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The Sterkfontein Caves Palaeontological and Archaeological Site

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Sts 14, a male subadult partial skeleton of *Australopithecus africanus*?

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STS 14 AND STW 431 ARE PARTIAL SKELETONS representing *Australopithecus africanus* from Plio-Pleistocene deposits at Sterkfontein, Gauteng, South Africa. Both include pelvic bones. Sts 14s is a right subadult innominate described by Broom *et al.*[1,2] and Robinson.[3] Stw 431 includes a right adult innominate described by Toussaint *et al.*[4] Determining the sex of australopithecines from innominate bones is difficult, especially in the case of subadult specimens such as Sts 14. In this article we discuss matters concerning the sex of Sts 14 and Stw 431, and conclude that both represent males, notably on account of the morphology of the anterior inferior iliac spine. Sts 14 is relatively small, not because of the possibility of its being a female, but instead on account of the fact that it probably represents an adolescent individual.

Sts 14 was considered by Robinson[3] to be an adult individual. However, more recent analyses of the sacrum,[5-7] coxal bone[6,7] and pelvis[6-8] demonstrate that this partial skeleton certainly represents a subadult. The sacrum (Sts 14q) shows the lack of fusion of the vertebral body between S1 and S2 and between S2 and S3, and an epiphyseal plate exists on the auricular surface.[5] On the hip bone, the auricular surface does not have striations characteristic of an unfused epiphysis. The iliac crest is not fused in Sts 14r.[6-8] All this evidence points strongly to Sts 14 representing a subadult individual.

Kibii *et al.*[9] used the sciatic notch to determine the sex of australopithecine fossils. They concluded that Stw 431 represents a male and agreed with Robinson[3] in suggesting that Sts 14 was a female. However, the greater sciatic notch is not necessarily a reliable feature for determining sex in all hominid specimens. For example, it is not a reliable character for determining sex in subadult humans, nor is it diagnostic in the case of modern adult African human populations, although its applicability is better in modern adult European *Homo sapiens*. Furthermore, the modern human pelvis does not have the same morphology and functionality as those of australopithecines.

The anterior inferior iliac spine (AIIS), shown for Sts 14s in Fig. 1, is a character that is more developed in male australopithecines than in females, and appears to be a good criterion for assessing sexual dimorphism. For example, the AIIS of SK 3155b, considered to be a female,[10] has a relatively small lamella separated from the acetabulum. By contrast, Stw 431, a male australopithecine,[4] has a distinctly robust iliac spine, adjacent to the acetabulum. Similarly, the same robustness of the spine is displayed in SK 50, which has also been identified as a male australopithecine.[10]

Significantly, the AIIS is well developed in Sts 14s as well as in Stw 431 (Fig. 2). The morphology is similar in both specimens, including the robust protuberance adjoining the superior margin of the acetabulum.

In the human pelvis, the AIIS is well developed, contrasting with the condition in apes.[11-14] The development of the iliac spine is evidently related to erect posture and locomotion,[13,14] since it is the locale of insertion of the iliofemoral ligament and the *m. rectus femori*, which are essential for habitual bipedalism. The reason that the iliac spine is more developed in males relates to greater stresses on the superior part of the pelvis in individuals of this sex.

It is apparent that the difference in robustness of the anterior inferior iliac spine is related to sexual dimorphism in

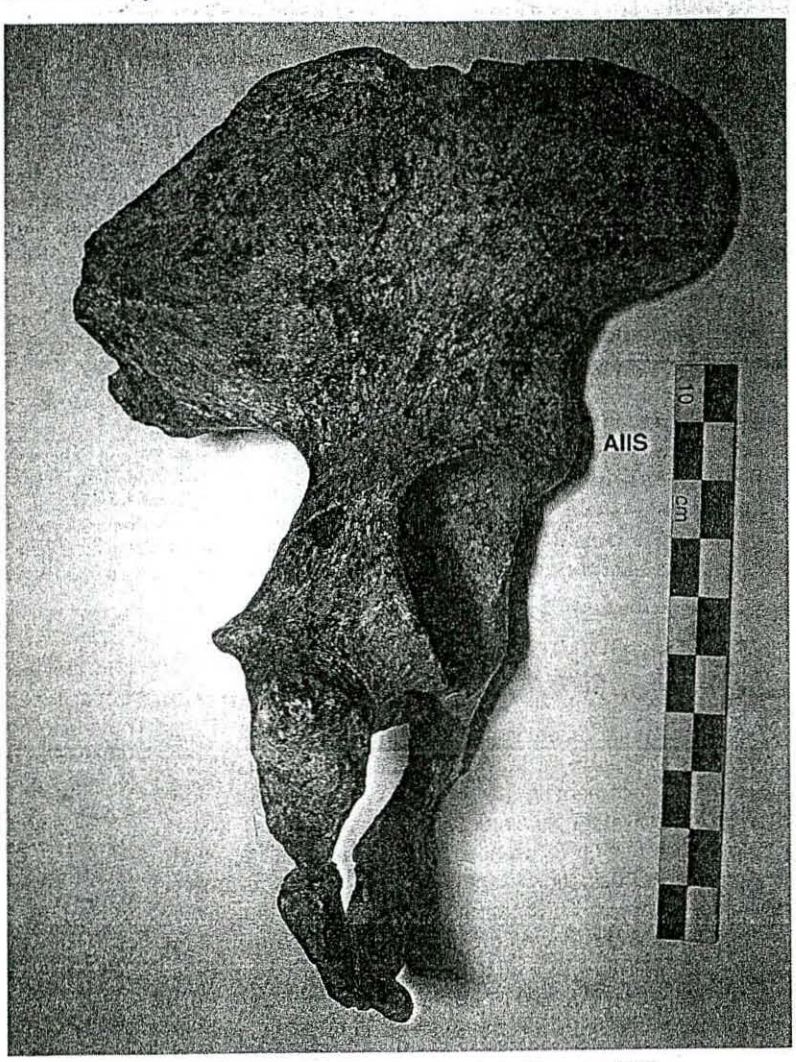

Fig. 1. Pelvis of Sts 14s, indicating the position of the anterior inferior iliac spine (AIIS).

