Quaternary Geochronology 24 (2014) 10–15

Contents lists available at ScienceDirect

Quaternary Geochronology

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

Research paper

Cosmogenic nuclide burial dating of hominin-bearing Pleistocene cave deposits at Swartkrans, South Africa

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ARTICLE INFO

Article history:
Received 5 June 2014
Received in revised form
21 July 2014
Accepted 24 July 2014
Available online 4 August 2014

Keywords:
Cosmogenic nuclide burial dating
Swartkrans Cave
Paranthropus robustus
Early *Homo*
Stone and bone tools
Fire

ABSTRACT

Based on the cosmogenic nuclide burial dating technique, we present new radiometric age estimates of 2.19 ± 0.08 and 1.80 ± 0.09 million-years-old (Ma) for Member 1, and 0.96 ± 0.09 Ma for Member 3 of the Swartkrans Formation in South Africa. Our data are consistent with, and expand upon, results from previous radiometric dating techniques used at the site. The burial ages of Member 1 are consistent with the uranium–lead (U–Pb) age provided by bracketing flowstones (Pickering et al., 2011), while the age of Member 3 is significantly more precise than the large age bracket provided by U–Pb dating of tooth enamel (Balter et al., 2008) and recently re-evaluated electron spin resonance data (Herries and Adams, 2013). These new dates provide the complete age range for the extinct hominin, *Paranthropus robustus*, as well as indicate the first appearance of the genus *Homo* in southern Africa. Our results also indicate: the first, as well as the last, manufacture and use of bone digging tools in South Africa; some of the earliest evidence of stone tool use and large animal butchery in South Africa; and one of the earliest archaeological indications of the domestication of fire in the world.

1. Introduction

Paleoanthropology—the field of human evolutionary studies—is not only concerned with tracking the biological and cultural development of our own genus, *Homo*, but also with that of the genera and species that gave rise to *Homo*, as well as that of its sympatric, collateral relatives. The latter category includes species of the megadont genus *Paranthropus*, represented in the Pleistocene fossil record of South Africa by *Paranthropus robustus*.[1] Since its fossils were first discovered at Kromdraai Cave (Broom, 1938), research on *P. robustus* continues to reveal this extinct hominin[2] as a fascinating and often unexpected animal. Although its highly derived skull anatomy—with large jaws, a heavily built, crested cranium and thickly enameled postcanine teeth—indicates that *P. robustus* was capable of subsisting on a coarse, low-quality diet (e.g., Robinson, 1962), occlusal microwear (e.g., Scott et al., 2005) and stable carbon isotope results reveal that it actually "had an extremely flexible diet, which may indicate that its derived masticatory morphology signals an increase, rather than decrease, in its potential foods" (Sponheimer et al., 2006, p. 981). *P. robustus* fossils are also commonly associated spatially with those of early *Homo*, as well as archaeological indications of tool manufacture and use, the butchery of large animals and the possible control of fire by early hominins (e.g., Brain et al., 1988; Brain, 1993a; Kuman and Clarke, 2000). Attributing these behaviorally important archaeological traces to *P. robustus* is confounded by its sympatry (Broom and Robinson, 1950) with South African early *Homo* (Wood and Strait, 2004; Pickering, 2006). We are also left to speculate why *P. robustus* went extinct in the wake of cofamilial *Homo's* eventual global ascendancy.

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[1] TRP and JLH prefer the use of *Australopithecus robustus* over *Paranthropus robustus*. However, in order to conform to prevailing usage, we employ the latter designation in this paper.

[2] KK and RJC do not recognise any validity to the term hominin and argue for retention of the family name hominid.

http://dx.doi.org/10.1016/j.quageo.2014.07.004
1871-1014/

Our current multidisciplinary research project at Swartkrans (Fig. 1A)—following in the steps of those conducted there previously by Robert Broom and John Robinson (1948–1949, 1951–1953) and then by C.K. Brain (1965–1986)—is focused on addressing these unresolved issues related to the behavior and evolution of *P. robustus* and early *Homo*. Key to shedding light on these issues is construction of an accurate chronological framework for the various fossil-bearing Pleistocene sediments preserved within the cave. To this end, cosmogenic nuclide burial dating (using ^{26}Al and ^{10}Be) was undertaken in order to determine the age of two of the members of the Swartkrans Formation.

Dating of early hominin sites in South Africa continues to be a contentious area of research, as often different techniques produce varying age results for the same deposit (e.g. Partridge et al., 2003; Pickering and Kramers, 2010). This variance has usually been attributed to the complexity of multiple episodes of karstification, infilling and erosion at these sites. As numerous dating techniques have been attempted at Swartkrans (see section 3), the site provides an ideal opportunity to compare results from burial dating (a method that is more commonly used in landscape denudation studies) to other established techniques used in research on hominin evolution in the region. Our data confirm, and expand on the results from these previous investigations, demonstrating agreement between several radiometric dating techniques. With this accurate chronological framework, paleoanthropologists and archaeologists now have a sound footing in order to begin to address several key evolutionary issues discussed above.

