Proc. Univ. Bristol Spelaeol. Soc., 1988, **18** (2), 241-257

THE LATE PLEISTOCENE SEQUENCE AT WELLS, SOMERSET

by

D. T. DONOVAN

ABSTRACT

Late Quaternary deposits and geomorphological features within a radius of about 4 km of Wells, Somerset, England are reviewed. The earliest well dated occurrence is the *Hippopotamus* fauna from Milton Hill, assigned to the warm interglacial episode corresponding to Oxygen Isotope Stage 5e in deep sea cores. The dissected Keward Gravel is thought to be older, perhaps O.I.S. 6. The Wookey Hole ravine developed during the early part of the last glaciation (O.I.S. 5?), the Ebbor gorge later (O.I.S. 3?)

The Wells and Wookey Station gravel spreads, the former with woolly rhinoceros and ?mammoth, are correlated with the maximum glacial advance of the Late Devensian.

INTRODUCTION

The City of Wells has in its immediate vicinity an unusually rich assortment of Late Pleistocene deposits and sites. Many of these were investigated by the late H. E. Balch, Curator of Wells Museum, and his finds are to be found in the Museum along with more casual discoveries. The present paper is an attempt to survey some of this material and its chronological significance.

It is convenient to deal in some detail with the Late Pleistocene as defined by Bowen *et al.* (1987, p. 299), that is, beginning at the base of Oxygen Isotope Stage 5e. Middle Pleistocene deposits of great importance are found at Westbury-sub-Mendip, only 6 km from Wells (Bishop, 1982) but at present they cannot be satisfactorily connected with the chronology of the later deposits.

MILTON HILL

The earliest Late Pleistocene mammalian fauna from the Wells area is that from Underwood Quarry, Milton Hill. The site has been quarried away and its location is not known. It was very approximately ST 540 468. The material is in Wells Museum. Like many other finds from the area, the bones have not been studied in detail. They were found in the filling of a cave system in the Carboniferous Limestone, and some of them are marked with the depth at which they were found, but otherwise there is little accompanying information. The faunal list (Balch, 1937b, table facing p. 180) was identified by the late J. Wilfrid Jackson and is given here with modernized nomenclature:

Hippopotamus amphibius—hippopotamus
Palaeoloxodon antiquus—straight-tusked elephant
Crocuta crocuta—spotted hyaena (including coprolites)
Bison priscus—bison (abundant)
Bos primigenius—aurochs
Cervus elaphus—red deer
Dama dama—fallow deer

Reindeer (*Rangifer tarandus*) was added by Balch (1948, table facing 142). It has been suggested (A. J. Sutcliffe, pers. comm.) that this record could have been a mistaken identification of an antler fragment of *Dama*.

There appear to be remains of at least two adult hippopotamuses, possibly more, and teeth of about half a dozen young *Palaeoloxodon* of several sizes. There are no adult *Palaeoloxodon* teeth.

The hippopotamus bones were found about 4 February 1935 (Anon., 1935). The *Wells Journal* reported that men clearing the overburden for an extension of the working face found a 'filled up pit descending vertically' into the limestone, and as they cleared it out began to find the hippopotamus bones 'embedded in the clay' at a depth of 14 feet (4.27 m). The bones were identified by Professor S. H. Reynolds of Bristol University. Nearly two years later, in November 1936, the *Wells Journal* (Anon., 1936) reported further finds, said to be 'in the same pit' and, a few lines later in 'an extension of the series of pits'. The other species were recovered on this occasion but hippopotamus was not present. The *Journal,* quoting Balch, said that the new finds were 'undoubtedly' contemporaneous with the hippo. Finds continued into January 1937 but no further newspaper reports appeared. This second lot of finds was sent to J. W. Jackson for identification.

Balch's brief references (1936, 1937a, 1947) give less detail than the *Wells Journal.* It appears from the newspaper reports that the bones were recovered by the quarry workmen, who were praised for their care in extracting them. A photograph in Balch's biography (Stanton, 1969, p. 33) shows Balch and helpers apparently at the top of the quarry face. It shows the overburden cleared, prior to quarrying, from around and inside a pit in the limestone, which agrees with the statements in Anon. (1935). No contemporary records of the work have been traced, and no attempt was made to write it up, although the major Badger Hole dig, for which log books were kept, was started a year or two later. The presence of, for example, numerous fragments of horn cores (? Bison) in Wells Museum suggests that an effort was made to collect all available material.

Museum labels contain little information. One, written by Balch, reads 'These bones are all from the Hunting Trap on Milton Hill, from that part of it which contained Elephas antiquus, Bos of several kinds, Cervus Browni [i.e. *Dama*], Hyaena one specimen only.' Most of the finds were from depths of between 20 and 30 feet (6.1–9.1 m) below the ground surface, and two bones (reg. nos. 1942, 1945) are labelled 'Bottom of pothole about 30 ft.' One of the last finds, on 8th January 1937, is labelled '35–40 feet (10.7–12.2 m) in the old Elephant Pit Swallet', which suggests that the cave was getting deeper before it was quarried away.

Was the site a hyaena den? Bones and coprolites of hyaenas were present, but not common although the *Wells Journal* (Anon., 1936) reported 'an unusual number of coprolites'. In general the bones have not been gnawed. The site does not seem to have had the characteristic features of a hyaena den, viz. (1) abundant hyaena bones and teeth of adult and young animals, and (2) gnawed bones of prey and of hyaenas themselves. Balch knew such material well from the Hyaena Den at Wookey Hole and its discoverer, W. Boyd Dawkins, and he did not interpret the Milton Hill site as a hyaena den.

