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News and Views

Deliberate body disposal by hominins in the Dinaledi Chamber, Cradle of Humankind, South Africa?

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1. Introduction

In responding to Val (2016), we welcome the opportunity to further clarify our interpretations of the taphonomic and geological context of *Homo naledi* in the Dinaledi Chamber of the Rising Star Cave as presented in Dirks et al. (2015). In so doing we want to state from the onset that, contrary to what is claimed in Val (2016), Dirks et al. (2015) do not reject mass mortality or death trap scenarios as possible explanations but, based on currently available evidence, consider deliberate body disposal to be the most plausible reason for the deposit. We also want to remind colleagues that the Dinaledi collection is accessible to researchers upon application. We are committed to promoting best scientific practice by making all data available for independent inspection, including observations on hominin remains, and broaden debate. We note that Val has not yet studied the collections directly or visited the cave, but has based her comment on re-interpretations of data presented in Dirks et al. (2015).

In reaching their conclusions, Dirks et al. (2015) collected data to test hypotheses known to explain other cave assemblages in South Africa (Brain, 1993; Clarke, 1994; deRuiter and Berger, 2000; Pickering et al., 2004; Kuhn et al., 2010; Dirks et al., 2010; Reynolds et al., 2011; Dirks and Berger, 2013; Val et al., 2015). To

account for the *H. naledi* deposits, a hypothesis must be consistent with all lines of evidence including geological, geochemical and taphonomic data. As such, the preferred hypothesis of Dirks et al. (2015) is based on a multi-disciplinary approach, and triangulated from multiple sources of evidence. In contrast, the fundamental point argued in Val (2016), i.e., that an alternative opening to the Dinaledi Chamber must have existed in the past, is based on incomplete taphonomic reasoning and does not consider geological constraints. The evidence presented in Dirks et al. (2015) and Berger et al. (2015) limits scenarios for hominin bone deposition in several important ways, which we review here.

2. Physical location

The floor of the Dinaledi Chamber is 30 m beneath the present ground surface and, in a straight line, 80 m from the closest surface entrance into the cave system. The Dinaledi Chamber is situated within a dolomite horizon that is capped by a 1–1.3 m-thick chert bed, which forms the roof to the chamber (Dirks et al., 2015). Mapping and laser scanning surveys indicate that within the Dinaledi Chamber and along the access route to the chamber, the capping chert bed is unbroken; i.e., it is a continuous layer not penetrated by significant shafts that open directly to the surface. The capping chert contains tight fractures through which water could enter, but no opening wide enough to allow coarse-grained, quartz-rich sediment and surface debris into the chamber (Dirks et al., 2015). Surface mapping also suggests that no major cave openings occur above the Dinaledi Chamber, a finding that we are testing further with geophysics.

The only way the Dinaledi Chamber can be accessed today is via the Dragon's Back Chamber, and involves a difficult climb along passageways in primary dolomite following a route that was never blocked or altered by sediment or flowstone deposition. In addition, *H. naledi* remains accumulated on a mud-rich, debris cone (Unit 2; Dirks et al., 2015) below the current entry shaft. These observations strongly suggest that the entry route into the Dinaledi Chamber from the Dragon's Back Chamber at the time *H. naledi* entered was

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similar to the one we see today. The geology also indicates that other aspects of the cave morphology did change over time, in particular along the route into the Dragon's Back Chamber where sediment accumulation and flowstone formation partly blocked passages (Dirks et al., 2015), possibly subsequent to the deposition of *H. naledi*.

3. Sedimentology

The best way to test to what degree the Dinaledi Chamber was isolated from the surface, is to look at the nature of the sediment surrounding the skeletal remains and compare these with sediment in the Dragon's Back Chamber (Dirks et al., 2015:13–15 and their Supplementary file 1). The Dragon's Back Chamber is the deepest part of the cave in which sediment from the surface can accumulate by gravitational means through the flow of water along the cave floor (Dirks et al., 2015, their Fig. 2b). The passage from the Dragon's Back Chamber into the Dinaledi Chamber is blocked by a dolomite wall that must be climbed before entry into the Dinaledi Chamber can be gained; i.e., the direct flow of sediment-laden water from the Dragon's Back Chamber into the Dinaledi Chamber is not physically possible. This is confirmed by the mineralogy and texture of the sediments in the Dinaledi Chamber, which are distinct from fill in the Dragon's Back Chamber (Dirks et al., 2015, their Fig. 8).

