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Cradle of Humankind Karsts in Southern Africa

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Abstract

The recent development of karstic and geoarchaeological studies in the karsts of Gauteng, in South Africa, has completely transformed interpretations in these prestigious hominid sites (Sterkfontein, Swartkrans, Kromdraai, Cooper's, Gondolin...). Despite the wealth of faunal and also of hominin fossils, a combination of stratigraphic complexities and dating difficulties kept this region of Africa in the background of evolutionary scenarios for a long time, in particular regarding the emergence of the *Homo* genus. Indeed, for several decades, the Great East African Rift has been considered as the "cradle of humankind". It has yielded many early hominin fossils, in particular the oldest Australopithecines. These fossils have been well dated thanks to simpler morphosedimentary contexts, which are much easier to reliably date than karstic contexts.

The approaches developed by us for more than 15 years in South Africa mobilize various disciplines. On the strength of these, several barriers between disciplines have been broken down and certain dates have been called into question, for example, on intrusive calcite floors that are, in actual fact, much younger than the fossils that they were supposed to date (BRUXELLES *et al.*, 2014). On the basis of this work, new dates place the South African fossils in the same age brackets as the East African fossils. Thus, the dating of the virtually complete Australopithecus fossil StW 563 (Little Foot) gave an age of 3.67 ± 0.16 Ma (GRANGER *et al.*, 2015), almost 1.5 Ma older than the dates accepted by the scientific community until then (WALKER *et al.*, 2006).

It therefore appears that two regions of Africa, more than 4000 km apart, record a comparable or even parallel evolution, with a similar succession of hominins. The fundamental question raised by these results is therefore whether there are two distinct "cradles of humankind" or whether these two geological traps (the rift and the karst) are only two fragments of a wider cradle, certainly on the scale of Africa. Elsewhere, in places with less auspicious geological contexts and geomorphological evolution, all the ancient hominin remains would have disappeared. Since 2015, we have therefore set up several missions to search for fossils in the karsts of Southern Africa, in Namibia, Botswana, Mozambique and Zimbabwe.

1. Introduction

About 35 km northwest of Johannesburg, South Africa (Fig. 1), a karst area harbors an extraordinary concentration of ancient hominin fossils (sub-tribe of *hominina* including Australopithecines, Paranthropus and *Homo* genus). They are preserved in former cavities, largely dismantled by erosion, and are still embedded in cave breccias. The density of these fossils is utterly exceptional. In 1999, UNESCO classified this region as a World Heritage Site and named it "The Cradle of Humankind" (CoH). However, this is not the region where the oldest fossils affiliated with the ancestors of the *Homo* genus were found, but where the highest concentration of hominin fossils has been discovered: more than a third of all the remains known to date in Africa (more than a thousand) have been found in this relatively small area of 47,000 hectares. Furthermore, these fossils span a key period for our understanding of the evolution of the human lineage, between -4 and -1 million years, marked by the appearance of our genus, the *Homo* genus. In addition, the fossils are in remarkable condition, like the more than 95% complete Australopithecus Little Foot, which fell into a shaft and remained virtually intact for more than 3 million years (CLARKE, 2011).

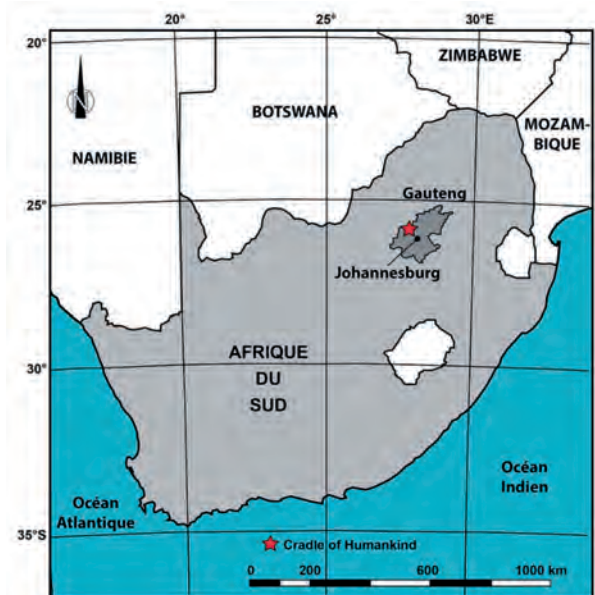


Figure 1: Location map of the Cradle of Humankind.

