Remains of a barn owl (*Tyto alba*) from the Dinaledi Chamber, Rising Star Cave, South Africa

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Excavations during November 2013 in the Rising Star Cave, South Africa, yielded more than 1550 specimens of a new hominin, *Homo naledi*. Four bird bones were collected from the surface of the Dinaledi Chamber during the first phase of the initial excavations. Although mentioned in the initial geological and taphonomic reports, the bird remains have not been formally identified and described until now. Here we identify these remains as the extant barn owl (*Tyto alba*) which is today common in the region and which is considered to have been an important agent of accumulation of microfaunal remains at many local Plio-Pleistocene sites in the Cradle of Humankind. Based on the greatest length measurement and breadth of the proximal articulation of the tarsometatarsus specimen, it is suggested that a single (female) individual is represented, despite the small sample sizes available for comparison. Although it is unclear how the remains of this female owl came to be accumulated in the remote Dinaledi Chamber, we suggest several possible taphonomic scenarios and hypothesise that these remains are not directly associated with the *Homo naledi* remains.

Significance:

- Owl bones from the Dinaledi Chamber are the only other macro-vertebrate remains from this Chamber.
- The other remains discovered are that of more than 15 individuals of the enigmatic *Homo naledi*.
- The remains of the Dinaledi Chamber owl further our understanding of the contents of the important material contained within the Dinaledi system as they are the only more recent fossils to be recovered from this area of the Rising Star Cave system and are therefore important in and of themselves as an indicator that more proximal parts of the Rising Star Cave system have been suitable for use by barn owls at greater time depths than the present.

Introduction

The Rising Star site

The Rising Star Cave system is located in the Cradle of Humankind UNESCO World Heritage Site, 50 km west-northwest of Johannesburg, South Africa (Figure 1). It is known that amateur cavers had periodically been visiting the cave system for a number of years (see Dirks et al.[1]); however, it was not until September 2013 that this system was formally investigated and fossil hominin remains were discovered in a very remote chamber named the Dinaledi Chamber.[1-3] Several excavations in the Chamber and adjacent spaces have yielded 1681 fossil hominin remains attributed to the new species *Homo naledi*.[1,2,4] Important to this study, approximately 300 bone specimens were collected from the cave surface of the Dinaledi Chamber and a further 1250 numbered fossil specimens were recovered from a small excavation pit in the cave floor no larger than 1 m^2 and less than 300 mm deep. This assemblage is the largest single collection of fossil hominin material found on the African continent to date, and the Rising Star Cave system is the only current location of remains of the hominin taxon, *H. naledi*.[1,2,4,5]

Dated to between 236 kya and 335 kya[5], geologically the Dinaledi Chamber and its fossil contents present an anomalous depositional environment in comparison to the 'classic' sites of the Cradle of Humankind in Gauteng

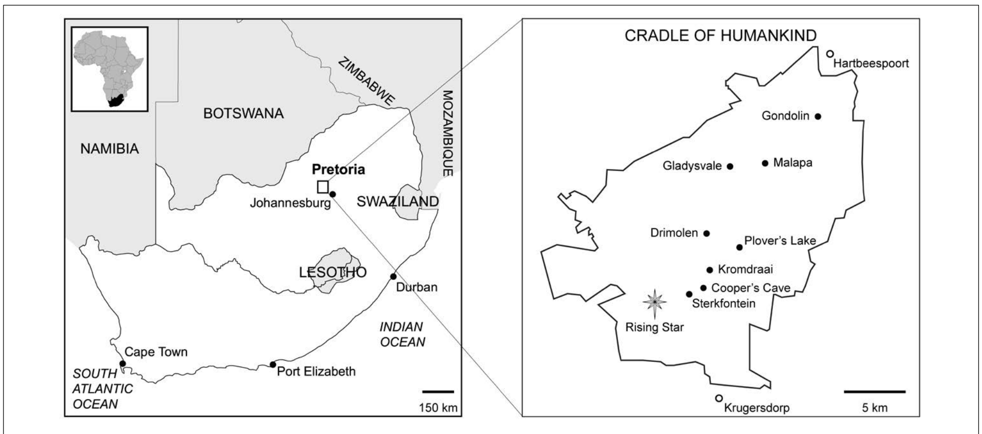


Figure 1: Location of the Rising Star Cave within the Cradle of Humankind UNESCO World Heritage Site. Other major palaeontological sites are also indicated.

