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HIGH LEVEL DRIFT DEPOSITS EAST OF BATH

by

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ABSTRACT

Information is summarised on the relics of plateau deposits which lie on the Middle Jurassic limestone outcrops east and south-east of Bath, between 150 m. and 200 m. above O.D. Clasts include flint, quartz, and sandstones in a clayey or loamy matrix. A possible glacial origin is discussed. Age of the original deposit, now mainly preserved in fissures or other cavities, is likely to be early to middle Pleistocene.

INTRODUCTION

Superficial geological deposits, presumed Quaternary or late Tertiary in age, on the hill summits east and south-east of Bath have attracted the attention of geologists from time to time but have remained elusive. Most of the occurrences have been revealed in temporary sections during quarrying or other works, and most are too small in extent to be shown on the published geological maps. The earlier authors to record these deposits did not usually give exact locations. The purpose of this paper is to summarise the available information, and attempt to reconstruct the sequence of events which produced the deposits as they occur today.

The summit plateaux are formed of Middle Jurassic rocks belonging to the Great Oolite and Forest Marble formations. The Great Oolite is made up entirely of limestones, much quarried for building stone. The Forest Marble in the area in question is mapped as limestone succeeded by clay. All quarries mentioned are in Great Oolite limestones unless otherwise noted.

HISTORY OF WORK

Conybeare and Phillips (1822, pp.227-8) seem to have been the first to record these deposits. After noting the presence of flints on Bathampton Down they wrote that "[flints] are also found on the summit of many of the adjacent downs ..". Buckland and Conybeare (1824, p. 308) write "The tooth of a rhinoceros has also been found in flint gravel on the oolitic summit of Kingsdown near Bath." This is the only record of a (presumed) Quaternary fossil from the deposits and as we have no further description of the tooth it cannot be accepted unreservedly. Woodward (1876, p. 162, footnote) wrongly attributed this record to Lonsdale (see below).

Lonsdale's account of the oolitic district of Bath (1832, p. 271) states: "The most interesting circumstance connected with the gravel of the district .. is the existence of chalk flints on some of the isolated downs and hills in the neighbourhood of Bath. They occur abundantly on Farleigh Down and Hampton Down..".

The first author to discuss the deposits in any detail, presumably from personal observation, was Charles Henry Weston (fl. 1828-1868). He read several papers to the Geological Society, of which he was a Fellow, but I have not found out anything more about him. Unfortunately only an abstract of his paper on the Bath drifts, read to the Geological Society of London on 5 June 1850, was published (Weston 1850), and the MS does not survive in the Society's archives.

The Rev. H. H. Winwood was a Bath clergyman who was a pillar of the Bath Natural History and Antiquarian Field Club for many years in the late nineteenth century. He published geological papers in local journals, and one of these described flint gravels on Farleigh Down. Winwood was the first to record quartz pebbles as well as flint. Joseph Prestwich (1890, pp. 143-144) referred briefly to a deposit on Kingsdown (see below). It is unclear whether he saw the deposit himself. The Rev. Benjamin Oriel, another Bath clergyman whose collection came to Bristol University in the 1950s, described the Kingsdown deposit in 1904.

William David Varney was born in Nottingham late in 1895 and graduated with first class honours in geology at University College Nottingham in 1916, proceeding to an M.Sc. in 1922. The subject of his M.Sc. was probably his research on the Geological history of the Pewsey Vale, on which he published in 1921. Varney differed from earlier authors in stating that deposits on Bathampton Down "form a surface deposit covering these hills .." and he also recorded rock types not found by earlier or later observers. His paper is the best-known description of the deposits. Unfortunately no thesis for the M.Sc., which might have given greater detail, survives at Nottingham University (Ms H. I. Cowling, letter dated 29 June 1995). Varney joined the Geologists' Association in 1917 and later membership lists give addresses in the Peterborough area, but no further information has been found.

After Varney's work the subject lay dormant until after the Second World War. Linsdall Richardson (1881-1967), well known for his meticulous work on Mesozoic rocks, published (1956) a detailed note on a temporary exposure on Bathampton Down. Meanwhile the Geological Survey was re-mapping the Bath (265) One-Inch (now 1:50,000) geological sheet and further information on the deposits was gathered. G. A. Kellaway of the Geological Survey and A. Brian Hawkins, of the University of Bristol, recorded temporary exposures on Bathampton Down. Dr Kellaway's recent book on the Bath hot springs includes discussion of the high level drifts (Kellaway 1991). Finally the present writer recorded several occurrences of flint gravel in the course of his field work on the Great Oolite in the 1950s.

DESCRIPTION OF OCCURRENCES

Figures in square brackets are National Grid References, all in 100-km square ST. Altitudes above Ordnance Datum have been estimated from the Six-Inch or 1:10,000 Ordnance Survey maps and are not to be taken as very accurate.

Bathampton Down

Old Quarry House, [767 645]. Alt. approx. 170 m. A disused freestone quarry showed fissures filled with brown clay containing 'fractured' (i.e. angular or subangular) brown

flints. One quartz pebble seen. This is the westernmost record of the high level deposits, seen by the writer in the early 1950s.

