Renewed investigations at Taung; 90 years after the discovery of *Australopithecus africanus*

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2015 marked the 90th anniversary of the description of the first fossil of *Australopithecus africanus,* commonly known as the Taung Child, which was unearthed during blasting at the Buxton-Norlim Limeworks (referred to as the BNL) 15 km SE of the town of Taung, South Africa. Subsequently, this site has been recognized as a UNESCO World Heritage site on the basis of its importance to southern African palaeoanthropology. Some other sites such as Equus Cave and Black Earth Cave have also been investigated; but the latter not since the 1940s. These sites indicate that the complex of palaeontological and archaeological localities at the BNL preserve a time sequence spanning the Pliocene to the Holocene. The relationship of these various sites and how they fit into the sequence of formation of tufa, landscapes and caves at the limeworks have also not been investigated or discussed in detail since Peabody's efforts in the 1940s. In this contribution we mark the 90th anniversary of the discovery and description of the Taung Child by providing a critical review of previous work at Taung based on our recent preliminary work at the site. This includes a reassessment of the Taung Child Type Site, as well as renewed excavations at Equus Cave and the lesser-known locality and little-investigated Black Earth Cave. Preliminary results suggest that much of our previous understandings of the BNL's formational history and site formation processes need to be reassessed. Only through detailed analysis on the BNL as a whole can we understand this complex depositional environment.

Keywords: Taung Child, Geochronology, *Australopithecus africanus*, Plio-Pleistocene, Equus Cave, Black Earth Cave, Later Stone Age.

INTRODUCTION AND BRIEF HISTORICAL BACKGROUND

In November of 1924, geologists R.B. Young delivered a 'cercopithecid' skull from the Buxton-Norlim Limeworks (BNL), near Taung (now the North West Province), South Africa, for description to Raymond Dart at the University of the Witwatersrand Medical School (Tobias 1985). This 'monkey' turned out to be something rather different, representing the first early hominin fossil ever recovered from Africa and the type specimen for *Australopithecus africanus* (Dart 1925). Numerous adult versions have since been found at the sites of Sterkfontein, the Makapansgat Limeworks and possibly Gladysvale (Berger *et al.* 1992; Broom 1938; Dart 1948). The identification of the 'Taung Child' as an early human ancestor changed contemporary perspectives on human evolution and generated interest in the site of Taung(s) as an important palaeoanthropological locality.

Immediately following Dart's 1925 *Nature* paper, a number of researchers made exploratory trips to the BNL and produced publications. These included Hrdlička (1925), Young (1925), Cipriani (1928), Dart (1926, 1929) and Broom (1925a,b, 1929, 1930, 1934, 1938, 1939, 1943, 1945, 1946, 1948a,b). Most collected fossils in no strategic or documented fashion. While Hrdlička (1925) attempted to recover *in situ* fossils at the proposed site of the Taung Child discovery, it seems this consisted of only a few fragments of primate skull due to the heavily calcified nature of the 'pinkish' deposits.

Despite these early investigations into the type locality of *Australopithecus africanus,* a proper exploratory foray into the region only occurred in 1947–48 when Frank Peabody and Charles Camp conducted work at the BNL as part of the University of California Africa Expedition (Camp 1948; Peabody 1954). This work identified several important fossil and archaeological sites at the BNL and in the surrounding area. This involved excavations at the proposed location of the recovery of the Taung Child and excavations at another site termed Black Earth Cave, although the descriptions of any actual excavations were minimal. This was followed by isolated

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geological work by Butzer (1974) and Partridge (1985) and excavations at Equus Cave in 1978 by Myra Shackley (1981) and by Peter Beaumont in 1982 (Klein *et al.* 1991). Until recently, the last expedition into the region was under the direction of Phillip Tobias, of the University of the Witwatersrand Medical School and run by Toussaint & McKee in 1988 and by McKee from 1989 to 1994 (McKee 1993a,b, 1994; McKee & Tobias 1990, 1994).

In 1994, McKee published a catalogue of fossil sites that still exist in the demarcated world heritage site. Some of these were previously identified by Peabody (Cooke 1990; Peabody 1954), while teams led by McKee discovered others. While Peabody's (1954) geological description of the BNL remains the most definitive to date, it was conducted at a time of active mining and as such much more of the deposit had been removed by the time the Tobias expedition took place. The 17 fossil deposits documented by McKee (1994) are the: Hrdlička deposits, Dart deposits, Tobias Pinnacle deposit, Berger Cave complex, Lucky Moon Cave complex, LSN Cave, Innominate Cave, Cut-through Alley, Quinney Cave, Black Earth Cave, Equus Cave, Peabody's Equus Site, Blom Cave, Acacia Cave, Satan Cave, Oxland Large Mammal Site and Alcove Cave (McKee 1994; Fig. 1). Sites documented earlier such as Spiers' Cave, Tobias Cave and Peabody Cave have yet to be relocated and may have been eroded away as mining at the site continued until the 1970s. Tobias and McKee's efforts mark the last period of scientific research at the site, now some 20 years ago, albeit most of these localities remain unexplored as they concentrated their efforts at the Taung Child Type Site; represented by the Dart and Hrdlička deposits.

A RENEWED MULTIDISCIPLINARY RESEARCH AGENDA AT TAUNG

Despite its pivotal role in redirecting human evolutionary studies towards Africa, the fact that: 1) only one hominin has ever been recovered from the Taung Type Site; 2) its distance (360 km) from the major research universities; and 3) the discovery of richer hominin sites in what is known locally as the Cradle of Humankind, just outside of Johannesburg, has meant that Taung has not undergone the extensive scientific work compared to other sites such as Sterkfontein and Swartkrans. Thus, despite 90 years since the discovery of the Taung Child there are many things that we do not know about the fossil, including its age and the local environments in which it lived. Yet these are extremely important questions given how little we know about early hominin evolution in southern Africa outside the 300 km^2 dolomite area of the Cradle of Humankind, or outside the time range between 2.6 and 1.4 Ma (Herries *et al.* 2009, 2013). Moreover, virtually nothing is known about the other sites at the Taung World Heritage Site, other than Equus Cave, whose exact age is still a matter of debate (Johnson *et al.* 1997). These other sites potentially preserve a rich record of the Middle Pleistocene to Holocene period. Investigations into the fossil and archaeological remains of this time period are sparse for the interior regions of South Africa. Black Earth Cave remains essentially unstudied beyond Peabody's (1954) very limited description of work at the site. While the Type Site may always remain the primary focal point of scientific interest at Taung, these lesser-known sites are potentially critical for illuminating the true expanse of time preserved at the heritage site.

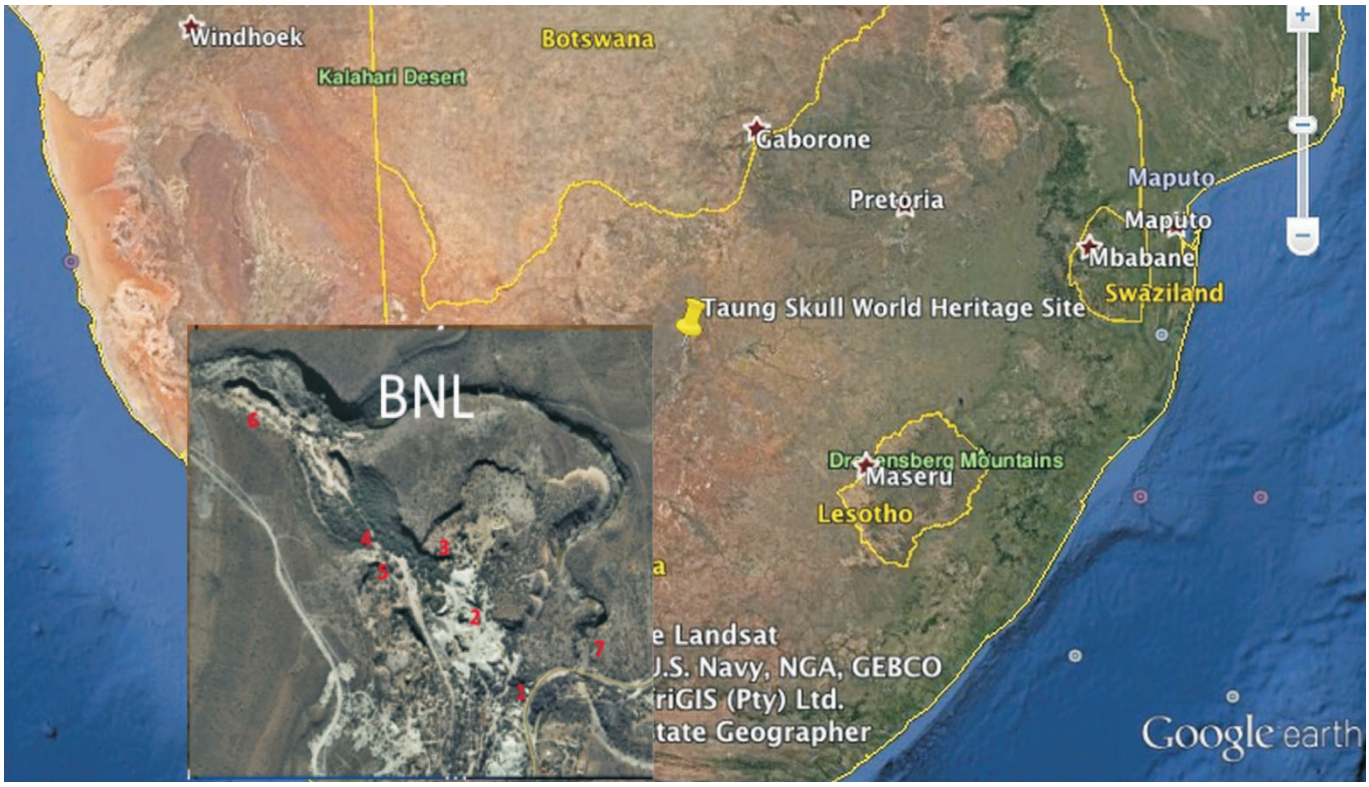

Figure 1. Map showing Taung in South Africa. The Buxton-Norlim Limeworks is 16 km south west of Taung. 1 is the location of the dump prior to recovery. 2 is the location of the Type Site. 3 is the location of Black Earth cave. 4 is the location of Quinney Cave. 5 is the location of Equus Cave. 6 is the Oxland large mammal site and 7 is the location of Power House Cave.

