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A re-examination of a human femur found at the Blind River Site, East London, South Africa: Its age, morphology, and breakage pattern

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ABSTRACT Modern human femoral features might have appeared in the early Middle Stone Age (156 ka to 20 ka) in South Africa, as demonstrated by the recent re-examination of a human femur fossil found at the Blind River Site, East London in the 1930s, if new dating results hold. Two optically stimulated luminescence dates from the relocated original Blind River shallow marine/estuarine deposits that contained the femur gave almost identical ages of ~120 ka, corresponding to the early part of the Last Interglacial (Oxygen Isotope Stage 5). Overall, the slender headless femur is of modern human form. The distal epiphysis bears some typical squatting features, including a newly recognized squatting facet on the anterior wall of the intercondylar fossa. With the typical V-shaped and oblique fracture pattern left by the missing head, the Blind River femur was most likely modified through human activity. But this style is not a cultural trait found in recent South African people. Further study is needed to place this specimen in its due context in the course of human evolution.

KEY WORDS: femur, squatting facet, Middle Stone Age

A left human femur without the proximal end was reported to have been found by P.W. Laidler in East London during his survey on prehistoric deposits at Blind River, East London, South Africa (Fig. 1). This femur was presented to the Department of Anatomy at the University of the Witwatersrand (now known as the School of Anatomical Sciences), given the catalogue number A. 1101,

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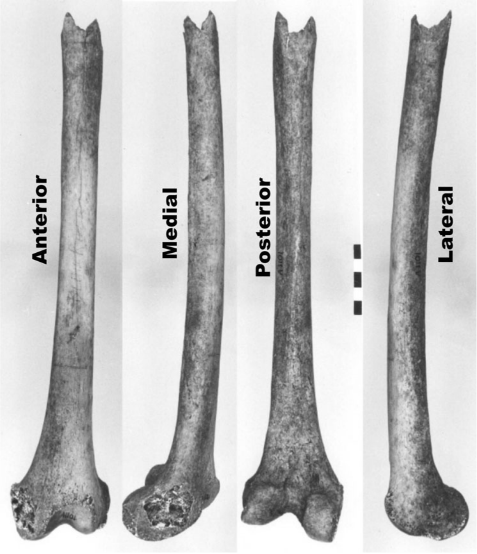

Fig. 1. The human femur found at the Blind River Site (A.1101).

and described by L.H. Wells (WELLS 1935). It has seldom been referred to since then, save that one of us (PVT) included it under "East London" among the South African entries in the pioneering *Catalogue des Hommes Fossiles* (VALLOIS and MOVIUS 1952). It was not, however, included among the South African entries (i.e., TOBIAS *et al*. 1977) in either the first or second editions of the Catalogue of Fossil Hominids published by the British Museum (Natural History) owing to the editors' stipulation of different criteria for the inclusion of specimens of uncertain antiquity (OAKLEY *et al.* 1977).

In this paper, we present the dating results of the layer containing the human

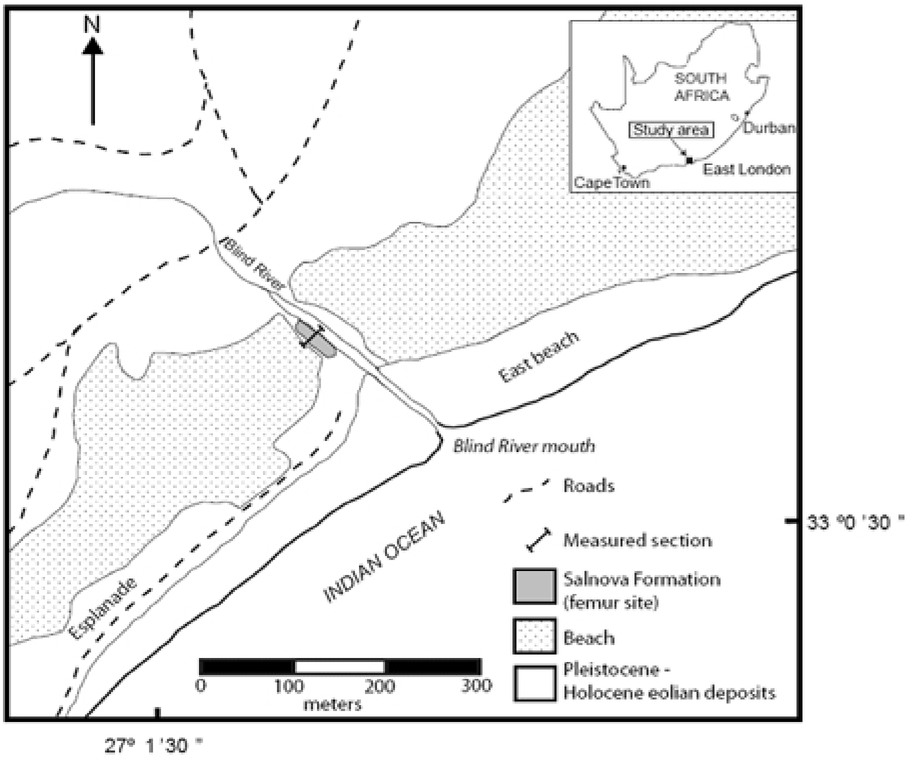

Fig. 2. Locality of the Blind River Mouth Site.

remains and stone artifacts, and re-examine its morphology and breakage patterns, with the aim of eliciting new knowledge of its significance in human evolution in light of its new chronology. The morphology of the femur is briefly reviewed with special emphasis on the squatting features. A suggested explanation for the breakage pattern of the femur through possible modification by human activity is provided.

OSL dating of the Blind River Site

The area of the Blind River where the femur was found was revisited in 2001 by one of us (DLR) based on the descriptions provided by LAIDLER (1933) and WELLS (1935). The stratigraphic unit which enclosed the femur is restricted to a ~40 m stretch along the southern bank of the Blind River, about 150 m from the river mouth (Fig. 2). The lower part of the succession is well exposed as a result of a recent landslide in the river bank (Fig. 3), and the upper part lies above a concrete walkway adjacent to the river. The latter part of the succession is more weathered, but sufficient fresh material was found to enable determination of the lithology. Two basic stratigraphic units, in a lower marine succession overlain by eolian (windblown) deposits, can be identified (Figs. 3, 4). The marine unit forms part of the Quaternary Salnova Formation of the Algoa Group (LE ROUX 1991).