Reservoir construction, 1955 [7742 6495], surface level approx. 200 m. Excavations at the eastern end of the reservoir were seen by the writer in November, 1955, who recorded pockets of unstratified brownish to greenish clay, incorporating flints as lenses and scattered. Some flints were irregular, rounded pebbles, up to 10 cm across. Many were angular, and some at least could have resulted from the splitting of the pebbles. Hawkins and Kellaway (1971, p. 278) recorded the same excavations and noted "masses of stiff plastic clay with pebbles of patinated flint, chert and limestone, and roughly bedded loamy gravel" Dr Kellaway has enlarged on this information (*in litt.* May 1995): The gravelly material was roughly bedded and interlayered with non-calcareous, or very feebly calcareous, sticky clay, which contained one or two streaks of black carbonaceous matter which resembled the sooty streaks of disintegrated coal commonly seen in the weathered Coal Measures underlying Triassic rocks. Many of the pebbles were of very hard siliceous rocks, like the quartzite, jasper and metamorphic rocks found in the Old Red Sandstone and in some of the Coal Measures conglomerates. There was some flint, mainly angular or nodular. The deposits had subsided into a shallow depression in the Great Oolite limestone which had developed above a fissure belt, but the tenacious clay had prevented the deposits from falling into open fissures beneath. The clay was examined for possible microfauna but was barren. It was free of limestone [and presumably decalcified - DTD] except at one side of the depression where it held a few pieces of deeply weathered limestone. The locality is noted as a fissure filling on the published 1:10,560 geological map (sheet ST76SE, 1978).

South of Reservoir [7736 6486], surface level 200 m. Richardson (1956) recorded a trench section running north and south. "The deposit occupied a hollow in the Great Oolite limestone: .. its surface sloped down for 10 feet to the bottom of the trench (4 ft. 6 inches deep), then disappeared, emerging almost vertically at 20 feet further on .. The slope for the first 10 feet suggested that the deposit might attain a further depth of some 3 feet .. below the bottom of the trench or 7 ft. 6 in., more or less, in all." The deposit consisted of flints, evidently broken as it was thought (wrongly) that some of them might have been worked by man, and "numerous" belemnites, in a sandy soil matrix. The belemnites were identified by L. Bairstow of the British Museum (Natural History) as *Cylindroteuthis puzosiana* (d'Orbigny), derived from the Oxford Clay.

Bath University, approach cutting [7678 6456] surface approx. 175 m. This was close to the Old Quarry House occurrence noted above. Hawkins and Kellaway (1971, p. 278) recorded "deposits of chert and flint gravel with loamy clay filling solution cavities in the [Great Oolite] limestone. .. locally one band of limestone had been dissolved out and the space infilled with gravel overlain by bedded loam." The cave fill had been strongly tilted since deposition as a result of cambering and the formation of dip-and-fault structure. Dr Kellaway (*in litt.* May 1995) records that most of the material seen was in gulls rather than solution cavities, and it included broken, unrolled Chalk flint, possible Upper Greensand chert, and a few tiny quartz pebbles. He did not see any rounded flint pebbles here.

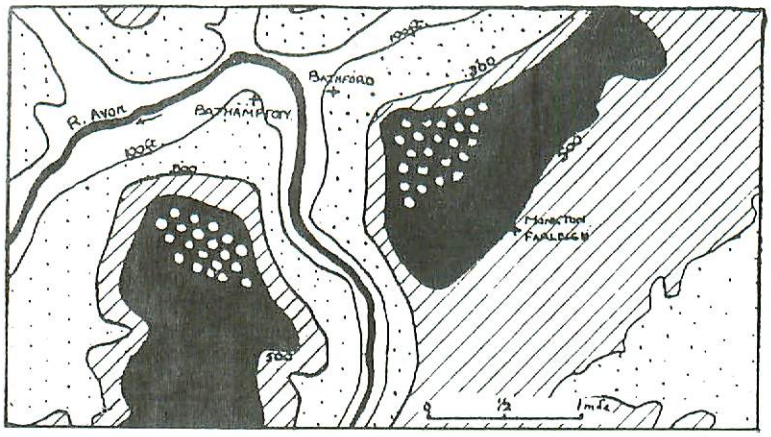

Figure 1. *Part of Figure 22 of Varney (1921). Original caption states: "Areas with white dots show positions of Gravels." Note that the shading indicates contours, not geology.*

Opposite Bath University main entrance approx. [773 638] Alt. 178 m. A former arable field here showed a lot of flint, chert and quartzite pebbles. A shallow excavation yielded pebbles up to 7.5 cm diameter, some of quartz but mostly "siliceous metamorphics of ORS type." No rounded flint occurred (Dr Kellaway *in litt.* May 1995).

Road cutting. Dr Kellaway records (*in litt.* 12 June 1995) seeing "masses of quartz pebbles, flint etc. in the fissures of the foundered rocks in the road cutting on the .. NE spur of Bathampton Down." and in Kellaway (ed. 1991, p. 225) notes that gulls in the cambered Great Oolite on the hillside are filled with chert and flint clasts.

Varney's locality/ies. Varney's work has already been mentioned. He wrote that the deposits on Bathampton Down "form a surface deposit covering these hills at a height of 500 feet to 650 feet above the Avon .. resting on the Great Oolite Limestone." The height "above the Avon" must be a mistake for above O.D. He gave a map, part of which is reproduced here as figure 1, showing the extent of the deposits on Bathampton and Farleigh Downs. This map is misleading in the experience of the present writer in that there is no continuous deposit, and this is confirmed by the mapping of the Geological Survey (Sheet 265) which does not show any superficial deposits on Bathampton Down. Varney evidently saw an exposure of the deposits but unfortunately does not say where it was or what was the relation of the deposits to the limestone. He recorded the following constituents in a matrix of reddish-brown sandy loam:

1 angular and subangular flints, thickly patinated and frost-shattered.
2 flint pebbles, often broken by frost.
3 quartz pebbles, white, pink and brown.
4 fine and coarse sandstone, in flat pebbles.
5 occasional pieces of conglomerate, containing quartz pebbles similar to 3.
6 fragments of Palaeozoic shales, similar to those of the Coal Measures.
7 rare small pieces of coal.
8 rolled and subangular pieces of the local oolite.

