Fred Shotton and his key role in the Wolstonian and Devensian stage controversies

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Abstract: Fred Shotton was a major player in twentieth century British geology. He was born and bred in the Coventry district of the English Midlands. His geological research initially focused on the Ordovician, Carboniferous and Permo-Triassic sediments. Later he adopted the Quaternary as his prime interest, thereby continuing a Birmingham University professorial tradition of engaging in Midlands glacial stratigraphy. Based on his own field research, he established the late Middle Pleistocene 'Wolstonian' and the Last Glacial 'Devensian' stages. Shotton's pivotal role in the formulation of the standard British Quaternary sequence, the unresolved debate surrounding the chronological status of the 'Wolstonian' and the change in the Devensian type site from Chelford to Four Ashes in the UK succession, are examined in detail from the writer's personal perspective.

Professor Frederick William Shotton, FRS (1906–1990) was not just a colossus in the context of twentieth century geology but was also a very distinguished natural historian in his home county of Warwickshire. His life and career were largely centred on the University of Birmingham and *Mercia*, the counties of the English Midlands. He occupied the Lapworth Chair of Geology from 1949 to 1974 (Fig. 1) and had previously been the Sorby Professor of Geology at the University of Sheffield since 1945. Several Fred Shotton obituaries are published, including Wymer (1990), Rosenbaum (1990), Worsley (1991), Goudie (2004) and Rose & Clatworthy (2008). His formal biographical memoir as a fellow of the Royal Society of London was compiled by his former colleague and protégé Russell Coope (Coope 1994). In this contribution Fred Shotton's work relating to two Midlands cold stage type sites – the Wolstonian and the Devensian – will be discussed, aided by some 30 years of a personal connection with him.

My first encounter with Fred Shotton was at the University College of North Staffordshire (now Keele University) when he addressed the student geological society on current issues relating to the glacial geology of the north-west Midlands. After graduation I moved to the University of Manchester where on my arrival, by happy coincidence, the 1962 Annual Meeting of the British Association for the Advancement of Science (BAAS) was about to open. The BAAS Section C (Geology) President was Fred Shotton, and he gave an inspirational address on the physical background to the Pleistocene in Britain (Shotton 1962). As usual, Section C sponsored several field excursions within the Manchester region and one of these was to the silica sand pits at Chelford, a locality near the Jodrell Bank Radio Telescope on the Cheshire Plain. Fred had a keen interest in Chelford. This was a good start for a student intent on glacial geological research. In those times most new postgraduate students had to contend with the then prevalent 'sink or swim' philosophy and the identification of a suitable thesis project was the responsibility of the student. I recall that initially, in order to better understand the techniques of glacial geology, two publications were particularly influential – Shotton (1953) which focused on the 'older drifts', and Coope, Shotton and Strachan (1961) which concerned the 'newer drifts'.

I settled on the Cheshire Plain as a field research area and this, of course, included Chelford. By good fortune, the inaugural long field meeting of the Quaternary Field Study Group (later to become the Quaternary Research Association – QRA) was held in the Easter period of 1964. The programme was the brainchild of Fred Shotton and unsurprisingly his Department of Geology hosted the meeting in Birmingham. The first day was primarily devoted to visiting the Chelford area and apart from Fred, the group included Richard West and Russell Coope both of whom had recently published on the biota there. By that time, I had located an in-situ

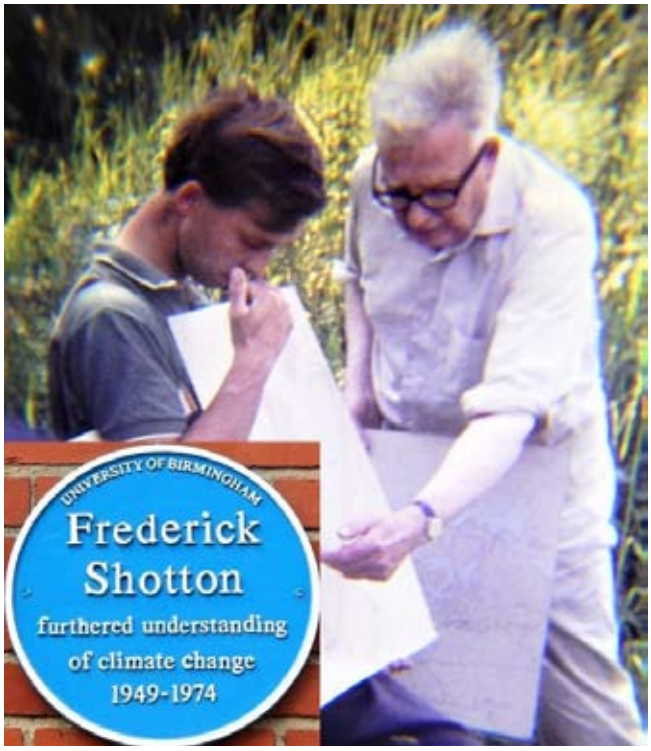

***Figure 1**. Fred Shotton field teaching c. 1961 (the student is Geoff Boulton). The blue plaque in the University of Birmingham, Edgbaston, commemorates Fred Shotton's tenure of the Chair of Geology.*