Optical Stimulated Luminescence (OSL) dating (AITKEN 1998) was applied to sedimentary quartz grains extracted from two samples (Sample 1 and Sample 2) of beach/estuarine sediments at Blind River (Fig. 4). The samples were taken below the femur horizon since it was not possible to insert a sample tube into the gravelly sediments above. Care was taken to avoid bioturbated and unhomogenous heavy mineral-rich zones. Briefly, the De values obtained were 85.3 ± 2.8 Gy (Sample 1) and 85.8 ± 2.6 Gy (Sample 2), and an additional uncertainty of 2% associated with laboratory beta-source calibration was included for purposes of age calculation. The internal dose rate due to alpha particles was assumed to be 0.03 ± 0.01 Gy/ka, based on previous measurements of South African quartz grains (JACOBS *et al.* 2003). The external beta and gamma dose rates were estimated from the concentrations of

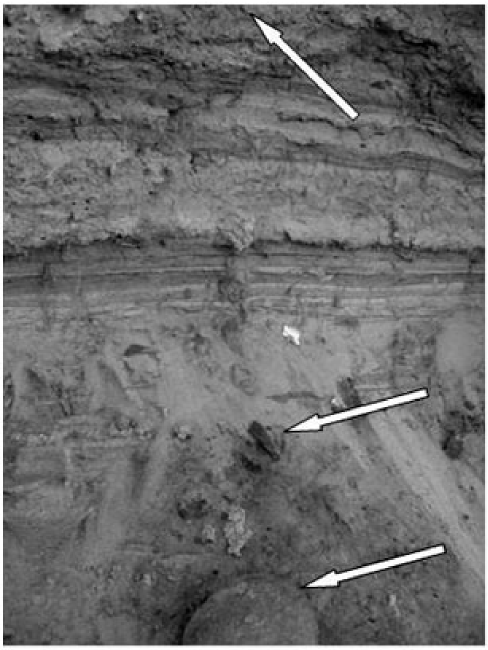

Fig. 3. The lower marine succession at Blind River, just below the marine gravel. Upper arrow points to the horizon in which the femur was found, middle arrow to *in situ* stone artefact and lower arrow to a rounded cobble.

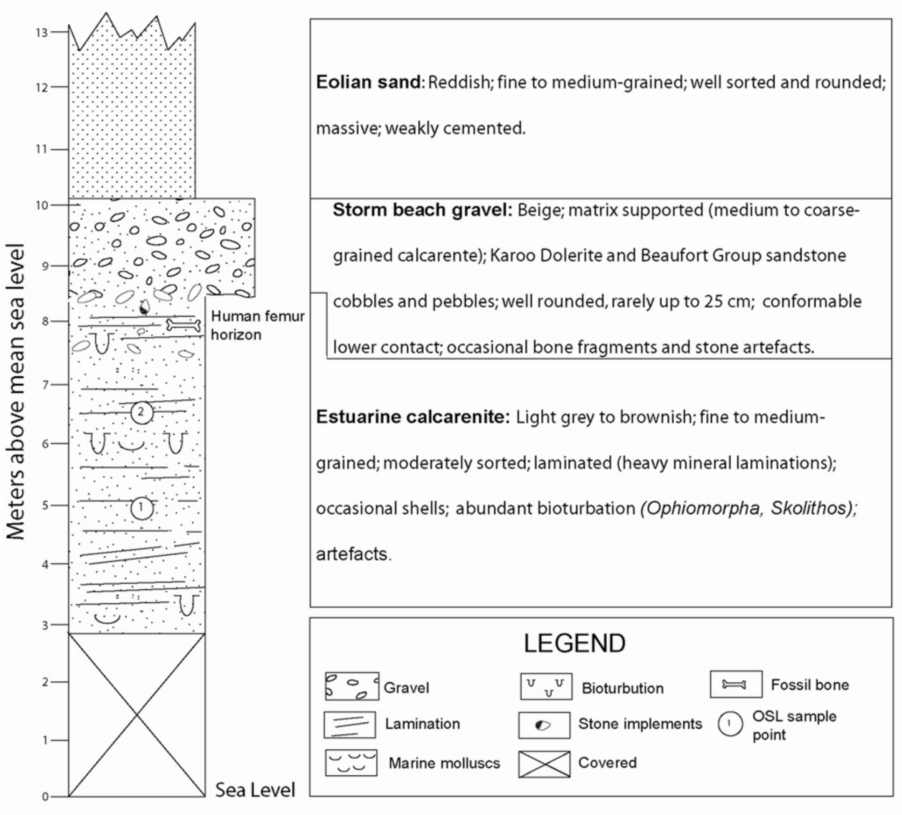

Fig. 4a. The stratigraphic succession at the Blind River. Optical dating was applied to sedimentary quartz grains extracted from two samples of estuarine sediments.

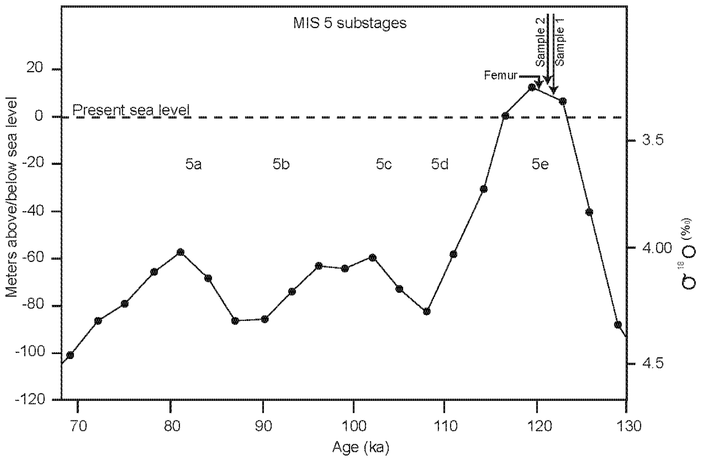

Fig. 4b. Oxygen isotope data from Shackleton and Pisias (1985). The isotope data is a proxy for global sea levels and the approximate sea level scale is from Shackleton (2000). The measured OSL ages of two samples and their relationship to global sea level is shown.