Balch at first thought that the animals had 'fallen into a dry swallet' (1937b, p. 160) but later suggested that the pit had been used to trap animals (1948, p. 143) and published a drawing (1948, pl. 34) showing prehistoric men driving an elephant into it. Balch stated (1948, p. 143) that 'every marrow bone had been crushed as with a stone or axe, and some bore traces of fire'. A brief re-examination of the material confirms that many of the bones are broken, but the cause of damage is not obvious. The effect of fire

is also unproved. No physical traces of man or his tools were found, and indeed man was probably absent from Britain at the time when the hippopotamus fauna flourished (Stuart, 1976, p. 235; Currant, 1986).

The cave is unlikely to have been a swallet in view of its situation, distant from the base of the limestone where swallets usually develop. A new explanation is offered here, that the fissure fed a resurgence which was used by animals as a water hole. If water welled up from depth animals could have slipped and drowned, or sediment slumped into it, carrying animals with it. A water hole would explain the abundance of bison and other herbivores. The remains of young elephants could suggest that the locality was frequented by family groups, although the rarity or absence of adults could also be attributed to selective killing of young by hyaenas. The complete absence of small mammals could be held to support the water hole interpretation, as a dry pit would be more likely to be a home for small rodents and/or a roost for birds of prey.

Hippos live to-day in broad, shallow rivers, and forage on land at night. Most authorities indicate that they do so on low ground adjacent to the water, with a radius of up to about 3 km. (Verheyen, 1954; Lock, 1972). Hippo is known in Britain from valley floor sites where such conditions probably obtained, but also from a number of caves (Stuart, 1983, p. 21), some in mountainous situations such as Victoria Cave, North Yorkshire, which lies about 290 m above the floodplain of the River Ribble. Stuart (1983, p. 22) supposed that hippos climbed there from the river each night. He did not consider the possibility that the local topography may have been different at the time. It is reasonable to assume, however, that most of the cave records are of bones brought in by carnivores.

If there was a resurgence at Milton Hill, it must have been because the impermeable Triassic mudstones ('Keuper Marl') and Lias clays extended higher up the south flank of Mendip at the time, and ponded back the underground water. The mudstones still surround the hill, and there are outliers of Lower Lias in the area. Dr W. I. Stanton has suggested (pers. comm.) that, if my interpretation is correct, the water which rose at Milton Hill could have been that which now emerges at the small spring below the EMI Factory west of Wells (ST 53534643).

The Milton Hill site as a pitfall or a water hole seems more plausible with gentle slopes leading up to it than with its present relief, surrounded by steep slopes. If the Keward Gravel represents aggradation during the previous cold period, as suggested below, then a flat marshy valley floor could have lain about 2 km from the Milton Hill site.

Although the contemporaneity of all the species is not proved, the assemblage as a whole, with the exception of reindeer, forms a plausible association and indicates interglacial conditions. Hippo in the Late Pleistocene of Britain is considered specific to a group of sites regarded as contemporaneous and attributed to the Ipswichian, and comparison with Stuart's (1982) table 7.4 shows that the Milton Hill fauna of large herbivores is very similar to those of Barrington, Cambridgeshire, and Trafalgar Square, London, which date from Pollen Zone IIb, the mildest part of the interglacial.

DRY VALLEYS

Several valleys of various sizes dissect the southern flank of the Mendip plateau near Wells — Ebbor, Smokham, Rookham, Walcombe, Biddle Combe, Dinder Wood, and Ham Woods. They mostly lie on Carboniferous Limestone or on Dolomitic Conglomerate and are now dry. They are

presumed to have been cut by surface streams in time(s) of permafrost (Ford & Stanton, 1969, p. 411). Ford and Stanton thought that the Ebbor system captured the headwaters of the Smokham and Walcombe valleys (1969, p. 408 & figs. 3A, B), and this would account for the fact that the smaller, more easterly valleys have no clearly defined catchment areas. Inspection of the map would suggest that the Ebbor system itself may have been beheaded by the eastern arm of the Cheddar network. Such a sequence of events, if correct, implies quite a long history, and indeed Donovan (1969) suggested that the valleys on the plateau were superimposed. The chronology of this will not be considered further here.

Ebbor Valleys and Gorge

Two main branches of the Ebbor valley system, from Dursdon Wood and Deer Leap, join to form a rather insignificant valley about 1 km north-west of Wookey Hole village. Part of the Deer Leap branch carries a small stream where it is floored by Upper Carboniferous rocks. The rest of the valleys are dry. There is no clearly defined catchment area, and the original headwaters may have been captured by the Cheddar system (see above). Alternatively, one could argue that development of the Ebbor system was inhibited by the existence of the Cheddar valleys which carried away drainage from all but a small area surrounding the Ebbor valleys.

The Ebbor system, like the present day Axe, drained through the gap between Wattles Hill on the west and Arthur's Point. South of the gap is a narrow, crescentic gravel train, deposited by Ebbor drainage, part of which is described below as the Wookey Station Gravel.

The 'gorge' is a small part of the Ebbor system originating at a nick point at ST 52624874 a short distance north of Balch's 'little spring' (Balch, 1932, p. 145). There is much exposed rock, and steep to near vertical walls. The floor of the gorge is partly filled with rock debris. There are a number of small caves, fragments of a long-abandoned phreatic system. Most of these lie between about +140 and +175 m. They must have been formed when the outlet of limestone water was at a level of +180 m or higher.