Pinus stump and Fred Shotton kindly offered to attempt a radiocarbon age estimate on it. As expected, the assayed sample was beyond the limits of age detection. On the second day we visited localities around the upper River Avon valley including the sand and gravel pit at Wolston. When I moved to Reading in 1965 I found that the Geography Club schedule included a lecture on 'Pleistocene pond dipping'. No guesses as to who the lecturer was.

Fred Shotton and Quaternary classification

By the early 1960s, British workers tended to use either north European or Alpine terms to name the main glacial/interglacial stages (see Fig. 2). In contrast, following the lead given by the American Commission on Stratigraphic Nomenclature in defining a code of practice, pre-Quaternary stratigraphers in the UK were attempting to put their house in order and ultimately a Geological Society of London Stratigraphy Committee brought forth proposals largely in accord with those suggested by the Commission. Emphasis was on using time-stratigraphical terms in interpreting the rock record.

As part of this process, a Quaternary Era sub-committee was established consisting of Fred Shotton (Chairman), Richard West (Secretary), Geoff Kellaway, Frank Mitchell, and Kenneth Oakley. They reported via the British National Committee for Geology at the Royal Society of London. Of these, Geoff Kellaway had a seat on the overarching Stratigraphy Committee chaired by Neville George. A Stratigraphical Code Sub-Committee (1965–68) was also chaired by Neville George with Terence Miller as secretary. The Quaternary sub-committee's remit was to: (i) compile a fully comprehensive succession, (ii) correlate this with local sequences, and (iii) create a framework for correlation with other areas outside the UK (Shotton 1973a). Miller was my undergraduate geology tutor and later head of department for a short period when he sensationally became the Professor of Geography at the University of Reading in 1965. He was responsible for encouraging an interest in rock classification issues and an early example of this was a discussion of glacial stratigraphical nomenclature in north east Cheshire (Worsley 1967).

In contrast with the older geological record, owing to its relatively short duration and restricted evolutionary changes, the practical subdivision of the Quaternary had to be based on cyclic climatic fluctuations with alternating cold (glacial) and temperate (interglacial) stages. Use of the term 'glacial stage' is potentially confusing since non-specialists tend to assume that such a stage necessarily features land ice glaciation per se. This is not always the case – for example in southern England beyond any glacial limit, a cold stage will be represented by the products of sedimentation and mass wasting in a periglacial environment. Within a cold stage, evidence based on climatic changes might enable the identification of severe and less severe climatic episodes which might witness the transition from steppe tundra to boreal woodland environments; respectively these characterise stadials and interstadials. In lowland Britain the boundaries between successive Quaternary stages were demarcated on biostratigraphic criteria where possible and failing this, on lithostratigraphy. In the presence of fossil biota, the base of a temperate stage occurs where the fossil assemblages, normally pollen, record the change from cool conditions with herb-dominated vegetation to warmer boreal woodland assemblages and later progression to a mixed oak forest. A specific marker horizon at a stratotype locality (sometimes these markers have been termed golden spikes), demarcates the stage base, with the top determined by reference to the base of the next overlying stage. Conceptually, this is important since the resultant stack of stages has the merit of flexibility, enabling, as evidence and understanding improves, hitherto unrecognised stages being inserted into an evolving standard succession. The

Some systems of terminology in use for the Middle and Upper Pleistocene of Britain

	Britain (after Shotton and West, 1969)	East Anglia	North Germany
Interglacial	FLANDRIAN		
Glacial	DEVENSIAN	LAST	WEISCHSEL
Interglacial	IPSWICHIAN	IPSWICHIAN	EEMIAN
Glacial	WOLSTONIAN	GIPPING	SAALE
Interglacial	HOXNIAN	HOXNIAN	HOLSTEIN
Glacial	ANGLIAN	LOWESTOFT	ELSTER
Interglacial	CROMERIAN	CROMERIAN	

***Figure 2**. Glacial and inter-glacial mid and late Pleistocene stage names, used in the 1960s – Shotton & West 1968 proposals for Britain, East Anglia and North Europe.*

