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Recent Paleoanthropological Excavations of *In Situ* Deposits at Makapansgat, South Africa – A First Report

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A B S T R A C T

The Makapansgat Limeworks is a significant Pliocene site both for its sample of 35 hominin fossils as well as its wealth of fossil fauna. The lithological and paleontological successions reveal local environmental changes that are important for understanding the context of hominin evolution in southern Africa. Yet most of the site's fossils were found in dumps left behind by quarry operations, and the paleoecological interpretations rest upon debatable assumptions about the original fossil provenience. We have recently initiated systematic paleoanthropological excavations at Makapansgat to recover well provenanced fossils in order to: 1) assess whether faunal successions are discernable in the Makapansgat sequence; 2) assist environmental interpretations of the site; 3) and potentially recover the oldest hominins in South Africa, roughly coincident with Australopithecus afarensis *in East Africa. This paper presents a summary of our current paleoenvironmental research at the Limeworks and preliminary results of ongoing in situ excavations.*

Key words: *Makapansgat, excavations, australopithecine,* A. africanus

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Introduction

The Makapansgat Valley has yielded a wealth of fossil fauna, including a significant sample of early hominins. The hominins from the Makapansgat Limeworks, considered to be between about 2.8 and 3.2 million years old[1–4], may be the oldest from southern Africa (depending on the age of the new STW 573 skeleton from Sterkfontein Member 2)[5,6]. As these fossils are broadly contemporaneous with the *Australopithecus afarensis* sample from East Africa, they hold key clues to understanding the diversity and phylogeny of hominins during the Pliocene. Moreover, the rich assemblage of fossil fauna from the Limeworks has provided valuable insights into the ecological context of hominin evolution in southern Africa, although interpretations have varied[2,7–9].

In addition, other sites in the Makapansgat Valley preserve a record of environmental change from the Pliocene through the Holocene. For example, recent excavations at Buffalo Cave have yielded a rich mammalian sample from the mid-Pleistocene[10] and fossils and artifacts from the Cave of Hearths represent much of the past several hundred thousand years of human occupation in the area[11]. The Makapansgat Valley thus provides a valuable opportunity to understand how global and continental environmental changes were reflected in a tightly constrained local context.

Given the significance of the Makapansgat Valley's sites, it is important to understand that the earliest sequence from the Limeworks has only recently undergone systematic excavation for *in situ* fossils. For the past half-century fossil collecting at the site focused almost exclusively on the *ex situ* breccia dumps left behind by miners decades ago. This simple fact – that most of Makapansgat's fossil fauna has been recovered from unprovenanced mine dumps – helps explain the difficulty in reaching consensus concerning paleoenvironmental and ecological reconstructions of this important early hominin site. For this reason, the primary objective of our current excavations at the Limeworks is to enhance and continue systematic paleoanthropological excavations of Makapansgat Members 2–4 in order to recover *in situ* fossils of undisputed provenance.

Background

The farm Makapansgat lies 12 miles east-northeast of Mokopane (formerly Potgietersrus), at 24° 12' S and 28° 57' E, in South Africa's Limpopo (formerly the Northern, and before that, the Transvaal) Province. Here the roughly N-S running Drakensberg Mountains of the Eastern Transvaal are mainly composed of Black Reef Quartzite and the overlying, relatively soluble, Malmani Dolomite. The soluble nature of the Malmani Dolomite is largely responsible for the existence of the many large caves in the area, and they often contain dolomitic breccias[12]. Covering some three acres, the main Makapansgat Limeworks site represents the calcified infill of one such enormous cavern within the dolomites. The cavern consisted of almost pure limestone speleothems that were mined for over a decade starting in the early 1920's. The fossil-bearing breccias were first brought to light because of the extensive mining operations at the Limeworks and at other sites in the valley.