Several caves excavated by Balch and his co-workers contained late Quaternary deposits, but details were not published. Some information was salvaged by McBurney. The best known site is Bridged Pot, at ST 52604866, +160 m, which contained thermoclastic breccia underlain by less stony deposits, resting on bed rock. The breccia yielded a 'cold' mammal fauna with a generally Late Pleistocene aspect (Balch, 1932, p. 144; 1937b, table facing p. 180; McBurney, 1959). The most straightforward interpretation is to regard the main breccia (McBurney's bed B) as marking the Late Devensian cold phase, and the beds beneath (his A1 to A3) as marking a milder phase, perhaps Upton Warren interstadial. Balch's excavation found a hoard of eleven large, white-patinated bifacial flint artefacts, which Balch thought to be Solutrean. Later opinion (e.g. the late A. D. Lacaille, pers. comm.) believes them to be a post-palaeolithic intrusion, and if this is so they do not affect the dating of the deposits.

Lion Cave at ST 52584871, +148 m is said to have yielded a single bone, a tibia of bear (Balch, 1932, p. 146) or cave lion (Balch, 1947, p. 97). The bone should be in Wells Museum but has not been traced, so not too much reliance can be put on the record. The history of lion during the Devensian is not well documented, but it occurs in Layer 3 at Picken's Hole, dated at 34,265 years BP (Stuart, 1982, p. 157). The cave at present shows a small section of breccia capped by laminated stalagmite similar to that overlying

'Cheddar Man' at Gough's Cave, Cheddar, which is later than about 9,100 years BP. The Lion Cave breccia probably dates from the last cold phase of the Devensian, like that of Bridged Pot. The two caves are close together in similar situations. They are high up, just below the nick point in the valley, and could have been exposed at an early stage in the downcutting of the gorge.

This evidence suggests that these rock shelters had been exposed by erosion before the Late Devensian glaciation, and the absence of deposits of substantially earlier date suggests that Ebbor Gorge in its present form dates from the earlier part of the Devensian. It remains possible that it is considerably older, and that the absence of caves with earlier deposits is due to the retreat of the cliffs in which they lay. Downcutting doubtless continued through the late Devensian glacial phase, or the partial filling of scree could perhaps date from this time.

Wookey Hole Ravine

Wookey Hole ravine is a steep-sided valley which ends abruptly at the River Axe resurgence, which lies at the foot of a vertical cliff of Dolomitic Conglomerate about 30 m high. The altitude of the resurgence is +60 m, the valley floor at the mouth of the ravine is about +52 m. Unlike Ebbor Gorge, the ravine is not cut into the floor of an earlier valley. Above the level of the Axe are higher-level dry passages, including the tourist cave, and Balch (1914, p. 20) thought that he could recognize five successively lower outlets of the river (including the present one), but in the absence of a modern study of the system this must be treated with caution. Ford and Stanton (1969, p. 425) thought that Badger Hole, at +76 m, was an earlier outlet of the river, and the highest and oldest outlet is on the hillside (now blocked) at +109 m (Barrington & Stanton, 1977, p. 179) fed by a passage from the Ninth Chamber with well-developed scalloping indicating outward water flow (Dr W. I. Stanton, pers. comm.).

Balch (1914, pp. 19, 20) thought that the ravine was formed by the unroofing of Wookey Hole Cave, but the volume of the existing cave is small compared with the ravine (cf. discussion of Cheddar Gorge in Ford & Stanton, 1969, p. 415). The ravine may have been partly formed by retreat of the cliff above the spring, partly by stream erosion.

The age of the ravine may now be considered. It must have been cut down to about two-thirds of its present depth, exposing the caves on its left bank, by the time these were occupied by man and animals. These caves (Badger Hole, Hyaena Den, and Rhinoceros Hole) all yielded abundant Late Pleistocene mammal bones. The closest dates are probably provided by the human cultures, of which the earliest is Mousterian of Acheulian tradition (MTA). The MTA from the Hyaena Den (Tratman, Donovan & Campbell, 1971) is old finds of unknown stratification, but at Rhinoceros Hole (Tratman, 1977) a small *boue coupé* handaxe, like the ones from the Hyaena Den, was found in the basal stratum 'resting nearly on rock floor'. MTA is not well dated in Britain, but in France MTA type B lasted until about 42,000 years BP, and type A, to which the Wookey Hole industry may belong, ended rather earlier, around 50,000 BP (Valladas *et al.*, 1986). Campbell (in Tratman *et al.*, 1971, p. 273) published a pollen diagram for the Hyaena Den which was interpreted as going back to 'Early Last Glacial', though if layer A3 represents 'Full Last Glacial' as supposed (i.e. the Devensian glacial maximum) the warmer floras below it seem more likely to indicate a Devensian interstadial. The