Province, South Africa. Sites such as Sterkfontein, Kromdraai, Swartkrans and Malapa are noted for yielding fossil remains typically contained in lithified breccias, or found in decalcified sedimentary units derived ultimately from clastic lithified breccia.[6-11] In the majority of Cradle of Humankind fossil-bearing caves, it is hypothesised that skeletal material was brought into the system through a variety of agents, before being lithified.[12] Such agents can be biotic or abiotic, and include processes such as the effects of gravity (for example a fatal fall into a natural death trap, or downslope movement on talus slopes), vertebrate accumulation (predation or scavenging by carnivores, or accumulation by rodents), mass movement of sediments, fluvial transportation, or animal movement into the systems, or a combination of such processes. These processes generally produce taphonomic markers within a fossil assemblage, the role in site formation of which can be inferred from factors such as body-part representation, bone breakage patterns, or traces of surface modification including those of weathering, tooth marks or insect damage.[13-18]

Although a large number of fossil specimens of *H. naledi* have been recovered from the Dinaledi Chamber, surprisingly no definitive contemporaneous fauna[1] has been found to date, apart from four bird bones which were collected from the surface of the Dinaledi Chamber during excavations in 2013. It is clear from the first pictures taken by the exploration teams upon entering the Chamber in September of 2013 that these bones were placed together on a raised stone in the Chamber with a few other bones, indicating likely human agency (by explorers) in their positioning prior to discovery by scientists.

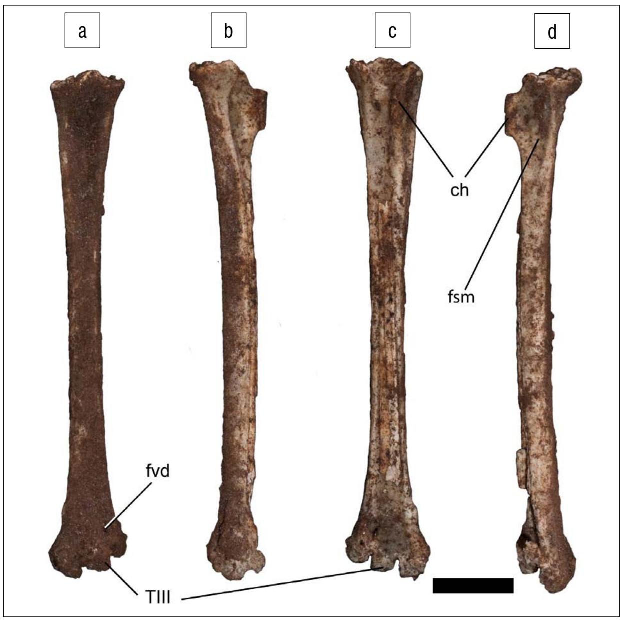
Based upon the physical state of the bones themselves as well as the clear lack of fossilisation as is typical on the hominin bones also found on the surface of the cave, we hypothesise that these remains are modern, or much closer to the present time, and not directly associated temporally with the *H. naledi* remains, likely being considerably younger. The appearance of preservation of these bones is clearly different from the hominin material found in the chamber.

While initially mentioned in the geological and taphonomic descriptions[1], the Dinaledi Chamber bird remains have not been formally identified or described until now. In this paper, we describe the four bird remains from the Dinaledi Chamber, using several possible explanations, expressed as hypotheses, to try explain how these bird bones were introduced into the Dinaledi Chamber.

Methods and results

The Dinaledi Chamber sample contains four bird specimens. Taxonomic diagnosis was made using comparative collections housed at the Ditsong National Museum of Natural History (formerly the Transvaal Museum) in Pretoria, South Africa. The measurements follow procedures given by Von den Driesch[19].

The most complete of these specimens, specimen U.W. 101 035 (Figure 2), a left tarsometatarsus, was used for skeletal measurements. This specimen is almost complete, with only the 3rd and 4th trochleas absent. The specimen is from an adult individual. The morphology of the proximal articulation distinctly places the specimen in the Strigiformes order, which consists of various species of owls. The morphology of the proximal articulation is identical to that of the extant barn owl (*Tyto alba*). This is supported by the greatest length of the specimen, which is also most similar to the barn owl (Table 1) among Strigiformes examined in this study. Very large- and small-sized owl species are not included because of the substantial adult size differences in these bones. In owls, the distal trochlea is similar in proportions. The presence of the 2nd trochlea is a reflection of maximum length.