uranium, thorium and potassium in dried and powdered samples and the conversion factors of ADAMIEC and AITKEN (1998); corrections were made for grain size, HF etching and long-term moisture content (AITKEN 1985). The moisture contents assumed in the calculations were based on the measured field moisture contents of the samples. The uranium (1.42 ± 0.12 µg/g for Sample 1 and 1.20 ± 0.10 µg/g for Sample 2) and thorium (2.0 ± 0.38 µg/g for Sample 1 and 2.01 ± 0.31 µg/g for Sample 2) contents were deduced from thick-source alpha counting, while the potassium contents (0.17 ± 0.1% for Sample 1 and 0.22 ± 0.01% for Sample 2) were obtained by X-ray fluorescence spectrometry. The resulting beta dose rates were 0.33 ± 0.02 Gy/ka (for both Sample 1 and Sample 2) and the gamma dose rates were 0.28 ± 0.02 Gy/ka (Sample 1) and 0.27 ± 0.02 Gy/ka (Sample 2). Cosmic-ray dose rates of 0.07 ± 0.03 Gy/ka (Sample 1) and 0.09 ± 0.03 Gy/ka (Sample 2) were estimated from overburden thickness (PRESCOTT and HUTTON 1994). The total dose rates obtained for the two samples were 0.72 ± 0.05 Gy/ka (Sample 1) and 0.73 ± 0.04 Gy/ka (Sample 2). Dividing the central age model estimates of De for these two samples by the corresponding total dose rates gave age estimates of 119 ± 9 ka and 118 ± 7 ka for samples Sample 1 and Sample 2, respectively with a weighted mean age of 118 ± 6 ka.

The OSL dating, which corresponds to Marine Isotope Stage 5e (MIS 5e) (Last Interglacial Period), is strongly supported by the presence of marine/estuarine deposits at up to ~10m above present mean sea level at Blind River (the femur horizon is about 8m above present mean sea level). Most sea level curves show maximum MIS 5e transgression at ~125-120 ka (SHACKLETON and PISIAS 1985, SHACKLETON 2000) and that shown in Figure 4b is at the younger end of this range at ~120 ka. The measured OSL ages of samples 1 and 2 are slightly younger than this range at 119 ± 9 ka and 118 ± 7 ka respectively, whereas being situated below the transgressive maximum marked by the top of the marine gravel at ~ +10 m amsl (Fig. 4a) the samples should be slightly older (i.e., >120 ka according to the sea level curve in Fig. 4b). However, taking into account the error bars for the dates, they can easily be accommodated into the MIS 5e sea level scenario and their interpreted age from their elevation in relation to MIS 5e sea level is indicated in Figure 4b. The femur horizon is ~2 m below the transgressive maximum (Fig. 4a) but is above that of samples 1 & 2. Its age should therefore lie between these values and is estimated at ~122 ka. However, the possible ages of the femur horizon are estimated at ~127-122 ka, because of the published temporal range of MIS 5e transgressive maxima being ~125-120 ka. There is no evidence of a significant sedimentary hiatus within the marine succession; even the upward transition into the gravel bed is gradual. The dating results therefore fall within the age range of the MSA which extends from ~152/156 ka to 25-20 ka (MITCHELL 2000). In this study, the highest OSL sample was more than a meter below the location of the femur; thus the femur was younger than the measured sample ages, but just how much younger was unclear. Future work will be directed to collecting samples from above the level where the femur was found to obtain narrower bracketing ages.

Morphology of the Blind River femur

Nearly the whole diaphysis or shaft is preserved (Fig. 1). The anterior, lateral, and medial surfaces are smooth, with no sign of significant abrasion. The anterior aspect of the remaining part of the upper third of the shaft is convex from medial to lateral, the lateral margin flaring out into a lateral flange. The medial border is rounded in the hypotrochanteric region but becomes rather angular distally. Anterior to the pilaster, a definite concavity forms a sulcus along the pilaster. The pilaster is well-developed though not prominent, with moderate *linea aspera* superimposed on it. The lateral lip is more prominent and extensive than the medial lip. Between lateral and medial lips, several roughened lines extend longitudinally, corresponding to the sites of muscle attachment. Thus, the Blind River femur has a cross-sectional morphology in the midshaft similar to an average modern human femur: a triangle with flattened apex directed posteriorly, flanked by two concave surfaces, in contrast to that in Asian and African *H. erectus* (e.g., Zhoukoudian, WT 15000) (WEIDENREICH 1941, DAY 1971, KENNEDY 1983a, WALKER and LEAKEY 1993), and early *Homo* in Dmanisi (D4167) (LORDKIPANIDZE *et al.* 2007) (Table 1).

The pilastric index is 104.4 (Table 2), within the range of modern human variation. The development of a high pilaster in the human is analogous to the formation of the sagittal crest in great apes, reflecting the need of the extensors and adductors for larger and more pronounced areas of attachment (WEIDENREICH 1941). According to TRINKAUS (1993), only recent humans have a pilastric index less than 100, but no ancient humans have an index exceeding 100. However, it is not a rigid delineation, as some earlier human forms such as *H. erectus, H. heidelbergensis* and the Neanderthals have pilastric index values greater than

Table 1. Character states of the Blind River femur, other early *Homo* and modern humans

	Blind River	WT 15000	Zhoukoudian	Dmanisi	ER 1481A	Modern humans
Development of Pilaster	Moderate	Weak	Weak	Weak	Weak	Weak to strong
Convexity of the medial border of the shaft	No	Yes	Yes	Yes	Yes	Majority no
Narrow medullary canal	No	No	Yes	Yes		No
Pronounced Subtrochanteric platymyria	No	No	Yes			No
Anteroposterior bowing of the shaft	Low	Low	Low	Low	Low	Low to moderate
Position of the minimum shaft breadth	Mid shaft	Distal shaft	Distal shaft	Distal shaft	Distal shaft	Distal to midshaft
Robusticity of the shaft	Slender	Slender	Robust	Robust	Robust	Slender to robust

Note: The information was summarized from Weidenreich (1941), Kennedy (1983a,b), Day *et al.* (1975), McHenry and Corruccini (1978), Walker and Leakey (1993), Wang *et al.* (2005), and Ruff (2008). The Blind River femur exhibits an array of characters that group it with modern humans, while "WT15000 appears more derived in several features", as observed by Lordkipanidze *et al.* (2007), which might be related to its young age at death.