The present writer noted "brown flint pebbles" in the soil north of the boundary wall at about [776 649], south-east of the reservoirs. Lonsdale's (1832, p. 271) record of "abundant" chalk flints has already been mentioned.

General. Conybeare and Phillips (1822, pp. 227-8, footnote) writing of Bathampton Down wrote "chalk flints are scattered pretty abundantly over this tract".

Claverton Down

This plateau lies to the south of Bathampton Down, at a slightly lower elevation, summit level about 175 m. Woodward (1876, p. 162) quotes a field note by H. W. Bristow of the Geological Survey that "Rolled pebbles of flint occur in clay on the top of Claverton Down.". Three patches of high level drift are shown on the One-Inch/1:50,000 geological map (Sheet 265) as "Head". They are centred on [775 636], [771 630] and [764 630]. Kellaway (in Kellaway, ed., 1991, p. 225) notes that they are "recycled pebbly or stony material mixed with clay derived from the Forest Marble and Great Oolite limestone."

Farleigh Down

Quarries below Brown's Folly approx. [794 661], Alt. approx. 195 m. Weston (1850, p. 450) noted "small quantities of the chalk-flint mixed up with the debris of the oolitic rocks, and partially converted by the infiltration of water charged with carbonate of lime into a conglomerate or breccia." Weston's (barometric) height of about 629 feet above the river Avon, i.e. about 700 ft [213 m.] above O.D., repeated by Winwood (see below) is wrong, as the highest ground level here is only 205 m. Weston also noted "a few flints scattered on the summit of the hill". The location of Weston's find is uncertain but is most likely in the extensive old quarries below Brown's Folly. The writer was shown flints embedded in stalagmitic calcite in a fissure in these quarries about 1985, but unfortunately failed to record any detail.

Old quarries west of Monkton Farleigh – Bathford road approx. [797 662], Alt. approx. 175 m. Winwood (1877, 1878 ?) described a quarry whose position is ambiguous; it could refer to the area of old quarries west of the Monkton Farleigh – Bathford road, but could also refer to the quarries below Brown's Folly described by Weston (1850). Winwood described a layer of flints interstratified with the Great Oolite limestones, a situation reminiscent of that described later by Hawkins and Kellaway (1971) on Bathampton Down (see above). Winwood published a section which is reproduced here in figure 2. The bed of flints, 1 ft 6 in thick according to the diagram, thinned out to the north, and also filled joints and fissures in the limestone bed on which it rested. The largest flint was 4.5 in x 3 in, the smallest were "little rounded pellets of about the size of No. 6 shot." The flints varied in colour from white to black, through yellow, bluish-white and red. Some were spotted with dendritic markings, others completely coated with black. Most of the larger ones were rounded, some of the smaller were quite sharp and angular, others subangular. There were also some white and yellow quartz pebbles. the matrix was described as reddish loam, which under the hand lens was "seen to consist of

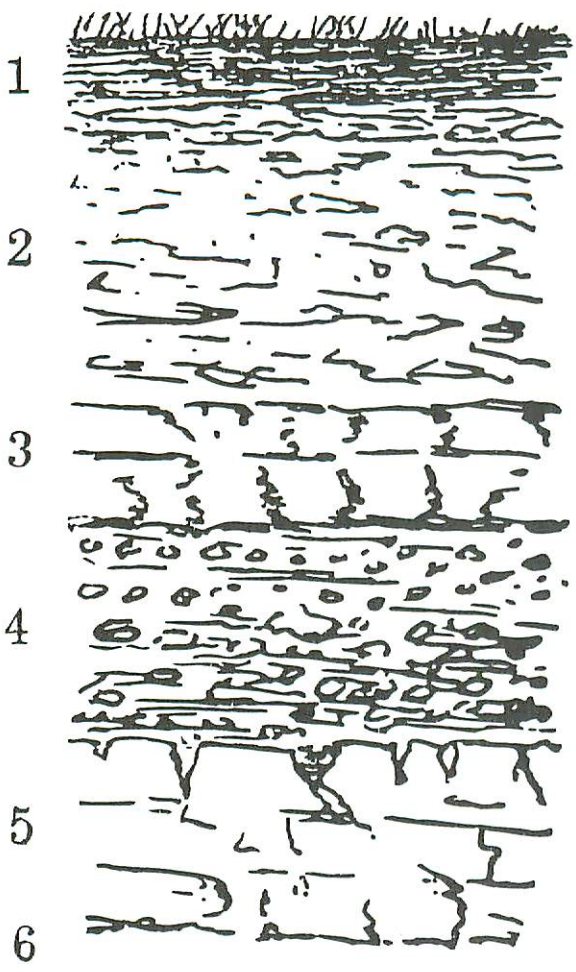

Figure 2. *Geological section of quarry on Farleigh Down from Winwood (1878, p. 83). Numerals indicate: 1, Humus, &c. 11 in.; 2, Oolitic debris 1 ft. 11 in.; 3, Solid bed of Oolite 10 in.; 4, Flint pebbles 1 ft. 6 in.; 5, "Rag beds" 1 ft. 2 in.; 6, Broken-up beds of Oolite fissured and dipping into hill 15 ft. 4 in.*

minute grains of quartz with little black and white chips of flint."

The record at the base of Winwood's section of "broken-up beds of oolite fissured and dipping into hill" shows that the apparently horizontal and undisturbed layers near the surface in his section in fact overlay the dip-and-fault structure which is so common near the margins of the Great Oolite plateau in the area.