In an effort to address these issues, a multidisciplinary team of international scientists (from South Africa, Australia and the U.K.) returned to the BNL in 2010 to gain a better understanding of the geology, palaeontology and archaeology of the site and to review previous interpretations. Current results of this renewed research are presented below according to site and interpretive focus, which includes the Type Site (geology, site formation and geochronology), Black Earth Cave (BEC; palaeontology) and Equus Cave (EQC; archaeology); as well as work on the overall sequencing of geological events at the Limeworks. A discussion of the historical interpretations of these sites is presented along with preliminary reinterpretations and discoveries resulting from the current research. These results demonstrate a significant need to reinvestigate and reinterpret the BNL localities using a wider research perspective than previously employed. The localities described below form an initial stage of ongoing investigation that will provide new insight into the potential for multidisciplinary studies at the BNL. In turn, this renewed agenda will re-establish the significance of the BNL as preserving a rich record of fossil and artefact accumulations that span well beyond the time of *Australopithecus africanus* stretching from the Pliocene to the Holocene.

THE TYPE SITE

While the Taung Child's exact provenance was not recorded during its removal from what is now referred to as the 'Type Site' locality (Figs 1 & 2) its association to the remaining deposits has been reasonably well established as outlined below; especially when new chronological data are taken into account. It is also well established that three main sedimentological types of deposit exist at the Type Site: the Thabaseek Tufa itself; a fluvially deposited (although with some aeolian influence), pale reddish-brown to pink claystone and siltstone (here termed PCS after terminology of Hopley *et al.* 2013); and an aeolian, yellowish-red sandstone and siltstone (here termed YRSS after the terminology of Hopley *et al.* 2013) (Butzer *et al.* 1978; Partridge *et al.* 1991; Peabody 1954; Tobias *et al.* 1993). What is debated more is the mode of deposition of the various deposits at the Type Site and their relationship to each other (discreet carapace caves, a large solution cave or landscape surface), as also outlined below.

Hrdlička (1925) notes the associations of the skull with a 'pinkish deposit' based on the skull matrix and *in situ* deposits of what became known as the Hrdlička Site or Pinnacle. Peabody (1954) conducted extensive interviews with miners who were around at the time the Taung Child skull was extracted and confirmed that it came from a location between and slightly to the south of the two remnants (the easterly Hrdlička Pinnacle and westerly Dart Pinnacle; the later also termed the *Australopithecus* Pinnacle; Fig. 2; McKee & Tobias 1994; Partridge 2000) of the Thabaseek Tufa and associated sediments that were left in place by the mine manager. The term Dart Pinnacle is used here as it does not infer an origin for the skull itself.

A number of interpretations of the geological and fossil accumulations associated with these Type Site deposits have been proposed, although they all suggest they represent a cave of some sort, as suggested by the geologist

Figure 2. North-facing photograph of the Type Site, Dart and Hrdlička Pinnacles in the BNL. Locations of cores taken in 2012, the Dart deposits and the purported location of the Taung Child Skull are all shown.

Young in 1925 and Broom in 1946 ('Dart Cave', 'Hrdlička Cave', 'Australopithecus Cave' and 'Spiers' Cave'), typical of most early hominin fossil deposits on the southern African landscape during the Plio-Pleistocene, and certainly true for the case of younger sites of Equus Cave and Black Earth Cave (see below). The hypothesis that the tufa formations were riddled with later cave systems has been widely accepted in publications describing the Type Site (Broom 1946; Butzer 1974; McKee 1993b; McKee & Tobias 1994; Peabody 1954; Tobias 1985; Young 1925). However, different opinions exist as to the nature of the caves.

Hrdlička (1925) notes the fossil material he collected as having come from a pinkish deposit. He notes that fossil turtle (actually terrapin (Pelomedusidae)) and eggs collected by the lime miners came from what was termed the 'long cave', whereas the monkeys occurred only in the in-filled tunnels and one in particular. Kuhn *et al.* (2015) recently identified eggshells from these deposits as belonging to two different, granivorous and carnivorous, avian guilds (Numididae [helmeted guinea fowl] and Aquilinae [black eagle]), the last perhaps associated with the suggested accumulator of the Taung Child itself (Berger & Clarke 1995). Hrdlička (1925) also notes that the endocasts of these monkey skulls were formed of fine reddish fill. He further notes that the remains of the tunnel from which the Taung Child was recovered could be distinguished from the surrounding limestone (tufa) by the slightly more pinkish rock. He also notes that a photograph he tried to take failed, due to lack of sufficiently clear demarcation between the filling and the surrounding limestone. So, at this early stage Hrdlička (1925) noted the occurrence of three types of deposits, the tufa itself, a pinkish deposit associated with the Taung Child skull that was not easily distinguishable from the tufa and a reddish deposit associated with monkey skulls. He also seemed to note a difference in the size and shape of these deposits in the tufa, the pinkish deposits being part of a larger cave and the reddish sediments the infill of tunnels. Broom (1948) also noted such differences between fossils collected at different periods with much lighter matrix on some fossil specimens than others. He also notes that the lighter material appears to be associated with *Parapapio antiquus,* while the darker (sandy lime) deposits contain *Papio izodi*. This is the first suggestion of a major difference that might be temporal in nature.

Peabody (1954) also notes the occurrence of two phases of deposition (other than much younger Middle Stone Age bearing fill), in the '*Australopithecus* (Hrdlička) Cave': an earlier dry phase consisting of red sand and a later wet phase consisting of horizontal layers of pure lime intercalated with layers of red sandy limestone. He additionally notes that both contain fossils and differ from each other in terms of colour, matrices and preservation of fossils. Early thin section analysis by Peabody (1954) suggested little difference between these two deposits and the matrix of the Taung Child skull, except subtlety in grain size. Peabody (1954) also notes the apparent large size of this 'long cave'. Peabody (1954) concludes that the earlier dry phase consisting of massive red sandy limestone that is then overlain by a wet phase of pure lime with intercalated layers of red, sandy limestone. The supposed earlier dry phases contained small mammals, rodents, baboons, crab (Potamonautidae) and terrapin fossils, whereas the later wet phase just baboons and small antelope. The occurrence of terrapins and crabs in his dry phase seems strange when such fossils were not noted in his wet phase. Peabody (1954) notes that the younger wet phase has calcitie formation seen on the Taung Child, but not seen in the older red phase and thus associated the Taung Child with the younger wet phase. Peabody (1954) then notes two younger phases of deposition, a massive fossilless, red sandstone and Middle Stone Age bearing black earth.

Butzer (1974) undertook sedimentological analysis of Peabody's (1954) wet (Taung Child Matrix) and dry phases and described the dry phase as sand and the wet phase as clayey silt. He further noted that the tufa itself contains detrital grains in the form of clayey silt and that pink to reddish-yellow pockets of sediments are commonplace. Butzer (1974) suggests that the dry phase is pinkish sand with tufa clasts and is similar to other reddish deposits containing baboon fossils. This contrasts with the wet phase skull matrix, which is also pink, but more fine-grained and with a lot of veins of calcite. He suggests this is a derived soil mixed with aeolian sand and that it compares most closely with the younger Norlim Tufa rather than being an aeolian sand like most secondary tufa fills. Butzer (1974) notes for the first time that 'turtle' carapace came from the Taung Child matrix, suggesting that the aquatic fauna described by the miners likely came from the wet-phase of Peabody (1954), thus stating the opposite of Peabody (1954) in this regard, and the long cave deposit described by Hrdlička (1925). He also suggests that all the baboon and perhaps macrofauna come from the dry phase sand and thus it has little to do with the Taung Child period of deposition. He follows Peabody's (1954) view that the dry phase is older than the wet phase. However, Butzer (1980) later suggests that there is no sedimentological difference between samples in Peabody's (1954) so-called wet and dry phases and that these 'baboon sands' are distinct from the matrix of the Taung Child, despite terrapin fossils apparently occurring in both the Taung Child matrix and Peabody's 'dry phase'.

Partridge *et al.* (1991) undertook a further sedimentological study of the exposed deposits around the Dart and Hrdlička Pinnacles and the matrix associated with the Taung Child itself. As in the earlier studies, Partridge *et al.* (1991) define a pink fill consisting of silt (26%), sand (35%), and clay (39%), thus comparable to Peabody's (1954) wet phase and matrix of the Taung Child as described by Butzer (1974) and a Red Fill of silty sand (74%), potentially comparable to the dry phase of Peabody (1954); 'Baboon Sands' of Butzer (1974). Partridge *et al.* (1991) also note a difference in the preservation of fossils in the two deposits, as also noted by Peabody (1954). Partridge *et al.* (1991) note for the first time that the red phase has filled cavities eroded through the older pink phase, inverting the sequence of the wet and dry phases suggested by Peabody (1954) or at least the baboon sands and hominid matrix as termed by Butzer (1980) for Partridge *et al.*'s (1991) red and

pink fill. Partridge *et al.* (1991) also note the remarkable similarity of the pink phase from the Hrdlička Pinnacle and the matrix of the Taung Child skull, concluding that the Hrdlička Pinnacle pink deposit sampled was a remnant of a much larger cave system that included the Taung Child deposits.