During these mining operations a local science and mathematics teacher, Wilfred Eitzman, first drew Raymond Dart's attention to the abundance of fossil bones being blasted out of the cave breccia by limeworkers. Dart[13] published a short note on Makapansgat as an early human occupation site but did not investigate the site thoroughly until 1947, at which time

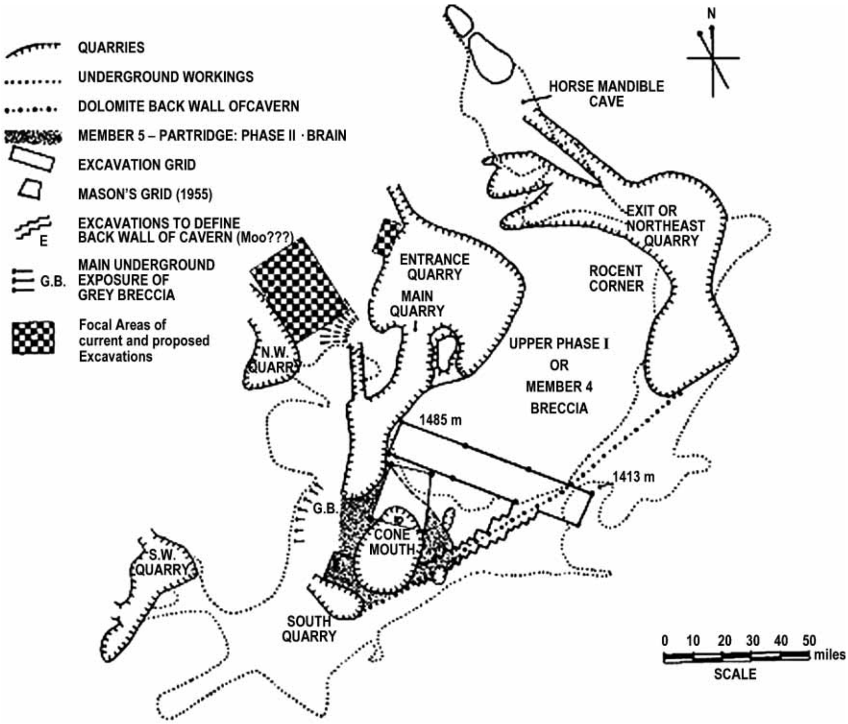

Fig. 1. Map.

he discovered that a sample of the vertebrate fossils contained free carbon, leading him to speculate that the bones had been intentionally burned by early hominins inhabiting the cave (although later studies would show that the free carbon interpreted as evidence of early hominin fire use was acutally caused by the miners' dynamite blasts). Later that year, James Kitching discovered the occipital portion of an australopithecine skull on one of the limeworkers' dumps. Reasoning that this early hominin might have been responsible for some of the burned bones in the deposit, Dart named the new hominin *Australopithecus prometheus*[14]. By the mid-1960's however, most workers concluded that the majority of australopithecine fossils previously described as *A. prometheus* and *Plesianthropus* (named for Broom's adult specimen discovered earlier at Sterkfontein) should be included in the single taxon, *A. africanus*[15].

Other important hominin discoveries soon followed, including an adolescent mandible, an infant's right parietal bone, several craniofacial fragments and isolated teeth, and two fragments of an adolescent pelvis[16]. The discovery of the pelvis was critical to paleoanthropological thinking at the time, since it proved conclusively that *A. africanus* was bipedal. Several alleged stone tools were also recovered from the site[17], but their context was initially unclear.

Dart also noticed that many of the vertebrate fossils from the site seemed to be artificially fractured and that some animal parts were more commonly preserved than others. This suggested to him that the hominins were responsible for the bone accumulation leading him to infer that many of the bones and jaws had been utilized as tools by the early hominins: teeth as saws and scrapers, long bones as clubs, and so on[18]. He named this the Osteodontokeratic (bone-tooth-horn) Culture. Dart's interpretation inspired a more rigorous assessment of cave taphonomy; such studies cast doubt on this interpretation, suggesting instead that many of these bone accumulations were the product of carnivore scavengers such as hyenas[19–21]. More recent taphonomic studies suggest that the fossil-rich Member 3 bones were mainly accumulated by the now extinct striped hyena, *H. hyaena makapani*, and by porcupines, and that the Member 4 bones were mainly accumulated by leopards and birds of prey[9,19,22,23].