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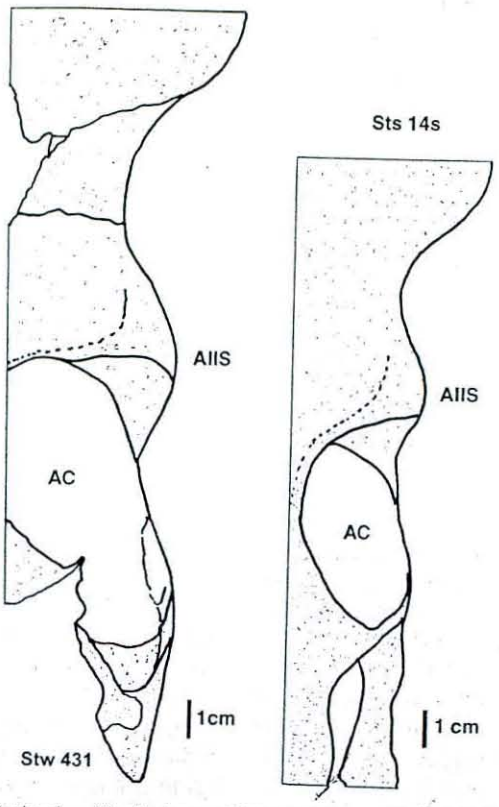

Fig. 2. Profiles of the anterior border of the hip bones of Sts 14 (**right**) and Stw 431 (**left**). Both display a prominent anterior inferior iliac spine (AIIS) adjacent to the acetabulum (AC). The prominent AIIS is considered to be a male feature. Stw 431 represents an adult male, whereas Sts 14 is here considered to be an adolescent male of the same species.

australopithecines. In terms of this criterion, Sts 14s represents a small male, and its smallness relative to Stw 431 relates in part to differences in individual age. Stw 431 is larger because it probably represents an adult male, whereas Sts 14s is a smaller (adolescent) male.

It has been suggested that Sts 5 ('Mrs Ples') and Sts 14 represent the same individual.[8] Both are adolescent individuals and both were found in close proximity to each other at the top of Member 4 at Sterkfontein.[16] It has also been suggested that Sts 5 represents a male.[17,18] If Sts 5 was indeed a male, it is consistent with the possibility that Sts 14 represents the same individual, since our present study indicates that Sts 14 was also male.

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1. Broom R. and Robinson J.T. (1950). Notes on the pelves of the fossil ape-men. *Am. J. Phys. Anthrop.* 8, 489–494.
2. Broom R., Robinson J.T. and Schepers G.W.H. (1950). Sterkfontein Ape-Man *Plesianthropus*. *Transvaal Museum Memoir* 4, 1–117.
3. Robinson J. (1972). *Early Hominid Posture and Locomotion*. University of Chicago Press, Chicago.
4. Toussaint M., Macho G.A., Tobias P.V., Partridge T.C. and Hughes A.R. (2003). The third partial skeleton of a late Pliocene hominin (Stw 431) from Sterkfontein, South Africa. *S. Afr. J. Sci.* 99, 215–223.
5. Berge C. and Gommery D. (1999). Le sacrum de Sterkfontein Sts 14Q (*Australopithecus africanus*): nouvelles données sur la croissance et sur l'âge osseux du spécimen (hommage à R. Broom et J.T. Robinson). *C. R. Acad. Sci. Paris, Ser. IIa* 329, 227–232.
6. Gommery D., Senut B. and Keyser A. (2002). Description d'un bassin fragmentaire de *Paranthropus robustus* du site Plio-Pléistocène de Drimolen (Afrique du Sud). *Geobios* 35, 265–281.
7. Haüsler M and Berger L. (2001). Stw 441/465: a new fragmentary ilium of a small-bodied *Australopithecus africanus* from Sterkfontein, South Africa. *J. Hum. Evol.* 40, 41–417.
8. Thackeray J.F., Gommery D. and Braga J. (2002). Australopithecine postcrania (Sts 14) from the Sterkfontein caves, South Africa: the skeleton of 'Mrs Ples'? *S. Afr. J. Sci.* 98, 211–212.
9. Kibii J.M. and Clarke R.J. (2003). A reconstruction of the Stw 431 *Australopithecus* pelvis based on newly discovered fragments. *S. Afr. J. Sci.* 99, 225–226.
10. Wolpoff M. (1976). Some aspects of the evolution of early hominid sexual dimorphism. *Curr Anthropol.* 17(4), 579–600.
11. Aiello L. and Dean C. (1990). *An Introduction to Human Evolutionary Anatomy*. Academic Press, London.
12. Swindler D. and Wood C. (1973). *An Atlas of Primate Gross Anatomy: Baboon, Chimpanzee and Man*. University of Washington Press, London.
13. Lessertisseur J. (1958). Signification de l'épine iliaque antéro-inférieure chez les primates. Première partie: étude ostéologique et myologique. *Bull. Mus. Nat. Hist. Natur., 2ème série* 30(6), 482–489.
14. Lessertisseur J. (1959). Signification de l'épine iliaque antéro-inférieure chez les primates. Deuxième partie: interprétation et conclusion. *Bull. Mus. Nat. Hist. Natur., 2ème série* 31(1), 80–84.
15. Lessertisseur J. and Saban R. (1967). Squelette appendiculaire. In *Traité de Zoologie. Anatomie, Systématique, Biologie, Tome XVI, Fascicule 1, Mammifères, Téguments, Squelette*, ed. P-P. Grasse, pp. 709–1078. Masson, Paris.
16. Thackeray J.F., Braga J., Treil J., Niksch N. and Labuschagne J.H. (2002). 'Mrs Ples' (Sts 5) from Sterkfontein: an adolescent male? *S. Afr. J. Sci.* 98, 21–22.
17. Thackeray J.F. (2000). 'Mrs Ples' from Sterkfontein: small male or large female? *S. Afr. Archaeol. Bull.* 55, 155–158.
18. Rak Y. (1983). *The Australopithecine Face*. Academic Press, New York.

Research opportunities with Europe: preparing for FP7

The Department of Science and Technology (DST) invites researchers interested in the European South African Science and Technology Advancement Programme (ESASTAP) to a workshop, on 18 August 2006 at the Innovation Hub, Pretoria. This will start the ESASTAP campaign to prepare the South African research community for participation in the European Union's forthcoming Seventh Framework Programme (FP7), to be launched in early 2007. The workshop will provide the latest information on the scientific content of, as well how to participate in, the FP7. It will also launch the ESASTAP FP7 summaries of intended participation (SIP) exercise, which is the main preliminary FP7 activity in which South African researchers will be invited to participate.

The first call for these SIPs will be published on 18 August and close on 30 September 2006. The ESASTAP team and other experts will then work closely with researchers who have submitted SIPs to refine their ideas and assist their collaboration with European consortia.

The submission of an SIP will be a criterion for FP7 seed funding applications to be submitted to the DST during the last quarter of 2006. A compendium of the South African SIPs will then be published and disseminated in Europe to assist South African researchers in finding European FP7 partners, and more generally to market South African science and technology in Europe.

