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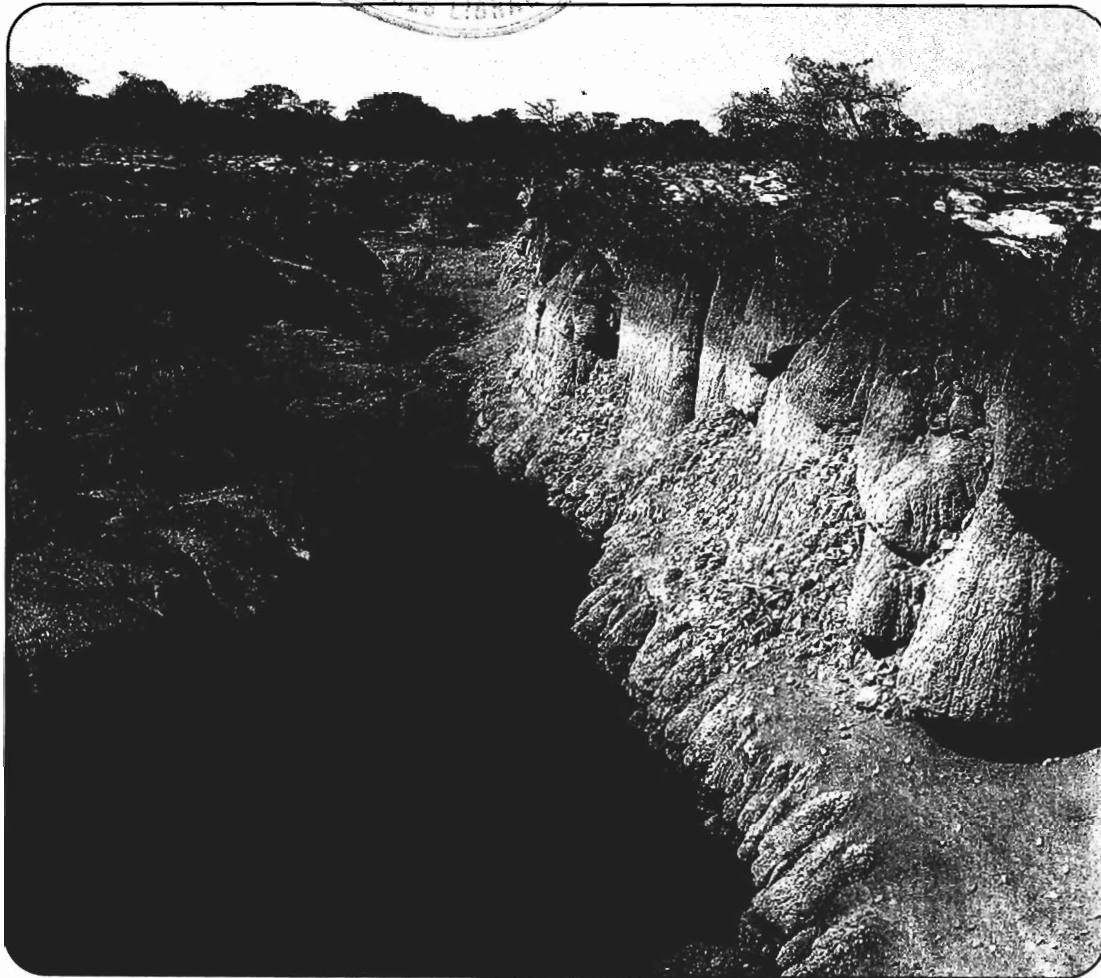
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The age of the Kirkdale Cave palaeofauna

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Abstract: The Kirkdale Cave palaeofauna represents the original and classic 'warm', interglacial mammalian cave deposit in Britain. Although long considered to be 'Ipswichian' in age, no previous attempts to obtain radiometric dates have been recorded. Here we report a uranium-series disequilibrium date of $121,000 \pm 4000$ yr BP on a flowstone capping that overlay the original bone bed. The precision of the date exceeds that obtained at any other British Interglacial cave site, and permits tentative correlation with the high precision ice core records now available.