At present, 35 hominin specimens (representing a minimum of about a dozen individuals) have been recovered from the Limeworks site. These include the recent discovery of two mandibular fragments found by the Paleoanthropological Field School at Makapansgat. All of the hominin fossils are currently referred to *A. africanus*, but it should be noted that Aguirre[24] suggested the presence of *Paranthropus robustus* in the sample on the basis of the MLD 2 mandible. Thus far, the fossil hominins are known only from Members 3 and 4 as judged by the breccia matrix from which they were extracted. Recent work on Member 2 in the Classic Section led to the conclusion that »the sediment is colluvium derived from the surface and was washed in through an entrance that was probably caused by the continuing retreat of the surface«[23]. Whereas Member 2 has not yet yielded any hominin fossils, our recent excavations have demonstrated that the sparsely fossiliferous nature of the deposit is sufficient to produce a good yield of fauna that will aid in the understanding of the paleoecological sequences and geological history of the Limeworks.

Chronological and Paleoenvironmental Studies

A number of ongoing research studies at Makapansgat directly relate to, and are complementary to, the excavations described here. These include stratigraphic studies, paleomagnetic studies, magnetostratigraphic studies, uranium-lead analysis, stable carbon isotope analysis, and faunal and taphonomic studies.

Our team has established a stratigraphic succession of the infilled western portion of the Limeworks from the »Original Ancient Entrance« from the Northwest Quarry to the alcoves and the Classic Section, above which lies the dense bone-bearing Member 3, or Grey Breccia. The strata from the Grey Breccia to the »Cone Mouth« are less securely connected, while the succession from the base to the top of the Cone Mouth is securely connected with no perceptible erosional breaks. Together, the two successions provide a record from the earliest to the latest strata at the Limeworks.

In the western side of the Limeworks, from which most of the macromammal fossils are derived, the stratigraphic succession is complete and traceable. The earliest deposits are the massive, pure carbonate stalagmites and columns of Member 1, now extracted for gold mining, but with many local traces on walls and roofs. These were succeeded by flowstones that came from the direction of the so-called »Original Ancient Entrance«. The stratigraphic succession is followed, throughout the entire Limeworks to a considerable height, by a sub-aqueous coating of calcite that formed under a deep carbonate-rich pool. In the western side, a fine mud was deposited into that pool that dried out occasionally. It is in this deposit, in the Original Ancient Entrance, that the first fossils are found; in particular there is an articulated skeleton of a small bovid that is attributed to *Makapani broomi* by Schrenck[25]. There are a few fossiliferous blocks of this unit that are clearly identifiable in the lime dumps. This depositional phase is followed by another subaqueous phase, which is then followed by the red silts of Member 2 that were also deposited from the region of the Original Ancient Entrance. Within the Member 2 Red Silts, there are localised concentrations of macromammal fossils that indicate animal denning.

The Member 3 Grey Breccia follows the 5 meters of Member 2 Red Silts in the area known as the Classic Section. In the Main Quarry, the Red Silts are interspersed with impure flowstones to end in pink indurated mud layers and a dolomite-clast breccia. It is in this breccia that the hominin cranium MLD 37/38 was found *in situ*. The rows in the lime dumps, recovered by Tobias, Kitching, and others came from the western side of the Limeworks, and they are largely made up of blocks recognizable as the Red Silts of Member 2, the Grey Breccia of Member 3, and the dolomite breccia (Tobias, personal communication to Latham). This permits the assessment of provenance for much of the fossil material in the dumps, albeit only very generally – to a particular member. Only with current controlled excavations have fossil specimens been provenanced well enough to allow fine-scale analyses that incorporate the relative provenance of fossil specimens *within* a member.

The Grey Breccia consists of a dense aggregation of bones with varied black and ochre patches of contaminated calcite. The bone accumulations are recognized to have been the result of denning animals, chiefly hyenas[19–21]. The animals appear to have come from the direction of the back of the Collapsed Cone, where there were gaps between the roof and the sediments of the Central Debris breccias (Member 4). There is probably a correlation of the Grey Breccia with similar bone deposits at the same level at the back of the Cone Mouth. If this is the case, the sequence can then be reconstructed, without a depositional break, from the earliest deposits of the Original Ancient Entrance to the top of the Cone Mouth.