Further information on ESASTAP or FP7 is available at http://www.esastap.org.za/esastap/events/events.ph. Those wishing to participate in the workshop should write to contact@esastap.org.za

The fat content and the fatty acid composition of the fourteen species are recorded in Table 1. This table shows exceptionally high fat contents of 22.7% and 19.3% for rudder fish (*Centrolophus niger*) and armourhead (*Pentaceros* species), respectively, whereas smooth- and roughskin oilfish (*Ruvettus* species) both had more than 13% fat. Fish containing such high fat contents where indigestible wax esters are present may lead to severe diarrhoea. The wax ester content of the 'butter fish' (*Lepidocybium flavobrunneum*) was 23%[3] and dietary recommendations were given to the public. The wax ester content of smooth and roughskin oilfish (*Ruvettus* species) is about 13% and similar dietary recommendations for these fish are suggested. The other fish species investigated in this survey require no special warning.

The fatty acid compositions show a very high content (>20%) of C22:6 (docosahexaenoic acid or DHA) in the lipids of alfonsino (*Beryx spendens*), jacopever (*Helicolenus maculatu*), dane (*Porcostoma dendata*) and bluenose (*Hyperoglyphe antarctica*). This phenomenon is common in fish having low fat contents and has been observed previously.[4] The results in this report, together with the health warning, should be included in the food composition tables of the Medical Research Council.

1. Bligh E.G. and Dyer W.J. (1959). A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.* **37**, 911–917.
2. de Koning A.J. and Evans A.A. (1991). Phospholipids of marine origin. The lantern fish (*Lampanyctodes*). *J. Sci. Food Agric.* **56**, 503–510.
3. Berman P., Harley E.H. and Spark A.A. (1981). Keriorrhoea, the passage of oil per rectum after ingestion of marine wax esters. *S. Afr. Med. J.* **59**, 791–792.
4. Evans A.A. and Wessels J.P.H. (1984). Fatty acid composition of various fresh and canned products and one smoked product. *Fishing Ind. Res. Inst. Ann. Rep.* **38**, 115–117.

A reconstruction of the Stw 431 *Australopithecus* pelvis based on newly discovered fragments

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A NEWLY DISCOVERED LARGE FRAGMENT of ilium belonging to the Sterkfontein *Australopithecus* pelvis Stw 431 has enabled us to make an accurate reconstruction of much of the pelvis. This shows that the blades of the pelvis flared out laterally, unlike those of modern humans, which are more vertically orientated.

Introduction

During May 2002, one of us (J.M.K.), while analysing boxes of fossil fragments from Sterkfontein Member 4, identified a posterior portion of hominid ilium that had, at the time of its recovery in 1987, been mistakenly classified as a bovid. The fragment, measuring approximately 8.5 cm long by 4.5 cm in depth, represents the postero-inferior portion of the left ilium extending from the middle of the greater sciatic notch back to the posterior superior iliac spine and adjacent portion of posterior iliac crest. This latter region is inflated in the form of a tuberosity and projects about 2.5 cm behind the auricular surface that articulates with the sacrum. The fragment was marked with the location Q/45 21'11"–22'11", and from this grid square and depth and from its state of preservation and colour, it could be concluded that it most probably belonged to the Stw 431 *Australopithecus* partial skeleton.[1] This was confirmed when it was found to fit at three small points of contact at its anterior end with the Stw 431 left acetabulum and along its auricular surface with the Stw 431 sacrum. A subsequent thorough search by both of us through the many bags of fragments from excavation squares associated with the 431 skeleton produced four more fragments. One piece fitted with the larger fragment along the posterior auricular surface, and another joined with the lateral surface behind the left acetabulum. The third fragment represented the posterior part of iliac crest and superior iliac spine of the right ilium, and the fourth was a small fragment of the right posterior auricular surface with adjacent superior and lateral surfaces of the right ilium (Fig. 1).

This discovery of a large portion of left ilium that links the sacrum and acetabulum was of great significance because previously the orientation of the ilium to sacrum had not been known, as the right ilium had no contact with the sacrum. Now it was possible, through mirror imaging of these uncrushed and undistorted left and right ilia, to obtain an accurate reconstruction of much of the pelvis and to see the exact orientation of the blades of the ilia (Figs 2, 3). This was achieved in the following way.

1) The sacrum was set vertically on plasticine on a turntable and the newly constructed left iliac portion was placed into position against the sacrum and supported with plasticine.
2) The two new small fragments of right ilium were placed into position with

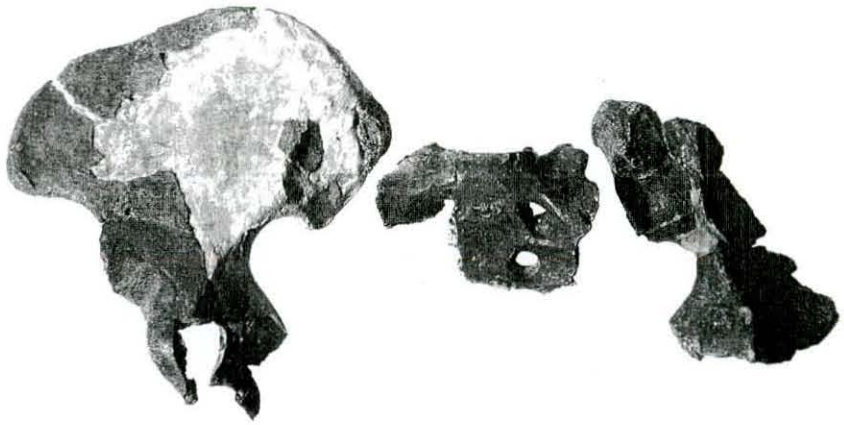

Fig. 1. Component parts of the pelvis: (from left to right) right ilium, sacrum and left ilium. Newly recovered fragments are the upper half of the left ileum and two small pieces at the right of the right ilium.

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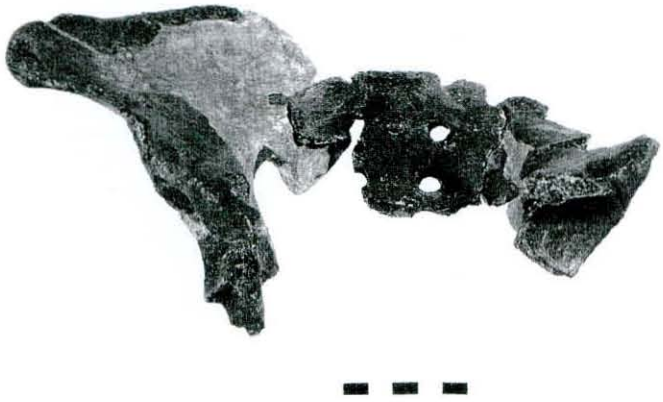

Fig. 2. Anterior view of the reconstructed Stw 431 pelvis.

