Journal of Human Evolution 59 (2010) 70–86

Contents lists available at ScienceDirect

Journal of Human Evolution

journal homepage: www.elsevier.com/locate/jhevol

# Re-appraisal of the stratigraphy and determination of new U-Pb dates for the Sterkfontein hominin site, South Africa

Robyn Pickering [a,b,*], Jan D. Kramers [a,c,d]

[a] Institute for Geological Sciences, University of Bern, Switzerland
[b] School of Earth Sciences, University of Melbourne, Victoria 3010, Australia
[c] Department of Geology, University of Johannesburg, Auckland Park 2006, South Africa
[d] School of Geosciences, University of the Witwatersrand, South Africa

ARTICLE INFO

*Article history:*
Received 4 November 2009
Accepted 26 March 2010

*Keywords:*
Sterkfontein
Stratigraphy
Cave sediments
U-Pb dating
Speleothems
*Australopithecus africanus*

ABSTRACT

Sterkfontein Caves is the single richest early hominin site in the world with deposits yielding one or more species of *Australopithecus* and possible early *Homo*, as well as an extensive faunal collection. The inability to date the southern African cave sites accurately or precisely has hindered attempts to integrate the hominin fossil evidence into pan-African scenarios about human evolutionary history, and especially hominin biogeography. We have used U-Pb and U-Th techniques to date sheets of calcium carbonate flowstone inter-bedded between the fossiliferous sediments. For the first time, absolute age ranges can be assigned to the fossil-bearing deposits: Member 2 is between 2.8 ± 0.28 and 2.6 ± 0.30 Ma and Member 4 between 2.65 ± 0.30 and 2.01 ± 0.05 Ma. The age of 2.01 ± 0.05 Ma for the top of Member 4 constrains the last appearance of *Australopithecus africanus* to 2 Ma. In the Silberberg Grotto we have reproduced the U-Pb age of ~2.2 Ma of for the flowstones associated with StW573. We believe that these deposits, including the fossil and the flowstones, accumulated rapidly around 2.2 Ma. The stratigraphy of the site is complex as sediments are exposed both in the underground chambers and at surface. We present a new interpretation of the stratigraphy based on surface mapping, boreholes logs and U-Pb ages. Every effort was made to retain the Member system, however, only Members 2 and 4 are recognized in the boreholes. We propose that the deposits formally known as Member 3 are in fact the distal equivalents of Member 4. The sediments of Members 2 and 4 consisted of cone-like deposits and probably never filled up the cave. The U-Th ages show that there are substantial deposits younger than 400 ka in the underground cave, underlying the older deposits, highlighting again that these cave fills are not simple layer-cakes.



## Introduction

The fossil remains of our earliest human ancestors are all found in Africa. The single richest location of early hominin fossils and other fauna outside East Africa is the series of caves about 50 km North-west of Johannesburg, South Africa (Brain, 1958), located today in the Cradle of Humankind World Heritage Site (Fig. 1). Fossils were first recognized in these deposits in the early 20th century, but the discovery of the Taung child skull from the Buxton Limeworks in 1924 (Dart, 1925) demonstrated the importance of these sites. The Sterkfontein cave site needs little introduction as it boasts the largest collection of *Australopithecus africanus* anywhere in the world, consisting of over 600 fragments (Tobias, 2000; Wood and Richmond, 2000) and contains the most complete hominin skeleton ever found (Clarke, 1998).

Accurate methods for dating the fossil remains of our earliest human ancestors are vital for understanding the chronology and exact location of humankind's development within Africa. The geological setting of the southern African hominin evidence differs greatly from East Africa. There are no volcanic ash layers in the southern Africa cave sites, so potassium–argon and argon–argon dating techniques are not applicable, precluding the consequent bracketing of fossil-bearing horizons using dated inter-bedded tuffs. Many of the current dating methods applied to the southern African sites are fraught with inherent inaccuracies. Biochronology assumes synchronous continent-wide first and last appearances of taxa and is confounded by the potential of refugia and relict

* Corresponding author.
*E-mail addresses:* r.pickering@unimelb.edu.au (R. Pickering), jkramers@uj.ac.za (J.D. Kramers).

0047-2484/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jhevol.2010.03.014

