FORMATION AND GEOMORPHOLOGY OF CAVES IN CALCAREOUS TUFAS AND IMPLICATIONS FOR THE STUDY OF THE TAUNG FOSSIL DEPOSITS

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SUMMARY

Models of cave site formation processes in calcareous tufa accretions are necessary for the interpretation of fossiliferous cave deposits exposed by quarrying and excavation. The ancient system of caves in the Thabaseek tufa at the Buxton Limeworks near Taung yielded the Taung hominid skull, type specimen of *Australopithecus africanus*, in 1924. Since then no consensus has been reached concerning the precise location of the Type Site, the geological age of the Taung hominid or the nature of the caves in which it became interred. Recent excavations of fossil deposits in the Thabaseek tufa, near the putative Type Site, in association with the historical records, have revealed new clues as to the provenance of the Taung hominid and the nature of the cave from which it was excavated. An investigation of caves in tufa accretions of the Ghaap escarpment and Eastern Transvaal has revealed four types of tufa caves that can be used as models for analysis of the fossil deposits. These include carapace caves, pipes (solution cavities and potholes), river-carved rock shelters, and vadose caves. The nature of the Taung fossil deposits suggest that the hominid and associated fossils were deposited within a series of successive carapace caves in the Thabaseek tufa. The relative positions of these deposits, with the putative Type Site being the deeper primary carapace cave within the Thabaseek tufa, suggest that the Taung hominid predates most of the fauna thus far used for dating of the formation.

INTRODUCTION

After quarry operations at the Buxton Limeworks released the Taung hominid skull in 1924 from an ancient cave deposit, much of the context of the skull was destroyed by further blasting (Young 1925, Hrdlička, 1925). Subsequent investigations of the hominid 'Type Site' and related cave deposits in the area have thus been as enigmatic as the child skull itself. Reconstruction of the cave environment in which the hominid was deposited depends in part on interpretations of the scant records of the fossil site in 1924 and shortly thereafter. Further insight may be gained from the models of cave formation processes provided by the karst systems that have formed or are presently forming in the Taung area and similar environments.

Numerous cave systems in the Taung district of Bophuthatswana are found in the calcareous tufa deposits that formed along the Ghaap escarpment, at the south-eastern margin of the Kalahari Desert. The tufa formed in an accretionary manner from a calcium bicarbonate solution of water that emanated from springs in the Ghaap Plateau Dolomite Formation; through the photosynthetic action of moss and algae and evaporation, layers of calcium carbonate precipitates accumulated as successive hemispherical sheets of nearly pure lime (Young 1925, Marker 1971, 1973, Brain 1985, Partridge 1985).

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Within cavities of the resulting carapaces, wind and water brought Kalahari sands, leaving deposits of unconsolidated red sands and solid pink lime matrix. It is in these 'impure' deposits that the fossil bones are most often found.

In 1919, the lime quarry operations at Buxton, in what is now the Taung district of Bophuthatswana, began to encounter the fossiliferous cave deposits at the eastern edge of the southern-most tufa accretion. This extensive deposit of cavitated tufa was named by Peabody (1954) as the 'Thabaseek tufa' and was thought to represent the oldest of four tufa formations at Buxton (Fig. 1). Most of the fossils from the cave deposits first encountered were of an extinct species of baboon, *Parapapio antiquus*, first described by Haughton (1925).

Late in 1924 the quarry exposure reached a point over 60 metres from the original eastern edge of the Thabaseek tufa (Hrdlička 1925, Young 1925, Cipriani 1928). Mr M. de Bruyn retrieved a block of pink fossiliferous breccia from a deposit on the quarry wall, a few feet to the left of a cavity filled with loose red sand (Young 1925). R. B. Young chose a sample of skulls, still encased in matrix, to provide to Raymond Dart at the University of the Witwatersrand. One of those skulls was the famous hominid skull, the type specimen of *Australopithecus africanus*.

Little attention was given by the early investigators of the Taung fossil sites to marking or recording the precise location from which the hominid skull was quarried. In order to place the Taung hominid in a palaeontological and temporal context, it is thus crucial to relocate the position of its cave deposit, referred to as the 'Type Site', and to determine its possible association with the other fossils retrieved since 1919. The locality of the Type Site can be reconstructed in part from the few historical records available. Young (1925) was the first to describe the cave site and publish a description and photograph of the quarry wall shortly after the discovery. He noted that the hominid skull came from a deposit a few feet to the left (west) of a body of loose red sand, over 15 metres from the top surface of the tufa formation. Unfortunately, quarrying continued and destroyed most of the cave deposit as well as the features illustrated in Young's photograph.