Fig. 3. Superior view of the reconstructed Stw 431 pelvis.

plasticine, one locking into the sacrum along its contact with the auricular surface, and the other just posterior to it such that both mirror-imaged the corresponding portions of the opposite ilium. The two fragments were then joined with plaster of Paris, which was extended anteriorly along the auricular surface of the sacrum but separated from it by a film of Vaseline.

3) A thin backing of plasticine was applied against the lateral surface of the right ilium and extended backwards across the missing area of the ilium to reach the posterior superior iliac spine. This right ilium was then placed on a plasticine pillar on the turntable and adjusted with levels and measurements until it was symmetrical with the left ilium in all aspects. Plaster of Paris was then used to unite the larger supero-anterior portion of the right ilium with the two small, newly discovered fragments close to the sacrum. This nearly completed ilium was then removed from its contact with the sacrum and the missing parts of ilium were reconstructed with plaster after the larger areas of internal bone had been sealed with plasticine. A separate inferior portion of right acetabulum was orientated on a small pillar of plasticine into its correct position relative to the rest of the acetabulum. The plasticine pillar was then covered with plaster, which was sculpted to conform with the adjacent pelvic surfaces.

Conclusions

When both ilia are joined to the sacrum, the iliac blades flare out laterally instead of rising more vertically as they do in modern humans. In this respect the Stw 431 pelvis resembles the reconstruction of the *Australopithecus afarensis* ('Lucy') pelvis made by Schmid[2] and differs from that made by Lovejoy,[3] as well as from the reconstructed Sterkfontein *Australopithecus* pelvis of Sts 14,[4] both of which have more vertically orientated pelvic blades. However, examination of this latter, slightly deformed specimen shows that the right side of the sacrum is completely reconstructed with plaster and the upper part of the left iliac blade is incorrectly aligned with the lower part by a large area of plaster. It is thus probable that slight adjustments to these reconstructed areas would result in a more lateral pelvic blade orientation.

In a description of the anatomy of the Stw 431 pelvis made prior to the discovery of these new fragments, Haeusler[5] published his reconstruction of the pelvis, which is now seen to be not quite correct in that he orientated the iliac blades somewhat more vertically, as they are in Sts 14. Furthermore, from the newly reconstructed left ilium, we now know for certain the form of the greater sciatic notch. It is tightly curved, as is usual in modern human males, and not broadly curved as in Haeusler's reconstruction. The smaller Sts 14 pelvis has a more open curvature to the sciatic notch, and this suggests the probability that it is a female and that the larger Stw 431 with the tighter curvature of the notch is a male. We cannot, however, be certain that they belong to one species of *Australopithecus*, and we cannot be sure at this stage that either of them necessarily represents *Australopithecus africanus* because a second species of *Australopithecus* is represented by cranial fossils in the Sterkfontein Member 4 assemblage.[6]

Of all the known australopithecine pelves, the Stw 431 specimen is the only one that is uncrushed and undeformed. Thus this reconstruction cannot be faulted for the same reasons as were reconstructions of the crushed AL 288-1 (Lucy) pelvis.[7] Instead, this reconstruction of Stw 431, based on undeformed fossil parts, is so similar to two of those made on the Lucy pelvis[2,7] that it tends to support the conclusion of Susman *et al.* that the lateral orientation of the iliac blades is 'well suited for a part-time climber and part-time terrestrial biped.'[7] This accords well with the previous suggestions that the older *Australopithecus* Stw 573 foot and hand from Sterkfontein Member 2 would have facilitated arboreal locomotion.[8–11]

We wish to express our gratitude for financial support from the L.S.B. Leaky Foundation, the National Research Foundation, the University of the Witwatersrand, and the Ford Foundation

1. Toussaint M., Macho G.A., Tobias P.V., Partridge T.C. and Hughes A.R. (2003). The third partial skeleton of a late Pliocene hominin (Stw 431) from Sterkfontein, South Africa. *S. Afr. J. Sci.* **99**, 215–223.
2. Schmid P. (1983). Eine Rekonstruktion des Skelettes von A.L.288-1 (Hadar) und deren Konsequenzen. *Folia primatologica* **40**, 283–306.
3. Johanson D.C. and Edey M.A. (1981). *Lucy, The Beginnings of Humankind.* Granada, London and New York.
4. Robinson J.T. (1972). *Early Hominid Posture and Locomotion.* Chicago University Press, Chicago.
5. Haeusler M. (2002). New insights into the locomotion of *Australopithecus africanus* based on the pelvis. *Evol. Anthropol.*, Suppl. **I**, 53–57.
6. Clarke R.J. (1988). A new *Australopithecus* cranium from Sterkfontein and its bearing on the ancestry of *Paranthropus*. In *Evolutionary History of the Robust Australopithecines*, ed. F.E. Grine, pp. 285–292. Aldine de Gruyter, New York.
7. Susman R.L., Stern J.T. and Jungers W.L. (1984). Arboreality and bipedality in the Hadar hominids. *Folia primatologica* **43**, 113–156.
8. Clarke R.J. and Tobias P.V. (1995). Sterkfontein Member 2 foot-bones of the oldest South African hominid. *Science* **269**, 521–524.
9. Clarke R.J. (1999). Discovery of complete arm and hand of the 3.3 million-year-old *Australopithecus* skeleton from Sterkfontein. *S. Afr. J. Sci.* **95**, 477–480.
10. Clarke R.J. (2002). Newly revealed information on the Sterkfontein Member 2 *Australopithecus* skeleton. *S. Afr. J. Sci.* **98**, 523–526.
11. Partridge T.C., Granger D.E., Caffee M.W. and Clarke R.J. (2003). Lower Pliocene hominid remains from Sterkfontein. *Science* **300**, 607–612.