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ch, crista medialis hypotarsi; fsm, facies subcutanea medialis; fvd, foramen vasculare distale; T, trochlea

Figure 2: Specimen U.W. 101 035, a left tarsometatarsus, is almost complete, with only the 3rd and 4th trochleas partially absent. The specimen is from an adult individual. (a) Dorsal, (b) lateral, (c) plantar and (d) medial views.

Table 1: Greatest length of tarsometatarsus (mm)

Taxon	Accession number	Greatest length of tarsometatarsus
Glaucidium perlatum (pearl spotted owl)	TM 71 880	22.74
Otus leucotis (white-faced owl)	TM 79 044	35.70
Strix woodfordii (wood owl)	TM 73 947	43.70
Asio capensis (march owl)	TM 80 555	51.84
Dinaledi specimen, identified as *Tyto alba*	U.W. 101 035	63.82
Bubo africanus (spotted eagle owl)	TM 76 097	69.62 (Note this species is much larger than the barn owl, as indicated by the measurements of this specimen: Bp: 12.52, SD: 6.46. See barn owl measurement in Table 2.)
Tyto capensis (grass owl)	TM 71 316	85.19

Bp, proximal breadth; SD, smallest breadth of the shaft

Based on measurement and morphology of the tarsometatarsus of the specimen from the Dinaledi Chamber, it is concluded that a barn owl (*Tyto alba*) is represented. In many bird species, male individuals are larger than female individuals, and this dimorphism can be reflected in anatomical measurements.[20] In the case of the barn owl, there is marked sexual dimorphism in terms of wing length (290–298 mm in male and 235–287 mm in female individuals[21]). Dimensions of the tarsometatarsus of specimen U.W. 101 035 from the Dinaledi Chamber appear to be more

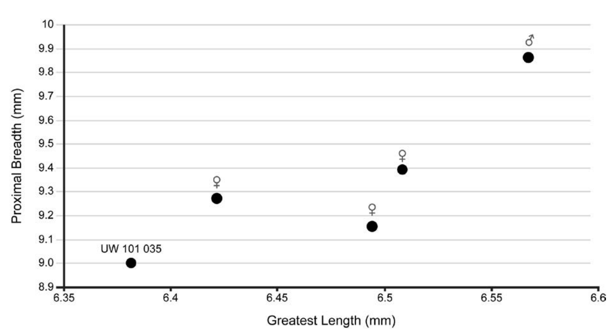

Figure 3: Tarsometatarsus proximal breath and greatest length measurements (in mm) for U.W. 101 035 plot closer to extant female specimens of *Tyto alba*.

Table 2: Barn owl tarsometatarsus measurements (mm) of male and female individuals

Specimen and sex	GL	Bp	SD	Bd
U.W. 101 035	63.82	9.0	4.01	10 (estimate)
TM 80 347 ♀	65.09	9.39	3.83	11.0
TM 80 242 ♀	64.22	9.27	4.08	11.36
TM 78 094 ♀	64.95	9.15	3.90	10.75
TM 80561 ♂	65.68	9.86	3.96	10.48

GL, greatest length; Bp, proximal breadth; SD, smallest breadth of the shaft; Bd, distal breadth

similar in size to that of female owls, but the comparative samples are small (Table 2; Figure 3).

A few other specimens accompanied the tarsometatarsus (Figure 4). These include: (1) a left tibiotarsus fragment of a bird, with the mid-distal shaft present, and part of the distal condyle (U.W. 101 40C; Figure 4a); (2) a right radius fragment of a bird, consisting of the distal, mid and proximal shaft, with the distal styloid process absent (U.W. 101 40B; Figure 4b); and (3) a right ulna fragment of a bird, consisting of the proximal, mid and distal shaft, with a small portion of the distal articulation present (U.W. 101 965 and 822; Figure 4c). In all cases, these specimens are similar in size and morphology to that of a barn owl, and are proportionally correct in size for an individual slightly smaller than the TM 80 242 and TM 78 094 specimens, and we conclude that they are most probably from the same individual as U.W. 101 035. However, the specimens are too fragmented to attempt to make an identification based on morphology alone. In this instance, the minimum number of individuals for *T. alba* is 1.