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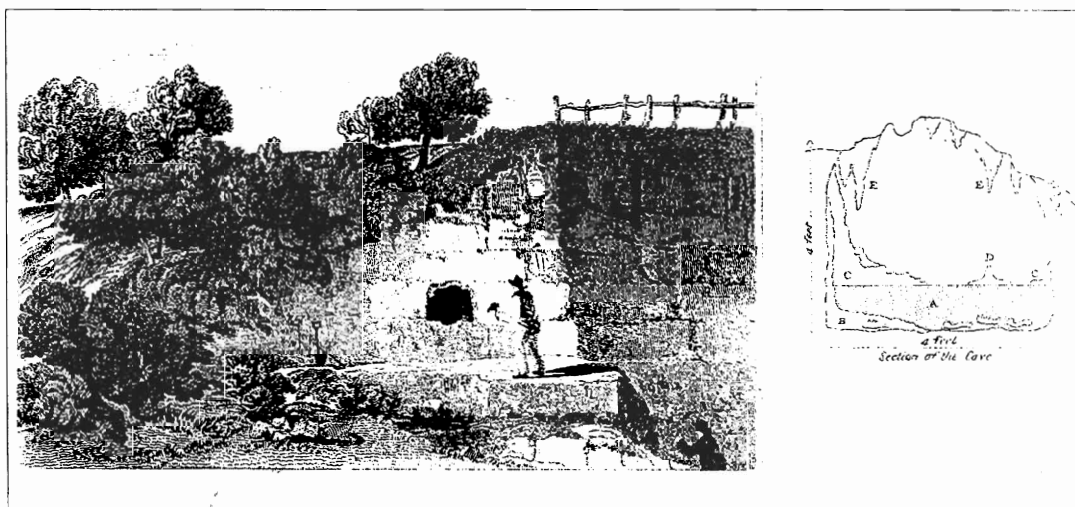
BACKGROUND AND HISTORICAL INTRODUCTION

*"By the crust of thy Stalactite floor,
The post-Adamite ages I've reckoned,
Summed their years, days & hours & more,
And I find it comes right to the second."
Coneybeare, 1822 [see also Figure 3]*

Kirkdale Cave [British National Grid Reference SE 6783 8562^a] is an abandoned phreatic resurgence cave, 175m in length, located 58m above sea level, on the northern edge of the Vale of Pickering, north Yorkshire. The cave first came to public attention in June 1821, when it was intersected by a quarrying operation on the east bank of the Hodge Beck. Before that time, the entrance had been completely choked and presented no indications of its existence (Young, 1823; Fig.1). Fortuitously, the local surgeon, John Harrison, noticed teeth and bone in road aggregate and traced the source to the ~15-30cm-deep layer of sediment on the cave floor. Over the next four months, a diverse group of local naturalists excavated in the cave, amassing a large collection of mammalian remains of unusual aspect. The existence of hyaena, hippopotamus, 'tiger', and other decidedly atypical Yorkshire fauna marked this discovery as one of some importance, and in November 1821 William Buckland (1784-1856), the first Professor of Geology at Oxford and later Dean of Westminster, was invited to visit the cave.

^a The national grid reference is reported inaccurately in Boylan, 1981.

Figure 1. Kirkdale Cave and the Hodge Beck Quarry as they appeared in late 1821, at the time of Buckland's visit.
From Buckland, 1823.



Buckland was profoundly influenced by his excavations at Kirkdale, and began a series of cave visits in Britain and Germany that culminated in his *Reliquiae Diluvianae* (Buckland, 1823), a volume of seminal importance to scientific speleology, the understanding of late Quaternary extinctions, and the progress of Natural Theology. Buckland's work and philosophy have been documented in some detail by North (1942) and Boylan (1967). The very large number of specimens collected from Kirkdale Cave came to be widely dispersed amongst a dozen museums. Tragically, those in the collections of Royal College of Surgeons and the museums of Bristol and Hull were subsequently destroyed during the hostilities of the Second World War. Boylan (1981) traced some 1,250 remaining specimens and provided a thorough revision of their taxonomic representation. Most notably, Boylan resolved the apparently enigmatic concurrence of a 'warm' fauna (eg, *Hippopotamus*) with 'cold' fauna (such as the woolly rhinoceros, *Coelodonta*) by demonstrating that the latter were erroneous identifications.