McKee (1992; also in Tobias *et al.* 1993) was the first to suggest that more than one fossil-bearing 'deposit' (i.e other than the Hrdlička deposits that were the focus of attention prior to the 1990s) occurred in the Thabaseek Tufa, at the base of the Dart Pinancle (McKee 1993a). He suggests that this Dart deposit is older than the Hrdlička deposits (which were already shown to contain two deposits other than the tufa itself) because it grew from west to east. In contrast, Tobias *et al.* (1993) caution that previous studies (Young 1920; Peabody 1954; Butzer 1974, etc.) suggested that the Hrdlička deposits were part of a labyrinth cave system that may have formed across and through the layering and growth of the tufa. This is in contrast to McKee's (1993a) idea that caves always form as carapace caves close to the front of tufa growth. This indicates that McKee and Partridge (both authors on the Tobias *et al.* 1993 paper) obviously had differing views on the stratigraphy and formation of the Type Site deposits. Both may be true as the early work also talks of both caverns and tunnels. McKee & Tobias (1994) also suggest that the PCS deposits of the Dart Pinnacle are more in keeping with the reconstructed site from Peabody's (1954) interviews with miners and as recounted to Partridge *et al.* (1991) by the son of a miner from 1925.

Partridge expanded the results of his sedimentological study in Tobias *et al.* (1993) and further confirmed the conclusion defining a pink to light reddish-brown fill (Pink Fill; PCS) and a yellowish-red fill (YRSS; Red Fill) in the Hrdlička Pinnacle and a similar pink fill (PCS) in the newly discovered and excavated Dart deposits. He also again concluded that the similarity of the Taung Child skull matrix to pink deposits at the base of the Hrdlička pinnacle and suggested the skull came from those deposits. While this two-phase model of sediment types, and thus deposits, dominated prior to the 1990s, McKee (1993a,b; *et al.* 1994), during his excavations, attempted to define separate carapace caves infilled with these deposits. McKee (1993a) uses the fact that the sediments of deposit H-B (McKee & Tobias 1994 defines this as pink heavily calcified with interfingered decalcified, loose sandy red breccia; he also suggests it corresponds to Peabody's [1954] wet phase; 38-5b locality) do not cut across the tufa as might be expected with a solution cavity. He notes that a solution cavity (much younger MSA bearing Black Earth Pipe) did later intersect the H-B sediments cutting across the tufa beds, as is also the case for deposit H-A (Red Fill) that contains very eroded bones. McKee (1993a) also notes that bones extend from the sediment into the tufa in deposit H-E, a situation not compatible with a later solution cavity, but suggesting formation at a time close to the tufa itself. McKee (1993b) notes that only *Parapapio antiquus* was found in H-B, whereas in H-E only *Papio izodi* was found, suggesting some vertical temporal variation in the Hrdlička Pinnacle; despite his suggestion that horizontal, rather than vertical stratigraphy is most important. McKee & Tobias (1994) in a preliminary, and as yet only description of the deposits that they excavated in the early 1990s, note that H-E is also a pink deposit and that it is separated by a large amount of sterile red sand. This suggests that the vast majority of fossils recovered by the Wits excavations were from deposits containing pink fill, although the red fill contains fossils in areas. However, Tobias *et al.* (1993) note that both red and pink fill is found in 'deposit' H-B, which in itself suggests that either these two deposits are synchronous or that this 'deposit' has sampled deposits, and thus fossils, of different ages.

In the Dart A deposit, McKee (1993a) suggests that both carapace and solution caves occur. He notes in deposit D-D that the pink breccia is horizontally bedded. It is his firm view that the Taung Child comes from these pink Dart deposits and not from the Hrdlička Pinnacle as suggested by Partridge *et al.*'s (1991) work. McKee (1993) quite rightly suggests that similar sedimentological characters could be found in different caves of different time periods and points out inadequacies in Partridge's Member systems at sites such as Makapansgat (Latham *et al.* 1999, 2003). As such, it could be possible that both PCS and YRSS deposits were deposited in the Dart deposits and then in the Hrdlička deposits. However, our recent work (Hopley *et al.* 2013) suggests that these two deposits have different magnetic polarities (PCS and Tufa are normal polarity and YRSS is reversed) and thus could not be synchronous. Instead this suggests that PCS may have formed across the two pinnacles and subsequently eroded through by solution cavities and infilled with YRSS; as envisioned by Partridge *et al.* (1991). Partridge (2000) again firmly asserts his view of the occurrence of a cave across both deposits with two main fills, a pale reddish-brown clayey infilling of fluvial origin and the yellowish-red sandy aeolian deposit. He further asserts that the pink infill underwent dissolution and channelling before the younger red sediments were deposited but that cercopithecoid remains occurred in both deposits. The confusion over Peabody's wet and dry phase and associations to pinkish or reddish deposits seems to stem from the fact that in some areas the older 'pink phase' has sandier components that are redder in colour and as such likely sample the same older 'pink phase' as defined by Partirdge. This is confirmed in our preliminary work by these older pink fluvial deposits having a normal polarity and the younger aeolian red sandstone deposits having reversed polarity.

Recently, Hopley *et al.* (2013) have proposed an entirely different model for the formation of the Type Site deposits of the Dart and Hrdlička Pinnacles. This potentially explains much of the contrasting data from the previous work. Thin section work undertaken on the pink sediments of the Dart deposits indicates that it contains microfossils and features indicative of a palaeosol that would have formed in on open, rather than a cave environment. When this is combined with macrofossil evidence for terrapins, crabs, bird eggs, ground nesting bees (Parker *et al.* 2016) and the stems of reed plants as described by McKee & Tobias (1994) it suggests that the

normal polarity pink deposits (PCS) likely formed at the same time as the normal polarity tufa. This could be in the manner envisaged by McKee (1993a) with the deposits forming in a carapace cave. However, in other areas of the BNL similar pink deposits can clearly be seen to be layered within the Thabaseek Tufa and represent phases of landscape stability and erosion, as shown by the large number of tufa blocks within the deposits. Similar tufa clasts can be seen in the pink Dart deposits. In contrast, the reversed polarity yellowish-red sandstone (YRSS) later filled caves formed within both the tufa and PCS.

McKee (2015) responded to Hopley *et al.*'s (2013) model and argued that PCS is not a single unit but a reoccurring type. This is actually made clear by Hopley *et al.* (2013) where they describe the interbedded nature of PCS-like deposits in the Peabody Pinnacle. PCS should be considered a type of deposit, not a single unit. McKee (2015) notes that his deposits H-E and H-B are different from H-A despite the commonality of the pink carbonate. In fact, deposit H-A seems to consist of yellowish-red sediment based on our work and that would be more consistent with the later YRSS infill, not the older PCS. This explains the difference McKee (2015) notes in preservation of fossils. Overall McKee (2015) agrees that much of Hopley *et al.*'s (2013) model could be correct, but argues this to not be the case for the PCS fills of the Hrdlička pinnacle due to the shape of the deposits he excavated. Part of the issue is that McKee has provided only a very preliminary description of his excavations (in McKee & Tobais 1994) that makes it difficult to reconcile them against the *in situ* stratigraphy.

McKee (2015) continues to argue that the PCS deposits of the Dart Pinnacle, from which there is extensive evidence the Taung Child was recovered, are older than those of the Hrdlička Pinnacle. This is entirely possible as the tufa dips steeply between the Dart and Hrdlička Pinnacle and as such, McKee (2015) is correct that the PCS of the Dart deposits are likely older than the PCS of the Hrdlička Pinnacle, which are in turn older than the YRSS cave fill deposits across the two pinnacles. As described in Hopley *et al.* (2013) this would further mirror the interlayered nature of PCS and tufa within the Peabody Pinnacle. The similar normal polarity for PCS in both Dart and Hrdlička Pinnacles as well as the tufa suggests this all formed within the same polarity zone; perhaps 400 000 years of deposition based on the palaeomagnetic interpretation of Herries *et al.* (2013). All the evidence clearly shows that PCS formed synchronously with the tufa, whether it was as an open-air deposit or a carapace cave. The crab and terrapin fossils (now in the collections of the Ditsong National Museum of Natural History), eggshell, ground nesting bees and fossil reed stems suggest that these deposits perhaps formed around pools within the tufa during phases of active erosion, that would have punctuated phases of formation of the Thabaseek Tufa. Such pools can be seen today formed within the Blue Pool Tufa at the BNL. Such cycling of phases of tufa formation, landscape stabilization and erosion is well documented along the Ghaap Plateau escarpment (Butzer *et al.* 1978; Curnoe *et al.* 2006; Doran *et al.* 2015). Moreover, early descriptions of a 'long cave' (Hrdlička 1925) forming over a very wide area may also suggest it was not actually a cave, whereas, the early description of tunnels may relate to the YRSS cave fills.

As outlined above, the palaeomagnetic analysis of the Type Site deposits indicates that the tufa and PCS micrite both have a normal magnetic polarity, while the YRSS has a reversed magnetic polarity (Hopley *et al.* 2013). This adds further evidence that PCS and the tufa were formed synchronously as suggested by Hopley *et al.* (2013) and that YRSS formed through the two deposits later. While Delson (1988) and McKee (1993a) have suggested biochronological age estimates for the deposits of between 2.6 and 2.3 Ma, these are based on the assumed age of many of the South African sites before recent chronometric dating that has significantly revised the age of correlated sites in many cases (Herries *et al.* 2010, 2013). Therefore these direct dates should be considered more accurate than the older biochronological estimates, and the older estimates no longer used without a reanalysis of the biochronological data. While McKee (1993b) suggests that few fossils are associated with PCS and the Taung Child, our research suggests that a large number of fossils in the collections have a matrix identical to PCS that are deposited within the same magnetic polarity zone. Thus while the deposits and fauna might not be exactly the same age, having come from a later layer of PCS compared to the skull, the age difference is likely not great and a reassessed biochronology of this later deposit is likely to help assess the age of the polarity zone and Taung Child. Others fossils have both YRSS- and PCS-style matrix. These fossils also likely came from the older PCS deposits given they are partly encased in the older PCS and it is known that solution tubes later in-filled with YRSS eroded through both the tufa and PCS, and around fossils (Partridge *et al.* 1991). Until the detailed publication on the contexts of the Wits excavations is published there will always remain some degree of uncertainty in the association of fossils with mixed matrix to the older PCS or younger YRSS in the Hrdlička Pinnacle; whereas there is no issue with the association of the fossils from the Dart deposit to PCS.

