AUTHORS:
Dominic Stratford[1]
Laurent Bruxelles[1,2,3]
J. Francis Thackeray[4]
Travis R. Pickering[5]
Sophie Verheyden[6]

AFFILIATIONS:
[1]Department of Archaeology, School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, Johannesburg, South Africa
[2]French National Institute for Preventive Archaeological Research, French Institute of South Africa (IFAS), Johannesburg, South Africa
[3]Sub-Saharan Africa (USR 3336), French National Center for Scientific Research (CNRS), Paris, France
[4]Evolutionary Studies Institute, School of Geoscience, University of the Witwatersrand, Johannesburg, South Africa
[5]Department of Anthropology, University of Wisconsin-Madison, Madison, Wisconsin, USA
[6]Royal Belgian Institute of Natural Sciences, Brussels, Belgium

CORRESPONDENCE TO:
Dominic Stratford

EMAIL:
Dominic.Stratford@wits.ac.za

DATES:
Received: 09 Sep. 2019
Revised: 06 Jan. 2020
Accepted: 07 Jan. 2020
Published: 26 Mar. 2020

HOW TO CITE:
Stratford D, Bruxelles L, Thackeray JF, Pickering TR, Verheyden S. Comments on 'U-Pb dated flowstones restrict South African early hominin record to dry climate phases' (Pickering et al. Nature 2018;565:226–229). S Afr J Sci. 2020;116(3/4), Art. #7094, 2 pages. https://doi.org/10.17159/sajs.2020/7094

ARTICLE INCLUDES:
☒ Peer review
☐ Supplementary material

DATA AVAILABILITY:
☐ Open data set
☐ All data included
☐ On request from author(s)
☐ Not available
☒ Not applicable

EDITOR:
Maryna Steyn

KEYWORDS:
palaeoanthropology, archaeology, palaeoenvironment, karst science, geomorphology

FUNDING:
None

Comments on 'U-Pb dated flowstones restrict South African early hominin record to dry climate phases' (Pickering et al. Nature 2018;565:226–229)

Pickering et al. (Nature 2018;565:226–229) utilised calcium carbonate flowstone deposits (i.e. speleothems) from eight Pliocene and Pleistocene South African Cradle of Humankind cave sites to propose that biases were created within the fossil record due to absent clastic sedimentation phases during wet periods, when caves were closed and only speleothems accumulated. Such a scenario has significant implications for our understanding of variability in hominin mobility, resource exploitation, functional repertoires and interactions with competitors in changing environmental and ecological contexts. We find considerable issues with the article. First, Pickering et al.'s contribution omits crucial fossil evidence from various stratigraphic units of the Sterkfontein Caves that indicates conditions were not always arid when the caves were open and sediments were deposited. Second, Pickering et al.'s proposal that clastic and speleothemic deposits (including faunal and floral material) form mutually exclusively is an overly simplified, binary depositional (and in this case environmental) framework that demonstrates an inherent bias in the sampling of cave deposits for dating. This creates the impression that either speleothems or clastic sediments are deposited and does not take into account the full spectrum of sedimentary complexity in karst caves. Third, closure of the caves across the Cradle of Humankind landscape during wet periods is not substantiated geomorphologically or speleologically; identification of the responsible process is critical to the proposed infilling scenario.

Significance:

- We propose that Pickering et al.'s interpretation of the environmental context of the South African early hominin record is problematic in that it omits crucial faunal and floral fossil evidence associating hominins with non-arid climates, is geomorphologically unsupported, and perpetuates biases against temporally and climatically representative clastic sediments due to challenges related to their dating.

Pickering et al. (2018)[1] utilise calcium carbonate flowstone deposits from eight Pliocene and Pleistocene South African Cradle of Humankind (also referred to as 'the Cradle') cave sites to propose that biases are created within the fossil record due to absent clastic sedimentation phases during wet periods. They propose a close correlation between cave closure, flowstone growth and 'phases of increased effective precipitation', suggesting that clastic sedimentation and calcium carbonate precipitation are mutually exclusive processes, with clastic deposits (including faunal and floral material) forming only during arid periods. This scenario has significant implications for our understanding of variability in hominin mobility, resource exploitation, functional repertoires and interactions with predators in changing environmental and ecological contexts. We find this proposition to be problematic as a result of oversimplification. Reducing environmental conditions to a 'binary' framework of such extreme end-member states of wet or dry does not realistically reflect the majority of time represented by intermediate, moderately variable climatic conditions during which deposits also accumulate. Reducing sediment accumulation to one end of the climatic spectrum limits the validity of nuanced interpretations of hominin ecological relationships represented by the diverse fossil assemblages interred in the extensive clastic deposits. Specifically, we find the following issues with the article:

1. Published evidence clearly associating hominins in part with wet ecological conditions, was not considered seriously enough in the article. For example, the authors omit crucial fossil evidence from the Sterkfontein Caves of liana vines that indicate the presence of ancient dense woodland or forest at ~2.5 million years ago.[2] The authors also omit important faunal data, notably the presence of fossil colobine monkeys, Alcelaphini bovids such as *Damaliscus* sp. and *Megalotragus* sp. (which are dependent on savanna grassland), and other broken-open country antelopes like *Tragelaphus* sp. and *Antidorcas* from various Sterkfontein stratigraphic levels.[3-6] These reflect at least some degree of savanna woodland, which, in turn, contradicts inferences of dry conditions. Similarly, micromammal samples from Sterkfontein[7] demonstrate a mosaic environment (that importantly include moist, woodland settings as suggested by the presence of *Elephantulus fuscus* fossils), and represent interglacial (comparatively warm and wet) conditions which prevailed during sedimentation and fossil accumulation. Further, stable carbon isotope data derived from tooth enamel of a range of taxa, including hominins[8-10], relate to diets that reflect consumption of a significant amount of C3 vegetation, indicating, in turn, that conditions were certainly not always arid at times when the caves were open and sediments were being deposited.
2. Generally, dates for clastic sediment deposits are ascertained through the application of U-Pb or palaeomagnetic dating of interstratifying (or assumed to be interstratifying) flowstones.[11] The clastic sediments (collectively known as breccias) themselves are not often suitable for dating using the comparatively broadly applied palaeomagnetic seriation and U-Pb methods.[12-14] Consequently, often only speleothems are sampled, creating the impression that speleothem or clastic sediments are mutually exclusively deposited. Clastic sediments deposited nearby at the same time will largely remain undated and therefore overlooked.
3. Pickering et al.'s proposal of Cradle-wide cave closure during wet environmental conditions is problematic from both karst geological and geomorphological perspectives. In many contemporary situations around

the world, flowstones form in open caves that are also actively accumulating sediments, for example: Aven d'Orgnac, France; Dadong Cave, southern China; Xkeken Cenote, Mexico; Kotilola Cave, Papua New Guinea; Cave of the Owls, Peru; Son Doong Cave, Vietnam; and Mbannza-Ngungu Caves, Democratic Republic of the Congo. Moreover, there is convincing evidence that coeval or penecontemporaneous clastic and speleothem formation occurred in ancient[12,15,16] and archaeological[17,18] deposits. Pickering et al. do not explain the geomorphological mechanisms that bind cave closing processes to wet periods. However, this physical process is important to identify and apply across the whole Cradle of Humankind karstic landscape, especially given the identified implications for landscape-wide cave closure during specific environmental conditions. The diversity of geological and geomorphological contexts across the Cradle of Humankind landscape[19] makes application of a uniform Cradle-scale cave closure process challenging and in this case unsupported. While speleothem deposition seems to have a strong relationship with climate, more specifically with water and CO_2 availability[20], the opening and closing of a cave system seems to be primarily determined by erosional cycles (and tectonic changes), and is therefore potentially strongly influenced at the local scale and only indirectly influenced by climate. While little literature exists on the mechanisms of cave entrance opening and closure in palaeokarst, authors describe vadose zone openings as enlarging during wetter periods due to increased recharge flow rates.[21,22] These processes result in a complex succession of sedimentation processes[23] and sedimentary deposition and speleothem deposition should not be considered mutually exclusive phenomena.

In summation, faunal and floral evidence clearly indicate that hominin fossils are not necessarily always associated with arid climates and that fauna and flora accumulate in open caves through a broad range of environmental conditions. Pickering et al.'s methodology for sampling cave deposits for dating, which focuses on the application of U-Pb or palaeomagnetic techniques to interstratifying (or assumed to be interstratifying) flowstones, produces ages (and by proxy cave sedimentation conditions) only for speleothems. The proposed correlation of speleothem formation with cave closure creates a convenient but largely unsupported deterministic interpretation of palaeoenvironmental conditions that necessarily excludes the significant clastic deposit record. Their resulting interpretation of the environmental context of the South African hominin record consequently perpetuates biases against temporally and climatically representative clastic sediments. Ideally, palaeoenvironmental reconstructions should be developed that integrate clastic and speleothemic evidence in coherent sequences prior to isolating and excluding evidence.

Acknowledgements

We thank the anonymous reviewers for their valuable input which helped us to improve this short contribution. D.S. thanks Aurore Val and Jennifer Fitchett for their comments and the editors of SAJS.

Authors' contributions

All authors contributed equally to the conceptualisation, data presentation and editing of the text.