Table 2. Measurements and indices of Blind River femur

	Blind River [1]	WT15000 [2]	Zhoukoudian *H. erectus* [3]	ER 1472[4]	ER 1481A[4]	D 4167 (Dmanisi) [5]	Omo I [6]	South African Black Female[7]
Physiological length, M. #2 (estimates)	459.7	429		401.0	395.0	384		372-479
A-P diameter at midshaft, M. #6	26.3	24.5	25.5 (0.9)	26.4	22.5	26.5		
M-L diameter at midshaft, M. #7	25.2	24.3	30.6 (1.1)	28.8	25.3	22.2		
Circumference of the shaft at midshaft, M. #8	82							
M-L diameter of subtrochanteric flattening, M. #9	25.5	31.0	35.2 (1.4)	31.4	31.3		31.1	
A-P diameter of subtrochanteric flattening, M. #10	32.2	29.5	24.5 (1.4)		22.0		29.0	
Length of the lateral condyle, M. #23	59.6			52.5	61			57.3 (7.3)
Length of the medial condyle, M. #24	55.5			50.2	56			54.6 (4.8)
Condylo-diaphyseal angle, M. #30	80.0°	80.0				81.5		64-82
Epicondylar breadth, M. # 21	74	(80)		69.3	71.0	72.4	76.3	72.5 (5.8)
Diaphyseal robusticity (100X M.#8/M.#2)	17.8							18.9
Robusticity index [100 X (M.#6 + M.#7)/M2]	11.2	11.4		13.8	11.9	12.7		
Midshaft breadth/ Physiological length (100 X M.#7/M.#2)	5.48	5.63				5.75		5.85
Position of minimum shaft breadth related to physiological length	48.3%	26.7% - 45.8%	44.9% (0.6%)	35.5%	31.6%	39.2%		22.1%- 49.6%
Dimension of medullary cavity relative to shaft breadth (BR at Subtrochanteric level, others at the level of midshaft)	66.5 % (A-P) 60.3% (M-L)	60.0% (A-P) 55.4% (M-L)	32.9% (A-P) 37.6% (M-L)					
Platymeric index (100 X M.#9/M.#10)	79.2	95.2	67.6-68.1	88.9	70.2			82.6
Pilastric index (100 X M.#6/M.#7)	104.4	100.8	83.3	91.7	85.7	119.4		
Intercondylar index (100 X M.#24/M.#23)	93.1			95.6	91.8			
Epicondylar index (100 X M.#21/M.#2)	16.1	18.6		17.3	18.0	18.9		16.9%
Estimate of height	1647.4	1505-1691				1449-1662	1620-1730	1541.2

Notes: [1] Details of the estimation of femoral length were detailed in Table 3 and Fig. 5. [2]Walker and Leakey (1993), Lordkipanidze *et al*. (2007), and Ruff (2008). [3]Weidenreich (1941), Kennedy (1983b). [4]Day et al. (1975), McHenry and Corruccini (1978), Kennedy (1983b), and Lordkipanidze (2007). [5]Lordkipanidze *et al*. (2007). [6]Pearson *et al.* (2008). [7]Wells (1935), McHenry and Corruccini (1978), Lundy (1983), Wang *et al*. (2005). Abbreviations: A-P, Antero-posterior; M-L, Medio-lateral.

100, while many recent and modern humans have values less than 100. Besides, from Middle Pleistocene *H. erectus* and *H. heidelbergensis* to Neanderthals, early *H. sapiens*, and modern humans, there is trend of increasing pilastric development, followed by one of decreasing development, the trend apparently reflecting changes in lifestyle and economic pattern. The surviving high pilaster in San people (99.5-133.5, KENNEDY 1983a), as in early *H. sapiens*, such as Liujiang (119.5, WOO 1959) and Upper Cave (125.6, WEIDENREICH 1941), is owing in large measure to their machine-free and strenuous lifestyle. Thus the developmental trend of the pilaster could reflect patterns of biomechanical stress in human evolution in general as well as the individual lifestyle of its possessor in particular.

The subtrochanteric area in the Blind River femur displays a low platymeria, 79.2, which is in the range of variation in modern humans with an average value around 82 (LUNDY 1983). This value is higher than those of *H. erectus* at Zhoukoudian with a range of 67.6-68.1 (WEIDENREICH 1941) and 74.4 in the Berg Aukas femur of archaic *H. sapiens* (measured from CT-section in GRINE *et al.* 1995), yet lower than that of WT 15000 (95.2). According to WEIDENREICH (1941), pronounced platymeria of the subtrochanteric region is due to the fairly prominent crista medialis and crista lateralis. Such flatness may appear similarly developed also in modern man (CAMERON 1934, WEIDENREICH 1941).

The minimum breadth is located at the midshaft region (WANG *et al.* 2005), while in *H. erectus* and other ancient *Homo* species it is distally placed (WEIDENREICH 1941, DAY 1971, WALKER and LEAKEY 1993, LORDKIPANIDZE *et al.* 2007). Compared to ancient and modern humans, the Blind River femur has a relatively slender shaft based on two indices (Table 2). First, the diaphysial robusticity index is 17.8, revealing a slender shaft compared with mean South African Black values (male, 19.2) and Khoi-San values (male, 19.8, female, 18.9) (GALLOWAY 1959), but it is close to values for Australian Aborigines and another group of Khoi-San, 17.3 and 17.8 respectively (MCCOWN and KEITH, 1939). Second, the ratio of midshaft breadth (M-L) to femoral length in the Blind River femur is 5.48%, indicating a slender femur compared to the South African modern Black femora, 6.07% (male) and 5.85% (female) (LUNDY 1983), and early *Homo* such as WT 15000 (5.63%) and D4167 from Dmanisi (5.75%) (LORDKIPANIDZE *et al.* 2007). The general slenderness of the bone indicated that it might belong to a female individual. Though the shaft is slender, the medullary cavity in the Blind River femur is relatively wide. About 10 mm below the assumed starting point of the base of the lesser trochanter, the medullary cavity occupies about 66.5% (A-P) and 60.3% (M-L) of the shaft dimensions. In contrast, the medullary cavity is relatively narrow in archaic *H. sapiens*, e.g., 37.9% (A-P) and 30.8% (M-L) at the subtrochanteric level of the Berge Aukas femur and the *H. erectus* femur, respectively (Table 2). However, the juvenile WT 15000 has relatively high values, 60.0% (A-P) and 55.4% (M-L) (calculations are based on measurements from cross section photographs of WT-15000 in RUFF 2008). The relative breadth of medullary cavity at the subtrochanteric level and the level of midshaft may be different (ERICKSEN 1979), but it is unlikely that any such difference would alter the large contrast between the *H. erectus* values and those of the Blind River femur.