Research at the Taung site since the discovery of the hominid has been sporadic. Ales Hrdlička was the first anthropologist to study the cave deposits (Hrdlička, 1925), followed by Lidio Cipriani in 1927 and Robert Broom who visited the site in 1937 (Broom 1946). Both Hrdlička and Broom recovered a number of fossils from the remaining cave deposits. The University of California African Expedition of 1947–1948 (Camp 1948) retrieved further fossils; one member of the team, Frank Peabody, remained at the site and conducted an extensive and definitive study of the tufa formations and their caves.

Extrapolating from historical records, interviews with quarry workers who had been present in 1924, and geological investigations, Peabody (1954) reconstructed the approximate location of the discovery site (Fig. 2). In 1985, on the occasion of the Taung Diamond Jubilee International Symposium, a monument was erected at this spot. Peabody conducted a detailed analysis of cave deposits in a quarry remnant known as the 'Hrdlička pinnacle', where Hrdlička had retrieved fossil baboons in 1925, to the east of '*Australopithecus* cave' (Type Site). Peabody (1954: 682) envisioned the Type Site and

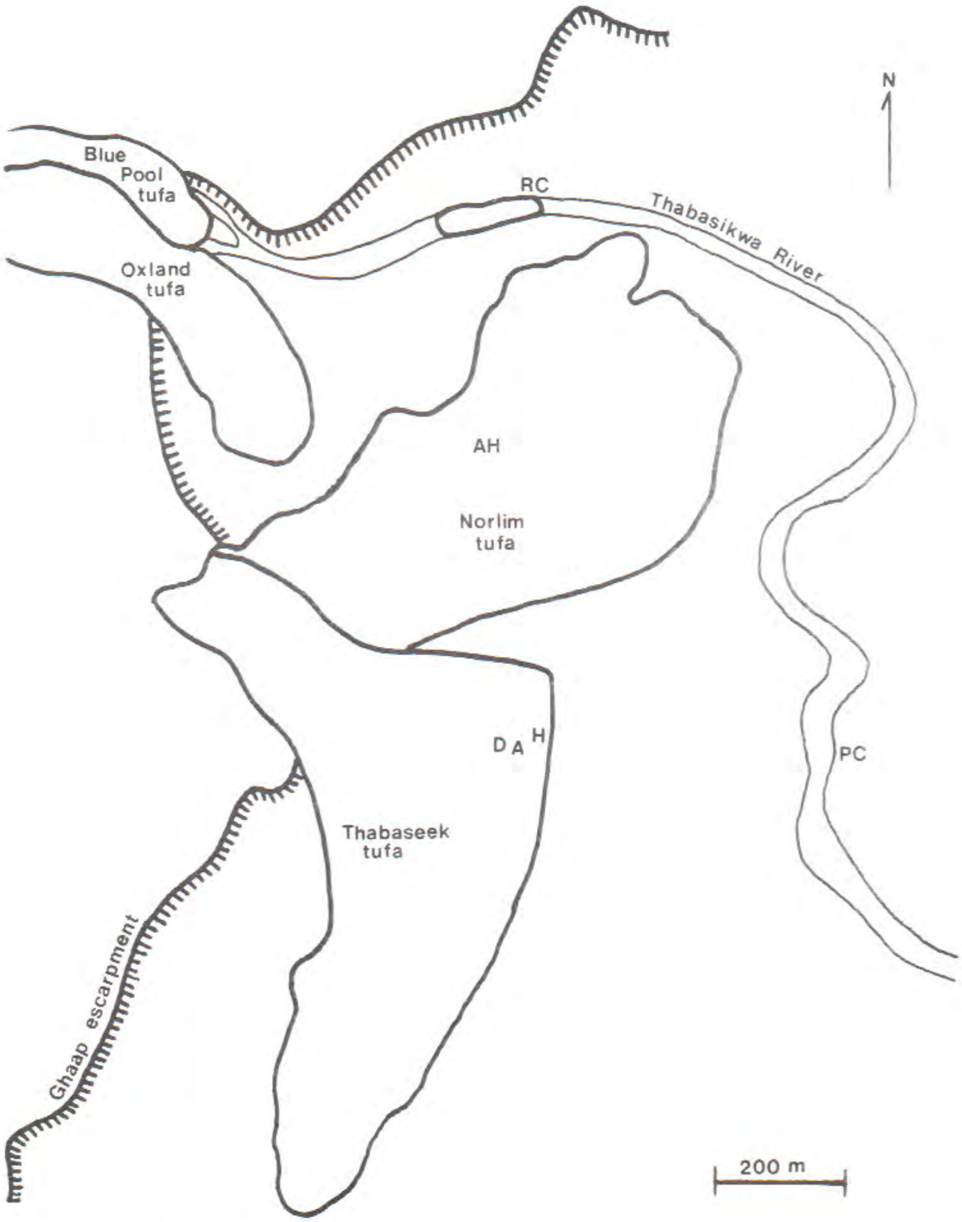

Fig. 1. Reconstructed outlines of tufa formations at Buxton, Bophuthatswana. The Taung hominid was found in the Thabaseek tufa near the point marked 'A'. 'D' = the Dart deposits, 'H' = the Hrdlička deposits, 'AH' = Acheulian Hole, 'RC' = Razor Cave (in the downstream continuation of the Blue Pool tufa), 'PC' = Powerhouse Cave. (Adapted and modified from Peabody (1954) and Partridge (1985)).

Hrdlička deposits as representing 'essentially one continuous cave system', with 'the two caves being the same or parallel galleries of one cave system developed along the strike of steeply dipping layers of travertine'. This interpretation has been used to date the Type Site by analysis of fauna from the Hrdlička deposits (Delson 1984, 1988, Cooke 1990).

Cave deposits within the Hrdlička pinnacle were interpreted as solution cavities which formed at the terminal phase of the Thabaseek tufa deposition (Peabody 1954). Butzer (1974) built a case for the solution cavity model on the basis of the cave deposits cutting across the bedding planes of the tufa, but reasoned that the cavities filled at a later stage when the next of the tufa formations, the Norlim, was accumulating.[1]