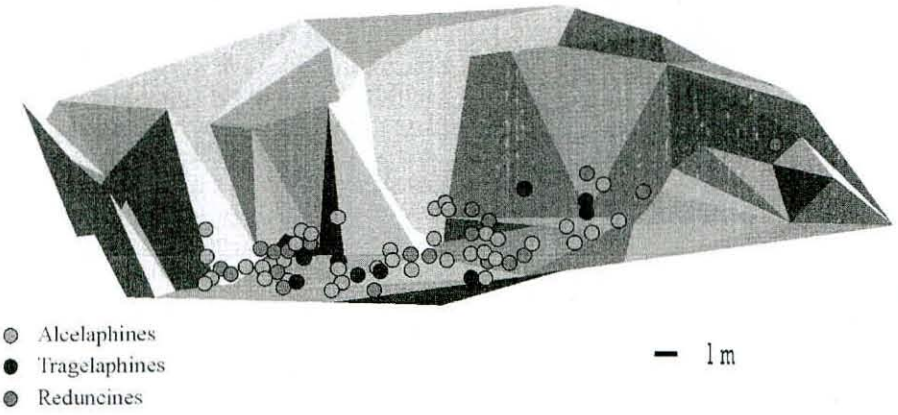

Fig. 2. This GIS-generated map shows the location of fossil specimens attributed to three different bovid tribes excavated from the Gladysvale External Deposits (GVED). The geological context is represented by the brown area. Members of these tribes have different habitat preferences that range from open to wooded areas and swamps. Their mixed location in the assemblage do not indicate a predominance of habitat types in the different areas of the deposits. Alcelaphines are the most abundant tribe in this assemblage.

habitats for these areas. Figure 3 shows the presence and location of bones damaged by carnivores and porcupines, taxa that have been identified as possible agents responsible for the GVED bone accumulation.[13] Varying spatial patterns for carnivore- and porcupine-damaged specimens would indicate differences in the accumulating agent in different parts of the deposit.

In both cases, no spatial discrimination between data sets was evident. The different antelope tribes have overlapping distributions, as do the carnivore- and porcupine-damaged bone remains. The random nature of their distributions is evident in the context of the topographic map of the site in each figure. No specific spatial patterns, vertical or horizontal, can be recognized. Therefore, these data provide no evidence for environmental differentiation or different taphonomic agents for the various areas of the deposit.

Discussion

The lack of spatial patterning between bovid tribes and between carnivore-damaged and porcupine-gnawed bones may be the result of post-depositional movement of fossils within the GVED due to loss of carbonate cement. A pilot study suggested a loss in $CaCO_3$ of 35% by volume in the decalcified sediments compared to the cemented breccias. This loss could have contributed to the movement of individual fossils within this section of the deposit. Other causes might be related to taphonomic processes such as selective carnivore behaviour. Analysis of fossils within the cemented breccias will likely provide more insights into those agents responsible for the accumulation and positioning of fossils within the Gladysvale deposits.

We conclude therefore that laser theodolite mapping of individual fossils and subsequent GIS analysis has the potential to reveal valuable information concerning environmental context and taphonomic agents responsible for the accumulation of fossils at sites such as Gladysvale.

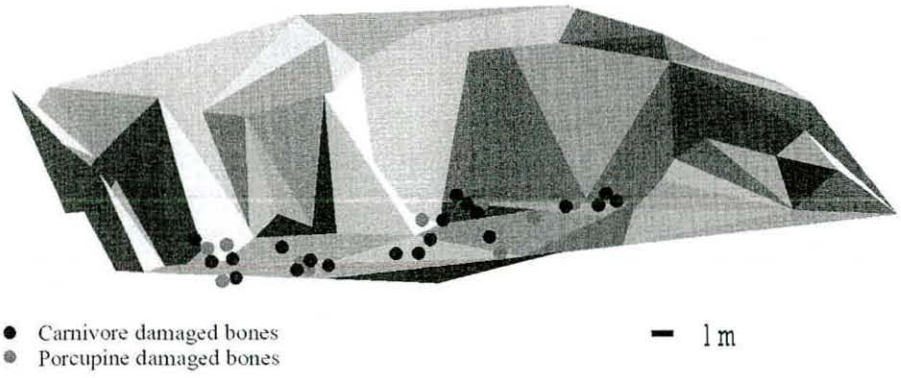

Fig. 3. This GIS-generated map shows the location of bones excavated from the Gladysvale External Deposits that display surfaces modified by carnivores and porcupines. Their position within the geological context, represented by the brown area, indicates that no spatial patterning can be recognized. Thus, we cannot determine the relative activity of carnivore or porcupine in different parts of the deposit.

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1. Berger L.R., Keyser A.W. and Tobias P.V. (1993). Gladysvale: first early hominid site discovered in South Africa since 1948. *Am. J. Phys. Anthropol.* **92**, 107–111.
2. Lacruz R., Brink J.S., Hancox P.J., Skinner A., Herries A., Schmid P. and Berger L.R. (2002). Palaeontology and geological context of a Middle Pleistocene faunal assemblage from the Gladysvale Cave, South Africa. *Palaeont. afr.* **38**, 99–114.
3. Berger L.R. and Tobias P.V. (1994). New discoveries at the early hominid site of Gladysvale, South Africa. *S. Afr. J. Sci.* **90**, 223–226.
4. Berger L.R. (1992). Early hominid fossils discovered at Gladysvale Cave, South Africa. *S. Afr. J. Sci.* **88**, 362.
5. Schmid P. and Berger L.R. (1997). Middle Pleistocene hominid carpal proximal phalanx from the Gladysvale site, South Africa. *S. Afr. J. Sci.* **93**, 430–411.
6. Moriarty K.C., McCulloch M.T, Wells R.T. and McDowell M.C. (2000). Mid-Pleistocene cave fills, megafaunal remains and climate change at Naracoorte, South Australia: towards predictive model using U-Th dating of speleothems. *Palaeogeog., Palaeoclim., Palaeoecol.* **159**, 113–143.
7. Curnoe D. (1999). *A contribution to the question of early* Homo *in southern Africa: researches into dating, taxonomy and phylogeny reconstruction.* Ph.D. thesis, Australian National University, Canberra.
8. Cooke H.B.S. (1963). Pleistocene mammal faunas of Africa, with particular reference to S. Africa. In *African Ecology and Human Evolution*, eds F.C. Howell and F. Boulière, pp. 65–116. Aldine, Chicago.
9. Brink J.S. (1999). Preliminary report on a caprine from the Cape Mountains, South Africa. *Archaeozoology* **10**, 11–26.
10. Lock G. and Stancic Z. (1995). *Archaeology and Geographic Information Systems: A European Perspective.* Taylor & Francis, London.
11. Petrie L., Johnson I., Cullen B. and Kvamme K. (1995). *GIS in Archaeology: An Annotated Bibliography.* Sydney University Archaeological Methods Series 1, Sydney.
12. Nigro J.D., Ungar P.S., De Ruiter D. and Berger L.R. (2003). Developing geographic information system (GIS) for mapping and analyzing fossil deposits at Swartkrans, Gauteng Province, South Africa. *J. Archaeol. Sci.* **30**, 317–324.
13. Lacruz R.S. (2002). *Analysis of stratified fossil deposits from the Gladysvale Cave, South Africa.* M.Sc. thesis, University of the Witwatersrand, Johannesburg.
14. Vrba E.S. (1980). The significance of bovid remains as indicators of environment and predation patterns. In *Fossils in the Making*, eds A.K. Behrensmeyer and A.P. Hill, pp. 247–271. University of Chicago Press, Chicago.
15. Reed K.E. (1996). *The palaeoecology of Makapansgat and other African Plio-Pleistocene hominid localities.* Ph.D. thesis, State University of New York, Stony Brook.