Fry's locality. location unknown. Altitude approx. 170 m. Mr T. R. Fry recorded a gravel pocket on Farleigh Down in 1933, and gave me a copy of his notes some time before 1990. It is just possible that this was the same quarry as that recorded by Winwood (1878) over 50 years previously. Fry's sketch section of the occurrence is reproduced in figure 3. His notes are as follows:

I extracted 450 pieces of flint of an average size 2" x 1". Occasional pieces measured 6" x 3". Most of the pieces were waterworn but angular in shape in still retaining much crust. .. Patination was chiefly of a light ochreous colour with white occasionally. Most pieces showed black stains of iron or manganese. Along with these flints were many quartz pebbles almost all being of the milky variety. Exceptional pebbles of quartz

measured 1.75" x 1", but they were mostly smaller than this. I washed down and examined 14 cubic inches of the finer material and obtained the following result:

Yellowish clay, 6.5 cubic inches
Flint - 63 pieces between 1" and 0.25" in diameter, 5 cubic ins
Milky quartz 120 well rounded pebbles 0.5" to 0.125" in diameter, 2.5 cubic ins
Grit consisting mainly of quartz grains with some flint grains, 2 cubic ins

Fry has the credit of being the only observer who has examined the matrix in detail. His record of quartz and flint particles agrees with Winwood's (1878) hand lens observation.

Summit of Farleigh Down. Woodward (1876, p. 162) wrote "The Rev. H. H. Winwood directed my attention also to the occurrence of Quartz pebbles on Farley Down .. They are found with subangular and unworn flints apparently filling pockets in the Great Oolite." This may refer to the occurrence described later by Winwood (1878) as "a pocket of flints cut through by the roadway leading to one of the quarries", i.e. one of the underground quarries, presumably. He also saw "a quantity of flints cemented together by a percolation of carbonate of lime, forming a recent breccia" recalling Weston's (1850) record.

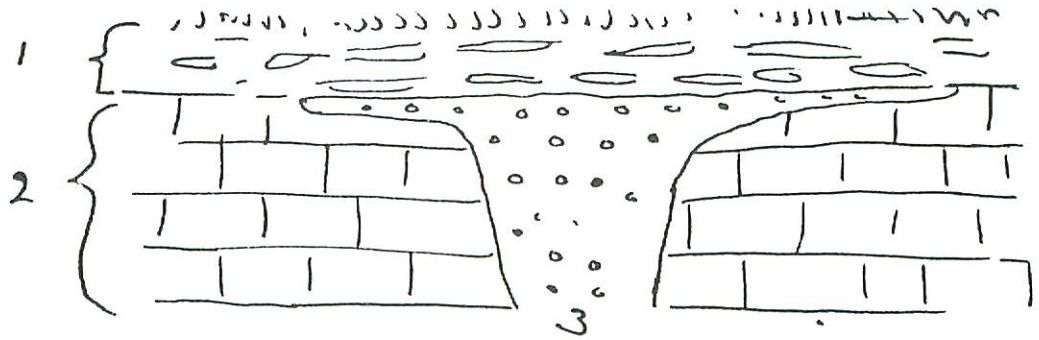

Figure 3. *MS section by T. R. Fry of part of quarry on Farleigh Down. The gravel pocket is seen to a vertical thickness of 5 feet. Numerals indicate: 1, probable quarry waste, 2, oolitic limestone in place, 3, gravel pocket.*

Sally's Rift cave [7943 6505], surface altitude approx. 180 m. A system of open joints in the Great Oolite limestones, resulting from cambering of the limestone over the underlying Fuller's Earth (Self 1986). Self (this volume, p. 100) records "a muddy clastic deposit containing pebbles of Carboniferous and Cretaceous rocks", derived from surface deposits. Details of clasts are in Self's paper. They may be summarised (excluding material of local origin), roughly in order of decreasing abundance, as: angular flints (recorded as chert), mainly white patinated, also red and brown; rounded buff-brown mudstone (possibly of local Jurassic origin); sandstone (Upper Palaeozoic?); white quartz pebbles (recorded as quartzite); Carboniferous chert.

Kingsdown

This term refers to an area of the Great Oolite plateau about 1.75 miles east-north-east of Farleigh Down. It is the easternmost locality at which the high level drifts have been recorded. None of the records is well located.

Weston (1850) noted "beds or considerable masses of chalk-flint diluvium on the crest of Kingsdown" (perhaps about 150 m. above O.D.) The deposit filled a fissure or gull. Except for occasional masses of the limestone, it consisted entirely of flints. Some were rounded and some "brecciated" (presumably shattered or broken up), while some were smoothed superficially but retained their nodular form. The matrix was ferruginous clay. In a nearby stone mine the flint gravel was found to fill fissures, having "penetrated from above".

Prestwich (1890, p. 143) gave a reference to Weston (1850), but seems to describe a different occurrence. He refers to a deposit 5 to 8 feet thick, preserved in a trough or hollow in the limestone. In addition to flints he mentions many pebbles of white quartz, and occasional pebbles of greenish quartz and of sandstone. He says the matrix was light brown sandy loam. He also says that Winwood had found a subangular fragment of sarsen (the only record of this rock from the deposits in question) and a pebble of black chert or hornstone. Prestwich may have seen the deposit or may have relied on Winwood's observations. Kellaway (*in litt.*) saw quartz pebbles in considerable numbers on Kingsdown.

The last writer to refer to Kingsdown was Oriel (1904) who quotes Prestwich (1890), but presumably visited the site himself as he adds information not in Prestwich, viz. that the occurrence was in a small quarry about 20 ft long, and that "in certain conditions of the working" the pebbles appeared to be interstratified with the oolite, recalling Winwood's observation at Farleigh Down. Oriel gives a diagram which is here reproduced as figure 4.

