20 µm. (D) Microphotograph of silicified grass epidermis showing articulated epidermal long cells with papillate ornamentations and stomata. Scale bar, 50 µm. LC, long cell; LCp, long cell papillate; SC, short cell; Pr, prickle; St, stomata.



**Fig. 4. Border Cave plant bedding observed in the field and in thin sections of 5WA-DBK sediment.** (A) East profile of part of the stratigraphy from Fig. 1B. Scale bar, 5 cm. (B) Magnified image of 5WA-DBK stratigraphy showing the position of the micromorphological sample (black-dashed square). Scale bar, 2 cm. (C and D) Microphotographs of 5WA-DBK thin section 1/1. Plant bedding traces and microfacies include homogeneous anthropogenic components (HACs), ash (As), and dark brown laminar units rich in organic matter (LOs) (16). Image in (C) was taken with plane polarized light (PPL) and that in (D) with cross polarized light (XPL) (16). Scale bars, 5 mm. (E) Magnified microphotograph of silicified, laminar bedding in black-dashed square in (C), taken with PPL. Scale bar, 2 mm. (F) Magnified image of plant remains in solid black square in (E), taken with PPL. Further detail is available in the supplementary text and fig. S15. Scale bar, 100 µm.

raked from hearths to create a clean, odor-controlling base for bedding. We speculate that such placement of bedding, as well as that on the ashes of previously burned bedding, was deliberate, because several ethnographies report that ash repels crawling insects, which cannot easily move through fine powder because it blocks their breathing and biting apparatus and eventually leaves them dehydrated (28).

Stone flake and blade manufacture (tables S9 and S10 and figs. S16 and S17) on 5WA-DBK bedding surfaces demonstrate their occasional use as workspace. The lithics described here cannot be assigned to a specific industry, but they resemble those in the 1987 Member 5 WA collection, labeled MSA 1 (29), from which a few pieces of ochre were also recovered. In 5WA-DBK bedding, red and orange ochre grains are up to 37 times as frequent as in over- and underlying layers, and they are smaller and rounder than the dark red, angular fragments from cave roof detritus that provides an ochre source (figs. S18 and S20 and tables S11 to S13). This evidence, together with reports of regular ochre use in Africa from ~300 ky ago (30), support the hypothesis that 5WA-DBK ochre particles were processed anthropogenically and became detached from objects or human skin when people used the bedding. Elemental and mineralogical analyses cannot distinguish grains from bedding and those from over- and underlying layers (figs. S20 to S22 and tables S14 to S17), so either people collected and processed ochre from the cave rock or the 5WA-DBK grains have a natural origin that we cannot explain.

Modern hunter-gatherer camps have fires as focal points; people regularly sleep alongside them and perform domestic tasks in social contexts (31, 32). People at Border Cave also lit fires regularly, as seen throughout the sequence (13) and not only in the layered ash and grassy sediment of 5WA-DBK. Before 200 ky ago, close to the origin of our species, people could produce fire at will and used fire, ash, and medicinal plants to maintain clean, pest-free camps. Although hunter-gatherers are characteristically mobile, cleansing camps can extend their potential for occupancy. The simple strategies inferred from the Border Cave data not only broaden our knowledge of life-ways in the remote past, but they also suggest an early potential for the cognitive, behavioral, and social complexity that is more widely evident in innovative material culture from ~100 ky ago (33).

#### REFERENCES AND NOTES

1. F. Berna et al., *Proc. Natl. Acad. Sci. U.S.A.* **109**, E1215–E1220 (2012).
2. S. Hlubik, F. Berna, C. Feibel, D. Braun, J. W. K. Harris, *Curr. Anthropol.* **58**, S243–S257 (2017).
3. M. J. Walker et al., *Antiquity* **90**, 571–589 (2016).
4. N. Goren-Inbar et al., *Science* **304**, 725–727 (2004).