Preliminary results of excavations at Lincoln Cave, Sterkfontein, South Africa

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RECENT EXCAVATIONS OF UNDISTURBED deposits within the Lincoln Cave, Sterkfontein, have conclusively demonstrated that at least one of the deposits is mid- to late Pleistocene in age. The artefacts recovered from this excavation are in a datable context, sandwiched between two flowstone layers which could be dated using uranium series methods. The excavation furthermore yielded good indications that a portion of an older breccia has been eroded and that fauna and artefacts from this older, reworked breccia have been redeposited within the younger deposit. These findings suggest that the Lincoln Cave system may be connected to the Sterkfontein Cave system and that the location of the possible link lies in the vicinity of grid square L/63 in the main Sterkfontein excavation.

Introduction

The Sterkfontein hominid site is situated within the Sterkfontein Valley, 50 km northwest of Johannesburg. In 1997 excavations were undertaken in the Lincoln Cave, an area of the Sterkfontein site which had not then been examined in detail. Prior to excavation, we postulated that the Lincoln Cave would contain a Middle Stone Age (MSA) deposit, as this part had previously been considered to be mid- to late Pleistocene in age by A. Hughes and E. Vrba (R.J. Clarke, pers. comm.). This report presents the results of dating samples taken for analysis and a brief overview of the deposit and material recovered during the course of excavations.

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Methods

A portion of the Lincoln Cave deposit to the south of the cave was uncalcified and could be removed with picks and shovels. From there the excavated material was wet-sieved. The calcified deposit at the northern side of the cave necessitated the use of hammers and chisels, however, which we found to be more effective and less destructive than a jackhammer. Small blocks of breccia were removed and the provenances recorded, after which bones and stones were released from the matrix.

Air-scribes and hand tools were used to remove the breccia from around the individual bones.

The fossils and artefacts analysed for this study were excavated from early 1997 to 1998. Material from subsequent excavations has been excluded here. These artefacts and fossils are presently housed at the University of the Witwatersrand.

Location of the Lincoln Cave

Lincoln Cave forms part of the Lincoln-Fault cave system, which lies adjacent to the Sterkfontein Cave system. Very little has been published on this cave, with the exception of a speleological survey by Boshoff and colleagues.[1] At that time, the Lincoln-Fault cave measured 1665 m in length, making it one of South Africa's longest caves. Despite the name, Boshoff and his colleagues could find no

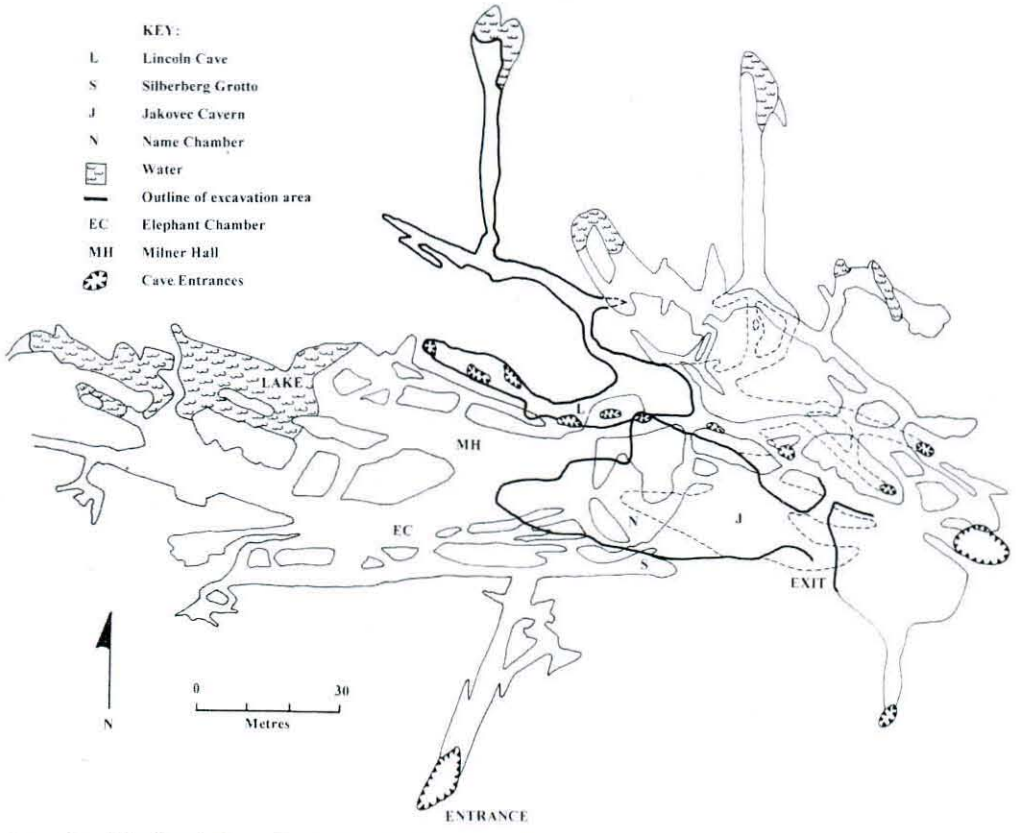

Fig. 1. South–north cross section of the Lincoln Cave. The deposit on the left is Lincoln Cave South and the deposit on the right is Lincoln Cave North.

* Captions are wrong and Errata will be published

sign of a fault or fracture inside the cave, nor did they consider it possible that there could be a link between the Lincoln-Fault and Sterkfontein cave systems owing to the chert barrier between them described as a 'formidable obstacle', permitting only water to pass through tiny cracks in the chert.[1]

The Lincoln Cave deposits

Lincoln Cave contains a broad band of deposit in one area (Fig. 1), which has been obscured in the middle by the lime miners who constructed a rubble ramp to facilitate the removal of the breccia and lime from the cave during mining operations over 60 years ago. The ramp effectively divides the deposit into two smaller deposits, which we designated Lincoln Cave North and Lincoln Cave South, and has been temporarily left there by us to facilitate access to the excavation.[2] Much of the surrounding deposit was blasted and removed by the mining operations. The Lincoln Cave North breccia is uniformly hard, and it appears in places to extend across the cave to the southern wall, although this material was not excavated. Rather, the softer material above was excavated from the most southerly area and this material is referred to as the Lincoln Cave South sample.