The distal end is well preserved, save for a flake missing from the medial condyle. The patellar or trochlear surface is well defined, relatively deep, with well elevated margins; the lateral is distinctly higher than the medial, as in modern human femora. The popliteal surface is so well preserved that fine details are detectable. There is a shallow and well-defined concavity in the popliteal surface just above the condylar region. The lowest part is pitted with small nutrient foramina. There is a marked impression area in the place of anterior cruciate ligament attachment that is either a "pathotypic" phenomenon or a "physiotypic" feature such as a squatting facet.

The physiological length of the Blind River femur is estimated to be 459.7 mm (Table 3, Fig. 5). This estimate is higher than TOBIAS'S and NETSCHER'S (1977) mean physiological length of 451.3 mm in 258 Black South African males including Xhosa (calculated from their separated values of three time-spaced groups). It is longer than the femur of the juvenile *H. erectus* WT 15000 (429 mm), yet shorter than the estimated adult length 508-534 mm of WT 15000 (RUFF and WALKER, 1993). Using the height formula generated by LUNDY (1983) from modern South African populations, the owner of this femur would be around 1647.7 mm in height. These estimates are slightly higher than the mean values for South African black populations obtained by FELDESMAN and LUNDY (1988) (male mean 162.93 cm, female mean 154.12 cm), the mean femoral physiological length values being 447.7 mm in males and 423.3 mm in females. No age correction factor could be applied here, since we have no idea of the age at death. It

Table 3. Estimates of physiological length [in mm] of Blind River Femur based on relative index values for physiological and subtrochanteric heights in femora from two modern human populations in the Dart Collection

		N	Mean	Range	S.D.	Estimate of physiological length	95% interval
European Male	Physiological length		467.6	420-503	65.7		
	Sub-T. length	44	356.9	314-392	49.6		
	Ratio (%)		76.3	72.4-78.8	1.4	463.8	461.3-466.3
European Female	Physiological length		432.1	370-475	57.5		
	Sub-T. length	52	333.6	283-368	43.1		
	Ratio (%)		77.2	74.0-80.7	1.3	458.5	456.4-460.7
Xhosa Male	Physiological length		451.1	405-496	57.5		
	Sub-T. length	55	341.8	306-389	43.3		
	Ratio (%)		76.9	73.3-79.3	1.2	460.2	458.3-462.2
Xhosa Female	Physiological length		421.3	381-479	54.7		
	Sub-T. length	53	326.7	293-381	42.3		
	Ratio (%)		77.5	74.8-80.1	1.3	456.7	454.6-458.8
Grand Mean Ratio		204	77.0	72.4-86.7	1.4	459.7	458.5-460.7

Note: Length unit: [mm]. Femora of the left and right sides from the same individuals were included to embrace intra-individual variation. In the Blind River femur, the subtrochanteric height was 354 mm, and the physiological length was estimated to be 459.7 mm.

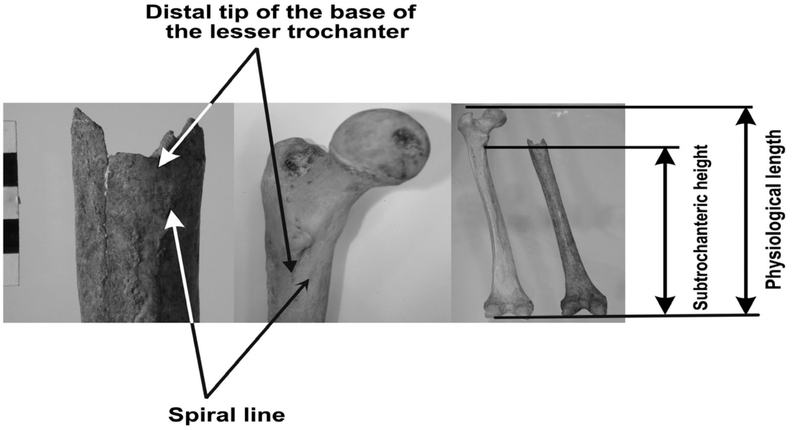

Fig. 5. The femoral physiological length was estimated from subtrochanteric height. The subtrochanteric height is the distance from the distal position of the base of the lesser trochanter to the bicondylar plane. The head of the Blind River femur was missing just at the level below the lesser trochanter with the subtrochanteric height of 354 mm. The physiological length of the Blind River femur was estimated to be 459.7 mm (Table 4).

obviously belongs to an adult individual. To judge by the slenderness of this femur, if it was of a male, it was a rather gracile individual. This led us to follow Wells's opinion and infer that it was more likely to have been a female individual. WELLS (1935) states, "No confident opinion regarding the sex of the specimen can be expressed. The general slenderness and slight muscular development of the bone suggest, however, that it is more probably female than male."

The principal component analysis (PCA) (Minitab 14.1) of four shape indicators (robusticity, minimum shaft breadth level, pilastic index, and epicondylar index) provides further information on the overall shape of the Blind River femur (Fig. 6). In the four-variable analysis, the first two components account for 77.3% of the total variance. The first component (41.3%) is mainly related to the level of the minimum breadth of the shaft, which groups the Blind River Femur and modern humans. The second component (36.0%) has negative loadings on all variables, and is mainly related to the rest of three indexes, indicating that Blind River femur has the least slender shaft in this sample group. In summary, both the shaft and the distal end of the Blind River femur displays no unusual features such as that would distinguish it from modern human femora, as WELLS (1935) stated.