Given the age of *Australopithecus africanus* in South Africa (3.03–2.01 Ma; Herries *et al.* 2013) it seems likely that the PCS deposit and the Taung Child were deposited during the Gauss Chron between 3.60 and 2.58 Ma, although perhaps more likely contemporary with the Makapansgat Limeworks between 3.03 and 2.58 Ma (Herries *et al.* 2013). If the Dart PCS is indeed older than the Hrdlička PCS then it might be that the Dart PCS fossils and Taung Child skull are closer to, or possibly older than, 3.03 Ma, making it one of the oldest, if not the oldest hominin in South Africa, whereas the fossils from Hrdlička PCS maybe closer to 2.58 Ma. The fact that the tufa and PCS formed at a similar time also means there is the likelihood that a uranium-lead date could be associated to the skull.

Prior biochronological analysis (Delson 1988; McKee 1993a) indicated that Taung likely formed at the same time as Sterkfontein Member 4 or between it and Swartkrans Member 1. Based on recent dates (Pickering *et al.* 2011;

Figure 3. Fossil-bearing breccia dump, fossils without tags (primate maxilla) as well as tags without associated fossils left by the 1988–1993 excavation team and found in an old warehouse at the BNL in 2010. This material has now been recovered and is under study.

Herries & Shaw 2011; Herries *et al.* 2013; Herries & Adams 2013) this would place the site around 2.6–2.0 Ma. Based on the polarity this is impossible, as deposits of this age would have to have a reversed polarity, like the YRSS deposits. An age in the earliest part of the Matuyama reversed polarity Chron (2.58–1.95 Ma) is thus likely a good age for the YRSS deposits. The older normal polarity deposits thus may have formed just prior to 2.6 Ma during the Gauss Normal Chron between Sterkfontein Member 4 and Makapnsgat Member 3

An extensive number of other well-preserved fossils, including many primates, were also recently discovered by our team abandoned in a large pile in the corner of an old storage shed at the BNL (Fig. 3). Tags associated with the fossils indicate they are from the 1988 to 1993 University of the Witwatersrand Medical School excavations with material represented from every year of excavation. Unfortunately many of these fossils have lost their association because the bags they were stored in have rotted away. However, we have started a programme to recover this material and have begun looking at the distinctive matrix of the fossils to associate them to either the PCS or YRSS depositions based on sedimentology and geochemistry. Many of these have pink (PCS) matrix and so the number of fossils available for an updated biochronology and to help reconstruct the environment in which the Taung Child lived is more extensive than previously thought. This, combined with research on previously accessioned material, is ongoing and will be the focus of future publications.

While almost all the PCS deposits have recorded a normal polarity and the YRSS deposits a reversed polarity there are a couple of exceptions. Some reversed polarity directions appear to occur in the top of the PCS deposits at the base of the Dart Pinnacle and this may suggest this deposit formed across the Gauss–Matuyama boundary at 2.58 Ma; however, this needs further confirmation, along with an analysis of tufa that is stratigraphically higher in the Dart Pinnacle, access to which is difficult due to a thick overburden of mining waste. Single normal and intermediate polarities were also recorded at the top of the Hrdlička Pinnacle. This deposit represents a series of stratified YRSS deposits (McKee & Tobias's, 1994 H-A deposit) and flowstone spelothem that has infilled a solution cavity at the top of the Pinnacle. It is possible that this deposit records a short normal polarity episode within the Matuyama Chron such as the Huckleberry Ridge event at ~2.05–2.01 Ma as recorded at Sterkfontein and Malapa (Herries & Shaw 2011; Pickering *et al.* 2011). The flowstone itself has been sampled for uranium-lead analysis and work is forthcoming. Further geochronological work is also being undertaken with electron spin resonance dating. Currently, the best age estimate for the Taung Child is between 3.03 and 2.58 Ma.

FORMATIONAL HISTORY OF THE BNL AND THE EXTENT OF THE THABASEEK TUFA

Since 2010 our investigations have primarily focused on the geology of the Type Site and consisted of sampling for palaeomagnetic analysis (Hopley *et al.* 2013), isotopic analysis (Doran *et al.* 2015), uranium-lead analysis, and the recovery of newly-excavated drill cores into the base of the Dart Pinnacle and through the length of the Hrdlička Pinnacle. These were undertaken to fully understand the complex depositional history of the Type Site. Partridge (2000) undertook similar core drilling of the Hrdlička

Pinnacle but never published a full description of those cores, which have yet to be re-located. Partridge (2000) recovered Precambrian basement rocks at a depth of >50 m from the top of the Hrdlička Pinnacle and inferred a broad 'L' shaped escarpment buried underneath the Thabaseek Tufa. In contrast, our cores, which were drilled adjacent to the core hole markers left by Partridge (2000) yielded different results. The underlying Precambrian shale was reached at a depth of 10.6 m below the base of the Dart Pinnacle and 48.5 m below the top of the Hrdlička Pinnacle. As the Hrdlička Pinnacle core is at an elevation of 7.5 m above the Dart Pinnacle core, the tufa is 30.4 m deeper where the Hrdlička Pinnacle is located, compared to where the Dart Pinnacle is located, despite only 62.3 m horizontal separation between the cores (Fig. 2). This indicates that there was a very steep and possibly a stepped escarpment (or valley) through or over which the Thabaseek river flowed, producing a >50 m thick succession of riverine, lacustrine, palustrine and pedogenic sediments. Our cores also suggest the depth of the tufa in the Hrdlička Pinnacle is at least 8.5 m deeper than estimated by Partridge (2000). The base of the cores consist of breccia that transition into shale. The edge of the Ghaap Plateau consists of a stepped escarpment where insoluable shale layers occur within the dolomite and the tufa seems to have formed over a similar steeply stepping escarpment as occurs at the BNL near Berger Cave and is similarly visible at Groot Kloof Locality D further down the escarpment, as well as at numerous places along the escarpment today (Butzer 1974; Curnoe *et al.* 2006). Between the Dart and Hrdlička Pinnacles, adjacent to the location of the 'Peabody Pyramid', the tufa can be seen to go from horizontal deposition, as seen all around the base of the Dart Pinnacle, to steeply dipping deposition (Hopley *et al.* 2013). This depositional change may mark this cliff edge. This is perhaps the best evidence to date that the tufa and PCS deposits in the Hrdlička Pinnacle may be younger than those in the Dart Pinnacle, as envisaged by McKee (1993a). Throughout the Hrdlička core numerous small cave conduits filled with more lightly consolidated yellowish-red sandy sediments occur consistent with the YRSS deposits (Fig. 4). Moreover, at a depth of approximately 40m the core hit an open void of 2.46 m, suggesting that a possible cavity exists near the base of the tufa. More detailed analysis of the core is ongoing to help understand the stratigraphy and palaeo-environment of the Thabaseek Tufa, as well as to date the entire sequence with palaeomagnetism and U-Pb.

Currently, the geological structure of the BNL is interpreted as a succession of lacustrine, riverine and palustrine tufas and calcretes modified by karstic processes as outlined by Peabody (1954), Butzer *et al.* (1978), Partridge (1985), McKee & Tobias (1994) and Hopley *et al.* (2013). Our recent survey work also suggests that previous interpretations regarding the layout and formation of the various tufa flows need revisiting. For example, Peabody (1954) argued that the Thabaseek Tufa was the oldest at Taung, however, the Norlim Tufa, into which Black Earth Cave is eroded, actually sits beneath the Thabaseek and was extensively eroded before the Thabaseek was deposited on top of it (Fig. 5). This major erosional contact can be seen along the northern and eastern edge of the North-East Quarry (Fig. 6). The two tufas are easily distinguished, as the Norlim Tufa has a grey colouration and greater inclusions, whereas the Thabaseek Tufa consists of purer calcium carbonate with a yellow to white colouration. The purer nature of the Thabaseek Tufa is the primary reason that it appears to have been mined more extensively. For the majority of the North East Quarry area the Thabaseek Tufa has been removed down to the contact with the Norlim Tufa, which was mined away in a few areas, such as to the south of Black Earth Cave. This has meant that Black Earth Cave itself was not mined away like many sites in the Thabaseek Tufa and remnants of the contact can also be seen near Quinney Cave in the northern part of the Eastern Quarry.

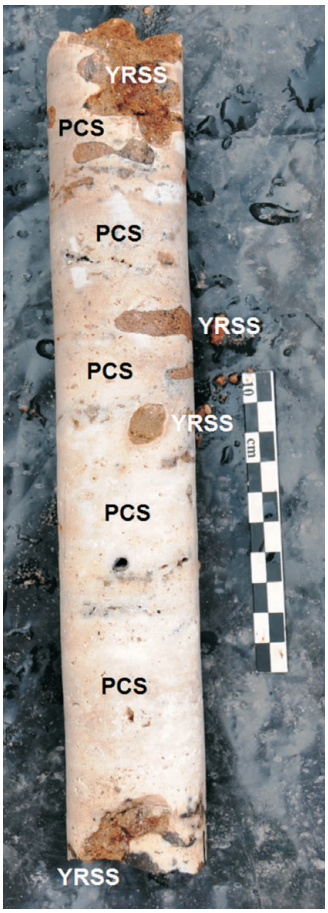

Figure 4. Part of the Hrdlička Pinnacle core showing the complexity of the stratigraphy. The pink PCS micrite contains tufa fragments from erosion of the underlying Thabaseek Tufa on an open landscape. The normal polarity PCS had obviously already become indurated, likely by later formation of the Thabaseek Tufa, before solution pockets were eroded through it and in-filled with later reversed polarity YRSS.