Observations of *in situ* breccia remaining in quarry remnants near the Type Site, located during reconnaissance visits between 1982 and 1987, led P.V. Tobias to initiate a programme of systematic excavation of the Taung fossil deposits in 1988 (McKee & Tobias 1990). These excavations have concentrated mostly on the Hrdlička pinnacle deposits, but in 1991 exposed a series of *in situ* deposits of fossiliferous pink breccia immediately south of another quarry remnant known as the Dart pinnacle (Fig. 2). This newly exposed deposit is just 16 metres west of the putative position of the Type Site reconstructed by Peabody (1954), and may represent a remnant of the cave which yielded the Taung skull.

Various interpretations of the Taung fossil sites are now possible with the new evidence emanating from the excavation. It is not necessarily true that the Hrdlička and *Australopithecus* deposits represent relatively synchronous depositional events in solution cavities as has been argued by Peabody (1954), Butzer (1974, 1978), Partridge (1985) and Partridge *et al.* (1991). Brain (1985) proposed an alternative view in which the caves formed as overhanging tufa carapaces. Furthermore, it may be proposed that the sites formed as separate and successive deposits as caverns in overhanging tufa carapaces. If this latter interpretation is true, then the *Australopithecus* cave would predate the Hrdlička deposits.

Each of a number of issues must be addressed in order to properly interpret the cave remnants and place them in correct chronological order. First, we must assess the type of cave formation represented by the deposits and, in particular, whether they are primary caves formed during tufa formation as overhangs of tufa or secondary solution cavities formed after the completion of the Thabaseek tufa. Secondly, it must be determined if it is likely that an extensive gallery cave system had connected the *Australopithecus* and Hrdlička caves. For these reasons, a survey of modern and ancient cave types in the tufas along the Ghaap escarpment and in the Eastern Transvaal was undertaken toward establishing substantive models for the interpretation of the Taung fossil deposits.

CAVE TYPES IN TUFA FORMATIONS

Research on cave types was conducted primarily at tufa formations along the Ghaap escarpment, including the Buxton Limeworks as well as Thoming, Little Witkrans, and Witkrans to the south and Mokgareng to the north. Similar tufa

[1] Recent investigations of the apparent interface between the Thabaseek and Norlim tufas along with reconstructions of the depositional sequence based on the geomorphology of the tufa remains suggest the likelihood that the Thabaseek tufa is a more recent formation than the Norlim.