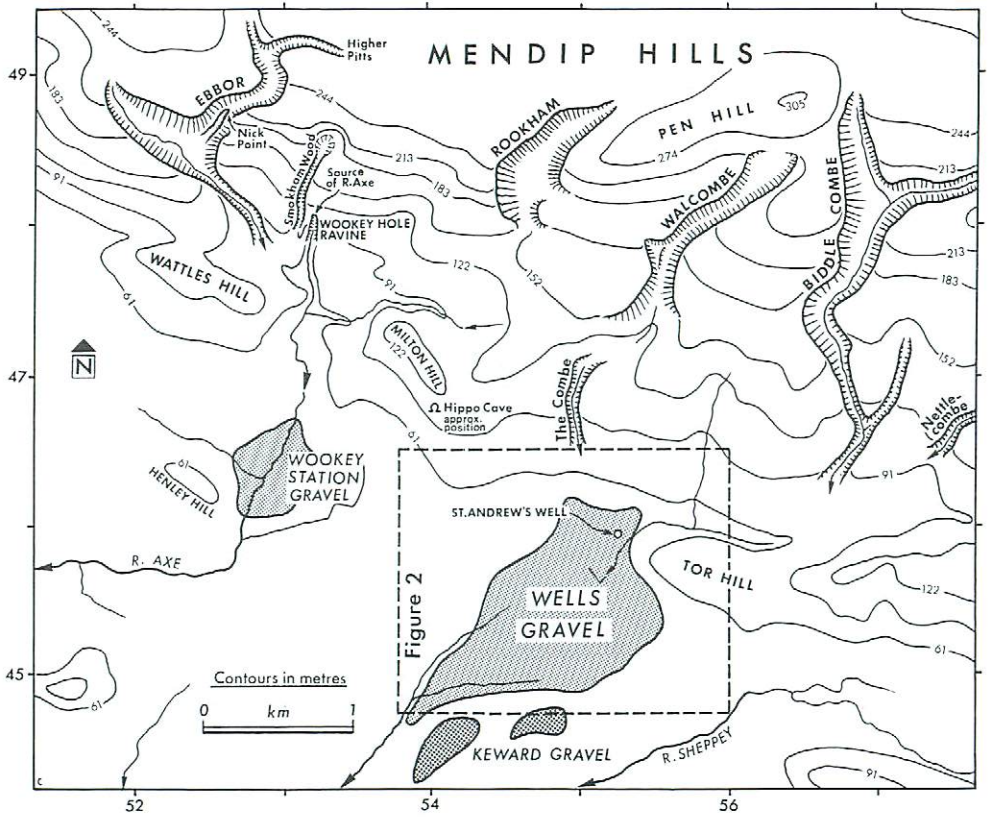

FIG. 1—SKETCH MAP OF THE COUNTRY AROUND WELLS, SHOWING THE CHIEF MORPHOLOGICAL FEATURES AND GRAVEL DEPOSITS

pollen and archaeological evidence are in reasonable agreement that deposition in the cave started not later than about half-way through the Devensian, some 50,000–60,000 BP*.

Downcutting of the ravine could have started during the interglacial climate of Oxygen Isotope Stage 5 and reached the level of the Hyaena Den by early–mid Devensian times. During the Late Devensian glaciation the system was presumably inactive, but at the present time the Dolomitic Conglomerate cliff is again retreating, and the Axe rising is being captured by the lower level spring at Glencot (ST 53174699).

Smokham Wood

Smokham Wood marks the site of a small V-shaped valley, about 50 m wide and 8 m deep, which starts at a small inlier of Carboniferous Limestone at ST 532484 and runs west of south on Dolomitic Conglomerate to about ST 530478 where it peters out as the slope flattens. Its lower part is separated from the Wookey Hole ravine by an interfluve only a few tens of metres across. The valley was clearly eroded by a surface stream, and its small size suggests that it was functional for a relatively short time. At the head of the little valley is an ill-defined concave area of hillside and the valley could perhaps have been formed by meltwater from snow in this 'cirque'. There is no evidence as to its date.

GRAVELS ALONG THE MENDIP FLANK

A series of gravel patches along the south flank of Mendip (FIG. 1) were briefly described by Clayden and Findlay (1960) and Findlay (1965). They are 'sub-angular, ill-sorted and unstratified', up to 15 ft (4.6 m) or more thick, and of composition varying with parent outcrops. They are generally sited at the mouths of gorges or combes. They rest almost entirely on 'Keuper Marl'. The Geological Survey map (Wells (280) sheet) differentiates some of them (as 'Head') and shows that in places they descend below later Alluvium. The shapes of the outcrops leave little doubt that they have been dissected by subsequent erosion. Some of them have been affected by later cryoturbation.

Clayden and Findlay (1960) thought that the constituents of the gravels were produced by frost shattering, then transported by periodic torrents. Cold and probably periglacial conditions are indicated. They proposed origin during a cold phase of the last interglacial, but glacial phases, Devensian or earlier, seem more probable.

The Wells Gravel, described below, is one of these deposits and is of interest as the only one which has so far yielded mammalian fossils. Two other deposits in the area, the Keward Gravel and Wookey Station Gravel, are also briefly considered.

*Two finds appear to contradict this statement. Dawkins (1874, p. 310) reported two teeth of *Rhinoceros hemitoechus*, an interglacial species, from the Hyaena Den. These teeth are in Oxford University Museum. Dr A. J. Sutcliffe and the writer examined them and compared them with the British Museum collections, and concluded that there is no basis for identifying them as *R. hemitoechus* rather than with Woolly Rhinoceros, the common species in the Hyaena Den. Hawkins and Tratman (1977, p. 207) briefly referred to *Hippopotamus* and *Dicerorhinus hemitoechus* from the basal levels of Rhinoceros Hole. Mr A. P. Currant (pers. comm.) informs me that he has examined the material but cannot confirm these identifications.

KEWARD GRAVEL

Gravel caps the hill south of Keward (ST 541445). It was mapped as Langford Series by the Soil Survey, while the Geological Survey map shows the area as Head. Material brought to the surface by an uprooted tree at ST 54154449 in 1987 was identical with Wells Gravel in constituents, shape and size range of components. A series of conspicuously flat summits to the east, the next one (ST 547447) having Langford Series soil, are the dissected relics of a gravel spread with its base at about 36 m above O.D. These deposits are here named the Keward Gravel.