Scale bar equals 1 cm

Figure 4: (a) Specimen U.W. 101 40C, a left tibiotarsus fragment of *Tyto alba*, with the mid-distal shaft present, and part of the distal condyle; (b) specimen U.W. 101 40B, a right radius fragment of *Tyto alba*, consisting of the distal, mid and proximal shaft, with the distal styloid process absent; (c) specimens U.W. 101 965 and 822, a right ulna fragment of *Tyto alba*, consisting of the proximal, mid and distal shaft, with a small portion of the distal articulation present.

Discussion and conclusion

*The common barn owl (*Tyto alba*)*

Tyto alba is the most widely distributed species of owl in the world, and one of the most widespread of all birds, occupying many ecological areas, except Antarctica and parts of the Sahara Desert.[22] While almost exclusively nocturnal, in rare cases, *T. alba* is known to hunt diurnally.[23-25] As for most owls, the diet of *T. alba* comprises mainly small vertebrates, with a large majority represented by rodents. Undigested remains of the consumed prey in the stomachs of owls form into pellets, which are regurgitated, and are often rich in bone and teeth.[26-29] These regurgitated pellets are often found on the ground, underneath the diurnal resting area occupied by the owl.[27] A study done by Duke et al.[23] showed a striking difference in the bone composition of pellets when comparing those found in owls (48%) with those of hawks (6.5%) based on weight. This richness and affinity for micromammal bone accumulation in the form of pellets are often found at palaeontological and archaeological sites around the world.

As the owl pellets fall to the ground, they slowly start disintegrating and start to be incorporated in the sediments. It is for this reason that owls are widely recognised as accumulating agents, and much work has been undertaken to examine the pellets of both modern and fossil owls[26,28,29], as the contents of these pellets serve as good palaeoenvironmental indicators[30-37]. In addition to serving as palaeoenvironmental indicators, owl pellets are also used in the study of stratigraphy at a particular site and the study of evolution of fauna.[27]

Barn owls are known to roost in a variety of habitats, occupying different types of cavity roosts. These habitats may include the twilight regions of rock fissures or hollow interiors of tree trunks (both dead and alive); owls are seldom found roosting in exposed roosts.[38] It is widely known that, in southern Africa, the protected openings and entrances of caves are often frequented by barn owls and used for roosting.[36,38-40]

Tyto alba is widespread in southern Africa and makes use of a variety of habitats ranging from woodlands to deserts, but excluding forests[21], and is known to roost in an assortment of places including cliffs, buildings, wells, mineshafts and caves. Owls have contributed microfauna remains to many Plio-Pleistocene sites in the Cradle of Humankind[41,42] including Gladysvale, Kromdraai, Sterkfontein and Swartkrans[29,37-39,43-48].

The Dinaledi Owl

Figure 5a shows the Dinaledi Chamber and the location, where recovered, of three of the four bird remains discussed here. As noted earlier, the remains had apparently been picked up and placed on a rock in the distal section of the Dinaledi Chamber (Figure 5b) by one or more cavers prior to the exploration of the Chamber by our scientific team. As noted by Dirks et al.[1], the owl remains are taphonomically distinct from the rest of the hominin assemblage as they lack surface modification and stain patterns seen on the hominin remains; in addition, they are covered in an adhesion of a thin film of calcite crystals. These crystals cover much of the surface of the owl bone, and thus suggest that they may have been deposited relatively recently.