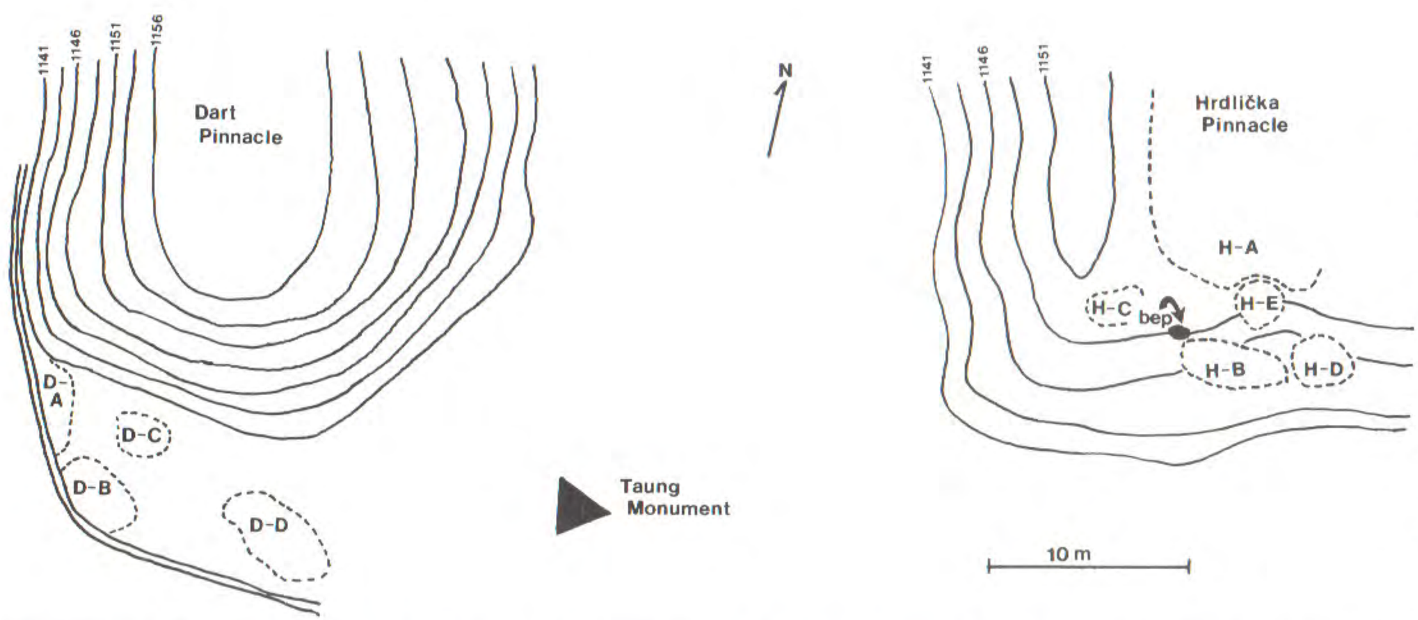

Fig. 2. Position of the putative Type Site of *Australopithecus africanus*, where the Taung monument now stands, relative to the exposed Dart depoits (D-A, D-B, D-C, D-D) and Hrdlička deposits (H-A, H-B, H-C, H-D, H-E, and the Black Earth Pipe (bep)). Countour lines are at 2,5 m intervals, representing metres above sea level.

accretions in the Eastern Transvaal at Abel Erasmus Pass (Marker 1971) and along the Kadishi Stream were studied as well (Marker 1973). Additional information was acquired from published descriptions of similar formations. Four types of caves were defined; their morphology, formation, variations and defining characteristics are described below.

Carapace caves

Among the largest cave systems are those that form as cavities underneath an overhanging roof of tufa carapace. These are *primary caves* that form during the process of tufa deposition. Brain (1985) described a carapace cave of this nature at the Namib-Naukluft Park in Namibia, and similar examples are common in the Taung area and Eastern Transvaal. Carapace caves are formed when overhanging hemispherical curtains of moss-derived tufa leave a natural cavity below and behind the curtain (Fig. 3). Carapace caves are necessarily derived during periods in which stream water is actively running over the tufa surface, and thus often have substantial water on the cave floor. Subsequent erosion, such as that from the backflow of stream waters, may enlarge the cavity (Brain 1985).

Numerous caves of this sort are apparent, ranging in size from small pockets, often used as shelter for rock dassies (hyraxes), to caverns large enough to shelter a troop of baboons. One example at Buxton, known as Razor Cave (Figs. 1 and 3), is still forming today downstream from the primary mass of the Blue Pool tufa. Its mouth stretches for 16 metres across nearly the entire dissected shale valley. Its maximum horizontal depth reaches back 8 m from the opening. The largest reported cave of this type is 'Dikbosch 1', which reaches 20 m in width at the opening, and extends horizontally to a maximum of 8 m into the tufa carapace (Humphreys & Thackeray 1983). A smaller cave at Mokgareng, however, has a horizontal depth of approximately 13 m against the strike of the tufa; at Abel Erasmus Pass, Tufa 'B' (Marker 1971) has a cave reaching a height of 13 m from floor to ceiling.

Deposits of sediment on the floor of carapace caves are usually horizontal or slope gently upwards toward the back wall of the cave. The backflow of stream waters may distribute these sediments evenly on the floor, sometimes seasonally. In dry portions of these caves, the floor often has rounded cobbles and sand, or in some cases the floor consists of bedrock.