When Peabody (1954) visited the BNL, the extent of the mining of the tufa was at a much different stage to what it is today, as mining at the BNL continued until the 1970s. This may explain why these quite obvious contacts were not noted at the time and all subsequent researchers have followed Peabody's sequencing of the deposits (Butzer 1974; McKee 1993b; Partridge 2000; Tobias *et al.* 1993). However, Figure 3 of Peabody's Plate 2 (Peabody 1954, 976) seems to show the North-East Quarry in a similar state as today. Based on the data presented below and by

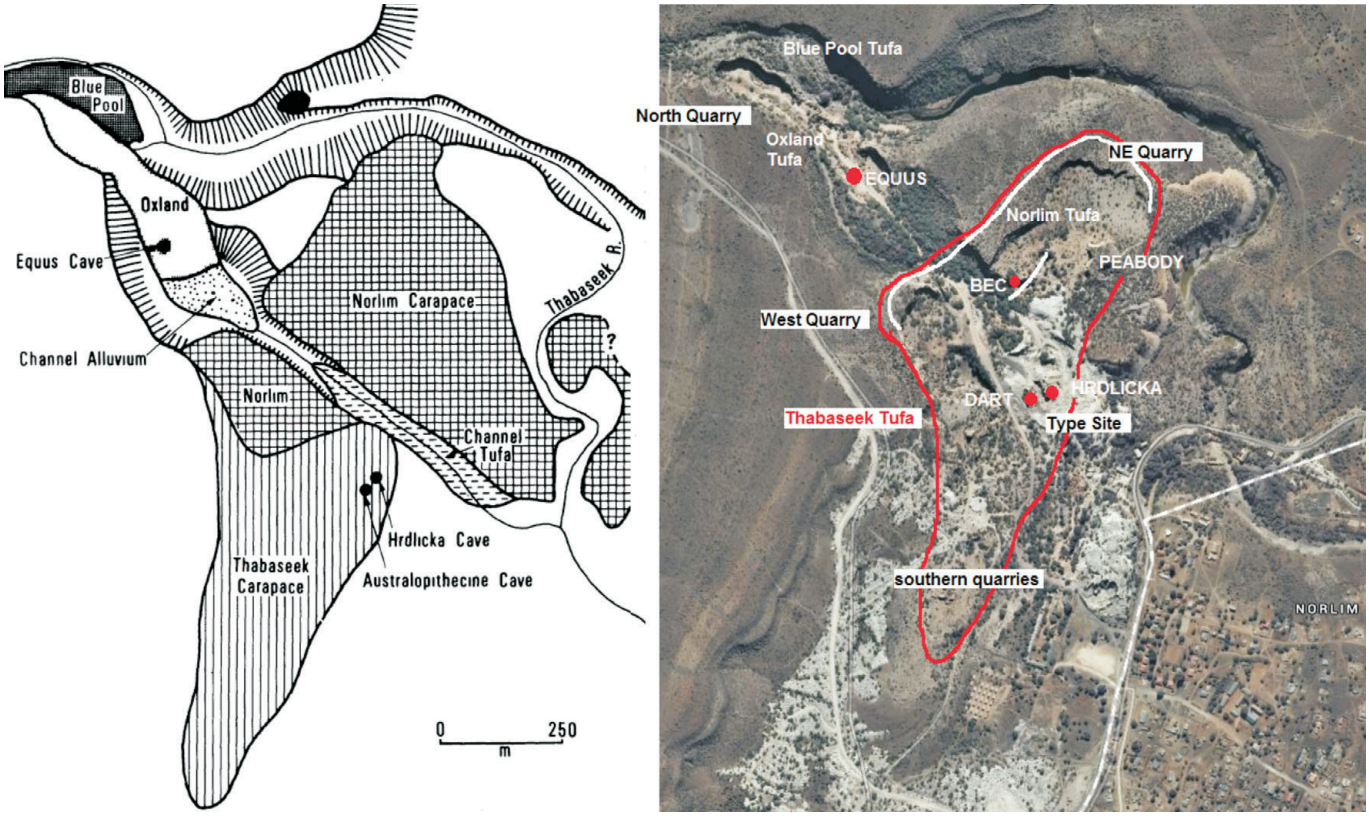

Figure 5. Sequencing of the Buxton-Norlim Limeworks tufa flows by Peabody (1954) and Butzer (1974) compared with 2014 Google Earth image showing the actual outline of the Thabaseek Tufa (red) and underlying Norlim Tufa (white). The locations of the Type Site (Dart and Hrdlička Pinnacles), Black Earth Cave (BEC) and Equus Cave are also shown.

Hopley *et al.* (2013) and Herries *et al.* (2013) the Thabaseek Tufa is considered to be terminal Pliocene to early Pleistocene in age and as such, the underlying Norlim Tufa could be considerably older. However, this does not mean that sites that are eroded within it, like Black Earth Cave, are older than the Pliocene as the geomorphic evolution of the palaeo-Blue Pool River caused it to cut through these older deposits and caused caves to be formed and in-filled within the Norlim Tufa much later.

Peabody (1954) also suggested that the Norlim Tufa occurred over the majority of what is now the North-East Quarry and also the northern part of the West Quarry. The Thabaseek Tufa is shown to occur exclusively in the Western Quarry, in the area of the Type Site and extending south to the Southern Quarries (Fig. 5), but not crossing the erosional feature that formed through the centre of the Norlim Tufa due to stream cutting by the palaeo-Blue Pool River when it was forming the Oxland Tufa; the same erosional episode that opened up Black Earth Cave. Peabody (1954) does not formally attribute tufa to the south of the North-East Quarry and across the River near Powerhouse Cave to a tufa phase, but Butzer (1974) does attribute this to the Norlim Carapace. Today the extent of the various tufas is impossible to determine as most of this area is covered by mining waste. However, the Peabody Pinnacle, which represents the southern extent of the North-West Quarry, shows evidence of only the Thabaseek Tufa, having similar interstratified pink micrites as noted at the Type Site (Hopley *et al.* 2013). This indicates either that the Norlim Tufa did not extend this far south, or that it remains buried beneath the North-West Quarry and the Peabody Pinnacle. Tracking its extent from just south of Black Earth Cave is impossible due to the occurrence of thick overlying mining waste. However, it is clear that the Thabaseek Tufa is much more extensive than previously suggested. It is also not the oldest tufa flow. The eroded nature of these tufas and the surrounding landscape since the Pliocene makes it difficult to identify their points of origin, but it is likely to have been to the Northeast of the BNL. At some point the river changed course significantly and broke through the escarpment where the road now connects the Western Quarry to the Northern Quarry. This episode also eroded a channel through both the Thabaseek and Norlim Tufas and eroded open Black Earth Cave. The Oxland Tufa formed and grew into the gap eroded through the escarpment. Part of the Oxland Tufa has been dated to ~230 ka (Vogel & Partridge 1984), similar to ages of ~250 ka for tufa from Groot Kloof, ~100 km to the southwest along the escarpment (Curnoe *et al.* 2006). This indicates that the cutting of this valley through the Thabaseek and Norlim Tufas occurred during or prior to the MIS7 interglacial. Speleothem within Black Earth Cave has produced U-Th ages in equilibrium, indicating an age of greater than 500 000 years, meaning that this flowstone must have formed before the BEC Valley was eroded through the Norlim and Thabaseek Tufas. After the deposition of the Oxland Tufa, the river again changed course, this time to the east, and eroded the rear side of the Oxland Tufa, forming the Blue Pools Tufa at sometime around 40–35 ka (Butzer *et al.* 1978). Caves such as Equus Cave then began to form within the end of the Oxland Tufa.

Figure 6. Erosion of the older Norlim Tufa before the deposition of the younger Thabaseek Tufa on the northeastern wall of the limeworks.

EQUUS CAVE

Equus Cave (EQC; Figs 1 & 7) is the next most well known site at the BNL. It is a solution cavity that opened within the western face of the ~230 ka Oxland Tufa (Butzer 1974, 1984; Butzer *et al.* 1978; Grine & Klein 1985; Klein *et al.* 1991; Peabody 1954). EQC was first excavated by Shackley & Beaumont in 1978, followed by Beaumont again in 1982, who identified four stratigraphic units (1A, 1B, 2A & 2B), approximately 250 cm in depth (Grine & Klein 1985; Klein *et al.* 1991). EQC has yielded over 30 000 fossil remains, as well as Middle Stone Age (MSA) and Later Stone Age (LSA) artefacts that are dated to the late Pleistocene and Holocene by radiocarbon dating and amino acid racemization (Johnson *et al.* 1997). The fossil accumulation is one of the largest in southern Africa spanning this time period, which has provided valuable

Figure 7. Excavations into rich archaeological talus slope deposits left at Equus Cave in 2012. The 1978 and 1982 excavations removed the entire area in the foreground and the excavation trenches were left open and have eroded extensively in the last 35 years. The wall to the right is part of the Oxland Tufa and is a wall of the now unroofed cave.

insight into environmental shifts that have occurred in southern Africa over perhaps the last 32 000 years (Grine & Klein 1985; Johnson *et al.* 1997; Klein 1986; Klein *et al.* 1991; Lee-Thorp & Beaumont 1995; Scott 1987, 1989, 2002; Sponheimer & Lee-Thorp 1999). The 13 human remains, comprised twelve isolated teeth and a fragmented mandibular corpus with two molars from EQC have provided an important biological perspective on the stasis in modern human dental variation and developmental growth patterns over the last 100 000 years (Grine & Klein 1985; Smith *et al.* 2006). However, the usefulness of these data has been limited by questions over the reliability of the dating of the site (Johnson *et al.* 1997). EQC stratigraphy and associated material has been a problematic issue since only three seemingly reliable dates from the uppermost unit have been produced, while samples from the lower units have yielded an erratic dating sequence with numerous inverted ages (Johnson *et al.* 1997; Hedges *et al.* 1995; Miller *et al.* 1992; Klein *et al.* 1991; Vogel *et al.*1986). Due to these difficulties we started new excavations at Equus Cave in 2012 with a view to reanalysing the stratigraphy and chronology of the site.