An extensive paleomagnetic re-mapping project of the western side of the Limeworks is currently underway. Current excavations are closely coordinated with the paleomagnetic mapping project. This work is crucial both for an attempt to establish a chronology and for a stratigraphic correlation that includes the new excavations. The existing paleomagnetic record for Makapansgat extends from the base of Member 1 to the uncorrelated Member 4, and its calibration to the Global Polarity Timescale is, at present, open to differing interpretations[26–28]. The paleomagnetic record, in conjunction with the faunal evidence, supports an age in the middle of the Gauss normal polarity chron involving the Kaena or Mammoth subchrons, providing an age close to 3 mya for Member 4. Because of the later recognition that the whole site consists of separate repositories and not just one sequence, the original magnetostratigraphy was called into question[22,23,29,30]. This also points, again, to the importance of current efforts to recover *in situ* fossils in order to interpret this site properly. Moreover, a suite of samples extracted from positions close to our *in situ* faunal sampling will help tie the polarity to the new detailed magnetostratigraphy. Faunal dating has been shown to provide dates that usually fall within 200 kyr of the actual date[3]; and thus current proposed ages could be delimited further by more accurate assessments of polarity.

Block samples were collected for magnetostratigraphy in order to assess whether a succession could correspond with the Global Polarity Timescale (GPTS). The speleothem samples exhibited weak magnetization, while the sediment samples exhibited moderate magnetization. This research has resulted in the identification of three additional reversals in the Western Repository beyond those reported by McFadden and colleagues[31]. Two of the reversals are located near the »Original Ancient Entrance« and one of the reversals is located above the Grey Breccia in the speleothem[25]. Unfortunately, a reliable age estimate for the Grey Breccia cannot be based solely on the polarity at this point. Faunal evidence still provides the best available age estimate for the Grey Breccia of approximately 2.8–3.2 mya. A more precise polarity sequence is being constructed based on differential rates of deposition of clastic sediments versus the more slowly deposited speleothems. In this way it might be possible to identify long and short polarity intervals more closely and thus make a more unambiguous fit to the GPTS.

We are also attempting a new variation of the U-Pb (uranium-lead) dating technique on secondary carbonates from Members 1–3[32]. This new U-Pb technique has recently been found to be suitable for young (< 5mya) precipitates (e.g. speleothems) under conditions of high U content and low common lead[32]. This method would permit age estimates for speleothems free of stratigraphic or faunal correlation. Thus far, however, the specimens having undergone this method are unreliable due to either having a U content too low or appearing to have partially remobilized U and Pb isotopes of the large, much older speleothems. Currently, it is only possible to say U-Pb data indicate a late Miocene age for the early Member 1 speleothems. It is possible, however, that later speleothems may have a higher U content, and so permit age assignment to the fossil-bearing strata.

Stable isotope analysis is currently underway on speleothem samples in order to provide paleoenvironmental indicators for Plio-Pleistocene sites in the Makapans Valley, especially at the Limeworks and at nearby Buffalo Cave. They have the advantage over most faunal studies in that they provide continuous records over many thousands of years. Minor changes in the proportions of stable oxygen isotopes, ^{18}O and ^{16}O, in speleothems are routinely analyzed in order to identify climatic signals (Milankovitch cycles). These climatic signals indicate changes in solar radiation that result from changes in the Earth's orbital parameters. In addition, the variation of carbon isotope proportions, ^{13}C to ^{12}C, is well known to represent a change in C3 to C4 plants in the tropics. While samples extracted from stalagmites of the Cone Mouth exhibit no C4 plant signals and must be re-analyzed at higher resolution in order to detect Milankovitch cycles, the speleothem from Buffalo Cave exhibits semi-cyclic variation of C3 to C4 plants and an exceptional Milankovitch cycle record with peaks at 43 kya (obliquity) and 23 kya (precession). Additional isotope data will contribute significantly to reconstructions of the paleoenvironment of the Makapans Valley and will inform current debate regarding South African Plio-Pleistocene faunal successions and regional environmental evolution in the valley.