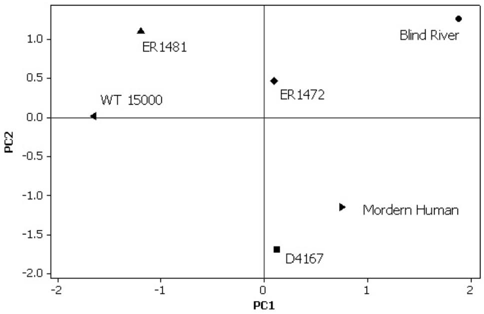

Fig. 6. Four-variable principal component analysis (robusticity, minimum shaft breadth level, pilastic index, and epicondylar index) of Blind River, other early *Homo* and modern humans. PC1(41.3%) is related to the level of the minimum shaft breadth and groups Blind River and modern humans together. PC2(36.0%) is related the rest of three indicators of femoral robusticity and indicates that Blind River femur is very slender.

Squatting traits

Numerous studies have recorded bone surface morphology and shape variation linked to habitual squatting positions (MARTIN 1932, TRINKAUS 1975, KENNEDY 1989, BOULLE, 2001*a,b*). As WELLS (1935) briefly noted, the Blind River femur shows some of Martin's criteria for squatting in people pursuing primitive or strenuous life styles (MARTIN 1932). Here we detail these traits.

[1] MARTIN (1932) points out that if one assumes the squatting posture and stands up again repeatedly, the patella is made to slide backwards and forwards in the groove to a much great extent than in motions of sitting down and standing up. Thus the patellar groove would be deeper in the former case. In this specimen, the patellar groove is 13 mm deep. The ratio of groove depth to the femoral estimated total length is 1.26/45, exceeding the value of 1/45 established by MARTIN (1932) for the values of most modern Irish people, which are less than 1/45, and even less than 1/60. In groups including Australian Aboriginals, San, and other populations practising subsistence economies, values are usually more than 1/45 (MARTIN 1932), and such is the case in the Blind River femur.

[2] Another Martin criterion is that the trochlear surface of the lateral condyle extends on to its lateral aspect. In the Blind River femur, the overflow area extends about 35 mm around the antero-posterior curvature. The extratrochlear surface suits the need of a greater range of movement in squatting and standing up.

[3] A relatively deep intercondylar fossa is another criterion demanded by the knee in hyperflexion while the posterior parts of the condyles are rested on the tibia. This depth is taken on a femur with its two condyles and the great trochanter resting on the same plane. In this case, as we could not read the depth directly, we applied a 5° angle between the femoral anterior surface and the resting plane. According to Thane, cited by CAMERON (1934), in the upright position, the axis of the frontal plane of the body and the axis of the anterior surface of the femur form a 5° angle. With the femur in this position, we read the depth of the intercondylar fossa and the height of the articular surface, the latter being measured from the impression of the medial semilunar cartilage to the resting plane. The values obtained are 16 mm and 44 mm, respectively. Thus the intercondylar fossa occupies over 1/2.75 of the articular surface height, between 1/2.7 and 1/2.8. Most values in modern humans (Irish) are between 1/3.2 and 1/3.6; and less than 1/3.2 in populations practising less advanced economic activities (MARTIN 1932), which is in line with femora bearing squatting traits and with the Blind River femur.

[4] One feature usually observed in a squatter's femur is that the auricular surface is continuous posterosuperiorly to the popliteal surface, which makes room for accommodation of the posterosuperior margin of the tibia while the knee is hyperflexed. In the Blind River femur, this proximal extension is present in the medial condyle, but not in the lateral one.

[5] In the Blind River femur, the posterior intercondylar line is slightly convex upwards, the convexity rising above the level of the upper limits of the condyles and being very slightly grooved in its medial part. This groove is for accommodating the tightly stretched posterior cruciate ligament while the knee is in hyperflexion, as in squatting.

In addition to these five criteria, we propose one more possible squatting-related feature. As mentioned in the morphology section, there is a smooth-surfaced, quadrilateral facet, 7 mm by 14 mm in size, in the normal position of the femoral attachment of the anterior cruciate ligament (Fig. 7). WELLS (1935) mentioned its presence, but did not relate it to squatting. We checked this region in the Dart Collecion. Several femora show a very similar facet (e.g., Xhosa female A552). We offer two possible explanations.

First, it is close to or part of the attachment area of the anterior cruciate ligament, but it might have been modified due to some developmental, functional or pathological process. However, there are no available data on this issue. Secondly, we suggest that it also is related to habitual squatting posture. In hyperflexion, the femur and tibia form an acute angle, being stabilized by the adductor muscles, while the posterior cruciate ligament tightly locks the knee. In this extreme position, the posterior cruciate ligament will be pressed against the anterior wall of the intercondylar fossa, which usually leaves a smooth groove-like impression, as in the Blind River femur. We might reasonably argue that, in the extreme and twisted position, the posterior cruciate ligament, together with the lateral semilunar cartilage, will be pressed not only against the anterior wall of the intercondylar fossa, but also against its lateral wall, just covering the anterior cruciate ligament. If this contact happens frequently and over a lengthy period, a facet such as this would be produced. If this argument holds, the elevation in question should be viewed as a squatting trait of marked degree, and it should be added to the family of squatting traits along with those on the tibia, talus and femur. However, further investigation of femurs from some populations, such as modern hunter-gatherers, is needed to confirm this point.

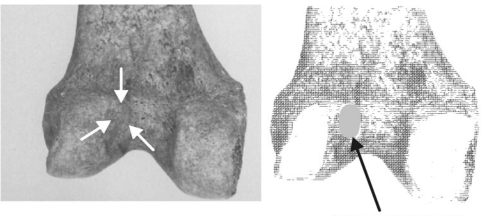

Fig. 7. The distal end of the Blind River femur (posterior view). There is a smooth-surfaced, quadrilateral facet (circled by arrows), 7 mm by 14 mm in size, in the normal position of the femoral attachment of the anterior cruciate ligament.