The presence in Unit 1 of microfossils presents no evidence of direct openings to the surface above the Dinaledi Chamber as hypothesized in Val (2016). Whilst micro-faunal remains may have originated from raptor activity near cave openings, these remains are also part of the sediment load (Andrews, 1990). Sand deposits in the upper chambers of Rising Star Cave contain abundant microfossils within beds that show grading and small-scale cross laminations, with bones distributed along bedding planes and fore-sets, i.e., the micro-fossils were washed in.

In the Dinaledi Chamber, microfossil remains are rare and restricted to two small sandy lenses (Facies 1b) in Unit 1, which were deposited before *H. naledi* entered the Dinaledi Chamber (i.e., the presence of the microfossils cannot be linked directly to *H. naledi*). Unit 1 was deposited in a low energy, wet environment (Dirks et al., 2015). The microfossil-bearing lenses accumulated from discharge points higher up within the Dinaledi Chamber (as opposed to water flow along the floor). The upper parts of the chamber present a complex morphology with chert ledges that weather out, to locally form false roofs that connect up-dip (i.e., in a direction parallel to layering, as opposed to vertically upwards) to chambers higher up in the system. It is likely that during deposition of Unit 1, some fine sand and microfossils washed into the Dinaledi Chamber along these chert ledges.

It is not correct to link the microfossils in Unit 1 to the sedimentary processes that resulted in the accumulation of the younger Units 2 and 3 that contain the *H. naledi* remains. Unit 2 resulted from the accumulation of angular, laminated mud fragments on a sloping debris cone below the current entry shaft; Unit 3 consists of loosely packed, angular mud fragments along the cave floor (Dirks et al., 2015:11–12). The units are rubbly and largely unconsolidated, and contain natural voids. The *H. naledi* remains are distributed amongst the rubbly mud clasts, and are water saturated and fragile. Whilst the sediments are damp, the sedimentology prohibits a depositional history that involved high-energy water transport of the type required to transport entire bodies of *H. naledi*.

The geological evidence, therefore, indicates that the Dinaledi Chamber was an isolated sedimentary environment. It is not possible that *H. naledi* remains were washed into the Dinaledi Chamber, irrespective of the presence of microfossils in Unit 1. These geological constraints put boundary conditions on the

interpretation of any taphonomic data, a fact that has not been given sufficient consideration in Val (2016). Knowledge of absolute timing of events would not alter these conclusions in any way.

4. Selectivity of the assemblage

The skeletal assemblage in Units 2 and 3 include parts of at least 15 hominin individuals, but no other macrofauna. This selectivity implies a depositional context from which other animals were excluded, a situation that differs from all other hominin-bearing caves within the area (Tobias, 2000; Partridge et al., 2006; Pickering et al., 2011).

The location of the Dinaledi Chamber entrance within the dark zone presents an obvious mechanism to explain this selectivity, by making the assumption that hominins themselves were involved in the deposition. Water or gravity-aided re-deposition of body parts from outside the cave, or from areas near cave entrances, which is not credible on sedimentological grounds, also cannot explain the selectivity of the assemblage, because the originating assemblage would have had to be comprised of only hominins as well, and, thus, be equally unique.

5. Surface modifications and fracture patterns

Val (2016) presents three arguments based on taphonomy. She suggests that: a. the skeletal representation and articulation of remains does not demonstrate that the Dinaledi Chamber is a primary depositional context; b. gastropod surface modifications are inconsistent with a deep cave environment; and c. evidence does not exclude carnivores as a primary accumulating agent.

5.1. Skeletal element representation and articulation

Val (2016) suggests that the number of elements in the hominin sample is small compared to the MNI of 15 individuals and biased towards elements that are more durable, and implies that this may reflect a destructive taphonomic process such as carnivore activity.