The dating for the EQC sequence is outlined in Table 1. Three coherent dates have been recovered from layer 1A, two of which were recovered from within hearth features. Charcoal from the top of the sequence dates it to 2544–2300 cal yrs[1] BP, while ostrich eggshell (OES) from the base of the sequence dates it to 8399–8050 cal yrs BP. A third sample of OES from just above the basal sample gave an age of 7576–7270 cal yrs BP. These dates suggest that layer A1 formed throughout much of the Holocene from ~8.5–2.4 ka. However, the two oldest dates are on ostrich eggshell (OES) and they do not take account of a possible Dead Carbon Fraction (DCF) occurring within the OES that could make the ages slightly older (Johnson *et al.* 1997). Given that this is a karst landscape, the OES can contain ancient, dead carbon absorbed from karstic rocks eaten by the ostriches to aid digestion.

Dates for layer 1B gave ages that are stratigraphically consistent with the 1A ages, with a date on tooth enamel from the top of the deposit of 11 618–10 754 cal yrs BP and a date of 13 871–13 446 cal yrs BP on OES from the base of the deposit. This would suggest that 1B dates to the Pleistocene to Holocene transition, however two other younger Holocene dates (~6.4–5.7 ka) on the inside and outside of the same OES fragment complicates this. While this variation may be due to a need for a DCF correction in these samples, with the site occurring at the contact between karst and non-karst landscape, and thus OES from ostriches eating carbonate and non-carbonate rocks, this latter sample is perhaps more a result of mixing from the overlying level 1A. Whether this is due to site formation processes (bioturbation, etc.) or excavation (OES falling out of the edge of the excavation wall) have caused potential mixing is a question that will remain unanswered. A third sample of OES from the top of level 1A was dated to 34 108–32 262 cal yrs BP and has been used to suggest significant bioturbation by Johnson *et al.* (1997).

No dates exist for level 2A and those for 2B are again mixed. Bone and tooth enamel ages suggest 2B dates just prior to and into the Last Glacial Maximum (LGM) with ages of 20 043–19 204 cal yrs BP and 25 531–24 375 cal yrs BP. Another bone sample has an age of 10 800 ± 270 yrs BP despite coming from the base of the sequence, but this may be due to collagen degradation. In contrast OES samples give older dates of 31 861–30 765 cal yrs BP, consistent with the OES sample found within 1A; but also younger dates of 1090 ± 55 BP again suggestive of mixing of some kind. As such, it would seem that 2B is somewhere between 32 and 19 ka, perhaps with OES ages being too old due to a DCF correction being needed and bone samples perhaps being slightly too young due to some degree of diagenesis. Layer 2A is thus perhaps somewhere between 19 and 14 ka and LGM or slightly post LGM in age. In contrast, Johnson *et al.* (1997) suggest that the 2B-1A deposits formed over the last 16.6 ± 1.3 ka, which would be partly consistent with the bone, teeth, and charcoal chronology. Butzer *et al.* (1978) claimed that the lower stratigraphic units at EQC likely predate samples taken from 2 metres below the top of the Blue Pool Tufa that produced a minimum age of 32 700 ± 1190

[1]Radiocarbon dates were calibrated using OXCAL 4.1 and calibration curve ShCal13 (Hogg *et al.* 2013).

Table 1. Conventional radiocarbon ages and calibrated radiocarbon ages (using OXCal 4.2 and ShCal13 calibration curve; Hogg *et al.* 2013) for EQC (data from Vogel *et al.* 1986 and Johnson *et al.* 1997).

Level	Depth (cm)	Material	Sample no.	Conventional age	Calibrated age
1A	~5 (top)	OES	AA17267	29 210 ± 390 yrs BP	34 108–32 262 cal yrs BP
1A (hearth)	25	Charcoal	Pta-2452;	2390 ± 60 yrs BP	2544–2300 cal yrs BP
1A	~30	OES	AA-17266	6565 ± 90 yrs BP	7576–7270 cal yrs BP
1A (hearth)	45-53(base)	OES	Pta-2495;	7480 ± 80 yrs BP	8399–8050 cal yrs BP
1B	(Top) ~55	Tooth	Oxa-4276	9830 ± 120 yrs BP	11 618–10 754 cal yrs BP
1B	~55	OES	Pta-2789	5060 ± 60 yrs BP	5907–5643 cal yrs BP
1B	~55	OES	Pta-2791	5460 ± 70 yrs BP	6321–5996 cal yrs BP
1B	(base) ~80	OES	AA-5826;	11 870 ± 105 yrs BP	13 871–13 446 cal yrs BP
2B	~145	Bone	See Klein *et al.* 1991	16 300 ± 160 yrs BP	20 043–19204 cal yrs BP
2B	~145	OES	AA-17268	1090 ± 55 yrs BP	1065–897 cal yrs BP
2B	~155	OES	AA-5827	27 330 ± 340 yrs BP	31 861–30 765 cal yrs BP
2B	~190	Tooth	Oxa-4277	20 760 ± 220 yrs BP	25 531–24 375 cal yrs BP
2B	~220	Bone	Pta4051/57	10 800 ± 270 yrs BP	13 215–11 930 cal yrs BP

B.P. (Butzer *et al.* 1978: 40 007–34 579 cal yrs BP). While this interpretation is contentious due to a lack of any supporting stratigraphic evidence, the current geochronology for the site does fit this interpretation.

Climatic conditions corresponding to the deposition of the stratigraphic units discussed above have been derived through pollen analysis from hyaena coprolites (Scott 1987) and stable carbon isotopes (Lee-Thorp & Beaumont 1995). Palynological data suggest that Unit 2A and the top of 2B represents the coolest period of deposition, averaging 4°C cooler than present temperatures and was predominantly a grassland habitat (Beaumont *et al.* 1992; Johnson *et al.* 1997; Scott 1987). This would be consistent with an LGM age for these deposits as outlined by the chronology above. Warmer conditions began to gradually prevail throughout the top of Units 2A and 1B with the introduction of increased tree pollen in coprolites when compared to those found in Unit 2B, indicating shrubby, open *Acacia* savanna conditions (Scott 1987). Again, this would be consistent with a warming of the climate from the LGM to the beginning of the Holocene, as also suggested by the existing selective chronology. Finally, the shift towards modern rainfall and temperature patterns occurred in Holocene Unit 1A, in which the Kalahari Thornveld habitat that dominates the area today originated (Scott 1987). This seems to show a gradual change in climate from cooler towards warmer conditions as might be expected over the last 20 ka, as suggested by Johnson *et al.* (1997). However, Johnson *et al.* (1997) did not sample from the majority of the 2B unit, if at all, and as such older MIS3 deposits could still occur based on the current data.

One of the most significant aspects of EQC is the abundance of fossil remains, which have yielded over 30 000 taxonomically identifiable specimens to date (see Klein, Cruz-Uribe & Beaumont 1991 for review). Species representation within the stratigraphy of EQC seems to present an interesting point of differentiation between unit 1A, composed of exclusively extant taxa, and Units 1B–2B, which include three extinct species, Bond's springbok (*Antidorcas bondi*), the Cape zebra (*Equus capensis*), and the giant hartebeest (*Megalotragus priscus*) (Klein 1986; Klein *et al.* 1991). These species represent taxa of the Florisian Land Mammal Age, which went extinct between ~16 and 8 ka (Faith 2014), again consistent with a terminal Pleistocene chronology. Furthermore, Klein *et al.* (1991: 104) have found that the average body size of carnivores from Units 1B–2B are larger when compared to their modern analogues, which corroborates the cooler conditions (Bergmann's Rule) indicated by the palynological evidence discussed above and the dating.

The analysis of the fossil assemblages from EQC has been pivotal towards interpretations of site function (Klein 1986; Klein *et al.* 1991). For instance, the presence of ground bone points typical of the LSA, hearths, cut-marked bone and the rarity of hyaena (Pa*rahyaena brunnea* and *Crocuta crocuta*) coprolites from Unit 1A has firmly attributed the accumulation of these fossil remains to human occupation (Klein *et al.* 1991; Scott 1987). On the other hand, the scarcity of artefacts, the absence of hearths and cut-marked bone and the increase in hyaena coprolites in Units 1B–2B was used to suggest that hyaenas were the principal accumulators within the lower stratigraphy (Klein *et al.* 1991). While the hyaena occupation of EQC has dominated interpretations of the site within the last two decades, renewed investigations may potentially challenge this view. If the dating samples have been mixed so extensively, as suggested by Johnson *et al.* (1997), then this must also call into question the potential mixing of other material, including the fossil and archaeological remains. Central to this dilemma are issues surrounding the long-standing debates over the attribution of the EQC cultural material to a Middle Stone Age (MSA) or Later Stone Age (LSA) context (see Morris 1991).