Moreover, the shaft was straight for the most part, with only very slight anterior bowing of the middle part. Wells reported a Pearson and Bell bowing index 1.78 for the Blind River shaft (WELLS 1935), indicating a mechanical environment of low bending forces. The anterior femoral curvature is related to mobility from a biomechanical standpoint. It is said that, with the apparent decrease in mobility after the last glacial maximum (ca. 18,000 B.P.), there is a decrease in anterior femoral curvature that is continued with urbanism and increasing industrialization (SHACKELFORD and TRINKAUS 2002). The evolution of human femur is closely related to the biomechanical stress and locomotor patterns (MCHENRY and CORRUCCINI 1978; LOVEJOY *et al.* 2002; RUFF 2008, in press). The effects of a low bowing shaft on the squatting behavior require further study using mechanical modeling, though the loss of femoral head has prevented a similar study in biomechanics as on the Maka Femur (LOVEJOY *et al.* 2002).

Breakage and fracture - evidence for human modification

The upper end of the femur is missing, the breach being along an irregular line just below the lesser trochanter (Fig. 8). From the breakage, two cracks run distally, one roughly along the midline on the anterior surface for around 60 mm, the other on the posterior surface, just medial to the gluteal ridge, extending for about 35 mm. They do not significantly change the shape and size of this region.

The completeness of the shaft and distal part, while missing the proximal part, affords an excellent opportunity to examine the breakage pattern and to further explore the possible cultural traits associated with the population represented by this femur. Breakage patterns of both animal and human long bones have long been the subject of intensive research, especially carnivore and hammer stone fracturing of fresh bone (e.g., DART 1957, BINFORD 1981, BRAIN 1981, MORLAN 1984, JOHNSON 1985, LYMAN 1987, BLUMENSHINE 1988, VILLA and MAHIEU 1991, BARTRAM and MARREAN 1999, PICKERING *et al.* 2004). Based on these findings, we take a closer look at the Blind River femur.

The bone breakage surfaces on the Blind River femur are unweathered, uneroded, and have sharp fracture edges. “This fracture evidently occurred while

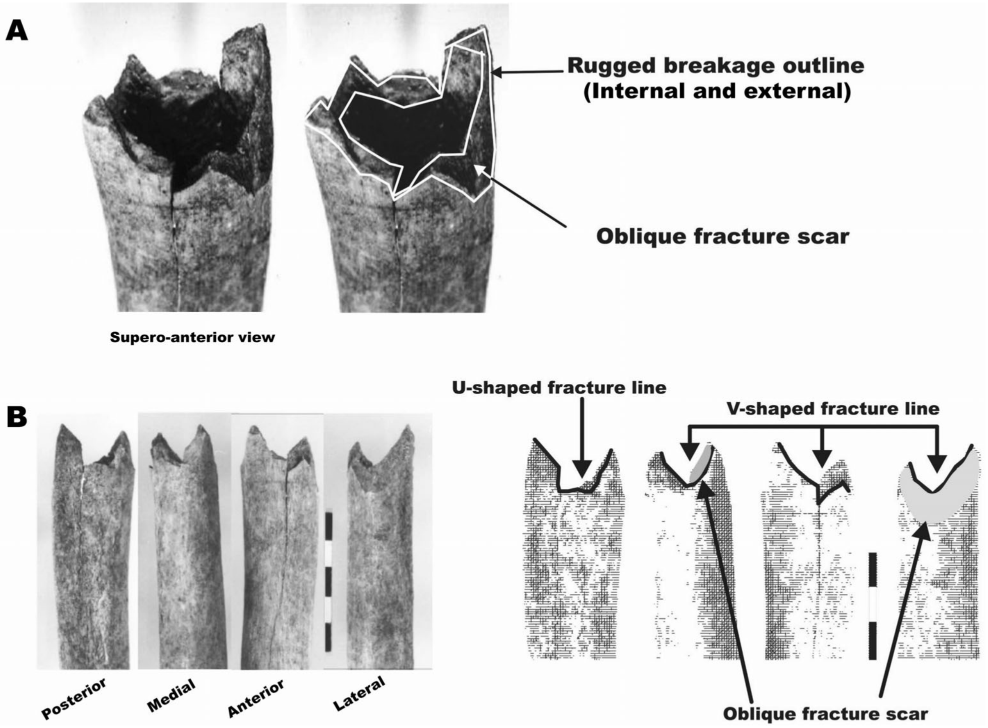

Fig. 8. The breakage of the Blind River femur. A: in the supero-anterior view, both outer and inner outlines of the breakage are rugged, in-between there are oblique fracture scars. B: V-shaped and U-shaped fracture line and the oblique fracture scars in four views.

the bone was still in the fresh state" (WELLS 1935), a view with which we concur. The outline of breakage is rugged (Fig. 8). The breakage surface shows an intriguing pattern. All five primary and secondary fracture scars are V-shaped, except the posterior one, which is U shaped. The fracture scars on the cortex in the wall show a typical oblique fracture pattern. The angles are acute, at around 40-50°, as commonly associated with in vivo green bone fractures (MORLAN 1984, JOHNSON 1985, VILLA and MAHIEU 1991). Right angles are said to be preferentially associated with dry or premineralization bone fractures.

Carnivore gnawing could be excluded by a total absence of tooth marks. Thus other natural forces or human activity should be considered. There are no clear cut-marks either, but the fact that it was "modelled" from various surfaces, with at least 4-5 strokes, and with three oblique outer angles, and two inner angles, makes it reasonable to argue that natural forces, such as pressure or falling stones, with a single direction of force, could not have made such a breakage with various force-receiving directions. Only a force with human involvement can be reasonable.

The femur does not appear to have been broken merely for the extracting of marrow; if it were, to totally smash it would be more practical. It might have been deliberately shaped for some other practical or ritual purpose. It was probably modified deliberately to remove the head, just distal to the lesser trochanter. The modified bone, with sharp end, would have been suitable for use as a tool or weapon, or a digging tool. However, no sign of its having been used in these ways could be judged by naked eye. Or it might have served as an ornament, or a symbolic totem bone. Even though we cannot determine the purpose for which the bone was broken, we are inclined to conclude that the Blind River femur was broken and fashioned by human hands. However, further analysis (such as using SEM imaging technique) and comparative work (e.g., to fashion a breakage in a similar pattern) are needed here to bring out the pattern and true meanings of this modification.

Discussion

The Blind River femur was discovered in 1933, yet is seldom if ever quoted in literature, despite the rarity and importance of such fossilized human remains with regard to human origins. This omission is a consequence of its hitherto uncertain chronology and provenance, the first of which has fortunately now been resolved through OSL dating, corroborated by stratigraphic correlation with an exceedingly well documented orbitally driven glacio-eustatic sea level highstand (MIS 5e). However, its exact geological age could possibly be further refined using a different dating method.