The Kirkdale fauna is now considered to be a classic example of an 'Ipswichian' warm interglacial mammalian assemblage, many other examples of which are known from epigeal sites and are assigned to Pollen Zone IplIb (Stuart, 1976). These faunas are characterised by the presence of hippopotamus (*Hippopotamus*), rhinoceros (*Diceros rhinus*), hyaena (*Crocuta*), lion (*Panthera leo*) and straight-tusked elephant (*Palaeloxodon*), and are often referred to collectively as the 'hippopotamus' fauna. Unfortunately, correlation of either the

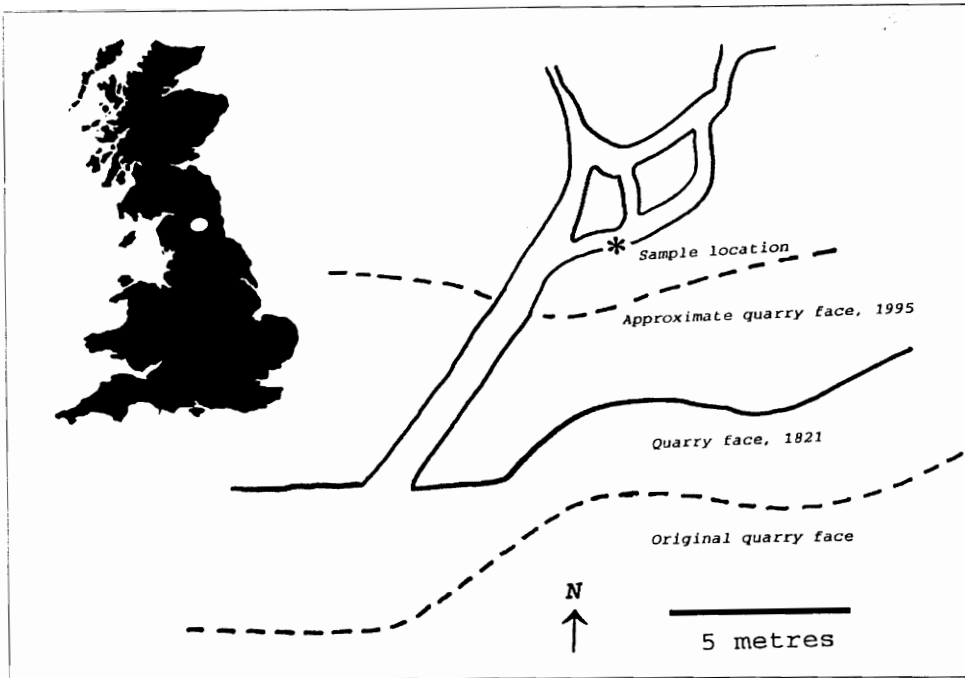


Figure 2. Survey of the entrance area of Kirkdale Cave, modified from the original in Buckland (1823).

'Ipswichian' or Zone IpIIb with the absolute time scale or the marine isotope record has been controversial (Gascoyne *et al.*, 1981; Stuart 1976), with Sutcliffe (1976) arguing that Ipswichian faunas represent unresolved components from several discrete temperate intervals. The availability of high resolution records from Greenland ice cores (GRIP, 1993; Grootes *et al.*, 1993) and the Lac du Bouchet (France) pollen sequence (Field *et al.*, 1994), together with improved precision in the dating of cave deposits, now provides new insight into these ideas.

DISCUSSION OF THE CURRENT WORK

Despite the great historical significance of the Kirkdale fauna, the site has never been dated radiometrically. In an attempt to effect closure on the 175 year saga of Kirkdale Cave, we undertook a uranium series disequilibrium analysis of remnants of the original flowstone floor, which both capped the bone-bearing sediment, and in some cases incorporated the bones that had their upper ends, "...projecting like legs of pigeons through pie-crust..." (Buckland, 1823:12). Subsequent to Buckland's work, quarrying removed a further 15-20m of the cave. Nevertheless, during a visit in 1995, we were able to locate remnants of the original calcite floor overlying pockets of undisturbed sediment (Fig. 2). A 47g sample of yellow flowstone with clay-filled vugs was removed and assayed by standard uranium-series disequilibrium alpha counting methods (Ivanovitch and Harmon, 1992), yielding an age of 121.4 +4.8 / -4.6kyr BP. The analysis was very satisfactory, with a high uranium content complemented by low amounts of detrital thorium (Table 1), a situation unusual in a cave entrance faunal deposit.