Today, more than ten paleontological sites are known in the CoH area, most of which have yielded hominin remains. The highest concentration lies along the course of the Blaauwbank River. These are the sites of Sterkfontein, Swartkrans, Kromdraai, Cooper's, Bolt's Farm, Rising Star, Wonder Cave, Minaar's Cave and Plovers Lake (Fig. 2).

Others are more sparsely distributed across the northern CoH, such as the sites of Malapa, Gladysvayle Cave, Gondolin, Haagsgat Cave and Motsetse Cave. Each of these sites corresponds to a paleokarst dismantled to varying degrees by the topographic surface. The fossiliferous deposits most often outcrop on the surface but they also extend downwards, like the Member 2 breccia in Sterkfontein. Only a few of these paleokarsts lead to a cavity that is still penetrable today, such as Sterkfontein Cave.

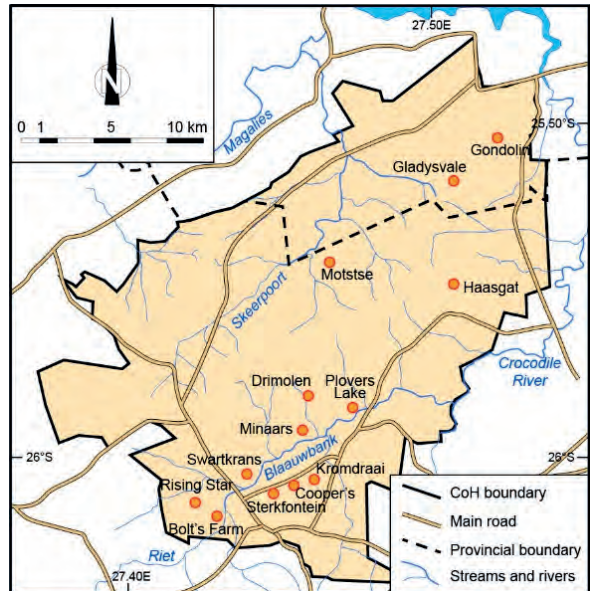


Figure 2: Map of Cradle of Humankind sites (UNESCO World Heritage Site), Gauteng.

2. Methods

In 2006, Ronald Clarke, a South African paleoanthropologist, contacted me to help him to reliably date the Little Foot fossil found at the bottom of Sterkfontein Cave. Indeed, since the discovery of this fossil in 1997, numerous dates have been advanced, with very divergent results, ranging from 2.2 to more than 4 million years for Member 2 (the breccia in which Little Foot was found), the oldest fossiliferous breccia of the site. Clarke was convinced that this divergence stemmed from a stratigraphic problem and asked me to come and study the sedimentary context around this fossil in order to relaunch targeted chronometric measurements. My approach cannot be

resolved by stratigraphic analysis alone and needs to take into account all of the interlocking scales in order to answer the initial question. Therefore, I gradually developed a complete research program, along several missions, including geologists, paleontologists, paleoanthropologists, archaeologists, but also geochemists, dating teams and, of course, geomorphologists and karstologists. It appeared essential to take into account the geological context and the very long evolution of this part of the Kaapvaal Craton, since the deposit of the Neoproterozoic dolomites, 2.6 billion years ago.

3. Results

A slowly changing landscape

The geomorphological analysis of the CoH area, with the addition of exposure measurements, cosmogenic and U/Pb dating, but also biochronology, show that this region experienced a generally very slow evolution. The entrenchment of the Blaauwbank valley spans a large part of the Neogene and the whole Quaternary period. The incision rate is very slow and can reach 3 meters per million years in the Blaauwbank! However, incision rhythms are variable in time but also in space, in the upstream or downstream parts of the river. These conclusions lead to two major perspectives for paleoanthropological research in this region: i) the best-preserved sectors from erosion dynamics are found where erosion surfaces are entrenched by the regressive erosion of watercourses, but not largely dismantled. This is also where the highest concentration of ancient fossiliferous sites is found (Fig. 2); ii) the upper section of the valley, between the African surface (S1) and

the S3 (Fig. 3) is likely to harbor even older sites than those currently known, possibly going back quite far into the Miocene. In addition to the geomorphological question, these conclusions open up new perspectives for research on fossiliferous sites in well-targeted parts of the CoH but also in other comparable geomorphological contexts in South Africa or even in southern Africa.