Recent studies by K. Reed[8,9] suggest that the bulk of the mammalian bones from Member 3 (more than 30,000 specimens, including at least two dozen hominins) were accumulated in the cave by fossil hyaenid and porcupine species. This conclusion is consistent with stratigraphic reconstructions of the cave by Latham and colleagues[23], which suggest that denning animals could access this part of the cave[23]. An alternative hypothesis that the bone accumulations resulted from floods is not tenable as the calcite matrix is indicative of a low energy environment. According to the analysis of Reed and Sponheimer and colleagues[52], there is a relatively high percentage of both frugivorous (~15%) and arboreal species (~5.5%), indicating the proximity of bushland and medium density woodlands. The presence of both fresh-grass grazers (~3.5%) and aquatic mammals (~2%) indicate the nearby presence of a river and some edaphic grasslands as well. Overall, the fossil mammalian fauna suggests a habitat mosaic that contained riparian woodland, bushland, and edaphic grassland. This paleoecological reconstruction has been confirmed by stable isotope analysis of tooth enamel from 20 mammalian species, including *Australopithecus africanus*[33]. Sponheimer and colleagues[52] has uniquely combined isotopic and ecomorphological data on Member 3 bovids to reconstruct the diets and habitats of the extinct bovid species (as compared to their extant relatives).

In contrast to Member 3, the Member 4 deposits contain only 3 hominins out of approximately 250 identified mammalian specimens. The bulk of these specimens are cercopithecines (~55%) and the likely accumulators were leopards and possibly birds of prey. There are, however, greater percentages of arboreal (7%) and frugivorous (20%) species than in Member 3, suggesting more wooded habitats. This, however, may simply be a function of smaller sample size and predation bias, that is, by birds of prey as opposed to hyenas[8,9].

Both palynological and carbon isotope studies all suggest fluctuating climatic and vegetational conditions during the period of sedimentation at Makapansgat[34,35,36]. Fossil pollens suggest that the region may have had higher rainfall patterns that supported patches of subtropical forest and thick bush as well as savannah when australopithecines occupied the area. However, due to contamination by modern pollens, the analysis is suspect. Evidence of more episodic rainfall patterns only begins to appear after the middle of Member 4 with the presence of a higher proportion of grazing mammals, signaling the onset of drier, more open conditions about this time[7,27,35]. These are intriguing and significant results, since they, along with paleoecological inferences drawn from the early hominin site of Aramis, Ethiopia, suggest that the preferred habitat of the earliest hominins in both East and South Africa (*Ardipithecus* and *A. africanus*, respectively) was most likely forest or forest margin, rather than open savannah[37]. Again, the importance of having a well provenanced fossil mammal sample against which to compare Makapansgat's pollen sample profiles[35] is obvious. Moreover, it is necessary in order to test whether the pollen sample and the mammalian sample are reflecting the same paleoecological signal. This is a major and critical part of our current research and excavation objectives.

Fossil Preparation, Excavations, and Results to Date

In recent years, research at the Makapansgat Limeworks has included both preparation of *ex-situ* breccias (from the dumps) and pilot excavations of *in situ* breccias considered to represent Members 2, 3, and 4. Our pilot excavations were conducted in order to document and validate the paleoanthropological potential and rewards of systematically excavating the *in situ* breccias and the excavation techniques employed. Excavations began in 1993 under the auspices of the Hominid Paleoecology Research Programme (directed by J.K. McKee), and concentrated on a section presumed to be Member 4. Since then, the Member 2 breccias have been the focus of an initial pilot study in 1995, preliminary excavations in 2000, and a more extensive and rigorous excavation begun in 2003 and scheduled to continue over the next two years. The following sections will detail recent hominin discoveries from the *ex situ* breccias in the Limeworks dumps and the methodology and preliminary results of our excavations.

Hominins recently recovered from the dumps

In 1998, the Palaeoanthropological Field School at Makapansgat (co-directed by K.L. Kuykendall and K.E. Reed) initiated the preparation and identification of fossil remains from *ex situ* breccia blocks (originally sorted in the dumps by P.V. Tobias and A. R. Hughes). Two new fragmentary hominin fossils were recovered during this process, which have recently been analyzed and put into a comparative framework by K.L. Kuykendall and A.D. T. Kegley at University of the Witwatersrand. Both of these specimens are mandibular fragments attributed to *Australopithecus africanus* and associated with Member 3, or the Grey Breccia (Kuykendall and Kegley, unpublished data). These specimens are informally designated MLD-FS-1999 and MLD-FS-2000, as they were discovered during the 1999 and 2000 Field School seasons, respectively.