5. W. Roebroeks, P. Villa, *Proc. Natl. Acad. Sci. U.S.A.* **108**, 5209–5214 (2011).
6. R. Shimelmitz *et al.*, *J. Hum. Evol.* **77**, 196–203 (2014).
7. R. Barkai, J. Rosell, R. Blasco, A. Gopher, *Curr. Anthropol.* **58**, S314–S328 (2017).
8. P. Vidal-Matutano, R. Blasco, P. Sañudo, J. Fernández Peris, *Environ. Archaeol.* **24**, 269–284 (2019).
9. L. Wadley *et al.*, *Science* **334**, 1388–1391 (2011).
10. A. M. Rosen, in *Neanderthals in the Levant: Behavioral Organization and the Beginnings of Human Modernity*, D. O. Henry, Ed. (Continuum, 2003), pp. 156–171.
11. D. Nadel *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **101**, 6821–6826 (2004).
12. D. Cabanes, C. Mallol, I. Expósito, J. Baena, *J. Archaeol. Sci.* **37**, 2947–2957 (2010).
13. L. R. Backwell *et al.*, *J. Field Archaeol.* **43**, 417–436 (2018).
14. L. Wadley, L. Backwell, F. d'Errico, C. Sievers, *Science* **367**, 87–91 (2020).
15. P. B. Beaumont, thesis, University of Cape Town, South Africa (1978).
16. Materials and methods are available as supplementary materials.
17. R. Grün, P. Beaumont, P. V. Tobias, S. Eggins, *J. Hum. Evol.* **45**, 155–167 (2003).
18. A. R. Millard, *Quat. Geochronol.* **1**, 159–166 (2006).
19. S. Schiegl, P. Goldberg, O. Bar-Yosef, S. Weiner, *J. Archaeol. Sci.* **23**, 763–781 (1996).
20. M. G. Canti, *Catena* **54**, 339–361 (2003).
21. H. J. Beentje, *Kew Bull.* **54**, 81–95 (1999).
22. P. Goldberg *et al.*, *Archaeol. Anthropol. Sci.* **1**, 95–122 (2009).
23. S. M. Mentzer, *J. Archaeol. Method Theory* **21**, 616–668 (2014).
24. S. Schiegl, P. W. Stockhammer, C. Scott, L. Wadley, *S. Afr. J. Sci.* **100**, 185–194 (2004).
25. R. M. Albert, S. Weiner, O. Bar-Yosef, L. Meignen, *J. Archaeol. Sci.* **27**, 931–947 (2000).
26. P. Karkanas, O. Bar-Yosef, P. Goldberg, S. Weiner, *J. Archaeol. Sci.* **27**, 915–929 (2000).
27. G. Zając, J. Szyszlak-Bargłowicz, W. Gołbiowski, M. Szczepaniak, *Energies* **11**, 2885 (2018).
28. T. Hakbijl, *Environ. Archaeol.* **7**, 13–22 (2002).
29. I. Watts, thesis, University of London (1998).
30. A. S. Brooks *et al.*, *Science* **360**, 90–94 (2018).
31. P. W. Wiessner, *Proc. Natl. Acad. Sci. U.S.A.* **111**, 14027–14035 (2014).
32. C. Mallol, A. Henry, *Curr. Anthropol.* **58**, S217–S229 (2017).
33. F. d'Errico *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **114**, 7869–7876 (2017).

# ACKNOWLEDGMENTS

L.W. and C.S. thank the South African National Botanical Institute, and they thank J. van Rooy for the use of the Phenom Pure SEM. A. Millard provided numerical data from his 2006 Bayesian analysis of electron spin resonance dates. **Funding:** L.B. was funded by National Geographic (NGS-54810R-19) and the DSI-NRF (Department of Science and Innovation–National Research Foundation) Centre of Excellence in Palaeosciences (COEOP2020-1). I.E. and P.d.I.P. acknowledge the DSI-NRF Centre of Excellence in Palaeosciences. D.E.R. was funded by the Fyssen Foundation, France, and the l'Oréal-UNESCO "Per le Donne e la Scienza" program (l'Oréal Italia and Italian National Commission for UNESCO, Italy). F.d'E. was funded by the Talents program of the Initiative d'Excellence of the University of Bordeaux, the

Agence Nationale de la Recherche – LaScArBx Cluster of Excellence (ANR-10-LABX-52), and the Research Council of Norway through its Centre of Excellence funding scheme [SFF Centre for Early Sapiens Behavior (SapienCE) project number 262618]. **Author contributions:** Botanical investigation, formal analysis, and project conceptualization: L.W. and C.S. Site excavation: L.B., F.d'E., L.W., P.d.I.P., C.S., and D.S. 5WA-DBK bedding excavation: L.W. Phytolith study and some attenuated total reflectance (ATR)–FTIR: I.E. Lithic study and Fig. 1: P.d.I.P. ATR-FTIR and Raman analysis: M.W. Energy-dispersive x-ray fluorescence (EDXRF) and SEM–energy-dispersive x-ray spectroscopy (EDS): D.E.R. Micromorphology: D.S. Charcoal analysis: S.L. Ochre analysis: F.d'E., D.E.R., and F.O. Writing: L.W. with contributions from all other authors. All authors reviewed and edited the manuscript.

**Competing interests:** The authors declare no competing interests. **Data and materials availability:** All data and materials are included in the text and supplementary materials. The Border Cave excavated material from 2015 to 2019 is housed in the Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa (Border Cave 2015/2019). See supplementary materials for additional acknowledgments.

# SUPPLEMENTARY MATERIALS

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10 May 2020; accepted 22 June 2020  
10.1126/science.abc7239