The role of ghost-rock karstification

The study of the very numerous examples of ghost rocks observed in this region shows that this alteration process is at the origin of most of the karstic voids and explains in particular the very high density of cavities (BRUXELLES *et al.*, 2018). The Sterkfontein caves form a typical labyrinthine network (Fig. 3) and decayed dolomite is still found *in situ* in many places in the cave but also in the whole cradle (Fig. 4). It is only slowly removed by the oscillation of the water table level, which led to the collapse of the porous decayed rock

and the removal of the alterite in a backward way (Fig. 5). The irregular entrenchment of the hydrographic network and the development of erosion surfaces hollowed out of part of the ghost rock, but also opened up a large number of entrances (Fig. 5). The weak dynamics of the karstic drainage and the absence of organized morphologies around the entrances contributed to a slow but progressive formation of gravitational talus colluviums which formed underground fossiliferous debris, subsequently cemented by calcite into breccia. Each breccia member can cover several hundred of thousand years (BRUXELLES, 2019; GRANGER *et al.*, 2022)!

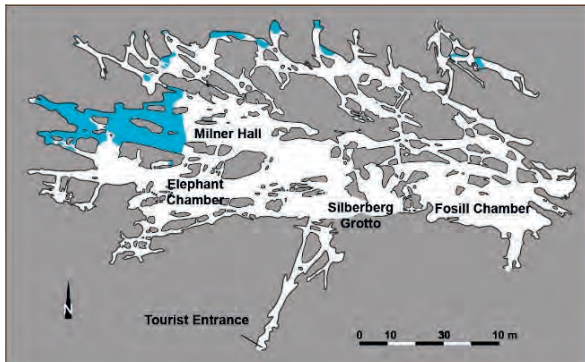


Figure 3: Simplified plan of Sterkfontein Cave. We clearly perceive here the very labyrinthine architecture of the network where alteration affects each lithological discontinuity (according to MARTINI *et al.*, 2003 modified).

In South Africa, this long phase of alteration paved the way for the formation of cavities. Once the weathered rock was hollowed out by regressive erosion, the caves connected to the surface hosted records of the surrounding fauna and flora. Even today, the erosion of these weathered rocks produces frequent collapses in Pretoria, creating genuine geotechnical problems.



Figure 4: Pseudo-endokarst in Bolt's farm quarry. The dark porous alterite just collapsed on itself and let space for white calcite development. Here the alterite was not removed by backward erosion process so it remained *in situ* (photo: L. Bruxelles).

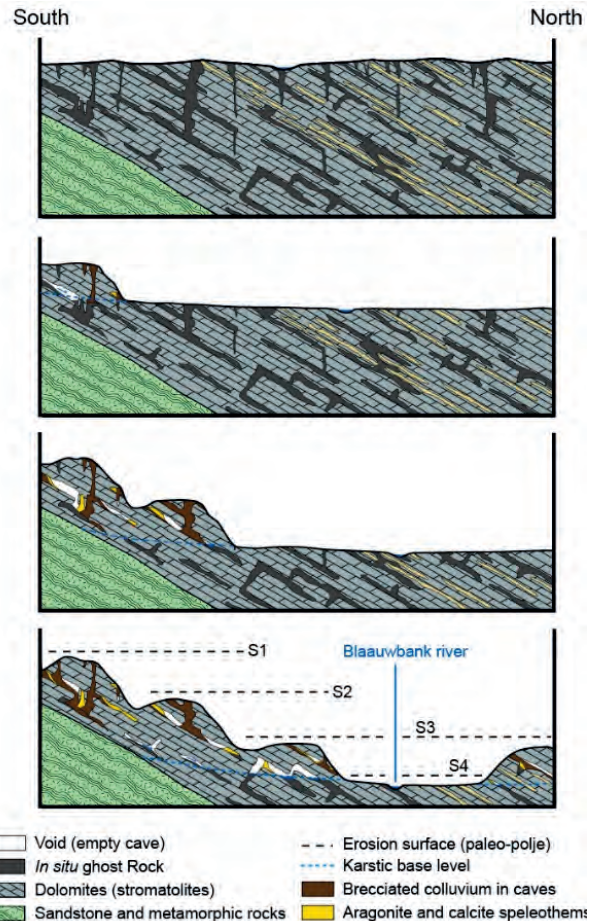


Figure 5: Synoptic diagram of the evolution of the Blaauwbank valley and the development of caves with their fillings (without scale; BRUXELLES *et al.*, 2018).