2. Swartkrans Formation

Swartkrans evolved as a phreatic maze cave within the impure dolomitic limestone of the Chunniespoort Group (Palmer, 1991; Brain, 1993b). The cave probably first opened to the ground surface sometime in the early Pleistocene. From that time, it began to admit materials of the Swartkrans Formation (Butzer, 1976; Brain, 1976, 1993b), which comprises five sequential sedimentary members, separated by erosional discontinuities. Because Members 4 and 5 are composed of more recently admitted sediments—accumulated, respectively, ≤110,980 (Sutton et al., 2009) and ~12,000–9000 years ago (Brain, 1993b; Watson, 1993)—they are not discussed here.

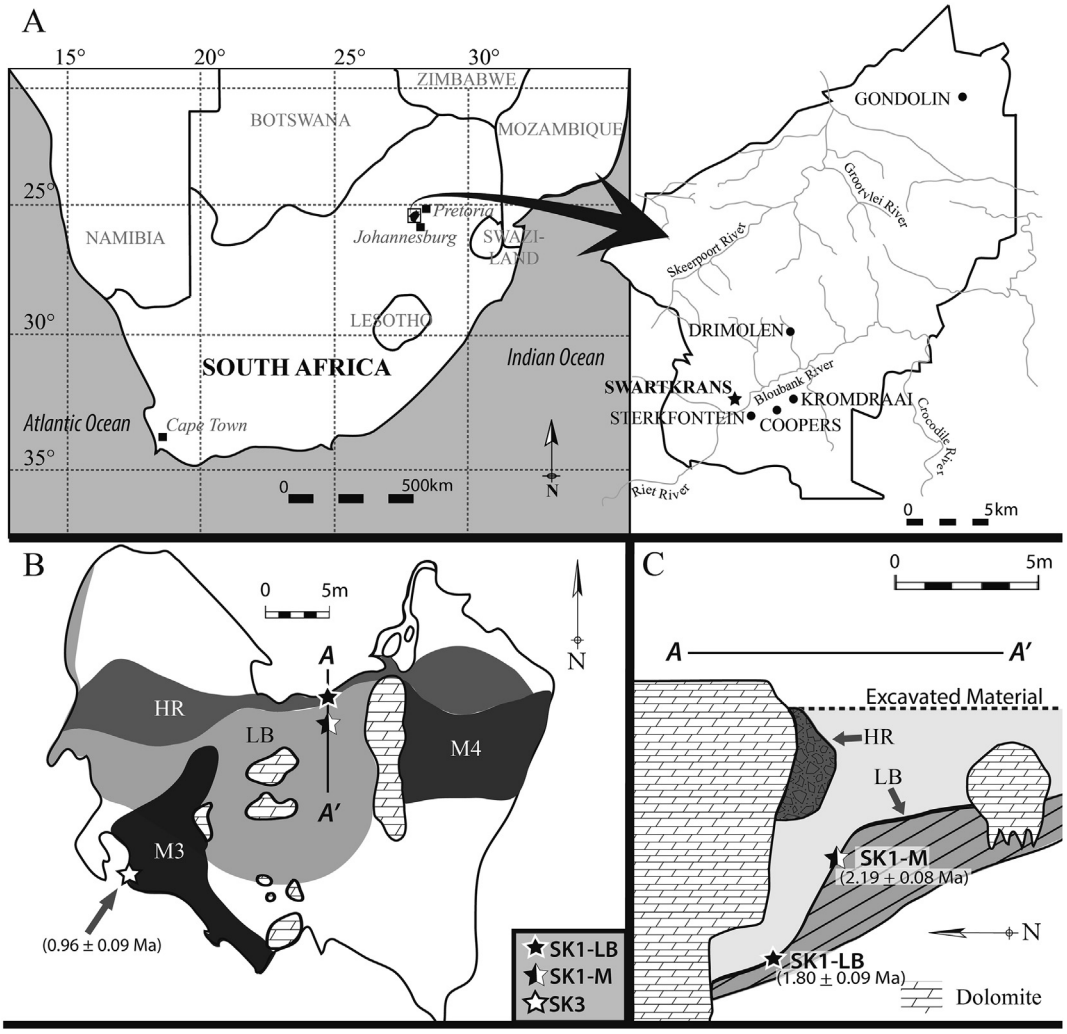

Fig. 1. (A) Political map of southern Africa (left), with the "Cradle of Humankind" World Heritage area in detail (right); Swartkrans Cave is indicated by a star, with other major *Paranthropus robustus* sites indicted by black dots. (B) Plan view of Swartkrans, illustrating the major depositional units of the Swartkrans Formation. From oldest to youngest, these are: the Lower Bank (LB) and Hanging Remnant (HR) of Member 1; Member 2 (not figured here in order to clarify the underlying deposits of Member 1); Member 3 (M3); the Member 4 Middle Stone Age colluvium (M4). (C) Schematic section, designated on the plan in (B), running north-south through the filling of the outer portion of Swartkrans Cave (the fabric of the LB deposit, with an inclination of 30°, indicates that clastic infill and associated paleoanthropological materials entered the cave from a location well-above the current cave opening and to its south). Approximate locations of cosmogenic nuclide burial dating samples are indicated on (B) and (C) with stars and their associated ages; all uncertainties are reported at one-sigma.