Kuykendall and Kegley describe MLD-FS-1999 as a partial left mandibular corpus which includes both the anterior border of the ascending ramus, the roots of M3, and the posterior root of M2. They describe MLD-FS-2000 as a fragment of a partial right mandibular corpus that includes the premolar and M1 roots. Kuykendall and Kegley found a significant difference in the transverse thickness in the region of M3 between specimens from Makapansgat (n=6) and Sterkfontein (n=4) preserving these regions (p=0.02), and the Makapansgat sample exhibits larger dimensions in both mandibular height and transverse thickness than the Sterkfontein sample. In particular, the Makapansgat specimens demonstrate similarities to some »robust« australopithecine mandibles attributed to *Paranthropus robustus*. Interestingly, on the basis of the limited Makapansgat sample, Kuykendall and Kegley found that the Makapansgat mandibular specimens are larger, but have smaller molars than the Sterkfontein sample. These data are interesting in light of previous suggestions that the Makapansgat assemblage may include multiple hominin taxa or may be distinct from the *A. africanus* assemblage at Sterkfontein[24,38–41].

Excavations of Members 3 and 4

An accurate grid system was erected over the so-called pink »cercopithecoid« breccias of Member 4 and surveyed onto the National Grid System. The major grid points were marked with reversed galvanized bolts and set into truncated concrete stones. These grids were then plotted on the 1/250 plan of the Limeworks Historical Monuments Reserve. The digitizing of the 1/250 plan of the Limeworks Historical Monument Area is now complete.

Large segments of the dolomite roof over Member 4 were removed and large blocks of breccia were drilled out. A number of *in situ* fossils were recovered from over thirty of these large fossiliferous breccia blocks, all from a densely fossiliferous deposit within 1 meter of the dolomitic roof. Preparation of an initial fossil sample from the Member 4 breccia blocks has revealed predominantly cercopithecid fossils, including at least three partial crania. Additional cercopithecid fossils are exposed on the surfaces of the breccia blocks along with identifiable material of carnivores, bovids, and suids. These are the first *in situ* primates recorded from the Makapansgat Limeworks site.

Even the small test excavations from Member 4 begun in 1993 have produced a large number of fossils, mostly cercopithecids, from within 1 m below the dolomitic roof. Initial taphonomic inferences from these test excavations suggest that this portion of the deposit may contrast with that of the total assemblage of Member 4 as determined from Limeworks dump fossils. Further excavation will be necessary to compile an accurate picture of the taphonomic and paleoecological context of Member 4 deposition. In order to continue these excavations, thoroughly and systematically, however, it is necessary to attempt new and more efficient mining techniques to remove the hard dolomitic roof (such as s-mite, a self-expanding material injected into holes drilled directly in the dolomite as at Rose Cottage), as traditional methods using power drills and hand-driven steel wedges are inefficient and impractical.

Initial faunal correlations using mainly fossil bovids, suids, and cercopithecoids, indicate that Member 3 faunas are most similar to East African faunal assemblages dated to between about 2.8–3.2 mya[1–4,42]. Over two-thirds of the species contained in Member 3 are extinct, and it shares no time-sensitive species with later Pleistocene *Homo*-bearing sites. The mammalian assemblage includes such ancient East African species as the chalicotheriid, *Ancylotherium hennigi*, the primitive buffalo, *Simatherium kohllarseni*, and two primitive suids, *Potamochoeroides shawi* and *Notochoerus scotti*[43,44].

Member 4 faunas seem more similar to those of Member 3 than to any other southern African site. Both members contain *Australopithecus africanus*, similar cercopithecoids, and the ancient artiodactyls, *Simatherium cf. kohllarseni* and *Notochoerus scotti*. Although a stratigraphic separation between Members 3 and 4 exists in some parts of the cave, the difference may not represent a geologically significant time period. Instead, the deposits may sample different parts of the same cave that exhibit slightly different taphonomic processes[1,4,45]. The answer to this problem can only be determined by recovery of in situ faunas from Members 3 and 4, along with further geological analysis and comparisons based on magnetostratigraphic correlation.

Excavations of Member 2 and adjacent exposures

The grid system used in the excavation of Member 4 has been extended to include an exposure of very ancient and largely unsampled Member 2 breccias between 1995 and 2003. Further excavation

Fig. 2. Member 2 exposure and strat. section.