Most of the deposit remains unexcavated within the Dinaledi Chamber, and we cannot be certain that the small excavation to date is statistically representative of the full assemblage. The bulk of material collected comes from the surface or top part of Unit 3, which consists of reworked sediment. Bone material is water saturated, with mineral precipitation limited to surface coatings, leaving the bones extremely fragile (in this respect the *H. naledi* remains differ from other fossil hominin deposits in the area). Reworking of material from Units 2 and 3 occurred repeatedly in response to wetting and drying cycles, and creep towards floor drains (Dirks et al., 2015, their Fig. 2c). This removed sediment from the chamber and caused fossils to move (Dirks et al., 2015:22), and led to bone fragmentation as demonstrated by the large number of small bone fragments in Unit 3 sediment (Dirks et al., 2015, their Supplementary file 1). The fragmentation process probably had a more profound effect on smaller and more delicate body parts, and creates issues in terms of precise anatomical attribution of small fragments. Thus, conventional methods of relative quantification must be used with care. It is worthwhile noting that all anatomical regions are represented within the assemblage, and, as work continues, an increased number of elements attributed to the axial skeleton have been identified.

Regarding remains that are in articulation or close spatial association, it is important that articulated material is more common in the lower 10 cm of the excavation (Dirks et al., 2015), which has been sampled in only one 0.8 × 0.8 m area. Apart from the four articulated bone groups referred to by Val (2016), on-going work on spatial patterning has resulted in the identification of three

additional partial foot associations (Harcourt-Smith et al., 2015) and two partial hand associations (Kivell et al., 2015). The hand and foot remains demonstrate that at least some fossil material in Unit 3 was not significantly reworked after deposition.

We cannot reject the hypothesis that articulated material may have desiccated within or outside the Dinaledi Chamber prior to deposition. Naturally desiccated bodies of mammals occur in caves in South Africa. However, the geological evidence excludes the possibility that mummified material was transported by water into the chamber.

5.2. Invertebrate surface modification

Val (2016) doubts our evidence for invertebrate activity in the Dinaledi Chamber, and believes it requires a nearby entrance. Our interpretation that modern gastropods, beetles and their larvae are taphonomic agents active in deep zones of Rising Star Cave is in accord with reports of troglo-faunal communities globally (White and Culver, 2012). Although not reported in Dirks et al. (2015), recent work has produced direct evidence of troglobite, invertebrate microfauna on the surface of *H. naledi* remains, including a transparent spider, frass (i.e. refuse including excreta left behind by insects), and a pupation chamber. The *H. naledi* remains and surrounding sediment are part of a subterranean food web that supports snails and other troglo-fauna, including beetles, moths, spiders and a potentially wide range of other invertebrates. Radula scrape marks associated with the removal of mineral coatings on bone surfaces (Dirks et al., 2015, their Fig. 11a) confirm that some invertebrate damage occurred late, and that invertebrates are active in the Dinaledi Chamber.

Val (2016) cites data on the feeding ecology of modern *Achatina* and *Cornu aspersum* (formerly *Helix aspersa*) (Herbert and Kilburn, 2004) to support the suggestion that the hominin remains were deposited near the surface. These species do not inhabit caves, and we do not propose that they were in the Dinaledi Chamber; however, like all gastropods they have radulas that produce distinct traces, and they provide a convenient experimental model for radula damage. We have not yet recovered snails from the Dinaledi Chamber, but *Gulella* sp. and *Euonyma varia* Connolly, 1910 are common in other deep areas of the Rising Star Cave. Subulinid snails (includes *Euonyma*) are known more generally from South African caves, most probably because of their calcium carbonate requirement for shell construction, and their omnivorous feeding patterns (D. Herbert, pers. comm.).