On the scale of the valley, erosional surfaces and cavities span a period of at least ten million years. They record the paleontological and paleoenvironmental history from the surface (BRUXELLES, 2019). However, on account of the hollowing out process of residual weathered rock, in conjunction with the complex long-term evolution of the entrances, it is difficult to interpret the relationships between the fossiliferous deposits trapped in these cavities. Stratigraphies are sometimes reversed and flowstones can infill older breccia (BRUXELLES *et al.*, 2014), which is also a trap for geochronologists (WALKER *et al.*, 2009; HERRIES et SHAW, 2011; PICKERING *et al.*, 2011 & 2019).

A long geomorphological and sedimentary record

The study of Silberberg Grotto, one of the networks of Sterkfontein Cave, entailed a multiscale stratigraphic analysis of the Member 2 breccias (BRUXELLES *et al.*, 2019). This enabled us to demonstrate that these deposits, bearing the Little Foot fossil, accumulated from a shaft entrance by the slow and progressive particulate accretion of colluviums. This debris slope is clearly stratified and its geometry and organization have remained unchanged since its formation. This work validates the dating of Little Foot at 3.67 Ma. In addition, this sedimentary analysis provides information on the stage of cave formation at that time, but also on the

position of the base level. Thus, the lowest part of the slope of Member 2 is located at a comparable altitude to surface S4, bordering the main bed of the Blaauwbank (Fig. 5). At that time, the valley bottom was therefore already situated at least at this level, which correlates perfectly with the dating of the terrace of the Kromdraai gold mine, also associated with surface S4 (BRUXELLES, 2019). The geomorphological arguments and the study of the karstic fillings converge to demonstrate the antiquity of the caves but also an extremely slow evolution of the CoH landscapes. It is this slow evolution that rendered possible the preservation of the multi-million-year-old fillings up to the present day.

New dates published this year (GRANGER *et al.*, 2022) were calculated on Member 4 of Sterkfontein, which lies stratigraphically above Member 2. They confirm the

intrusive nature of the calcite flowstones used until then for dating at Sterkfontein (WALKER *et al.*, 2006; HERRIES and SHAW, 2011; PICKERING *et al.*, 2011 & 2019). These dates also validate the age of the deposits, Member 4 and the numerous Australopithecus fossils from these breccias, now dated to around 3.4 Ma. This is in complete agreement with the sequence and the general geometry of the site deposits: Member 4 breccias overlie Member 3 and Member 2 in which Little Foot was found (3.7 Ma). The top of Member 4 is truncated by a major erosive unconformity sealed by Member 5 (2.2-1,8 Ma). These results and their perfect consistency demonstrate the relevance of the karstological and geoarchaeological field approach to such ancient and complex sites. It successfully positions the hominin fossils trapped in Sterkfontein Cave over a period of more than 1.5 Ma in their correct timeline.

4. Discussions

Like the work carried out on Sterkfontein Member 2, the systematic review of the stratigraphy of the paleontological and archaeological sites of the CoH shows the inevitability of new research perspectives, whether in terms of dating, excavation potential, or even new deposits or fossiliferous sites. This work should now form the basis for research on each CoH site, but in order to do so, it must first of all be standardized. This is the only valid strategy for establishing inter-site correlations and for addressing common paleoenvironmental and paleoanthropological perspectives. It must become the cornerstone of the dating strategy for every site in order to avoid the repetition of previous errors.

On the scale of the CoH, targeted prospecting based on our knowledge of the local geology and geomorphology led to the discovery of a new site contemporary with Sterkfontein. This methodology seems to be successful and we are planning a prospecting program aimed at the identification of older sites, related to the S2 surface, in order to confirm that this region can harbor sites dating back to the Miocene. More broadly, on the scale of the province of Gauteng, other outcrops of Malmani dolomite display auspicious characteristics for the presence of fossiliferous sites and have still not been prospected. A new research program has therefore been set up in a region virtually untouched by this type of approach in the Pretoria area.