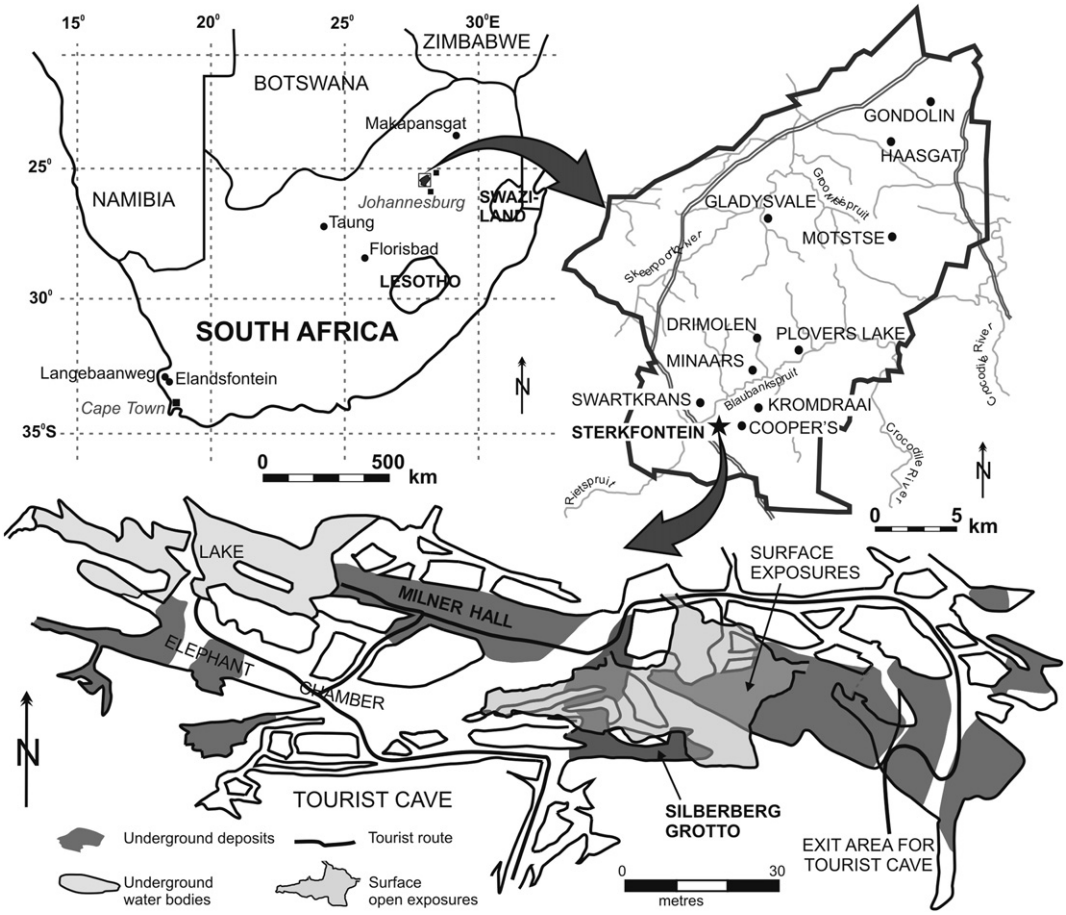


**Figure 1.** The position of the Cradle of Humankind within South Africa (left), the position of Sterkfontein relative to the other cradle sites (right) and a map of the underground cave network at Sterkfontein (after Wilkinson, 1973) with the outline of the current excavations superimposed.

populations (e.g., Vrba, 1988; Hill, 1995; White, 1995; Reynolds, 2007). Magnetostratigraphy is a relative technique that relies on biochronology to resolve cases where more than one fit with the reference column is possible (e.g., McFadden et al., 1979; Partridge et al., 1999, 2000; Herries et al., 2006a, b, 2009). U-Pb dating of fossil teeth (Balter et al., 2008) is prone to unacceptably high (up to 60%) associated errors resulting from uncertainty regarding post-depositional U-uptake.

Speleothems, such as the flowstones, can, under favourable circumstances, be directly dated by U-Pb to provide ages for the fossils preserved in the sediments in between them (Walker et al., 2006; de Ruiter et al., 2009). The U-Pb speleothem ages are also more precise than existing methods, with errors that are in the range of 2–10% (Pickering et al., 2010). Here we present new U-Pb and U-Th age determinations for flowstones from both the underground and surface exposed deposits at Sterkfontein, which provide the first comprehensive set of direct, absolute dates for the site. We propose a revision of the stratigraphy, based on observations of the deposits and re-logging of the boreholes drilled through the site, and the dating results.

## Sterkfontein Caves

The Sterkfontein Caves occupy the south side of the Bloubank River valley, which is host to several other hominin bearing cave sites, including Swartkrans, Cooper's, Kromdraai, Drimolen, Gladysvale and Plover's Lake (Fig. 1). These caves occur in the Neoarchaean to Palaeo-Proterozoic Malmani dolomites of the Transvaal Supergroup. Sterkfontein is situated about 35 m above the level of the north-east flowing river and lies below a small hill (Wilkinson, 1983) at an elevation of 1482 m a.s.l. (Tobias and Hughes, 1969). The cave system at Sterkfontein developed by a simple solution excavation of the dolomite host rock (Brink and Partridge, 1965) and the present underground cave morphology is determined by the shape of the original solution voids (Wilkinson, 1983). Surrounding the main cavern are several other smaller caves and sink holes (Wilkinson, 1983), including the Lincoln Cave (Reynolds et al., 2003, 2007).

The caves at Sterkfontein have formed receptacles for surface sediments over the last few million years and, given the abundance of early hominin and other fossils preserved in these sediments, they have been the subjects of much investigation. The most enduring interpretive description of the sediments is the Member system proposed by Partridge (Partridge, 1978, 2000; Partridge and Watt, 1991) where the deposits are classified into six Members, 1–6, oldest to youngest. Today, few fossiliferous sediments occur underground, notably in the Jakovec and Silberberg deposits (Clarke, 1998; Partridge et al., 2003). To produce the present topography, i.e., the exposure of the Member 4 and 5 sediments at surface, the site must have undergone significant surface erosion and removal of the dolomite roof of the cave. Most of the caves in this region have likewise been de-roofed suggesting significant regional surface-down wasting. This is confirmed by recent new cosmogenic isotope evidence from Malapa Cave (Dirks et al., 2010) suggests ~3–5 m erosion per million years for this area.

The sediments infilling the Sterkfontein Caves have yielded an abundant Late Pliocene to Early Pleistocene fauna (Pickering et al.,