5.3. Carnivore modification

Val (2016) suggests that the post-depositional cortical bone removal by invertebrates may have obliterated evidence for surface modification of bone by carnivores (gnawing, tooth scores or pits, gastric polish, punctate markings), asserting that only 1.1% of the assemblage preserves the cortical surface. We examined every specimen in the assemblage and focused microscopic attention on a sub-sample of 559 attributed elements representing all anatomical regions. These were analyzed for 35 variables (Dirks et al., 2015, their Supplementary file 2), and cortical surface removal was scored as present or absent to indicate any removal of cortical surface, and not removal of the entire cortical surface. Surface removal on the Dinaledi material has a patchy distribution (Dirks et al., 2015, their Fig. 11), and significant portions of original bone surfaces are intact on most elements. No light tooth scores made by carnivores have been found, and if they had been present, subsequent cortical surface removal might have destroyed a fraction of them, but it is unlikely that all would have been removed. Moreover, such cortical surface removal could not eliminate evidence of

deeper tooth scores and pits, which are also completely absent, nor could invertebrates eradicate biomechanically-mediated fracture patterns associated with carnivore damage, which are likewise absent (Dirks et al., 2015:24). We further emphasize that no large African carnivore is known to exhibit the extreme prey selectivity required to explain the Dinaledi assemblage (deRuiter and Berger, 2000; Power, 2002; Hayward et al., 2006; Kuhn et al., 2010).

Val (2016) suggests that Figure 1 of Berger et al. (2015), which depicts a subset of the Dinaledi hominin assemblage, shows evidence of destruction by carnivores. As stated in Dirks et al. (2015), there are no bone cylinders in the collection with evidence of the morphological patterns (spiral fractures, edge polish, crenulated, scalloped margins [Haynes, 1983; Pickering et al., 2004; Kuhn et al., 2010; Pokines, 2013]) consistent with carnivore activity, and there is no evidence for this in the bones shown in the image to which Val (2016) refers.

5.4. Dispersal and fracturing of fossil remains

Val (2016) asserts that Dirks et al. (2015) fail to answer what processes led to the dispersal and fragmentation of the remains in the cave. In fact, we discuss these processes in detail (Dirks et al., 2015:23–26). We state that some bodies may have been introduced into the chamber by other hominins and left there (which could explain the near-vertical position of some remains). We further explain that the remains were introduced over a period of time, concomitant with reworking of sediments. The process of reworking in combination with water-saturation that weakened the bones, and possible trampling at the time of deposition of the bones, or at a later stage due to entry by cavers are all possible reasons for the dispersal and fragmentation of the bones. Geological evidence excludes sub-aerial weathering and water transport as possible processes (Dirks et al., 2015).

With regards the fracture analysis presented in Dirks et al. (2015), we undertook a forensic trauma evaluation based on studies of peri- and post-mortem responses of bone tissue to trauma (e.g., Galloway, 1999; Loe, 2009; Randolph-Quinney et al., 2009; Symes et al., 2013). This was done in conjunction with conventional morphological methods of fracture analysis (e.g., Villa and Mahieu, 1991). In following this approach, we recognize that mechanical properties of skeletal tissue alter over time, such that green versus dry mechanical failure can be distinguished. For dry bone fractures, this includes right-angled breaks on the shafts of long bones, block-comminution between major breaks, step-fractures that follow the longitudinal axis, or fractures that fail to follow biomechanical principles. Dirks et al. (2015) make a clear case that all breakage patterns observed in the *H. naledi* assemblage resulted from dry bone breakage indicative of post-depositional processes as the primary agents of skeletal damage.

Considering our observations, no fracture criterion is consistent with the accumulation of *H. naledi* remains by carnivores. The lack of involvement of carnivores is further illustrated with Figure 1, which compares fossil elements (i.e., biomechanical homologs) from the Dinaledi Chamber with human skeletal remains recovered from sealed archaeological burial sites (with no evidence of carnivore activity). Both sets of bones show near-identical wear patterns in terms of surface condition and taphonomic criteria, including the effects of sediment corrosion and abrasion, as well as end plate damage patterns in long bones and dry-bone fractures associated with sediment loading.

6. Conclusion

Dirks et al. (2015) do not present evidence to prove deliberate deposition of the *H. naledi* assemblage, but test a series of