References

1. Pickering R, Herries AIR, Woodhead JD, Hellstroom JC, Green HE, Paul B, et al. U-Pb dated flowstones restrict South African early hominin record to dry climate phases. Nature. 2018;565:226–229. https://doi.org/10.1038/s41586-018-0711-0
2. Bamford M. Pliocene fossil woods from an early hominid cave deposit, Sterkfontein, South Africa. S Afr J Sci. 1999;95:231–237.
3. Vrba ES. Some evidence of chronology and palaeoecology of Sterkfontein, Swartkrans and Kromdraai from the fossil Bovidae. Nature. 1975;254:301–304. https://doi.org/10.1038/254301a0
4. Vrba ES. The fossil Bovidae of Sterkfontein, Swartkrans and Kromdraai. Transvaal Museum Memoir 21. Pretoria: Transvaal Museum; 1976.
5. Brain CK. The hunters or the hunted: An introduction to African cave taphonomy. Chicago, IL: University of Chicago Press; 1981.
6. Luyt CJ. Revisiting palaeoenvironments from the hominid-bearing Plio-Pleistocene sites: New isotopic evidence from Sterkfontein [MSc thesis]. Cape Town: University of Cape Town; 2001.
7. Avery DM. The Plio-Pleistocene vegetation and climate of Sterkfontein and Swartkrans, South Africa, based on micromammals. J Hum Evol. 2001;41:113–132. https://doi.org/10.1006/jhev.2001.0483
8. Lee-Thorp JA, Van der Merwe NJ, Thackeray JF. The hunters and the hunted revisited. J Hum Evol. 2000;39:565–576. https://doi.org/10.1006/jhev.2000.0436
9. Sponheimer M. Hominins, sedges, and termites: New carbon isotope data from the Sterkfontein valley and Kruger National Park. J Hum Evol. 2005;48:301–331. https://doi.org/10.1016/j.jhevol.2004.11.008
10. Hopley PJ, Maslin MA. Climate-averaging of terrestrial faunas: An example from the Plio-Pleistocene of South Africa. Paleobiology. 2010;36(1):32–50. https://doi.org/10.1666/0094-8373-36.1.32
11. Walker J, Cliff RA, Latham AG. U-Pb isotopic age of the StW 573 hominid from Sterkfontein, South Africa. Science. 2006;314(5805):1592–1594. https://doi.org/10.1126/science.1132916
12. Herries AIR, Shaw J. Palaeomagnetic analysis of the Sterkfontein palaeocave deposits: Implications for the age of the hominin fossils and stone tool industries. J Hum Evol. 2011;60:523–539. https://doi.org/10.1016/j.jhevol.2010.09.001
13. Jones DL, Brock A, McFadden PL. Palaeomagnetic results from the Kromdraai and Sterkfontein hominid sites. S Afr J Sci. 1986;82:160–163.
14. Schmidt VA, Partridge TC. An attempt to establish a magnetostratigraphic framework for sediments deposited in Sterkfontein Cave, South Africa. Eos. 1991;72:44–136.
15. Herries AIR, Curnoe D, Adams JW. A multi-disciplinary seriation of early *Homo* and *Paranthropus* bearing palaeocaves in southern Africa. Quat Int. 2009;202:14–28. https://doi.org/10.1016/j.quaint.2008.05.017
16. Herries AIR, Pickering R, Adams JW, Curnoe D, Warr G, Latham AG, et al. A multi-disciplinary perspective on the age of *Australopithecus* in southern Africa. In: Reed KE, Fleagle JG, Leakey RE, editors. Paleobiology of *Australopithecus*. Vertebrate Paleobiology and Paleoanthropology Series. Dordrecht: Springer; 2013. p. 21–40. https://doi.org/10.1007/978-94-007-5919-0_3
17. Haddad-Martim PM, Hubbe A, Giannini PC, Auler AS, Pilo LB, Hubbe M, et al. Quaternary depositional facies in cave entrances and their relation to landscape evolution: The example of Cuvieri Cave, eastern Brazil. CATENA. 2017;157:372–387. https://doi.org/10.1016/j.catena.2017.05.029
18. Pirson S, Flas D, Abrams G, Bonjean D, Court-Picon M, Di Modica K, et al. Chronostratigraphic context of the Middle to Upper Palaeolithic transition: Recent data from Belgium. Quat Int. 2012;259:78–94. https://doi.org/10.1016/j.quaint.2011.03.035
19. Murszewski A, Edwards TR, Cruden AR, Armstrong B, Boschian G, Herries AIR. Regional geological formation and speleogenesis of the 'Fossil Hominid Sites of South Africa' UNESCO World Heritage Site. Earth-Sci Rev. 2019;188:498–513. https://doi.org/10.1016/j.earscirev.2018.09.016
20. Dreybodt W. Chemical kinetics, speleothem growth and climate. Boreas. 1999;28(3):347–356. https://doi.org/10.1080/030094899422073
21. Palmer AN. Speleogenesis in carbonate rocks. In: Grabrovšek F, editor. Evolution of karst: From prekarst to cessation. Postojna-Ljubljana: Inštitut za raziskovanje krasa, ZRC SAZU; 2002. p. 43–59.
22. Osborne RAL. Cave breakdown by vadose weathering. Int J Speleology. 2002;31:37–53. https://doi.org/10.5038/1827-806X.31.1.3
23. Auler AS, Smart PL, Wang X, Pilo LB, Edwards RL, Cheng H. Cyclic sedimentation in Brazilian caves: Mechanisms and palaeoenvironmental significance. Geomorphology. 2009;106(1–2):142–153. https://doi.org/10.1016/j.geomorph.2008.09.020