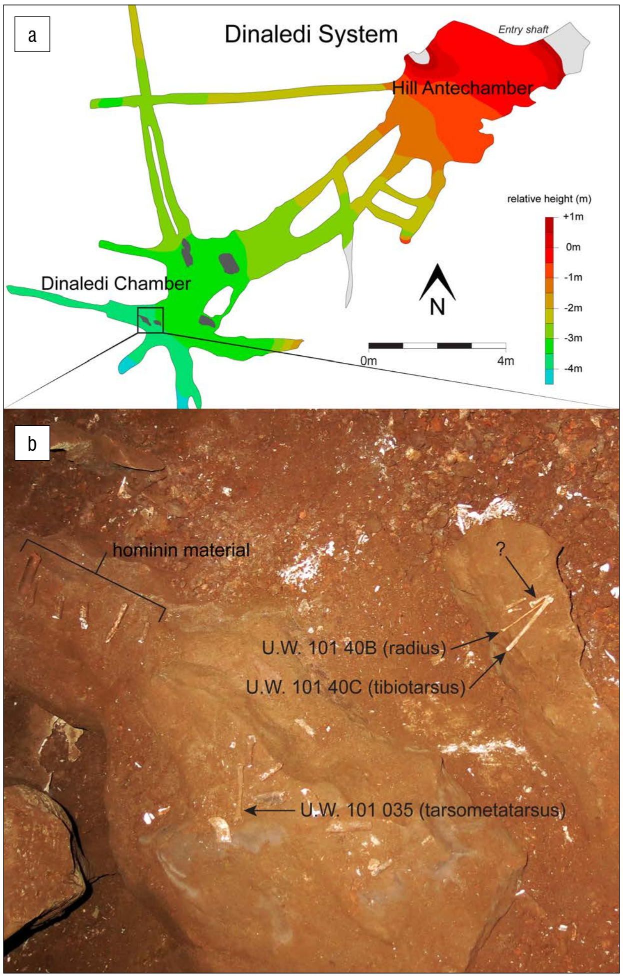

Figure 5: (a) Map of the Dinaledi Chamber in the Dinaledi system, Rising Star Cave (modified after Dirks et al.[1]); (b) location of three of the four owl remains found within the Chamber. The remains were seemingly placed on a rock, amongst other hominin material, by an unknown caver prior to investigations by the University of the Witwatersrand. An unidentifiable fragment (denoted by ?) is possibly remains of a bird, but lacks enough morphology for a proper diagnosis.

There are several possible scenarios to explain the placement of these bird remains. A modern owl may have become lost in the system and, by way of flying around in the dark, found its way into the Dinaledi Chamber (Hypothesis 1). It is also possible that the remains fell down the narrow chute – a 12-m drop immediately above the Dinaledi system, and the only currently known accessible route into this system (Hypothesis 2). If this were the case, it is possible that more remains from this individual are still to be recovered, possibly from the base of the chute, in what is now called the Hill Antechamber of the Dinaledi system[49], although in this scenario, human agency would be required for the bones to find their way into the more distal Dinaledi Chamber.

Alternatively, but less likely, the remains of this modern owl could have been introduced into the system by a caver carrying them in, possibly from the main entrance of the Rising Star Cave (Hypothesis 3). This hypothesis is supported by the fact that the four remains were found on a rock within the Dinaledi Chamber, although why a caver would carry remains into such a difficult to access area and then leave them there is not obvious. In this scenario, it is possible that the owl died at the entrance of the Rising Star Cave, as this area has a constructed entrance (created by limestone miners at some point in the 1930s) and a natural cave roof opening, both of which open up into a rocky cave wall approximately 6 m high. This rock face is a suitable roosting area, and is currently inhabited by bats, swallows and other bird species including occasionally barn owls. This open area has a relative abundance of light, and as is commonly known, barn owls will seek out roosts which are dark and enclosed, even when roosting in trees or on the ground.[38]

An alternative entrance into the Dinaledi Chamber, as suggested for example by Thackeray[50], is another possible scenario for the introduction of the modern owl remains (Hypothesis 4). However, extensive and exhaustive exploration by cavers from the University of the Witwatersrand has, to date, failed to identify another entrance to the Dinaledi system.

We favour one of the first two hypotheses as the most likely origin of this material in the position of their discovery: the owl became lost in the system and found its way either into the Dinaledi Chamber, or to the top of the chute, before perishing.

The owl remains from the Dinaledi Chamber help further our understanding of the contents of the important material contained within the Dinaledi system. They are also the only more recent fossils to be recovered from this area of the Rising Star Cave system and are therefore important in and of themselves as an indicator that more proximal parts of the Rising Star Cave system have been suitable for use by barn owls at greater time depths than the present. Once described, some of these bones will be subjected to radiocarbon dating to establish if they might be useful in placing an uppermost date on the bone content of the Dinaledi Chamber as perhaps they date the last depositional event to occur within the relatively closed Dinaledi system.

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Authors' contributions

A.K. conducted the research and wrote the original draft of the manuscript. S.B. took all measurements and undertook the identification. Both authors contributed equally to manuscript revisions and editing.

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