Fig. 2b. Member 2 exposure and strat. section.

of *in situ* Member 2 breccia began in 2000 and yielded 12 fossil-bearing breccia samples that are currently undergoing preparation, but are known to include bovid and cercopithecoid fossils. These older Member 2 deposits are a primary objective of current work at the site, because any hominins and associated fauna in Member 2 may significantly predate 3.2. million years in age, a time period roughly coincident with the *A. afarensis* in East Africa and could reveal the earliest known morphology of the southern African hominins.

A more intensive field season in 2003 concentrated excavations in two perpendicular grid units in order to assess fossil density across the exposure. While fossils are scanty at best in the exposed Member 2 deposits, pockets of increased fossil density have been encountered and are the focus of future work. Excavations of the Member 2 *in situ* breccia have been enabled by traditional methods (e.g. large drills, wedges, and pry bars) and new methods adopted from the geological sci-

Fig. 3. Blasting and blasting caps.

Fig. 4. Blasting and blasting caps.

ences. Explosive cap technology is a method widely used by geologists, but up until now it has not been utilized in paleoanthropological excavations of fossil-bearing breccia deposits.

Explosive, or blasting, caps come in a variety of strengths, which may be used in combination when necessary (in fact they are less likely to fail to detonate when two blasting caps are used simultaneously). The method entails using an 8-mm drill bit to drill into the breccia at a shallow angle. It is imperative that no air pockets or chasms are encountered during this drilling or the drill hole must be abandoned. The depth of the hole is measured and blasting caps are gently pushed into the base of the hole with a flat-tipped rod with a heavy anvil at its upper end to provide inertia to prevent accidental blow-out. The depth is measured again in order to establish that the blasting caps have indeed reached the base of the hole. In preparation for detonating the blasting caps, a protective industrial rubber mat is placed over the area and an 8-mm diameter detonating rod with a sharpened tip is placed into the drill hole. An anvil with an 8-mm hole drilled in its base is placed over the exposed end of the detonating rod (to keep the rod from rebounding). Finally, the individual employing the blasting caps should be clothed in protective eyewear and thick gloves and should keep his or her body out of alignment with the rod and anvil at all times. In order to detonate the caps, a large rock hammer is used to strike the anvil quickly and firmly. Usually, the blasting caps will explode with little noise and only minor dust and will produce cracks in the breccia. Often, multiple blasting cap detonations are necessary to sufficiently crack the breccia to remove the blocks. Explosive caps are useful in that they seem to provide a somewhat less labor-intensive method for removing several smaller blocks, when compared with large drills, wedges, and pry bars. Moreover, they allow greater control during excavation so that more precise provenance can be recorded and may produce less damage to fossils remaining in the breccia blocks.

Our efforts during the 2003 and 2004 field seasons produced 125 provenanced

Fig. 5. An excavation trench of in situ *deposits near the base of Member 2.*

blocks of breccia, 289 bags of fossil material, and well over 500 fossils. Reliable field identifications indicate the presence of bovids, rodents, and primates in the assemblage. Collecting agents resulting in the presence of both very large and very small mammalian taxa can only be assessed after further analysis. The fossil material is currently undergoing preparation at University of the Witwatersrand. Preparation of fossil material from breccia is clearly a prolonged and labor intensive process that must be completed before detailed faunal lists can be constructed or more sophisticated paleoecological and taphonomic issues can be addressed.

An *in situ* exposure adjacent to Member 2 was revealed during the removal of Member 2 overburden and has facilitated the recovery of the first fossil material from Limeworks deposits that are not accounted for by the member system, including an articulated bovid skeleton. While the Member 2 and adjacent exposures are not richly fossiliferous, the fossils they contain provide critical provenanced information important not only for the hominin remains they could produce, but also for documentation of faunal successions that will aid environmental interpretations of the Limeworks deposits. Preliminary studies indicate that Member 2 holds some of the oldest mammalian fossils of South Africa, including *Dinofelis barlowi* and a hyaenid, but thus far little work has been done to explore its biodiversity and possible hominin content. Members 3 and 4 are better known, but critical taphonomic and environmental issues can only be resolved with attention to the details of the fossil spatial distribution within the cave fill, requiring the recovery of provenanced fossil material.

Significance

For many years, the focus of paleoanthropological research dealt with hominin morphology and taxonomy. Contextual issues were secondary considerations, with tacit or explicit acceptance of the »savannah theory« of hominin origins – that we owe our unique evolutionary path to the need for adaptations to the expanding savannahs and diminishing forests of Africa. As noted above, the past fifteen years or so of research has brought paleoecological issues to the forefront of paleoanthropology, and along with it major modifications to the savannah hypothesis[7,35,37,46].