The age of the Kirkdale Cave flowstone falls within marine isotope stage (MIS) 5e, which spans the interval 115-132kyr BP and represents the Last (or Eemian) Interglacial (*sensu* Mangerud *et al.*, 1979) of continental Europe. The flowstone floor that capped the bone-bearing sediment clearly postdates the episode of hyaena occupation. However, the partial incorporation of bones implies that the flowstone was

emplaced relatively quickly after the site was abandoned by these animals. Buckland's contemporary cross section of the cave stratigraphy (Fig. 1) demonstrates that in some areas flowstone actually underlay the bone deposits. It is interesting to speculate that the original Kirkdale Cave deposit may have evidenced two episodes of climatic optima within MIS 5e, producing the upper and lower flowstones respectively. Such an interpretation is consistent with a variety of recent evidence for rapid climate reversals during MIS 5e (Thouveny *et al.*, 1994; Field *et al.*, 1994; Hillaire-Marcel *et al.*, 1996).

The date for the Kirkdale Cave flowstone floor is statistically indistinguishable from the age of the flowstone that caps the Lower Cave Earth of Victoria Cave, Yorkshire (Gascoyne *et al.*, 1981), the remarkable dwarf deer deposit of Belle Hogue Cave, Jersey, (Lister, 1989), and the 'Sandy Cave Earth' fauna of Bacon Hole, Wales (Stringer *et al.*, 1986) - all classic 'Ipswichian' hippopotamus-fauna sites. In reviewing the Bacon Hole sequence, Stringer *et al.* (1986) brought attention to the apparently novel continuance of the characteristic interglacial mammals *Palaeoloxodon* and *Dicerorhinus* into the "early Devensian" (glacial), an interpretation based on the dating of the 'Upper Cave Earth', which contains these taxa together with *Microtus oeconomus*, the northern vole (a 'cold' form). However, the age of the Bacon Hole 'Upper Cave Earth', assumed by Stringer *et al.* (1986) to postdate the cold 'wolverine' deposit at Stump Cross Caverns, Yorkshire (83 ± 6kyr BP; Sutcliffe *et al.*, 1985), is poorly constrained radiometrically. The Bacon Hole 'Upper Cave Earth' is not dated directly, but rather by an overlying stalagmite layer, which at 81 ± 18kyr BP places its 95% confidence limits within late MIS 5e time at approximately 115kyr BP, providing only a minimum age for the underlying fauna. Certainly, it cannot be considered significantly younger than the Devensian Stump Cross fauna.

An alternative interpretation is to consider that the tenure of the Bacon Hole interglacial fauna falls entirely within MIS 5e, with the anomalous *M. oeconomus* marking one of the dramatic climatic deteriorations within later MIS 5e (GRIP members, 1993; Field *et al.*,

Sample Code	Uranium content	$^{234}\text{U}/^{238}\text{U}$	$^{234}\text{U}/^{238}\text{U}$ at deposition	$^{230}\text{Th}/^{234}\text{U}$	$^{230}\text{Th}/^{232}\text{Th}$
DAM 95-34	0.675 ppm	1.448	1.63 ± 0.035	0.706	51
Calculated Age = 121,400 + 4,800 / - 4,600 yrs BP.					

Table 1. Uranium-series dating results on the Kirkdale Cave flowstone.



Figure 3. Coneybeare's satirical cartoon of Buckland in Kirkdale Cave. From Coneybeare, 1822.

1994; Thouveny, 1994; Johnsen *et al.*, 1995), and the classic Zone IpIib hippopotamus fauna correlating to the 5e5 climatic optimum. This interpretation supports arguments for the complexity of 'Ipswichian' climate change (Stringer *et al.*, 1986; Gordon, *et al.*, 1989), albeit spanning a much shorter time interval than these authors have supposed.

Stuart (1983) reported 14 'Ipswichian' vertebrate cave sites in Britain. All of these were originally discovered and excavated in the 19th century or first half of the 20th century, before radiometric dating techniques were developed. Several of these sites were subsequently lost to quarrying, although modern re-excavations of the remaining sites have yielded a bounty of information, the potential value of 'new' interglacial vertebrate cave sites cannot be overstated. Such discoveries, if they are to be made, will depend on the vigilance of the caving community.

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