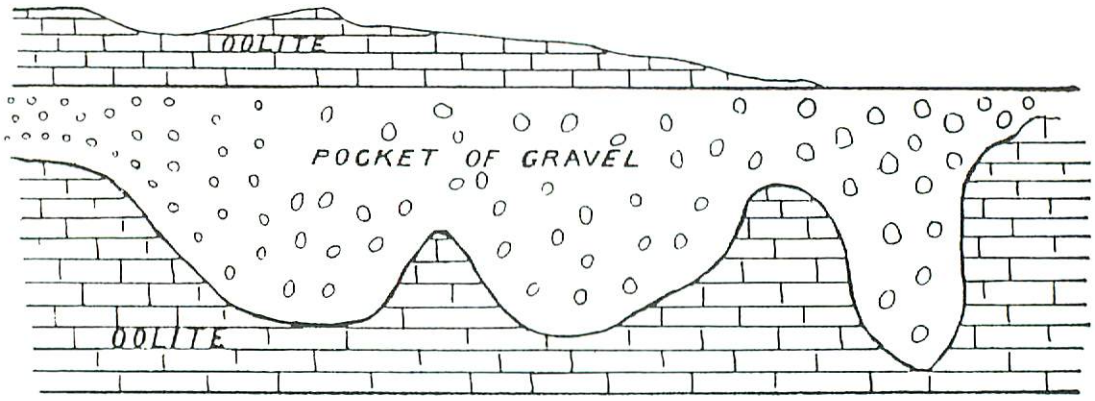

Figure 4. *Geological section of quarry on Kingsdown from Oriel (1904, p. 230). The original has no scale but the text states the gravel to be 5 to 8 feet thick.*

Great Oolite plateau between Midford and Freshford

Field west of Hayes Wood [773 606], Alt. 150 m. Conybeare and Phillips (1822, p. 227, footnote) wrote that "The summit of this hill is covered with transported chalk flints." A ploughed field seen by the writer in 1959 yielded flint (red, brown and grey) and chert in clayey soil. The flint occurred as pebbles and fractured pebbles.

Hayes Wood stone mine approx. [773 608]. Surface level 150 m. About 300 yards from the entrance an open joint in the roof, about 15 cm wide, contained brown flint, mainly angular to subangular, in pieces up to about 10 cm across. I did not note it at the time, but my memory of the occurrence is that the flint was clean, as if the flints had been 'washed'; there was no sign of any matrix.

Summary of occurrences

It is noteworthy, but unexplained, that the deposits are restricted to the areas described above (Figure 5). No similar deposits have been reported from the Great Oolite plateaux north of the Avon (Lansdown, Charmy Down, Bannerdown) or from the Odd Down/Combe Down plateau west of Bathampton and Claverton Downs. The surface altitude of localities ranges from about 150 m O.D. (Limpley Stoke and Kingsdown) to about 200 m O.D. (Bathampton Down).

LITHOLOGY OF THE DEPOSITS

Clasts and their sources

Flint occurs at all sites. Some observers note flints that retained a nodular shape, i.e. smooth, but not rounded. Shattered or broken flints are also common and probably outnumber pebbles or nodules. Varney (1921) noted pebbles (presumably rounded) often "broken by frost". Kellaway (*in litt.*) remarks on the relative rarity of rounded flint pebbles. The flints are generally brown or ochreous in colour though the writer also noted red and grey flints near Hayes Wood, and white patinated flint occurs in Sally's Rift.

The flints were ultimately derived from the Chalk but no fresh flint is recorded, though "unrolled nodular flint" was seen in fissures on Bathampton Down. It is unlikely that the flints were the result of the destruction of an immediately overlying chalk cover, and more likely that they were derived via an intermediate deposit. Flint is abundant in early Tertiary rocks, but the nearest Tertiary outcrops today are south-east of Marlborough, about 50 km away, and not necessarily a good guide to deposits which may once have existed nearer to Bath. Flint is abundant in the Quaternary river gravels of southern England but these would appear to be too low in elevation and too late in age to be a source, though earlier, now-destroyed gravels should perhaps not be ruled out.