This gravel spread would have extended northwards over the area now occupied by the Wells Gravel, but at a higher level, towards its source on the Mendip flanks. It indicates an earlier phase of gravel deposition, separated by an interval of erosion from the accumulation of the Wells Gravel.

THE WELLS GRAVEL

The medieval City of Wells stands on a spread of Quaternary gravels, briefly mentioned in the Geological Survey memoir (Green & Welch, 1965, p. 118). Woodward (1876, p. 158) wrote 'Besides Secondary rocks [the gravels] contain a large proportion of Carboniferous Limestone pebbles, of Old Red Sandstone, &c., in fact pebbles of all the rocks of the neighbourhood. . . . Sections may be seen at the Great Western Railway Station, and in several stream and ditch sections in and about the town.' Green and Welch (1965, p. 118) describe the gravels as 'mainly subangular, locally derived Palaeozoic and Mesozoic rocks in a loamy sand matrix'. Dolomitic Conglomerate is usually present, and the abundance of Carboniferous Limestone is probably due to breakdown of the Dolomitic Conglomerate rather than to direct derivation from the limestone outcrop. The gravels are poorly sorted, with a range of grain size from sand grade particles to 120 mm or so.

There are now no good exposures of the gravels. The Ordnance Survey 1:500 plan of Wells (Somerset Sheet XLI.5.9), surveyed and published in 1886, marks a 'Gravel Pit' in the grounds of the Bishop's Palace at ST 55354580. It was small, about 35 ft square, and probably for the private use of the Bishop's estate. It is said to have been used for paths and in St. Andrew's Well. Gravel may have been dug further north, at about ST 552459, where there is a sudden drop of level into a garden and a car park.

Green and Welch (1965, p. 118) record 6 feet (1.8 m) seen in the banks of the Keward Brook at ST 546449. This exposure is now much obscured.

An excavation in April 1987 behind the house in the angle of New Street and North Liberty, at ST54954600, showed 1.10 m of made ground overlying 0.80 m of Quaternary deposit. This was roughly divided into an upper half which has 'worn', subangular pieces of Carboniferous Limestone up to about 110 mm long, rather smaller well-rounded pebbles of Old Red Sandstone, and numerous small pebbles and granules a few millimetres in size, in a dark reddish-brown clayey matrix. The lower half was similar, but with few large stones.

In and around the Cathedral shallow excavations produce gravel with pebbles up to about 50 mm in size. Similar gravel can be found near the foundations of the Chain Gate at ST 55154592. Doubtless all this material has been reworked by human agency.

In 1897 subsidence beneath the Chapter House (ST 55174590) of the Cathedral was investigated and it was found that water 'had washed away the soil and smaller stones which bound together the big stones beneath the foundation' and that these big stones were 'large smooth boulders' (Colchester, 1986, p. 19). This would indicate coarse, ill-sorted gravel in this area. E. A. Martel's inference that the foundations were in solid rock is considered unjustified (see Shaw, this issue).

Two boreholes (Athletic Ground No. 2 at ST 54554497 and Vowles' at ST 54984544) were recorded by Green and Welch (1965, pp. 204, 205). Others have not previously been published. A group of three holes was drilled in 1936 by F. G. Clements in the Camery at Wells Cathedral to prove the nature of the subsoil on which the Cathedral foundations rest, and are included by courtesy of Mr Bert Wheeler, formerly Master Mason to the Cathedral, who recorded them. No. 1 borehole was in the angle made by the south wall of the quire and the west wall of the quire transept, at about ST 55184587. Gravel appears to have been reached at 9 ft 6 ins (2.90 m), and at 15 ft (4.57 m) a bed of sand 1 ft 6 ins (0.45 m) thick was struck. Gravel was proved again below this, but the sand gave trouble by collapsing into the hole, which appears to have been abandoned.

There seems to be no record of no. 2, presumably also unsuccessful. The most complete sequence was given by No. 3, which was 49 ft (14.9 m) south of the wall of the Lady Chapel (ST 55204586). The section was

	ft	ins	m
Made ground	9	6	2.90
Gravel (fine)	15	6	4.72
Keuper Marl ..... seen	2	0	0.61

The ground surface, by hand levelling from the bench mark at the east end of the Lady Chapel, is about 153 ft 6 ins (46.80 m) above O.D. The base of the gravels therefore lies at 128 ft 6 ins (39.20 m).

In 1979 a trial hole was dug south of the south wall of the South Transept of the Cathedral. It showed the foundations of the building resting, 8 ft 4 in (2.54 m) below ground level, on a deposit identified by Mr J. D. Hanwell as 'solifluction deposit'. This is presumed to have been the weathered or cryoturbated top of the Wells Gravel at about 147 ft 6 ins (45 m) above O.D. The considerable depth of the foundations suggests that they rested on more or less the original surface of the gravels; on account of the sloping site the north side of the Cathedral was excavated into the hillside while the south side had to be built up.

A borehole was drilled in 1979 at Parkwood Estate by W. Sparrow Ltd. for Clares Ltd. The site was at ST 54854521, surface level not recorded. The log is not very helpful, but 'made up ground' to 20 ft (6.1 m) depth is interpreted by Mr G. W. Green as gravel, resting on Triassic mudstones. Estimation of the surface level puts the base of the gravels at about 29.5 m above O.D.