Preliminary results of taphonomic experiments started early in 1991 demonstrate that bones of dead animals become less widely distributed in the dry than the wet portions, but further redistribution of bones in flood stages has yet to be witnessed and assessed. Some of the smaller dry caves with soil floors are evidently used by jackals, which occasionally leave gnawed bones behind.

On the roofs and floors of carapace caves there is usually a variety of speleothems, revealing the common wet nature of the caves. Concentrically layered nodular limestone and pisoliths characterize the inside walls of the caves, and are not known to occur in the other cave types considered below.

Localized collapses of carapace cave roofs can form temporary shelters that may accumulate sediments and bones under the fallen roof. This is important because after

Fig. 3. Entrances to Razor Cave, a carapace cave on the Thabaseek River in which taphonomic experiments are being conducted.

such deposits are covered by subsequent tufa accretion, the resulting morphology would look rather confusing when sectioned by quarrying or excavation, often with the horizontally deposited layers of tufa becoming oblique (or *vice versa*).

Pipes: Solution Cavities and Potholes

In his study of the Buxton tufas, Peabody (1954) noted the common occurrence of pipes that extend from the top surface of a tufa down to varying depths. Pipes form in two distinct ways, and may thus be subdivided into solution cavities and potholes.

Solution cavities in tufa have origins similar to those found in dolomite, forming from the corrosive and decalcifying action of plant roots (Brink & Partridge 1980). Although Peabody (1954: 685) suggests that solution cavities tend to form 'roughly along the strike of the steeply dipping layers of lime', they frequently cut across the bedding planes of the tufa layers (Fig. 4). Solution cavities derived from plant roots are irregular in form but usually terminate in cone shapes; alternatively, when plant roots reach into open fissures or filled caves, deep within the tufa, their termination may be more irregular.

Helicoidal pipes, referred to as *potholes*, form from the strong action of water tunnelling into the tufa as sinking streams. The water, aided by the inclusion of scouring pebbles, may carve a pipe through the tufa to the depth of the river below. The characteristic helicoidal or spiral shape of the pipes distinguishes them from solution

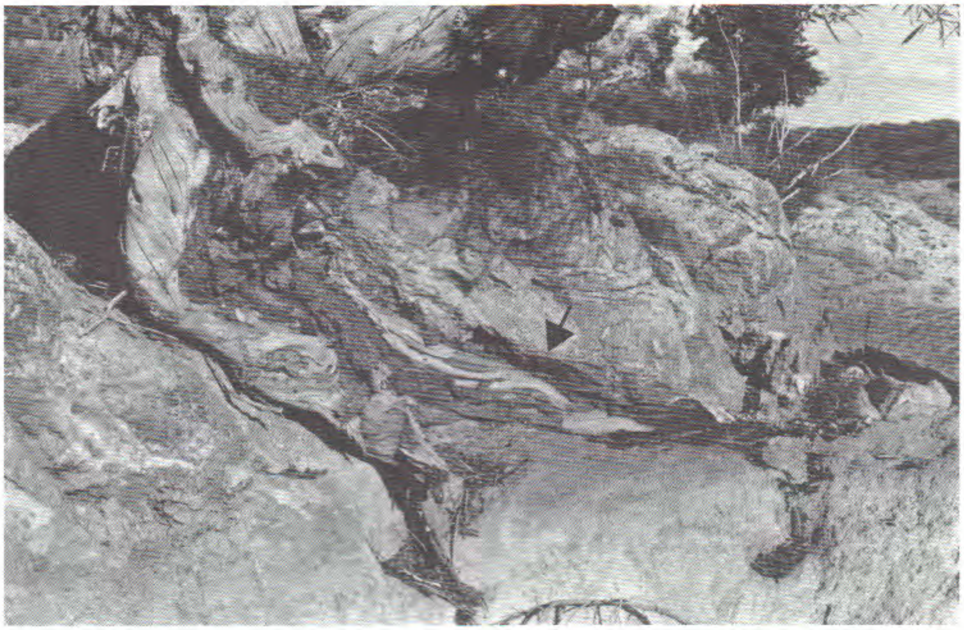

Fig. 4. A tree root forming a solution cavity in the Blue Pool tufa, clearly cutting apart the bedding planes at the arrow.

cavities (Fig. 5). Furthermore, the walls are distinctly more smooth than those created from plant roots in a solution cavity. On the Blue Pool tufa there are a number of examples of potholes, with diameters as large as 3,5 m. The bottoms of the cavities are typically filled with well-rounded, water-worn rocks and pebbles tumbled in and swirled by the flow of stream water.

The two types of pipes are not mutually exclusive. A cavity begun by a plant root during active tufa formation may predispose a section to water-borne erosion. Likewise, when a pothole becomes filled with sediment, it can leave a likely spot for plant growth.