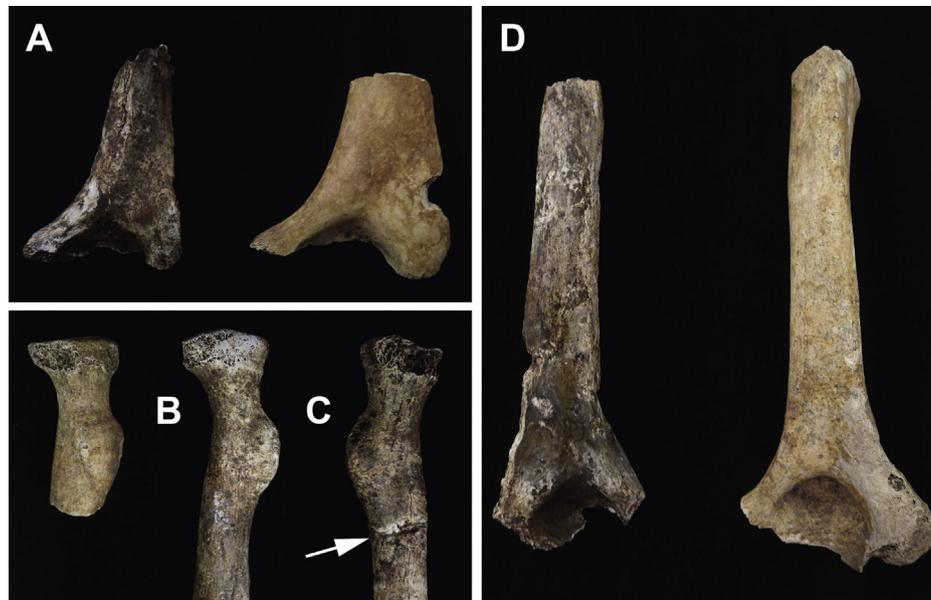


Figure 1. Comparisons between fossil remains of *Homo naledi* and homologous, dry bone specimens of *Homo sapiens* derived from recent archaeological burial sites. The examples illustrate the similar patterns in bone preservation and post-mortem breakage. A: U.W. 101-1240 distal humerus shown to the left of the archaeological specimen. B: U.W. 101-070 and C: 101-1345/1346 proximal radii, shown to the right of the archaeological specimen. Note the pattern of radial head erosion, and the similarity between the location of shaft breakage of the archaeological specimen and U.W. 101-1345/1346 (arrow indicates position of breakage between conjoined fragments). D: U.W. 101-744 humeral specimen shown to the left of the archaeological specimen.

hypotheses that have been suggested previously to explain cave assemblages elsewhere in southern Africa. Using multiple lines of evidence, we have excluded hypotheses that are inconsistent with current geological and taphonomic data. As stated (Dirks et al., 2015:30), the deliberate body disposal hypothesis provides the most plausible explanation, but we recognize that mass mortality of groups of hominins within the Dinaledi Chamber, due to a death trap scenario, is possible. We will continue to test these hypotheses by searching for new evidence and collecting additional data.

Should we be surprised at the idea of a small-brained hominin species caching bodies in an inaccessible place? Val (2016) reacts to this proposition with disbelief – not just at the act of deliberate disposal, but also at the supposed need for generational transfer of cultural knowledge in a species with the brain size of an australopith. We note that such transfer of information is known from non-human primates (e.g., Horner and de Waal, 2009), and happened in culture-bearing, early hominin taxa, as evidenced by the Oldowan Industry of the Early Stone Age (Whiten et al., 2009; Hovers, 2012; Ferraro et al., 2013).

H. naledi is a newly-discovered species and we consider it unwise to adopt any prior assumptions about its behavioral repertoire. Although living non-human apes do not cache bodies, they do exhibit emotional, cognitive and social prerequisites of such behaviors (Pettitt, 2011). The closest living relative of *H. naledi* is our own species, which exhibits elaborate mortuary behavior in every culture. Evidence of body deposition in *H. naledi* merely extends a behavior already observed in archaic and pre-modern humans (Formicola and Buzhilova, 2004; Carbonell and Mosquera, 2006; Pettitt, 2011; Geiling and Marín-Arroyo, 2015) to a deeper node of our phylogenetic history. The geological age of the assemblage is presently not known, but is irrelevant to interpretation of this behavior.

We welcome alternative scenarios that explain the data, but they must explain all the data. The suggestions put forward in Val (2016) that a more direct entrance into the Dinaledi Chamber existed, and that the bones could have accumulated on the surface as a result of carnivore activity before being transported into the

Dinaledi chamber, ignores basic geological constraints and is inconsistent with the evidence.

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