Extent of the Wells Gravel

The gravels are differentiated on the Geological Survey 6 Inch (sheets ST 54 NW, 1960, NE, 1961) and One Inch (Wells (280), 1963) maps, labelled as 'Alluvial Cone'. They are indicated, approximately, on the One Inch Soil Survey map (Wells Sheet, 280, 1962) by the Langford and Max Soil Series. For much of the boundary of the outcrop the geological and soil maps agree closely, and their lines have been adopted in the present map (FIG. 2).

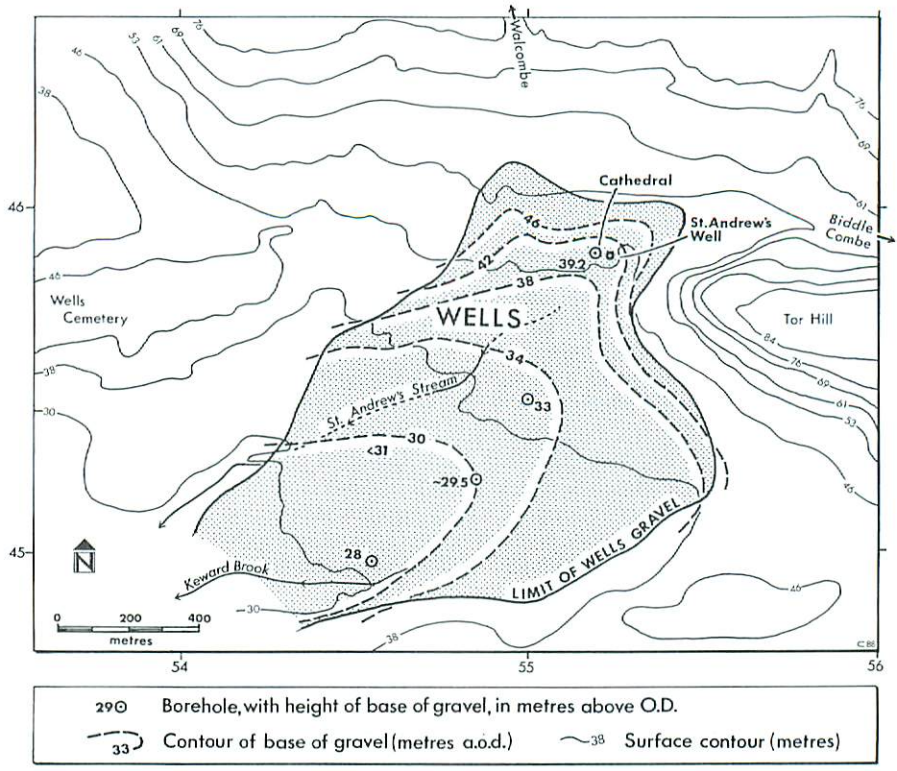

FIG. 2—SKETCH MAP SHOWING EXTENT, SURFACE CONTOURS AND CONTOURS ON THE BASE OF THE WELLS GRAVEL

The northern boundary is taken by the Geological Survey along the High Street, presumably on topographical criteria as the area is built up. The Soil Survey places the limit of the Langford Soil Series about 500 ft (152 m) to the north, along Chamberlain Street. There is evidence that Quaternary deposits extend still further north. A temporary exposure at the junction of North Liberty with New Street is described above, and the find of Woolly Rhinoceros (see below), described by Balch as in 'pleistocene gravel' may have been in a similar deposit, to judge from the traces of matrix adhering to the specimen. Gravel may be found in the soil both east and west of the lower end of New Street. A tongue of 'gravel' is therefore thought to extend up the line of New Street towards the mouth of the Walcombe valley. After recording the New Street find, Balch wrote (1928b, p. 31) 'It is of interest that this gravel lies so far up the slope of the hill, and this must be held to indicate at least one route by which the debris composing it was swept down from the Mendips. Walcombe Valley must have provided much of it and certain clearly defined channels of the new road close by, exposed in cutting that road, were doubtless the marks of floods of that ancient time by which the gravel was transported.'

Contours on the base of the gravel have been drawn from the borehole and outcrop information (FIG. 2). This map shows that the gravels occupy a

valley in the underlying Triassic mudstones, relatively narrow and steep-sided at the north-eastern end near St. Andrew's Well, becoming broader and flatter southwards and westwards. The maximum thickness of the gravels is likely to be about 25 ft (8 m).

Palaeontology

Balch (1928a, p. 10; 1928b, p. 31) recorded a tooth of Woolly Rhinoceros 'from eight feet deep in the roadway in New Street'. This is Wells Museum no. 1894, *Coelodonta antiquitatis,* right upper second molar. The tooth is complete except for parts of the roots. The surface is matt and pitted, the enamel having lost its glossy appearance. On the grinding surface the ridges of enamel stand up about 1 mm above the dentine, in a way that is not due to wear but appears to be the result of differential solution. I conclude that the somewhat battered appearance of the tooth is due to solution by groundwater rather than to mechanical abrasion as Balch thought (1928b, p. 31). Findlay (1965, p. 83) noted that slight acidity is normal in the surface soil of the Langford Series, becoming neutral or alkaline at greater depths. The crevices of the tooth retain reddish-brown clayey silt with larger particles up to about 0.5 mm in diameter.

Balch (1937b, p. 182) also recorded Mammoth and Wild Boar from the gravels, both said to be in Wells Museum. The specimens have not been found. The *Wells Journal* (Anon., 1935) quoted Balch as saying that 'a mammoth tooth was found a few years ago when the gravel was quarried at a spot close to the Somerset and Dorset station', i.e. at about ST 545452. The 'Wild Boar' has not been traced. It could have been Pleistocene or may have been a medieval intrusion.