While the LSA context of Unit 1A has been accepted due to the corroborated dating scheme discussed above, the age and archaeology of the lower stratigraphic units remains somewhat contentious, particularly for 2B. In fact, MSA artefacts have been reported from Units 1B–2B (Beaumont *et al.* 1984; Klein *et al.* 1991; McKee *et al.* 1995), which has supported a late Pleistocene age for these deposits (Butzer 1984). However, it has been suggested that the abraded nature of the MSA lithics when compared to the fresh appearance of the LSA material supports that the MSA was potentially washed in from an open-air site further upslope from the mouth of EQC (Klein *et al.* 1991; Morris 1991; Scott 1987). Scott (1987) mentions the possibility that all the archaeology of EQC might have entered into the cave in this manner. However, this point seems unlikely due to the lack of widespread abrasion amongst the archaeological assemblage, which is currently under study by one of the authors (M.V.C.). While recent studies have labelled EQC as an MSA site (see McKee *et al.* 1995; Smith *et al.* 2006), its archaeological context continues to be obscured by the lack of systematic description of any of the cultural material from the site. Moreover, the interpretation of how fossil assemblages from the lower stratigraphic units of EQC were accumulated, i.e. a hyaena accumulation, is based on a paucity of archaeological remains in Units 1B–2B (Klein, *et al.* 1991). While this hypothesis predominates the literature, without a detailed understanding of how artefacts are distributed throughout the stratigraphy, it is difficult to confirm given recent studies illuminating cave usage patterns by multiple species (including carnivores and bovids) in South Africa (Bountalis 2012; Bountalis & Kuhn 2014). In fact, the archaeological assemblage from the site, and notably the sharp unabraided nature of most of the assemblage, consisting of thousands of artefacts also calls into question the idea that Equus Cave is purely a carnivore accumulation as it is so often described. Thus, it is imperative to describe and classify the archaeological assemblages from EQC.

Current research

In 2012 our research team re-located the un-backfilled excavation trenches of the 1979 and 1982 field seasons, which had been subjected to widespread erosion of material out of the unconsolidated sections at the site. This task was also complicated as the excavation grid was oriented at 32 degrees negative from true north, which is twice the

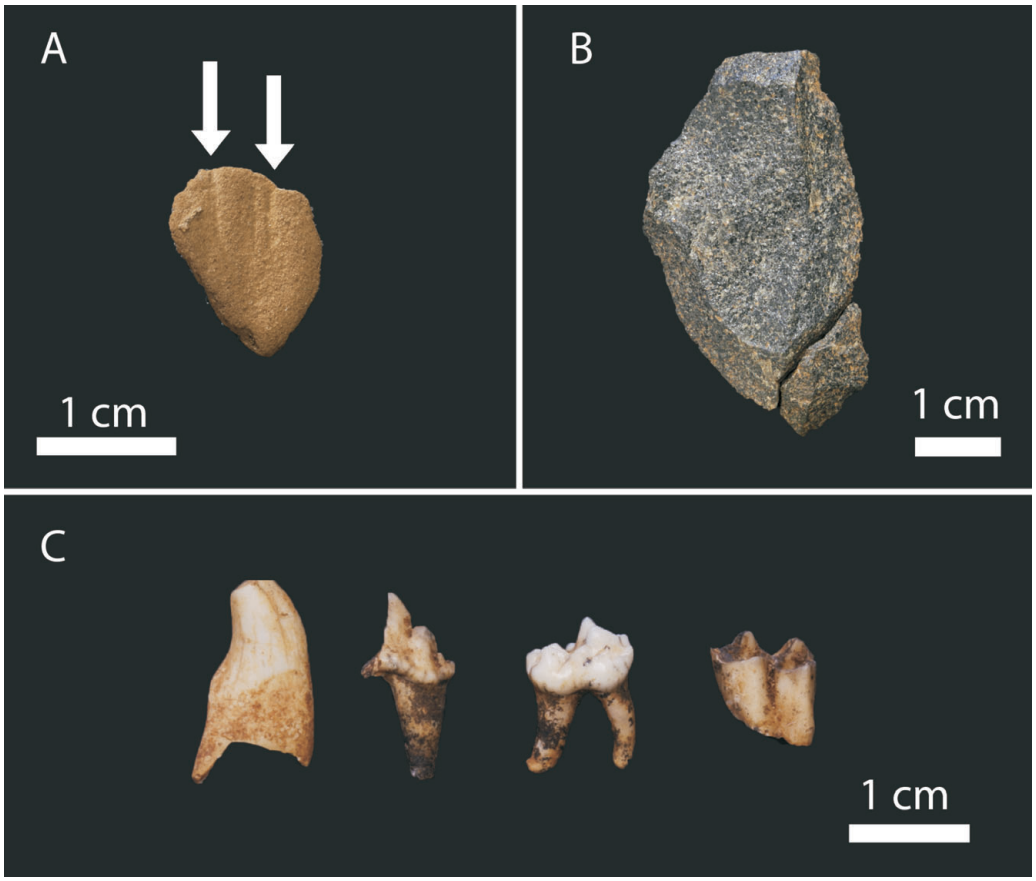

Figure 8. Remains recovered from Equus Cave. **A**, Ochre piece, arrows indicate areas possibly worked. **B**, Fresh lithic with break refit. **C**, Small teeth (Left to right: Hyaenidae canine, Canidae premolar, Mustelidae premolar, Bovidae molar).

local magnetic declination at the site. The main issue is that very little *in situ* deposits remain that can easily be excavated due to the steep and eroded nature of the site. We therefore began a 1 × 1 m excavation into a remnant of the talus cone of the cave, a feature that does not seem to have been previously excavated in any great detail.

This work has yielded a number new archaeological remains, which will aid in resolving the dispute over the presence of MSA tools at the site. Moreover, this new material includes *in situ*, possibly worked, ochre and extensive unweathered archaeological remains, including refitted material (Fig. 8) that is unlikely to have been washed into the site. This casts doubt on a purely non-human accumulation model, at least for this part of the site. In conjunction with the analysis of archaeological remains from the McGregor Museum (Kimberley, North West Province, South Africa) our research indicates that the cultural remains from EQC should strictly be affiliated with the LSA techno-complex. This ongoing analysis will be presented in detail elsewhere, which will serve as the first complete analysis of the archaeology from EQC.

Another important issue to be addressed is the loss of some archaeological material within the dumps of previous excavations, likely due to the sieving methodology (Shackley 1981). The loss of smaller teeth (see Fig. 8), generally less than 2 cm was established by excavation of the dumps of the earlier excavations in 2012. This work also showed that extensive amounts of charcoal occur in the deposits that may aid future radiocarbon dating work. In fact, numerous pieces of charcoal have so far been recovered from the *in situ* talus cone excavations and as such this is hoped to produce a robust chronology for the site independent of issues related to DCF offsets in dating OES and issues of collagen preservation in bone.

BLACK EARTH CAVE

The fossil deposits at Black Earth Cave (BEC; Fig. 9) were first noted by Peabody (1954), with excavated material sent off to the museum at the University of California Museum of Paleontology (UCMP) at Berkeley. To date this fossil material remains unpublished in detail, despite the fact that human remains were recovered. In addition, no dates have been published for the site. The site is eroded into the Norlim Tufa and was eroded through by waters draining from the formation of the Oxland Tufa (not the Thabaseek Tufa as suggested by Peabody (1954)). As such, it must have first formed prior to the formation of the Oxland Tufa at around 32 ka, although infill of the cave could have occurred after this. Peabody (1954) designated three galleries at BEC (A-C), however in the UCMP collections these are referred to as BEC1 (Gallery A; Peabody 38-14; UCMP V67279) and BEC 3 (Gallery B and C; Peabody 38-18; UCMP V67280). The small BEC2 (Peabody 38-17; UCMP V67281) collection in the UCMP is currently of unknown provenance (Justin Adams, pers. comm.).

In 2012, we surveyed the site and re-located Galleries A–C. The largest faunal collection at the UCMP is from BEC1 (A) but that site has been fully excavated of material and so no work can be done to assess its age other than directly dating fossils from UCMP or by stratigraphic

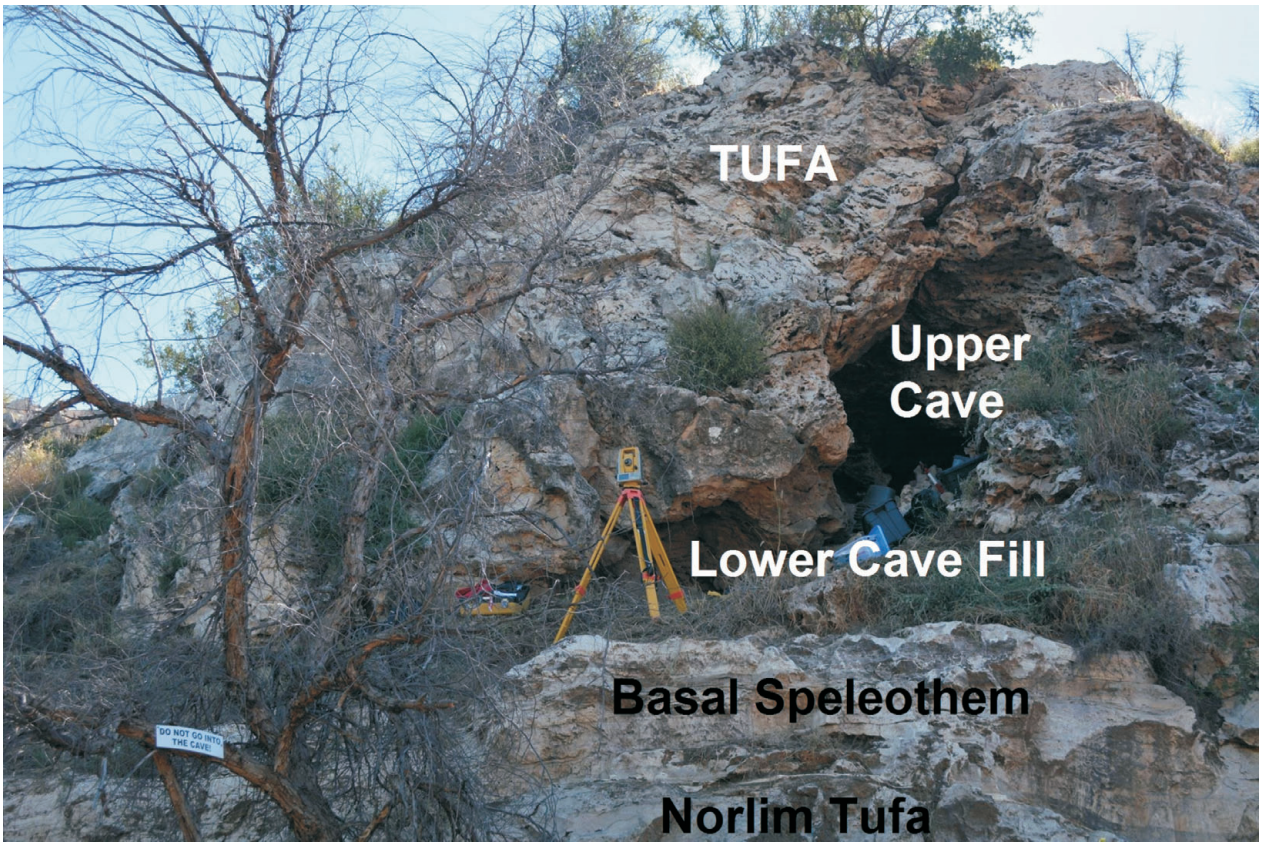

Figure 9. 2014 Excavations into the lower cave fill of Black Earth Cave gallery B. Basal flowstone speleothem >500 ka that was also discovered in 2012 is shown.