Hypotheses concerning the time and nature of formation of the pipes exposed on the quarry walls of the Taung area can be tested with observations on their shapes and contents. They have usually become filled with unconsolidated dark soil or red sand. Only rarely has the infill become heavily calcified, and this may indicate a greater likelihood that the cavity was created by and later filled with running water. Both types of cavities have been found to contain fossils and/or stone artefacts.

Exposed walls of the pipes are typically lined with either a black varnish, probably of manganic origin (Peabody 1954), or a reddish layered patina. As the colour and thickness of the patina or varnish may indicate the environmental conditions and age in which the pipes filled (Dorn 1991), detailed studies of the pipe linings may reveal more about the natural history of the pipes. This in turn may be relevant to an understanding of the fossiliferous and artefactual contents.

Fig. 5. A large pothole forming from the top surface of the Blue Pool tufa, demonstrating the helicoidal shape formed by swirling water and pebbles.

Because of the local decalcification and sinking of sediments in pipes, there has often been admixture of materials transported from the surface (Brink & Partridge 1980). Lithic artefacts frequently are found in these cavities at Buxton, but bones are sometimes found as well. The dating of bones and artefacts found within these *secondary* cavities may be somewhat uncertain, because pipes might have formed at any time from the successive surfaces of the tufa and the contents subjected to considerable mixing. Evidence for such mixing is found in a pipe of the Norlim tufa known as Acheulian Hole (Fig. 1) in which Middle Stone Age artefacts have been found below Early Stone Age artefacts.

River-carved rock shelters

Rivers and streams along the Ghaap Escarpment have carved a number of rock shelters into the valley walls. Some of these are cup-shaped cavitations that have formed at river bends, apparently from torrential flood waters, either within or below the tufa (Fig. 6a). They often have high ceilings, but do not extend beyond a few metres in depth horizontally. Alternatively, high waters have apparently dissected through and under tufa where the underlying substrate is more prone to erosion than the tufa. Such processes seem to have resulted in more irregularly shaped caves, such as 'Lost Sole Cave' at Mokgareng, where the waters have eroded out a fossiliferous breccia deposit underneath a tufa overhang (Fig. 6b).

(a)

(b)

Fig. 6. *(a)* A river-carved rock shelter along the Thabasikwa river, formed in the shales under the tufa roof at a bend in the river. *(b)* Lost Sole Cave, at Mokgareng (8 km north of Buxton), where stream water has dissected through a breccia deposit underneath the tufa.

A river-carved rock shelter may form in tufa, breccia, dolomite or the underlying shale. One example, Powerhouse Cave (Fig. 1), was carved from the shales, its roof being formed by the 'basal apron' of the Norlim tufa (Peabody 1954). In actively forming areas such as Blue Pool, it is apparent that such shelters may be covered by subsequent tufa deposition, thus burying and preserving bones or artefacts on the floors.

Vadose Cave

Inference of a closed vadose cave in tufa, comparable to those which form in dolomite (Brain 1958, Brink & Partridge 1965), can be drawn from reports of quarry workers interviewed by Peter Beaumont (pers. comm., 1991). It was named Stalactite Cave when it was exposed by quarry operations in the Oxland Tufa (Fig. 1); the quarried entrance has since been closed and thus the extent of the chamber is not known.

Narratives by the quarry workers revealed that Stalactite Cave apparently contained large speleothems and had a substantial water reservoir at its base. It is likely that a good portion of the chamber still exists and provides the water source for a strong spring in Blue Pool, immediately below the putative location of the cave. It is unknown whether the chamber contained any fossils, or if it had an opening to the surface before it was exposed by quarry operations.

DISCUSSION

Studies of the calcareous tufa formations along the Ghaap escarpment and in the Eastern Transvaal have led to the identification of four main types of caves that form in the tufa: carapace caves, pipes, river carved rock shelters and vadose caves. These cave types are not mutually exclusive in that often two or three types can be combined, e.g. a solution cavity from the top surface of the tufa may burrow through the carapace to a chamber below, providing an additional entrance to a carapace cave (as is apparent at Witkrans).

Hypothetical reconstructions of the ancient cave systems in which the Taung fossils were deposited can be modelled on the basis of observed characteristics of the four cave types, born of the processes by which they formed. Discussion here will be restricted to an application of the observations to the deposits in the immediate area of the *Australopithecus* Type Site.