Mode of Occurrence

The hollow in which the Wells Gravels lie (FIG. 2) has the appearance of having been cut by the waters from St. Andrew's Well which lies at its north-east end. The gravels themselves are noteworthy for their lack of sorting, and are interpreted as the deposits of violent, short-lived torrents, probably melt-water from ice or snow (Clayden & Findlay, 1960). These would chiefly have been channelled down the Walcombe valley and Biddle Combe. As soon as the torrents reached the nearly flat area previously scooped out by the St. Andrew's water, they were dissipated and their load deposited. Subsequent or penecontemporaneous solifluction may have produced the material with clayey matrix such as that exposed near New Street. Mr G. W. Green (pers. comm.) has suggested that the present outcrop may derive largely from redeposition of previously soliflucted material by the St. Andrew's waters.

Age of the Wells Gravel

The above conclusion as to its mode of origin, together with the undissected state of the outcrop, suggests to the writer that the Wells Gravel should be attributed to the last intensely cold phase of the Devensian, i.e. the Late Devensian glaciation, rather than to an earlier glacial episode, especially as the earlier Devensian cold phases are thought not to have given rise to glaciation in Britain (Shotton, 1979) and were probably, therefore, not accompanied by permafrost in southern England. Permafrost was inferred at Oldbury-upon-Severn (Allen, 1984), and although its age is unproved, a late Devensian date is plausible on account of the preservation of the resulting structures in poorly resistant mudstones.

The Late Devensian glaciation has been dated as from 18,000 to 15,000 BP, the earlier date being based on a ^{14}C determination from sediments below the Holderness tills. Shotton (1981, p. 142) has, however, pointed out that the Holderness tills probably mark a late surge of the ice, and Bowen *et al.* (1987, p. 310) concluded that the expansion of glaciers took place some time after about 26,000 BP. Until recently latest occurrences of Mammoth and Woolly Rhinoceros were dated at around 18,000–20,000 BP (Stuart, 1982, p. 156), but this was based on comparatively few dates, and mammoth has recently been reported (Coope & Lister, 1987) from around 12,800 BP. The faunal evidence is thus consonant with a deposition of the gravel during the Late Devensian glaciation.

WOOKEY STATION GRAVEL

A narrow crescentic gravel train extends southwards from the mouth of the Ebbor valley system (see above), mapped as Head by the Geological Survey and as Langford Series by the Soil Survey. Woodward (1876, p. 158) wrote 'in the railway cutting near Wookey, gravel is exposed. It is of very irregular thickness, attaining 8 and 10 feet in places . . .'. These deposits have recently been studied by Macklin and Hunt (1988) who showed that they are largely of Postglacial age. A small area around Wookey Station is older and is named by them the Wookey Station Gravel (Fig. 1). They interpret it as a fan deposited by a low-sinuosity bedload stream. There is no clear evidence of date but Macklin and Hunt think the gravel was 'deposited in stadial conditions during or more probably before the Devensian Late-glacial substage c. 13,000–10,000 BP' (*op. cit.*, p. 54). The surface of the gravel shows involutions which may have developed during the Younger Dryas, c. 11,000–10,000 BP, according to Macklin and Hunt.

The Wookey Station Gravel and the Wells Gravel are similar in lithology and in their relationship to the present drainage and these similarities suggest that they are contemporaneous. The Wells Gravel covers about five to six times the area of the Wookey Station Gravel, and a similar relationship exists between the sizes of the catchment areas which supplied sediment to the two deposits (Fig. 1).

CHRONOLOGY

General Remarks

I have not used the Geological Society's Quaternary Correlation Chart (Mitchell *et al.*, 1973) as a framework for correlation. Unfortunately it was 'Based on information supplied . . . up to 1 January, 1971 with some later additions' (p. 1) and was compiled at the time that doubt was being cast by members of the British Geological Survey on the validity of the Gipping Till of East Anglia as representing a distinct glacial advance (Bristow & Cox, 1973), and by inference on the separate identity of the Wolstonian Stage of Mitchell *et al.* (1973). This in turn cast doubt on the identity of the cold phase which was believed to separate the Hoxnian and Ipswichian interglacial stages, the latter suggested by Bristow and Cox (in Mitchell *et al.*, 1973, p. 12) to be perhaps different episodes of the same interglacial. These disagreements were not resolved in time for the publication of the correlation chart, and in fact have dogged British Quaternary stratigraphy ever since. A succinct account of the situation up to the mid-1970s was given by Bowen (1978, pp. 32–38).

More recently the Geological Survey has questioned the reality of the Wolstonian episode on its home ground (Sumbler, 1983). Part of the problem has lain in the difficulty of correlation between the Midlands, where the type Wolstonian occurs, and East Anglia which is the reference area for much of the British Quaternary. A correlation has recently been developed by Rose (1987) which is claimed to support the Survey's view. Work on mammalian faunas has suggested to Sutcliffe (1975, 1976) that the term Ipswichian has been used for more than one mild episode during the Late Pleistocene, and the details of the sequence of events between the Hoxnian and the Ipswichian (*sensu stricto*) are not yet generally agreed.

The deep-sea oxygen isotope record has therefore been used as the framework for correlation (TABLE I). Although only two or three points in the relevant part of it can perhaps be correlated directly with events on land (cf. Turon, 1984), at least it is based on a stratified sequence, and appears to provide an objective record of the major climatic oscillations. I have used the term Devensian which seems to be widely accepted and unambiguous in its meaning (Mitchell *et al.*, 1973, p. 5).