Important East African sites such as Aramis, Hadar, and Maka have played a role in establishing that early bipedal hominins were living in tropical and subtropical forested environments, not exclusively in open savannahs. Makapansgat's

Fig. 6. Adjacent exposure.

fauna[9] and flora[7] are similarly reconstructed and provide additional data regarding the range of habitats in which early hominins survived. This paleoenvironmental reconstruction is in contrast to the southern African *Australopithecus* site of Taung, which appears to have had mostly savannah-adapted fauna[47]. On the other hand, Sponheimer and Lee-Thorp[33] have suggested that *Australopithecus* consumed either grassland vegetation or animals that subsisted on grassland foods.

The lack of detailed contextual and provenance information for the Makapansgat fossil assemblage renders this important data set somewhat problematic, for contextual information gleaned from assumptions regarding breccia types from the dumps are in need of confirmation and/or correction. It is our continuing objective to recover *in situ* fossils that may influence the paleoecological reconstructions for southern Africa's earliest hominins. Only in this way can it be tested whether the mammalian fossils are giving the same paleoecological signal as the pollen profiles and carbon isotope samples.

As previously noted, there is considerable debate on varied theories concerning the possible relationships between environmental change and hominin evolution in Africa[46,48–51]. In order to test such theories, more and better provenanced fossil data are needed. It is not possible to adequately test the pace of evolution, or the effects of global climatic change on local faunal composition from geographically separate deposits. The Makapansgat Limeworks site provides a study area sampling a poorly known time period in early hominin evolution in southern Africa. Improved data from the Makapansgat Limeworks site will provide a start toward unifying the evidence from both East and South Africa concerning the earliest phases of the australopithecine radiation. This can only aid in our understanding of the causative environmental forces that may have driven and shaped human evolution.

More extensive and systematic investigation of these important breccias is clearly warranted at Makapansgat and will contribute immensely to current debates about the context of human origins. As just one example, an important focus of current paleoanthropological investigations is the role climate has played in the evolutionary process. Some have argued that changes in Plio-Pleistocene global climates actually caused hominin evolutionary changes in Africa[52–57]; others question whether such faunal turnovers are indeed real in the African fossil record or whether these apparent faunal turnovers actually pre- or postdate any significant climatic change[46,48,50,58,59]. In order to choose among these various models of evolutionary change, a better understanding of the faunal succession at southern African sites is imperative. As noted earlier, evidence from both East and South Africa strongly hints that early hominin habitats may have been more forested than traditionally believed. Excavations of *in situ* fossils at Makapansgat provide an opportunity to test this hypothesis, but only if provenanced, *in situ* fossils can be compared with the pollen profiles and other sources of data.

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NOVIJA PALEOANTROPOLOŠKA ISKOPAVANJA *IN SITU* DEPOZITA NALAZIŠTA MAKAPANSGAT, JUŽNA AFRIKA – PRELIMINARNO IZVIJEŠĆE

S A Ž E T A K

Rudnik Makapansgat važno je pleistocensko nalazište, gdje je uz brojne faunističke nalaze do sada otkriveno i 35 hominidnih fosila. Paleontološke i litološke analize ukazuju na promjene okoliša koje su od velike važnosti za razumijevanje konteksta evolucije hominina na prostoru Južne Afrike. Većina fosilnih nalaza, međutim, dolazi iz stratuma poremećenih tijekom radova, te njihov primaran kontekst ostaje upitan. U novije vrijeme započeta su sistematska istraživanja lokaliteta Makapansgat sa ciljem pronalaženja fosila unutar znanog konteksta i to kako bi: 1. odredili da li je moguće zamijetiti promjenu u fauni unutar sekvence nalazišta Makapansgat; 2. pridonijeli razumijevanju okoliša nalazišta; 3. po mogućnosti, pronašli najstarije hominine prostora Južne Afrike, istovremene vrsti *Australopithecus afarensis* prostora Istočne Afrike. Ovaj rad donosi pregled naših novijih istraživanja ovog nalazišta kao i preliminarne rezultate iskopavanja koja su u tijeku.