In previous studies, the breccia deposits of the Hrdlicka pinnacle have been interpreted as solution cavities (Peabody 1954, Butzer 1974). The recent excavations, however, have exposed enough of the cave morphology to alter this interpretation. The two deposits of the Hrdlička Pinnacle that have yielded the majority of the baboon fossils show distinct characteristics of carapace caves (Fig. 2). Deposit H-B has a back wall and floor lined by successive layers of tufa, with the floor sloping upward toward the back of the cave. At no point does the cave breccia of Deposit H-B cut across the bedding planes, as suggested by Butzer (1974). However, the former roof apparently eroded away during the deposition of Deposit H-A, which intersects the oblique bedding planes of the tufa. There is a solution cavity which intersects Deposit H-B and cuts across the bedding planes of the back wall tufa; this is the 'Black Earth Pipe' noted by Peabody (1954), which contains intrusive dark soils and Middle Stone Age artefacts.

Subsequent deposition of the overlying Deposit H-E created a smaller version of the same phenomenon, but its walls contain the nodular and pisolitic limestone characteristic of carapace caves. Some bones from this deposit extend from the breccia into the tufa, a situation which is incompatible with the deposits having formed as a solution cavity.

Breccia deposits near the base of the Dart pinnacle (Fig. 2), dubbed the 'Dart deposits', are a composite of primary caves and secondary solution cavities. On the basis of historical records, it is reasonable to hypothesize that this cave system was directly associated with that which yielded the Taung hominid in 1924. This is supported by the reconstructions by Peabody (1954), and is entirely consistent with the clues given by Young (1925), Hrdlička (1925), Gordon (1926), Dart (1926), Cipriani (1928), and Broom (1946). It is likely that the original fossils found from 1919 to 1924 were associated with the Hrdlička deposits as the quarry was worked along the long axis of that cave system (Peabody 1954, Tobias 1985), near the eastern edge of the Thabaseek tufa. However, only the Dart deposits could have been a full 60 metres from the eastern terminal edge of the pre-quarry Thabaseek formation and thus be consistent with the records of Hrdlička (1925), Young (1925) and Cipriani (1928) for the provenance of the Taung hominid.

Observations on the Dart deposits, despite most of the cave having been destroyed by quarrying, reveal distinct clues left in the floor of the cave where fossils have been recovered in pink breccia. The layer of pink breccia in Deposit D-D is horizontally bedded, and overlies nodular limestone structures that form the floor and sloped wall. The structure of the deposit and the distribution of bone are similar to those in the wet portion of Razor Cave where goat bones are in the process of redistribution and deposition. Thus it is suggested that Deposit D-D was the floor of a carapace cave. The presence in the cave matrix of isolated pockets dense in rodent bones is indicative of the deposition of owl pellets (Shipman 1986); this suggests a roof within the 'twilight' zone of a cave (Andrews 1990), further supporting the notion that the cave had been a carapace cave with an opening nearby.

New evidence from a sedimentological analysis using particle size distributions (Partridge *et al.* 1991) demonstrated that breccia from the Hrdlička Pinnacle Deposit H-B was nearly identical in composition to that from which the Taung hominid skull had been extracted. It was concluded that skull had probably come from the immediate vicinity of the current Hrdlička pinnacle. This is difficult to reconcile with the view expressed here and elsewhere that the Taung hominid skull came from the area of the Dart deposits. We are thus left with three possibilities: (1) It is wrong to associate the Dart deposits with the cave from which the Taung hominid came, despite the inferences drawn from the historical record; (2) there was a greater degree of sedimentological homogeneity among temporally distinct deposits than that allowed for in Partridge's analysis; (3) the two deposits were somehow connected as part of the same extensive cave system.

Evidence from particle size distributions within the cave matrix that allegedly ties the Hrdlička deposits to that of the Taung skull (Partridge *et al.* 1991) is somewhat suspect, for the temporal specificity of the technique at Taung cave sites remains inadequately tested. It is likely that similar depositional circumstances in a stable cave environment could result in similar constitutions of the sediments, but at different times. Such is the case with the sediments of McEachern's Cave in south-eastern Australia where Link (1967) observed temporally distinct layers with nearly identical particle size distributions. Thus the sedimentological techniques employed by Partridge *et al.* (1991) may be useful as corroborating evidence along with considerations of the historical record, geomorphology, and faunal analyses (Butzer 1974), but in isolation can say little about contemporaneity of deposits.

Speculation that the Dart and Hrdlička deposits were connected as one extensive cave system (Peabody 1954) is unsupported by the evidence preserved in the limeworks. The exposed quarry floor between the Dart and Hrdlička pinnacles (Fig. 2), consisting almost entirely of solid tufa, demonstrates that it is unlikely that the respective fossil deposits were connected. One section to the east of the newly discovered deposits shows a distinct change in tufa character with a section of cavities containing loose red sands. This is consistent with the position of a large mass of unconsolidated sandy cave deposit reported by Young (1925) and illustrated by Dart (1926), which was indeed to the east of the hominid deposit. The differences in content and dip of the tufa in this sandy section may indicate a difference in environmental conditions of formation (e.g. amount of water flow), between the depositional phases of the Dart and Hrdlička deposits.