Local Correlation

The oldest deposit of those considered here may be the Keward Gravel, but there is no intrinsic means of dating it. If my interpretation is correct, it comprises small remnants of a much more extensive spread, laid down under very cold conditions. Its prolonged dissection could have been initiated by the forerunner of St Andrew's Well during the 'Last Interglacial' (i.e. Oxygen Isotope Stage 5e). Accordingly it is tentatively assigned to the cold O.I.S. 6, but could be earlier.

A good fixed point is provided by the reasonably secure dating of the Milton Hill mammal fauna to Oxygen Isotope Stage 5e, with which Zone IIb of the Ipswichian is commonly correlated (Gascoyne *et al.* 1981). At this time there was a more gentle slope down to the vale to the south, largely on Lower Lias Clay which at the outcrop north of Upper Milton still extends to +170 m, and nearer to Wookey Hole must have lain above the tiny remnant of Lias at ST 53564812 at +145 m. The Milton Hill resurgence would have been the lowest point locally of the clay outcrop, at +100 m or higher. This would correspond to the 120 m level at St. Cuthbert's Swallet (Ford & Stanton, 1969, p. 417). As denudation progressively removed the Lias clay, the resurgence was abandoned for lower channels.

The Wookey Hole ravine was deepened during milder climatic phases when the underground drainage was functioning. Although the full interglacial of O.I.S. 5e is regarded as short, there is evidence from the continent (Woillard, 1979) as well as from deep sea cores that stages 5d to 5a were chiefly of mild climate, with deciduous woodland in northern France (Woillard's stages St. Germain I and II), with two rather short colder intervals (her Melisey I and II). Although this detailed sequence has not been established in Britain, Stringer *et al.* (1986) established at Bacon Hole, Glamorgan, a 'warm' fauna with *Palaeoloxodon* said to be 'post-Ipswichian' in date which may denote a local equivalent of one of the St. Germain mild phases. Wookey ravine would have had perhaps 50,000 years of mainly mild climate during which to be cut down to the level of the rock shelters.

At the same time St. Andrew's Well would have been active and its waters eroded the hollow in which the Wells Gravel was laid down when permafrost conditions supervened.

Rather later the gorge at Ebbor was cut, perhaps starting in O.I.S. 4, but more probably during the Late Devensian (O.I.S. 2). The proto-Ebbor valley in its lower reaches would have been excavated largely in Lower Lias Clay, and the stripping off of this left the present rather insignificant lower part of the valley cut into the underlying Dolomitic Conglomerate.

TABLE I—*Correlation of local events referred to the deep sea oxygen isotope record*

'000 Years BP	Oxygen isotope stages	British Sequence	Events in the Wells area	Grande Pile (Note 4)
0				
10	1	Younger Dryas		
15	2	Lateglacial interstadial	Ebbor shelter breccias	
20		Maximum of last glacial advance in Britain (Note 1)	Wells and Wookey Station Gravels deposited	
30		start of Late Devensian glaciation		
40		COLD	erosion of Ebbor Gorge	
50	3	Upton Warren interstadial		
60		COLD		
70		Chelford/Brørup interstadial (Note 2)	basal deposit of Rhinoceros Hole	
80	4	COLD		
90	5a	Stump Cross?	down-cutting of Wookey Hole ravine	St. Germain II
100	5b			Melisey II: cold
110	5c	Bacon Hole, upper fauna (Note 3)		St. Germain I: mild
120	5d			Melisey I: cold
130 to 150	5e	'Ipswichian' interglacial Victoria Cave (Lower Cave Earth)	Milton Hill fauna	
	6		Keward Gravel deposited?	

Notes to Table I

1. The Late Devensian glacial phase in Britain is usually dated between 18,000 and 15,000 BP, but Shotton (1981, p. 142) pointed out that the Holderness tills, below which ^{14}C dates between 18,900 and 18,000 BP were obtained, probably mark a late surge of the late Devensian ice, and that the glacial advance could have begun earlier. Bowen *et al.* (1987, p. 310) have since reviewed the evidence and conclude that the 'maximum expansion of glaciers occurred some time after about 26,000 BP', reached a maximum around 18,000–17,000 and wasted from most of England by about 14,500 BP.

2. The correlation of this interstadial is not certain; it could correspond to Oxygen Isotope Stage 5a.

3. Possibly O.I.S. 5a. The relationship of the deposits at Bacon Hole to those at Stump Cross is unproved.

4. Pollen-based climatic stages based on the apparently uninterrupted sedimentary record at Grand Pile, north-eastern France (Woillard & Mook 1982). These cannot be clearly correlated with British stratigraphy.

Ford and Stanton's chronology (*op. cit.*, p. 424) puts the formation of Ebbor Gorge earlier than this, but they did not take into account the late Devensian start of occupation of the rock shelters, although it could be argued that caves with earlier deposits have been destroyed by cliff retreat during later cold phases.

At the same time (late O.I.S. 3, O.I.S. 2) the Wells Gravel was laid down, with a larger 'catchment area' than the Wookey Station Gravel which resulted from the Ebbor drainage. Of the same date in the Late Devensian could be the parent material of the Nordrach Series soils on the Mendip plateau, thought to be of loessic origin by Findlay (1965, pp. 16, 48).

ACKNOWLEDGEMENTS

I thank G. W. Green and W. I. Stanton for reading a draft of the paper and making helpful suggestions, and A. P. Currant and A. J. Sutcliffe for discussion and information. Colin Stuart drew the maps.

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Prof. D. T. DONOVAN, Dept. of Geology, University of Bristol, Queens Road, Bristol BS8 1RJ, U.K.; and PHG Consulting, London