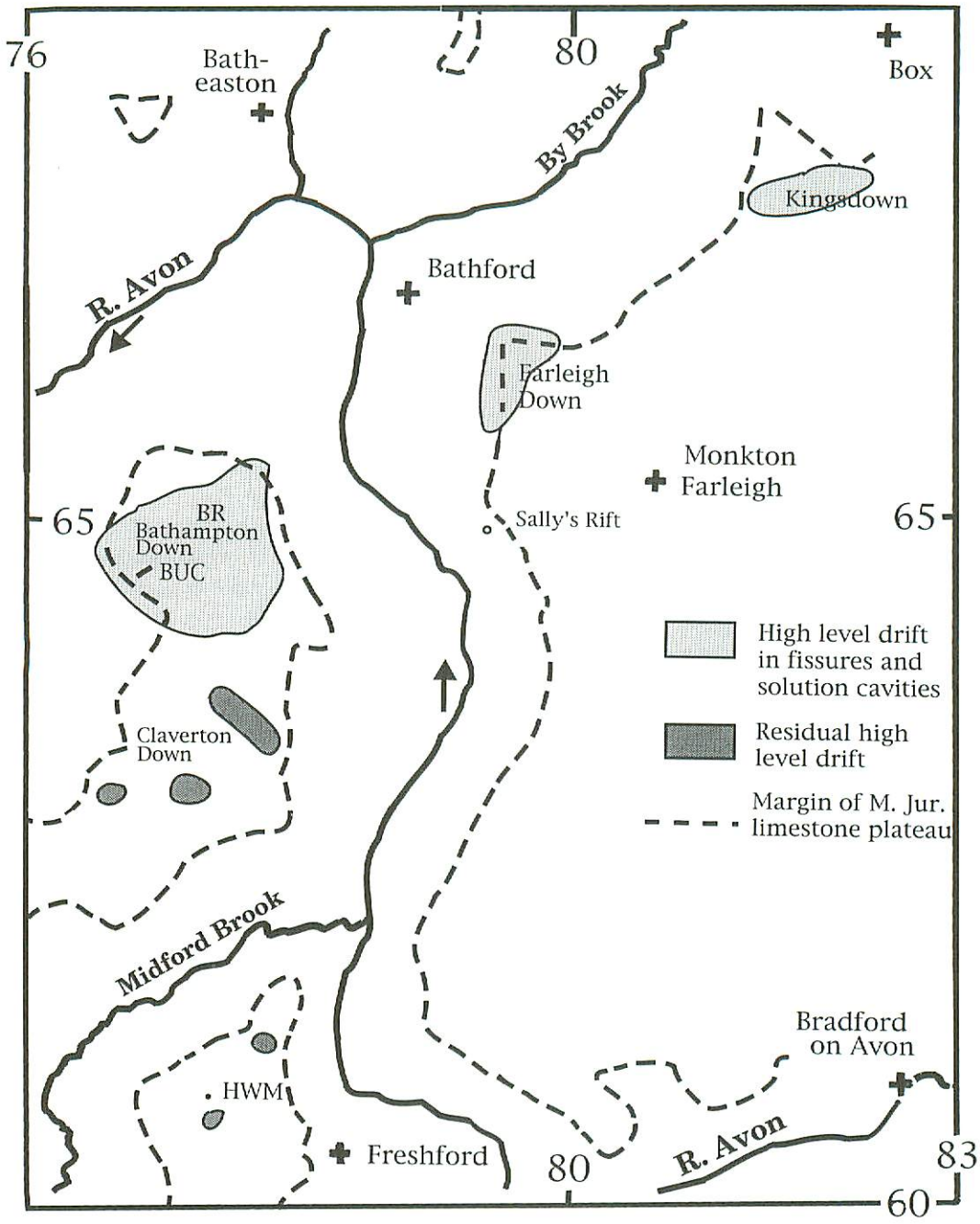

Figure 5. *Distribution map of high-level drifts. Based on information in this paper and a MS map by Dr G. A. Kellaway. BR = Bathampton Down reservoir; BUC = Bath University approach cutting; HWM = Hayes Wood Mine, location of flint-bearing fissure.*

Quartz pebbles are probably the next most frequently noted clasts. Mostly they are white though other colours are recorded. Quartz conglomerate, which may have been the source of the quartz pebbles, was recorded by Varney.

Quartz, like flint, is a very persistent mineral in sedimentary cycles. Authors have suggested that the mainly white quartz pebbles of the Bath deposits came from the quartz conglomerates of the Upper Old Red Sandstone. Quartz pebbles also occur in the 'Pennant' sandstones (Middle/Upper Coal Measures). The O.R.S. and the Pennant outcrop in eastern South Wales and in the Bristol district. Except for the O.R.S. of the Mendips, the outcrops in the Bristol area are low-lying and still partly covered by Mesozoic strata, and may not have been exposed when the Bath deposits were formed.

Barrow (cited by Wooldridge & Linton 1955, p. 105) derived white quartz pebbles in the Pebble Gravel north of London from the Lower Greensand (Lower Cretaceous) of Bedfordshire and Buckinghamshire, though this is not a very likely source in the present case. Quartz pebbles also occur in the Lower Calcareous Grit (Corallian Beds, Upper Jurassic) which at present outcrops about 20 km east and east-south-east of Bath.

Chert is recorded on Bathampton Down and near Hayes Wood. Some of it at least is of the brown or honey-coloured type characteristic of the Upper Greensand of the Warminster area, and common in the lower-level river gravels of the Bristol area. Prestwich (1890) recorded Winwood as having seen "black chert or hornstone" on Kingsdown. Presumably this was of Palaeozoic origin, probably from the Lower Carboniferous.

Sandstone of Upper Palaeozoic type was reported by Varney from Bathampton Down and by Prestwich from Kingsdown. Oriel reported "an occasional pebble of sandstone" from his Kingsdown gravel pocket. Kellaway found some soft, rotted arenaceous rocks on Bathampton Down some of which may have been Coal Measures sandstones.

The nearest source would be the Bristol and Somerset coalfields but South Wales and the Midlands also have extensive areas of Upper Palaeozoic sandstones. Kellaway (in Kellaway, ed., 1991, Fig. 14.4, p. 253) has given a map of possible source areas.

Shale of Palaeozoic, Coal Measures type is recorded only by Varney from Bathampton Down. Dr Kellaway *(in litt.)* is sceptical of this record as he does not think shale would have survived frost weathering during the Devensian and earlier glaciations.

Coal. "Rare small pieces" of coal were recorded by Varney from Bathampton Down. Possible sources are the Bristol, South Wales and Midlands coal fields. Kellaway saw carbonaceous streaks in pale grey clay in the same area, possibly a Tertiary pipe clay with lignite.

Sarsen. One piece recorded from Kingsdown by Prestwich on the authority of Winwood.

The clasts fall into two groups: one derived from the Cretaceous, the other from Palaeozoic (Devonian and/or Carboniferous) sources. In both cases the derivation could have been indirect, via Tertiary and Triassic deposits respectively.