Repeatedly accreted layers of tufa left a total of 50 metres of tufa formation between the fossiliferous deposits of the Dart and Hrdlička pinnacles, including a thick section of tufa preserved on the western 9 metres of the Hrdlička pinnacle (Fig. 2). If the deposits had been connected as galleries of an extensive cave, then this would have been the deepest cave (modern or ancient) that has been observed in tufa along the Ghaap escarpment or in the Eastern Transvaal. Furthermore, the Dart deposits are to the west of the currently exposed western 'back wall' of the Hrdlička Deposit H-B, at a level 6 m lower than the exposed floor of Deposit H-B; to propose a connection between the two sets of deposits would thus require a very convoluted and unprecedented cave formation model. The tufa carapaces cascade down, away from the dolomitic escarpment. In no case has a carapace cave been seen to burrow within the tufa *toward* the escarpment *down* for more than 2 m against the strike of the tufa; the floors usually slope up toward the back of the cave. As it would take a model with no analogue to propose that the cave systems were continuous, it seems more reasonable to suggest that they represent distinct caves that formed at separate times. This is consistent with the statement by Gordon (1926), who observed the quarry between 1916 and 1919, that the tufa contained a *series* of cave deposits.

Examinations of the preserved structures leave little doubt that the primary cave deposits near the base of the Dart pinnacle would have formed prior to those of the Hrdlička pinnacle, for the tufa accretion proceeded roughly west to east, away from the escarpment. However, this principle does not exclude the possibility that two distinct caves *filled* at the same time. It is conceivable that the Dart cave deposits could have maintained an opening despite the continued accretion of tufa, or that subsequent solution cavities, which are evident, could have reopened the primary cave. However, this would not easily explain the horizontal bedding of the pink breccia deposit abutting against a wall of nodular limestone, that is more consistent with a notion of a carapace cave at the level of the ancient stream. Furthermore, a deep cave of this nature would not allow for the accumulation of owl pellets in the twilight zone of the cave if it were 60 m within the Thabaseek tufa where owls would not roost.

Local exposures have revealed over 30 known fossil deposits throughout the Buxton limeworks from vastly different time periods, demonstrating that cave formation and filling was a continuous process. It thus seems *less* reasonable at this stage to assume that the Hrdlička and Dart deposits were precisely contemporaneous, than that the Dart deposits were formed at an earlier time. One of the unknown factors is *how* much older. The proof that the two deposits are not contemporaneous, and a calibration of their potential chronological differences, can best come with further analysis of the fauna that is being extracted from the cave matrices.

SUMMARY AND CONCLUSIONS

Efforts to interpret the fossil deposits found in calcareous tufas require an understanding of cave formation processes and the resultant range of geomorphological structures. Once the type of cave deposit becomes clear, it becomes possible to assess the depositional processes leading to fossilization, interpret the taphonomic agents that led to bone deposition, and place the cave deposit in a chronological context relative to other such deposits.

An investigation of modern caves found in the tufa accretions along the Ghaap escarpment and in the Eastern Transvaal was used to construct hypothetical models of formation for the ancient caves exposed by quarrying and excavation at the Buxton Limeworks. The multiplicity of processes leading to cave formation results in four main cave types: carapace caves, pipes (solution cavities and potholes), river-carved rock shelters, and vadose caves. Although these types are not mutually exclusive, each has characteristic geomorphological features that are recognizable in fossil deposits.

Specific applications of these findings to the Type Site of *Australopithecus africanus* and nearby deposits has led to a new interpretation of the cave systems. It has been thought that the deposit which yielded the Taung hominid skull was within a large interconnected gallery of solution cavities that had formed after the Thabaseek tufa carapace had been completed. The geomorphology exposed by recent excavations, however, is more consistent with a model of carapace caves forming concurrently with tufa accretion. Furthermore, successive caves formed as the accretion built away from the escarpment, implying a likely chronological separation of the Dart deposits, closely associated with the Type Site, from the Hrdlička deposits which have been used for faunal dating of the hominid.

Emerging from this study is the conclusion that the fossil deposits from which most of the 'Taung' fauna has been derived probably accumulated as floors of primary caves during the formation of the Thabaseek tufa. As no known model can accommodate both the Dart and Hrdlička deposits in one cave system, it is highly likely that the Dart deposits, further west and deeper within the Thabaseek tufa carapace, predate the Hrdlička pinnacle fossils that have been used for faunal dating.

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