The stratigraphic profile of the Lincoln Cave North deposit (Fig. 2) reveals that the fossiliferous breccia is sandwiched between two layers of flowstone and that this breccia varies in thickness. Uranium series dating can be applied to such flowstone to give chronological boundaries for the deposit. The procedure is briefly as follows: The radioactivity of the uranium and thorium isotopes is determined by alpha particle counting and the age of the flowstone is given by the activity ratio of ^{234}U and its daughter isotope, ^{230}Th. The presence of non-radiogenic ^{232}Th in the samples indicates that some ^{230}Th also would have been present when the layer was formed and a correction for this initial ^{230}Th needs to be made. Experience has shown that the initial $^{230}Th/^{232}Th$ ratio commonly is about unity.[3] When this correction is made, the capping flowstone gives an age of 115 300 ± 7700 years and the lower flowstone dates to 252 600 ± 35 600 years ago (Table 1). The North breccia in between is thus firmly placed within the earlier Middle Stone Age. The earliest date for an MSA assemblage in southern Africa is from Florisbad, *c.* 259 000 ± 35 000 years,[4] and the MSA persists until *c.* 22 000 years ago.[5]

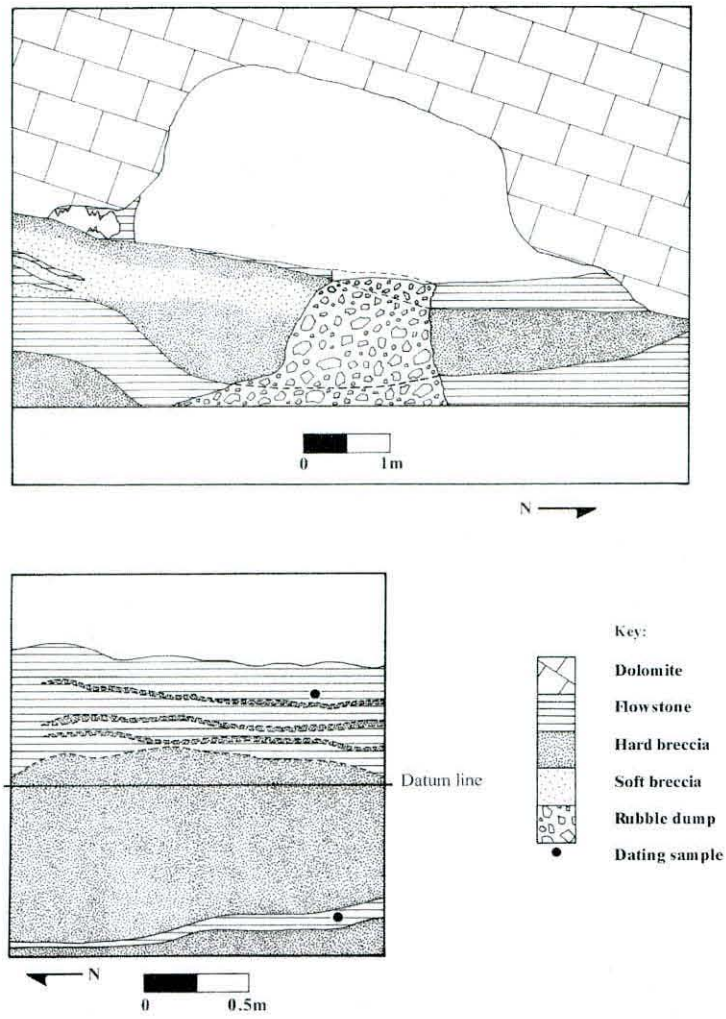

Fig. 2. North–south stratigraphic profile of the Lincoln Cave North deposit of the western side of the deposit. The triangle indicates the approximate location of the second dating sample, which was taken from the eastern side of the profile (after ref. 2).

Results

Faunal samples from the Lincoln Cave North and South samples were analysed separately and species identified are listed in Tables 2 and 3. Lincoln Cave North contains fauna typical of the mid- to late Pleistocene. All but one species (*Megalotragus* species) are extant. *Equus burchellii, Antidorcas* species and Alcelaphinae species identified from this deposit are associated with grassland environments.[6] Although the artefact assemblage from Lincoln Cave North is small (five specimens), these artefacts appear typologically older than the MSA and may indicate possible mixing between older and younger deposits.

Analysis of the faunal material of the Lincoln Cave South sample (Table 3) likewise indicates possible mixing between older and younger deposits. Two extinct species of hominid, *Homo* cf. *ergaster* and *Paranthropus* species, have recently been recovered from this deposit.[6] The artefact assemblage recovered from Lincoln Cave South (69 specimens) contains four artefacts diagnostic of the MSA. These are three quartz flakes with faceted platforms, and a diabase blade.[7] However,

Table 1. Dating results for flowstone from Lincoln Cave North deposit.

Analysis no.	Sample position	(ppm)	Activity ratios			Age (kyr)*	
			U-234/U-238	Th-230/U-234	Th-230/Th-232	$f = 0$	$f = 1$
U-587	Capping	0.103 ± 0.003	1.468 ± 0.053	0.725 ± 0.027	18.5 ± 1.9	126.8 ± 8.6	115.3 ± 7.7
U-614	Base	0.109 ± 0.002	1.358 ± 0.028	0.977 ± 0.04	111 ± 35	260.6 ± 37.9	252.6 ± 35.6

*The ages given in the last column are those corrected for an initial $^{230}Th/^{232}Th$ activity ratio of unity, that is, $f = 1$.

Table 2. Macromammalian taxa recovered from Lincoln Cave North.

Primates	
Papio cf. *cynocephalus*	Chacma baboon
Carnivora	
Canis mesomelas	Black-backed jackal
Vulpes chama	Cape fox
Hyaenidae indet.	Unidentified hyaena
Artiodactyla	
Antidorcas sp.	Springbok
Pelea capreolus	Grey rhebok
Tragelaphus cf. *scriptus*	Bushbuck
Cf. *Megalotragus* sp.	Extinct giant hartebeest
Damaliscus dorcas	Blesbok
Phacochoerus aethiopicus	Warthog
Hippopotamus amphibius	Hippopotamus
Perissodactyla	
Equus burchellii	Plains zebra
Rodentia	
Hystrix africaeaustralis	Porcupine

Table 3. Macromammalian taxa recovered from Lincoln Cave South.