Matrix

The matrix of the deposits is variously described as clay, loam and in one instance "sandy soil". It is an open question to what extent similar deposits may have been described as clay or loam by different observers. Clay has been reported from all areas. It seems to have been mostly brown, reddish or ferruginous. Fry, by washing his sample, proved the presence of "grit" (presumably sand grade) of quartz and flint, in the clay, and Winwood with his hand lens observed quartz and flint grains of presumably about the same particle size. Clay on Bathampton Down was recorded as non-calcareous, and barren of microfauna.

In view of the presence of sand-grade material in sediment described by Fry and by Winwood as clay, records of loam and sandy loam are not surprising. It seems likely that matrix was variable depending on the circumstances of reworking (see below).

The source of the clay is a matter for speculation. The Forest Marble formation which formerly overlay the area includes major clay units, and the Oxford Clay would have lain not far above it. The Oxford Clay belemnites found by Richardson (1956) raise the possibility that all or much of the clay could be local Jurassic in origin, associated limestones such as the Cornbrash having been removed by an intensive period of decalcification. Alternatively the clay could be glacial in origin, as discussed below. There are too many possibilities and no useful evidence.

Flints cemented by calcite were described on Farleigh Down by Weston (1850), Winwood (1878) and the writer (above).

COMPARISONS WITH OTHER HIGH LEVEL DRIFTS

Plateau deposits of south-west England

High-level superficial deposits rest on Cretaceous rocks at altitudes ranging from 150 m to 310 m. about 80 km south-west of the present area (Waters, 1960). Some of these deposits are regarded as clay-with-flints, a supposedly residual deposit from solutional weathering of the Chalk, although its origin remains controversial. These deposits differ from the Bath deposits in lacking quartz pebbles and Palaeozoic sediments, and in the presence of siliceous breccia. East of a line from Taunton to Lyme Regis the plateau deposits include rounded flint pebbles regarded as beach pebbles, possibly a remnant of early Tertiary (?Bagshot Beds) sediments. Similarity to the Bath deposits does not seem to be strong.

The Haldon gravels of south-east Devon, regarded as Eocene in age, include residual Upper Cretaceous material (the Tower Wood Gravel) and an overlying deposit of more varied composition (the Buller's Hill Gravel) which was ascribed by Hamblin (1973) to deposition by sheet-floods, much disturbed by later periglacial action. This origin was queried by Green (1974; reply by Hamblin, 1974) who doubted the reality of sheet-floods. Most of the disagreement however centred on the interpretation of the clay minerals present, a matter on which we have no evidence for the Bath deposits.

The Northern Drift

This has been studied most intensively (Hey, 1986) in the country north-west of Oxford, about 60 – 80 km north-east of the present area. In north-west Oxfordshire the description "So far as is known, it consists for the most part of unstratified reddish sandy clay with pebbles, the latter often matrix-supported" (Hey 1986, p. 293) could apply to some of the Bath deposits. A major difference is the abundance in the Northern Drift of the well-known and distinctive liver-coloured quartzite derived from the Permo- Triassic ("Bunter") conglomerates of the Midlands, which has never been reported from the Bath area. Most occurrences are dominated by pebbles of quartz and quartzite, but all yield some flint and four localities have between 17.6% and 72.2% of flint (Hey, 1986, Table 1, p. 295). Hey (1986) favours a fluviatile origin, with several stages of aggradation by rivers flowing from the north. The rivers seem to have reworked material deposited by an ice sheet moving from north to south. This does not appear to account for the flint, unless Upper Cretaceous rocks remained in areas to the north. A glacial origin was postulated for an occurrence of Northern Drift near Northleach (Worssam, 1987).

Relics of high level gravel occur about 30 km north-north-west of Bath in the Malmesbury district (Cave, 1977) where rare erratic pebbles, including liver-coloured quartzite, have also been found. Flint is common in some localities. These deposits have been ascribed to a periglacial or subglacial origin.

MODE OF EMPLACEMENT

It is improbable that any of the deposits recorded here were in their primary position, with the possible exception of neptunian dykes (see below). All were in depressions in the limestone surface, in cavities or in fissures. Several authors have recorded deposits in horizontally-extended cavities within the limestone.

Material could have reached its present locations in several ways:

1 By original deposition in existing hollows or fissures; neptunian dykes of Robinson (1957).

2 By collapse into hollows or fissures which formed after deposition of the primary deposit; sagged-cover dykes of Robinson (1957).

3 By reworking of the primary deposit by water or by solifluction and re-deposition in cavities or fissures.

1 is the least likely in the present case. The emplacement of the primary deposit probably pre-dated the downcutting of the present valleys, while the fissures which are common features of the Great Oolite were formed after the downcutting. However, it is difficult to maintain that no fissures existed prior to valley formation (they could have had a tectonic origin, for example), so that neptunian dykes remain a possibility.

Kellaway *(in litt.)* regards the Bathampton Down Reservoir deposit as probably the only one which may represent the primary deposit, more or less *in situ*.

2 The fissure fills at Old Quarry House and in Sally's Rift may have been of this type.

3 Most of the deposits probably fall into this category, and certainly those which filled cavities in the limestone or appeared "interbedded" with it, and the fissure fills of clean washed flints such as that in Hayes Wood Mine.