These results also open up research prospects on the scale of the African continent (Fig. 6). Indeed, the history of this region appears to be as old as that recorded in the East African Rift.



Figure 6: Map of the main hominid sites in Africa, according to their geological context (BRUXELLES, 2019).

This means that this sector can also be considered as a cradle of Humankind. But how can we explain the existence of two cradles, more than 4000 km apart, with the same chronologies and very comparable fossils? Perhaps we must admit that there were hominins everywhere between these two regions and over a large part of Africa, but that vestiges are only preserved in geological traps such as the rift or the karst. The African rift or the CoH would thus merely be pieces of the same cradle of Humankind. Starting from this postulate, we can therefore consider that other fossiliferous traps should exist in Africa. Consequently, we have set up several research missions in other karsts of Southern Africa:

- The mission Human Origins in Namibia (French Ministry of Foreign Affairs, MEAE) is the first field application of the geological and geomorphological model demonstrated in CoH, South Africa. The Aha Hills and

the Otavi triangle combine all the characteristics conducive to the existence of comparable sites to Sterkfontein. We observe cavities dug out by ghosting, a very slowly evolving landscape, but also signs of paleokarsts or even fauna extending back over the last few million years;

- A second sector is currently being studied: Mozambique (MITI 80, CNRS). It is located at the southern outlet of the rift and these are the first karsts crossed by fauna and hominins leaving the rift from the south. A first mission carried out in 2018 identified some fossiliferous breccias, and a new one is now planned for August 2022, just after the congress!
- More recently, we have initiated research programs in Botswana (Hominins in Botswana: Karst Research project), in collaboration with the Botswana National Museum and the Desert and Steppes Institute. The first field mission carried out in 2021 resulted in the discovery of several fossiliferous sites and the excavation of two of them (Fig. 7). The rate of evolution of the landscape, the state of dismantling of the paleokarsts and the identified fauna converge to indicate that the breccia records a period between -3 and -2 Ma, which corresponds to the emergence of the Homo genus.
- In June 2022, the first field trip was organized in the framework of the HOPE-Z research program (R. Hanon and S. Prat dir., MNHN and Engie). Two karstic areas were studied and several new caves were found. The first Zimbabwean fossiliferous breccia was discovered!

What now needs to be done is to identify hominin remains among the faunal bones visible in the breccia, the frequency of which is 1/1000. But the stakes are high since the discovery of a single ancient hominin bone on these sites would be sufficient to confirm that probably all of Africa can be considered as the cradle of Humankind. This would open up immense research prospects in African karsts.



Figure 7: Excavation of a fossiliferous site in the hills of Koanaka (Botswana) in December 2021 (photo: C. Bruxelles). The ground is constituted of fossiliferous breccia and flowstones which shows that there was a cave here before it was unroofed by erosion.

5. Conclusion

By proposing innovative approaches, new research directions and new fields of investigation, our work renews issues linked to the geomorphological evolution of paleokarsts and is clearly at the heart of currently debated themes in the international arena, concerning the mechanisms underlying the evolution of the human lineage. Despite the large number of fossils discovered in the CoH, several questions of primary importance are still pending: How did the first representatives of the Homo genus evolve in South Africa and under what circumstances did they adapt to the surrounding environment? What are the evolutionary relationships between the different identified hominin genera and species, in South Africa but also between East

Africa and Southern Africa? What does the currently available sample of human paleodiversity from that time really represent? In the same way as the recently discovered *Homo naledi*, are there other, as of yet unknown hominin taxa in South Africa?

Our results show that geomorphology and geoarchaeology can contribute to answering these key questions. They also show that the karst constitutes an environment of prime importance as its unique characteristics can preserve fossils for millions of years (Fig. 8). These results and new perspectives for research on the African continent owe a lot to the work of karstologists, but also, and this is fundamental, to that of speleologists!

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Figure 8: *Australopithecus Little Foot* under excavation in the Silberberg Grotto, Sterkfontein caves (photo: L. Bruxelles).

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