Regarding provenance, the discovery of the femur was made during the earlier 20th Century when photographic records were the exception rather than the rule. The description and interpretation of the stratigraphy, sedimentology, and archaeology of the Blind River succession rendered by Laidler were both competent and accurate. Furthermore, our discovery of *in situ* bone in the Blind River succession witnesses both the geochemical capacity of this sedimentary setting to preserve bone and its actual presence in the Blind River succession. However, many possible sources of error could be involved in handling historic discoveries like the Blind River femur. More meticulous studies on the femur and the Blind River site are needed to further confirm the provenance of this femur and to refine the dating results. The history of the bone prior to its incarceration in the marginal marine deposits is indeed uncertain in some respects.

However, it was reasonable to argue that: [1] The bioturbation in the estuarine sediments had no relevance to the issue of provenance. As noted above, the bioturbation was localized and took the form of small burrows of the ichnogenus *Ophiomorpha*, considered to be made by the small crustacean *Calianassa* sp (sand prawn). Such minor faunal activity could not have moved the femur in either a vertical or horizontal sense. [2] The bone could not have been exposed above ground for very long prior to its burial or it would have undergone the usual decomposition by various agencies (biological, weathering, etc.). [3] The femur underwent minimal transport in the marine setting prior to its burial as it had suffered no noticeable abrasion in what would have been a highly abrasive environment. We noted in particular that the broken surfaces are sharp and unabraided, and the most likely scenario is that the bone (which we believe was modified by human activity) was left on the beach by a human and rapidly buried by marine sedimentation. Artifacts are found in Last Interglacial beach deposits in the immediate vicinity of the Bind River site (DEACON 1966, JACOBS and ROBERTS in press), as well as in the Blind River deposits themselves as seen by us and LAIDLER (1933). This may relate to the availability of cobbles for raw materials for lithics and food gathering activities. This would also explain the absence of other human skeletal remains.

The Blind River femur, so far as it is preserved, does not reveal any essential or even trivial differences from those of modern humans. Based on its modern features and its geographical setting, we have the remarkable occurrence of an essentially modern femoral morphology and signs of human modified human bones, as early as the Last Interglacial. It is interesting to note that the Blind River femur might come from a slender individual considerably predating the Klasies River Mouth people, possibly the earliest African population (WOLPOFF 1996), but it is not of a person of small stature. Does this slender femur belong to a population similar to that from Klasies River Mouth, represented by a gracile mandible? Or, what are their links to later modern human forms represented by Hofmeyr skulls dated 36k years B.P. (GRINE *et al.* 2007)? All these questions wait for more morphological and phylogenetic analysis. Further biomechanical and cultural study on the Blind River femur is likely to yield insights into behavioral and social aspects of human evolution in southern Africa.

The principal purpose of this re-examination in morphology and geochronology is to bring this long-forgotten specimen out of obscurity. Further work in comparative anatomy, (i.e., comparison to *H. erectus*, *H. heidelbergensis*, and early *H. sapiens* such as Omo I), behavior, biomechanics, geochronology, and cultural context (i.e., comparison to that of the Lower Omo Valley Kibish Formation; SHEA 2008) of the Blind River femur are needed to bring the relevance of this specimen to the study of human evolution in Africa amongst all its uncertainties.

Conclusions

The age of the geological horizon containing the Blind River femur was estimated from OSL dating (further refined by reference to global sea level curves) to be around 118ka, slightly older than MIS5e transgressive maxima. Regarding morphology, our conclusions are not at variance with those of WELLS (1935). However, in spite of its cultural association and probable antiquity, the human femur found in the Blind River Site is fundamentally modern in morphology and most of its features are compatible with those of the recent South African Black or big-bodied Khoi-San populations. Most importantly, these findings underpin the concept of the essential modernity of Last Interglacial hominins. The Blind River femur belongs to a habitual squatter and was most likely modified through human activity. The proposed human modification of the specimen is, however, not a cultural trait found in recent South African people. However, further work in anatomy, behavior, biomechanics, geochronology, cultural context of the Blind River femur are needed to accord this specimen its due place in the course of human evolution.

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Streszczenie

Kość udowa z Blind River została odkryta w East London (Afryka Południowa) w 1933 r., pozostawała jednak niezauważona w literaturze, mimo, że znaleziska takich sfosylizowanych kości zdarzają się rzadko, a ich znaczenie dla badań pochodzenia człowieka jest duże. Przyczyną tego było niepewne datowanie znaleziska, przeszkodę tę jednak ostatnio udało się pokonać dzięki zastosowaniu metody stymulowanej optycznie luminescencji (OSL). Datowanie OSL estuaryjnych osadów, z których pochodzi kość, wskazuje na wiek około 120 tys. lat, co odpowiada początkowej fazie ostatniego interglacjału.

Kość udowa z Blind River, w stanie, w jakim się zachowała, nie wskazuje żadnych, nawet drobnych różnic w stosunku do dzisiejszego człowieka. Jej nowoczesne cechy i lokalizacja geograficzna potwierdzają związek nowoczesnych populacji ludzkich z południową Afryką. Omawiana kość ma bardzo smukły trzon. Jest ona pozbawiona głowy, a jej dalsza nasada wykazuje typowe dla nawykowego kucania cechy, w tym pogłębiony dół dla rzepki i głęboki dół międzykłykciowy. Trzon kości jest przełamany, a powierzchnia przełomu jest niezerodowana i ma ostre krawędzie. Brzeg złamania wykazuje cechy charakterystyczne dla złamania świeżej kości i nosi ślady modyfikacji na skutek działania człowieka. Modyfikacja ta jednak nie przypomina jakichkolwiek znanych kulturowych zabiegów dokonywanych przez ludy Afryki południowej. Jeśli zaakceptujemy wiek geologiczny kości z Blind River, mamy do czynienia z zasadniczo nowoczesną kością ze śladami modyfikacji dokonanych ludzką ręką już w czasach ostatniego interglacjału lub środkowej epoki kamiennej (MSA), tj. 156-20 tys. lat temu.