MODE OF ORIGIN OF THE PRIMARY DEPOSIT

Glacial or periglacial origin

The hypothesis that the primary deposit was of glacial and/or periglacial origin is attractive. The deposit contained a wide range of particle sizes, from clay to clasts up to 10 cm or more in size. Such a range is typical of glacially/periglacially transported material but would not be expected in water laid deposits where better sorting by size would occur. A difficulty with this explanation is the apparent predominance of flint and quartz among the clasts, whereas one might expect a greater variety in a till. The absence of the well-known and distinctive liver-coloured quartzites derived from the Permo-Triassic ("Bunter") conglomerates of the Midlands, common in the Northern Drift, could be accounted for if the constituents were transported from the west or north-west. In that case one might expect stronger presence of resistant Palaeozoic rocks including Carboniferous Limestone, quartzites and sandstones. The existing deposits appear to be almost wholly decalcified, however, so it can be argued that limestone clasts would be absent, as they are, for example, from the fan gravels on the flanks of the Mendips. It is likely that the deposit has been subjected to very severe weathering which has destroyed most of the sandstones as well, only the most resistant siliceous rocks surviving in any quantity.

No striations of glacial type have been reported and this argues against glacial transport, though not against a periglacial origin. As Bowen remarks (1978, p. 183) "Often ... it is difficult to distinguish periglacial slope deposits from till" and it would be rash to try to do so in the present case where records of most sections are inadequate.

The dominance of flint and chert, and the presence of fossils derived from the Oxford Clay, would appear to require derivation of some constituents from the east or south-east. On the other hand, later Jurassic and Upper Cretaceous rocks presumably once extended over the Bristol area and their destruction may have contributed to the Bath deposits.

A feature requiring explanation is the occurrence of flint only at several localities. This could be explained on the (untestable) assumption that a glacial till included masses of Chalk or of whatever deposit was the immediate source of the flint. The Oxford Clay belemnites recorded by Richardson on Bathampton Down could be explained likewise by assuming a mass of Oxford Clay transported by glacial till. Given the decalcified state of the deposits, the belemnites are a strong argument in favour of glacial transport. Likewise the rare coal recorded by Varney would not have survived river transport but could have been included in a mass of till.

Fluvial origin

Varney (1921) and others have cited the deposits as evidence for a major river flowing south-eastwards from the Welsh uplands, before the formation of the Severn valley and estuary, and a similar origin has been invoked for the Northern Drift (Hey, 1986). We might again expect a wider variety of rock types, though later intensive weathering could have removed them as is postulated above in the case of glacial origin. Possible fluvial (sheet-flood) origin for the Buller's Hill Gravel of south-east Devon is mentioned above.

Reworked early Tertiary

Kellaway (in Kellaway, ed., 1991, p. 213, Fig. 13.5, section A) suggests that Eocene deposits formerly extended as far west as the Bath and Bristol area. However, he thinks it unlikely that the plateau drifts are relict Eocene because of the rarity of rounded flint pebbles, which are common in surviving outliers of Eocene further east (Kellaway, in Kellaway ed., 1991, p. 225; and *in litt.*). However, a residual deposit of early Tertiary age could account for the occurrence of flint only at several localities.

There is some attraction in a parallel with the Haldon gravels, as a similar origin could account for the presence of flint only at some sites, though white patination of the Haldon flints suggests more direct derivation from the Chalk. The Cretaceous in the Bath area is likely to have rested on Upper Jurassic rocks rather than directly on the Middle Jurassic.

A composite origin remains an attractive possibility, the flints being mainly derived from a Tertiary deposit which once covered the area, while other components were of glacial origin.

SEQUENCE OF EVENTS

The following would appear to be a minimal sequence of events:

1. Removal of superincumbent strata to expose the Middle Jurassic limestones.

2. Possible deposition of early Tertiary ?fluviatile deposits.

3. Phreatic dissolution along joints and bedding planes in the Middle Jurassic limestones. Beginning of river valley excavation enabling development of karstic drainage in the limestones, without being deep enough to initiate cambering.

4. Emplacement of a drift deposit more or less continuously covering the outcrop of the Tertiary (if present) and Great Oolite and Forest Marble.

5. At least partial destruction of the deposits, redeposition (in the later stages?) in cavities in the limestones.

6. Downcutting of the valleys into the Fuller's Earth and below with associated cambering and gull formation. Deformation of the deposits seen in Bath University approach cutting. Further collapse/washing of deposits into fissures.

7. Cementing of clasts by stalagmite in fissures on Farleigh Down.

CHRONOLOGY

Episodes 1 and 2 would be early Tertiary. 3-5 were prior to deposition of the terrace gravels of the Bristol Avon, but these in turn are not well dated. Some are clearly Late Pleistocene. The gravels at Twerton, near Bath, yielded 'warm' mammals including *Palaeoloxodon antiquus* and red deer, as well as 'cold' species (Green, 1992, p. 158) and may be partly of Last Interglacial (oxygen isotope stage 5) age. River gravels with Acheulian-type biface implements are probably earlier, oxygen isotope stage 7 or 9?.

Of relevance is the earliest uranium date of >350,000 yr (- oxygen isotope stage 11 or earlier) obtained for stalagmite in Sally's Rift (Self, this volume, p. 100). The downcutting of the Avon, at least well into the Fuller's Earth, must pre-date this. If we assume (not very safely?) that active downcutting of river valleys tended to occur during cold periods (less vegetation cover, more erosion, lower sea level) then episode 5 (above) would be oxygen isotope stage 12 at latest, dated at around 450,000 yr. If the primary deposit was a till it would have to be earlier than this, in the early Middle Pleistocene or before. Early Pleistocene glaciations are not well known in Britain though evidence for glaciation in the North Atlantic area in general goes back as far as about 2.5 my (Shackleton *et al.* 1984; Kellaway 1991) so there is no difficulty about a late Pliocene or early Pleistocene till.

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