Primates	
Homo cf. *ergaster*	Extinct hominid
Paranthropus sp.	Extinct hominid
Papio cf. *cynocephalus*	Chacma baboon
Carnivora	
Canis mesomelas	Black-backed jackal
Vulpes chama	Cape fox
Otocyon megalotis	Bat-eared fox
Suricata cf. *suricatta*	Suricate (meerkat)
Artiodactyla	
Hippotragus sp.	Large hippotragine
Raphicerus campestris	Steenbok
Antidorcas sp.	Springbok
Pelea capreolus	Grey rhebok
Cephalophinae indet.	Indeterminate duiker
Cf. *Megalotragus* sp.	Extinct giant hartebeest
Damaliscus dorcas	Blesbok
Phacochoerus aethiopicus	Warthog
Perissodactyla	
Equus burchellii	Plains zebra
Hyracoidea	
Procavia capensis	Hyrax
Rodentia	
Hystrix africaeaustralis	Porcupine
Pedetes capensis	Springhare
Lagomorpha	
Lepus cf. *capensis*	Hare

certain artefacts recovered from this deposit, including a quartzite bifacial chopper core, are more similar to Early Acheulean artefacts recovered from the Member 5 West deposit in the main Sterkfontein excavation.[8-10] This combination of characteristic ESA and MSA tool forms suggests mixing between older and younger deposits.

Discussion

The recovery of typologically older artefacts and hominids in association with diagnostic MSA artefacts from the South deposit indicate the erosion of older deposits and subsequent redeposition of this material within the Lincoln Cave context. During the course of the excavation, it became apparent that the deposit extended across the cave into breccia at the southern wall of the cave. We continued the excavation into the southern breccia deposit and found that we had excavated to within approximately seven metres of the main site, while the breccia deposit continues in a southerly direction. No sign has yet been found of the chert barrier between them described by Boshoff and colleagues,[1] thus the infill appears to be continuous, possibly linking Lincoln Cave with the main Sterkfontein excavation in grid square L/63.

The age of the deposit in the area of L/63 is not known because its contents are not definitive for a relative age and it lacks datable materials, although Clarke is currently expanding the excavation of this area to obtain further information. A single tooth assumed to represent early *Homo sapiens* has been recorded.[6] The L/63 area is almost certainly of a similar age to the Lincoln Cave deposits and is thus assumed to date from the mid- to late Pleistocene.[7] Stratigraphic information suggests that the L/63 intrusive infill is younger than the contiguous Member 5 West deposit, which has been dated to 1.7–1.4 million years on the basis of the age of the Early Acheulean stone tool industry and the associated hominids and fauna identified from this deposit, including specimens of *Homo ergaster*.[6,10,11]

Conclusions

The Early Acheulean artefacts identified from both Lincoln Cave North and South assemblages, and the *Homo* cf. *ergaster* identified only from the South sample, appear to have been eroded out of the older Member 5 West breccia and deposited into the Lincoln Cave by means of a connection in the L/63 area, which became choked with deposit during the formation of the younger deposit. The isolated *Paranthropus* incisor recovered from the South sample most likely eroded out of the Member 5 East Oldowan deposit, where three teeth from *Paranthropus* have been recorded.[11,12]

Differences between the uniformly hard breccia from the North deposit and the softer, unconsolidated South deposit suggest that different depositional phases of the same deposit were excavated. Further investigation of the faunal and artefactual material contained within these deposits would seem to confirm this. The Lincoln Cave North deposit is most likely the earliest phase of deposition, with the Lincoln Cave South deposit representing a slightly later phase, whereas the L/63 deposit is the youngest in the depositional series.

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1. Boshoff P., Durrheim R., Fraser A., Martini J.E.J., Ralph A. and Sefton M. (1990). The Lincoln-Fault Cave System. *Bull. S. Afr. Spel. Assoc.* **31**, 60–64.
2. Reynolds S.C. (1998). *Excavation at Lincoln Cave, Sterkfontein.* B.A. Honours thesis, University of the Witwatersrand, Johannesburg.
3. Kaufman A. and Broecker W. (1965). Comparison of Th230 and C14 ages for carbondate materials from Lakes Lahontan and Bonneville. *J. geophys. Res.* **70**, 4039–4054.
4. Grün R., Brink J.S., Spooner N.A., Taylor L., Stringer C.B., Franciscus R.G. and Murray A.S. (1996). Direct dating of the Florisbad hominid. *Nature* **382**, 500–501.
5. Wadley L. (1993). The Pleistocene Later Stone Age south of the Limpopo. *J. World Prehist.* **7**(3), 243–296.
6. Kuman K. and Clarke R.J. (2000). Stratigraphy, artefact industries and hominid associations for Sterkfontein, Member 5. *J. Hum. Evol.* **38**, 827–847.
7. Reynolds S.C. (2001). *Sterkfontein: Exploration of some lesser known archaeological and fossil deposits.* M.Sc. thesis, University of the Witwatersrand, Johannesburg.
8. Kuman K. (1994). The archaeology of Sterkfontein: preliminary findings on site formation and cultural change. *S. Afr. J. Sci.* **90**, 215–219.
9. Kuman K. (1994). The archaeology of Sterkfontein — past and present. *J. Hum. Evol.* **27**, 471–487.
10. Field A.S. (1999). *An analytical and comparative study of the Earlier Stone Age archaeology of the Sterkfontein Valley.* M.Sc. thesis, University of the Witwatersrand, Johannesburg.
11. Pickering T.R. (1999). *Taphonomic interpretations of the Sterkfontein early hominid site (Gauteng, South Africa) reconsidered in the light of recent evidence.* Ph.D. thesis, University of Wisconsin-Madison, Madison.
12. Clarke R.J. (1994). On some new interpretations of Sterkfontein stratigraphy. *S. Afr. J. Sci.* **90**, 211–214.

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Dear Dr Clarke

We acknowledge that the following reports, received in the last few years, have been entered into the database:

1. A reconstruction of the Stw 431 *Australopithecus* pelvis based on newly discovered fragments
2. Preliminary results of excavations at Lincoln Cave, Sterkfontein, South Africa
3. Site formation in the early South African Stone Age sites and its influence on the archaeological record
4. The Sterkfontein Caves palaeontological and archaeological sites.
5. Progress Report on Sterkfontein and associated research

In future please ensure that all permit reports have the permit number(s) on the front page and that all publications feature the permit number(s) in the acknowledgements.
Yours sincerely

Mrs Mary Leslie
SAHRA: Manager of the Archaeology, Palaeontology and Meteorites Unit
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