correlation. BEC1 (A) consisted of four stratigraphic zones with the upper fossil-bearing portion covering 150 cm: 1) the lowest layer consisting of sterile black clay after which the cave gets its name; 2) this is followed by 60 cm of rotted fossils in red and black streaky clay; 3) 60 cm of deposit with reddened bone and hyaena coprolites then follows from which the *Homo* fossils were recovered; 4) and is capped by 40 cm of dusty black earth, ash-bearing in parts and containing light coloured fossils and complete animal skulls.

The BEC3 Gallery C has a small trench in one side of it that may relate to Peabody's (1954) excavations. He noted few fossils from this deposit but the remaining *in situ* deposits are quite significant still. BEC3 Gallery B has also been mostly emptied, either by Peabody's excavations or due to other processes such as guano extraction and erosion. Peabody (1954) noted that most of the deposits were destroyed by mining prior to 1947 and suggested that at one time all three galleries were part of the same cave. Peabody (1954) describes the stratigraphy of Gallery B as consisting of the upper two levels of Gallery A, but with a confusing stratigraphy because of slumping and the collapse of a large roof block of tufa. The upper layer contained charred bone and a bone awl but no other evidence of human occupation. There was no evidence of the fallen tufa block as described by Peabody (1954) in Gallery B today and two clear stratigraphic layers can be seen that link to his descriptions from Gallery A and B. The inside of Gallery B contains a thin loose sediment containing abundant white fossil bone that is also scattered all over the walls and bare rock floor of the cavity. This is equivalent to the upper layers in Gallery A as described by Peabody (1954). A small section of darker earth with reddened bone occurred along the wall of the lower, exterior part of the cavity and correlates with the lower layers described for Gallery A, from which Peabody (1954) describes the only extinct species recovered from the site, that of a large horse, probably *Equus capensis* and suggesting a Pleistocene or very early Holocene age. This section disappeared beneath slumped earth that led down to the edge of the ledge that now marks the edge of the gallery. In 2014, we conducted *in situ* excavations into Black Earth Cave Gallery B at the base of this remnant section to recover datable material and explore the stratigraphy. This excavation revealed intact, *in situ* black clay and silt deposits with a number of articulated partial skeletons (one bovid and one carnivore) and a coprolite midden suggestive of a hyaena accumulation; again consistent with layer 2 of gallery A as described by Peabody (1954). No archaeology was noted and the base of the deposits was not reached. The fauna from the site is suggestive of carnivore accumulations and our excavations to date confirm this. A more detailed study of the fauna from this excavation is ongoing.

In 2012 we also identified a thick basal flowstone at the site for the first time, which is described by Peabody (1954; D in his figure 5) as the cave floor (Fig. 9). This flowstone is a few metres deeper than the current base of the excavations in gallery B and as such suggests there may be some significant depth and age to the deposits in that gallery. This flowstone also forms the ledge at the edge of Gallery B as described above. While BEC has generally been con-

Table 2. U-series isotopic and concentration data for Black Earth Cave, South Africa. All ages reported to 2σ error.

Sample name	U (ppm)	^{232}Th (ppb)	(^{230}Th/ ^{232}Th)	(^{230}Th/^{238}U)	(^{234}U/^{238}U)	Uncorr. age (ka)	Corr. age (ka)	Corr. initial (^{234}U/ ^{238}U)
BEC04	0.0356 ± 0.00003	21.3 ± 0.079	5.39 ± 0.05	1.062 ± 0.008	1.103 ± 0.003	299 ± 12	284 ± 22	1.275 ± 0.018
BEC05-A	10.6 ± 0.02	0.91 ± 0.013	35579 ± 571	1.005 ± 0.007	1.004 ± 0.001	>500	>500	n/a
BEC05-B	0.1308 ± 0.0001	1.54 ± 0.002	259 ± 0.92	1.003 ± 0.003	1.000 ± 0.002	>500	>500	n/a
BEC 11_T	0.3597 ± 0.0002	0.23 ± 0.001	5580 ± 22	1.175 ± 0.003	1.092 ± 0.001	>500	>500	n/a

Ratios listed in the table refer to activity ratios normalized to the corresponding ratios measured for the secular-equilibrium HU-1 standard. ^{230}Th ages are calculated using Isoplot/Ex 3.0 (Ludwig 2003). Non-radiogenic ^{230}Th correction was applied assuming non-radiogenic ^{230}Th/^{232}Th = 4.4 ± 2.2 × 10^6 (bulk-earth value), and ^{238}U, ^{234}U, ^{232}Th and ^{230}Th are in secular equilibrium.

sidered to be late Pleistocene in age based on the fauna listed by Peabody (1954), preliminary uranium-thorium analysis yielded ^{238}U/^{230}Th ratios in equilibrium, indicating that this flowstone is older than 500 ka (Table 2). The base of the sequence has a normal magnetic polarity and so it may date to <780 ka, or perhaps as old as between 990 and 1.07 Ma. Further palaeomagnetic analysis is being undertaken to resolve the dating, along with uranium-lead dating of the sequence. One date on a secondary calcite infill within the main flowstone dates to 284 ± 22 ka and perhaps suggests the cave was still sealed at this time; just prior to the ~230 ka age for the formation of the Oxland Tufa, which caused the erosion through the Norlim Tufa that opened the cave to the surface. Regardless, it suggests that either a long period of time occurred between the deposition of the flowstone and the opening of the cave to allow sediments to in-fill or there is the possibility that much older deposits also occur within the cave. Excavations have so far progressed as far as a sterile looking 'Black Cave Earth' deposit but will continue in 2017.

DISCUSSION AND CONCLUSIONS

Our work at the BNL has so far concentrated on three of the 17 identified fossil sites, the Type Site, Equus Cave, and Black Earth Cave to develop a multidisciplinary understanding of the BNL and Taung World Heritage site. This is the beginning of a long programme of work to reconstruct the entire depositional history and age of the tufa flows and associated fossil and archaeological bearing deposits. This review highlights the lack of work done on many of the sites at the BNL and the many questions that remain unanswered. The current work at the BNL has already identified a number of issues with the stratigraphic work of Peabody (1954) and subsequent authors and shows that the Thabasek Tufa is not the oldest tufa flow at the site. It is also much more extensive than previously thought.

Our preliminary work at the Type Site suggests that the Taung Child (*Au. africanus*) skull is not associated with a cave but the older, PCS open air, Pliocene deposits that have an unusual aquatic fauna (crabs and terrapins). Our current best estimate for the age of the Taung Child is sometime between 3.03 and 2.58 Ma, making it contemporary with, or perhaps even slightly older than the *Au. africanus* remains from the Makapansgat Limeworks. Depending upon validity of recent work by Granger *et al.* (2015) with regard to the age of 'littlefoot', the Taung Child is one of, if not the oldest, hominin fossil in South Africa. A much larger number of fossils appear to be associated with this older PCS deposit than originally suggested and this makes reconstructing the environment at the time when the Taung Child was alive a distinct possibility. In addition we have begun the recovery and analysis of a large number of fossils that were abandoned at the BNL between 1988 and 1993. Abundant fossils also occur at the Type Site from the same period as Sterkfontein Member 4 and these did infill a series of fissure caves eroded through PCS and the tufa.

Renewed excavations at Equus Cave has recovered archaeological material, such as stone tools and utilized ochre, inconsistent with the current interpretation of the site as solely a hyaena den. Parts of the site do fit this pattern, but this new work suggests that carnivores and humans occupied the cave at different periods. Our work at EQC has also shown that a large number of smaller fossil elements (particularly teeth <2 cm) were lost in the excavation dumps from the 1970s and 1980s. The sampling at the site is thus biased towards larger elements, which can only be resolved through continued excavations. Furthermore, our work at Black Earth Cave has identified a thick basal flowstone for the first time that dates to >500 ka and suggests that the depth of that cave is much greater than previously expected. We have also re-located *in situ* deposits at BEC with no evidence to date for archaeological material, but evidence for hyaena occupation in the form of a coprolite midden. Partial skeletons were also recovered including that of a canid.

Together these results highlight the need for an ongoing research to reassess previous interpretations of the Taung World Heritage site. Furthermore, its localities preserve an important palaeontological and archaeological record of Pleistocene to Holocene transition that is rarely discussed. Thus the significance of the site ranges well beyond the discovery and the Taung Child skull discovered 90 years ago. To expand our understanding of the palaeo-scientific record preserved within the Taung localities, we employed a multidisciplinary approach that seeks a reinterpretation of previous conclusions about geological, geochronological, palaeontological and archaeological history of Taung. While the results of this renewed scientific agenda are preliminary, continued research will illuminate the importance of this site from the time of *Au. africanus* to recent hunter-gatherer occupations. The long record of time preserved within the various localities at Taung make it one of the most unique sites in southern Africa. Yet many of these localities remain unexplored and

thus 90 years after the discovery of *Au. africanus*, the true significance of Taung is still under examination.

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