Stage	G.R. type locality	Notes on boundaries, lithostratigraphy, etc.	References
Flandrian	(post glacial, Holocene)	Begins at base of pollen zone IV (F I)	
Devensian	Chelford, Cheshire (pit) SJ 810733	Late 26,000 B.P. to end of zone III Middle 50,000 B.P. to 26,000 B.P. Includes Upton Warren inter-stadial complex Early That part preceding 50,000 B.P. Includes Chelford interstadial. A definition of the base is necessary, and awaits the study of a suitable site.	Coope and Sands (1966), Proc. R. Soc., B, 165, 389-412.
Ipswichian	Bobbitshole, Ipswich (excavation) TH 148414	Ipswichian lake muds (base at beginning of I I (zone c of West 1957))	West (1957), Phil. Trans., B, 241, 1-31.
Wolstonian	Wolston, Warws. (pit) SP 411748	Includes Baginton-Lillington gravels, Baginton sand, Wolston series, Dunsmore gravels. Lower limit at base of Baginton-Lillington gravels	Shotton (1953), Phil. Trans., B, 237, 209-260.
Hoxnian	Hoxne, Suffolk (pit) TH 175767	Hoxnian lake muds (base at beginning of zone H I (zone IIa of West 1956))	West (1956), Phil. Trans., B, 239, 265-356.

Figure 3. *The post-Anglian portion of the original IGCP version of the 'Stratigraphical Table of the British Quaternary' with Chelford as the proposed Devensian type site (Shotton & West 1968).*

original recommended stratigraphic table of the British Quaternary proposed by the sub-committee (Shotton & West 1968), featured 14 climatically defined stages (alternating cold and temperate). Many new stages were defined for the first time and all 14 stages remain in current use. An extract showing the youngest stages is presented in Fig 3.

After extensive consultation, the final report of the Quaternary sub-committee was published by the Geological Society of London in its Special Report series (Mitchell *et al*. 1973). Curiously, no explanation was offered for the replacement of Kellaway and Oakley by Frank Mitchell and Lewis Penny as committee members. A major change from the first proposals was the substitution of Four Ashes, in mid Staffordshire, as the Devensian type site in place of Chelford (the reasoning behind this switch will be discussed later). Fig. 4 shows stratigraphic relationships of later stages. Another variation arose when the Waltonian stage (the basal part of the Red Crag Formation), was reclassified as being of Late Pliocene age – informally a new cold stage – identified in a borehole at Stradbroke,

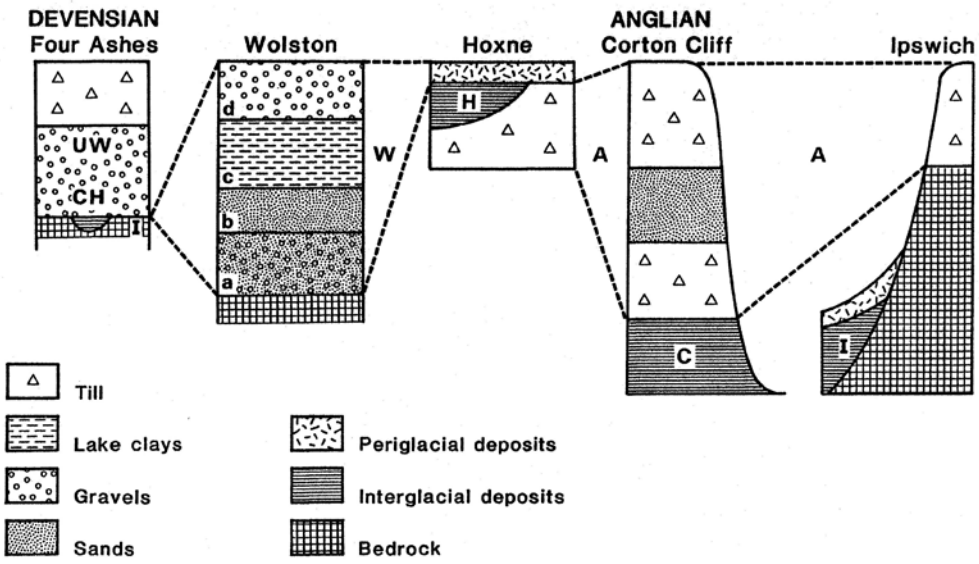

Figure 4. *Cartoons showing a correlation of the main post-Cromerian glacial and interglacial stages, adapted from Bowen (1978) Fig. 2–12. UW Upton Warren Interstadial: Ch Chelford Interstadial: a b c d the original lithological units of the Wolston Series.*

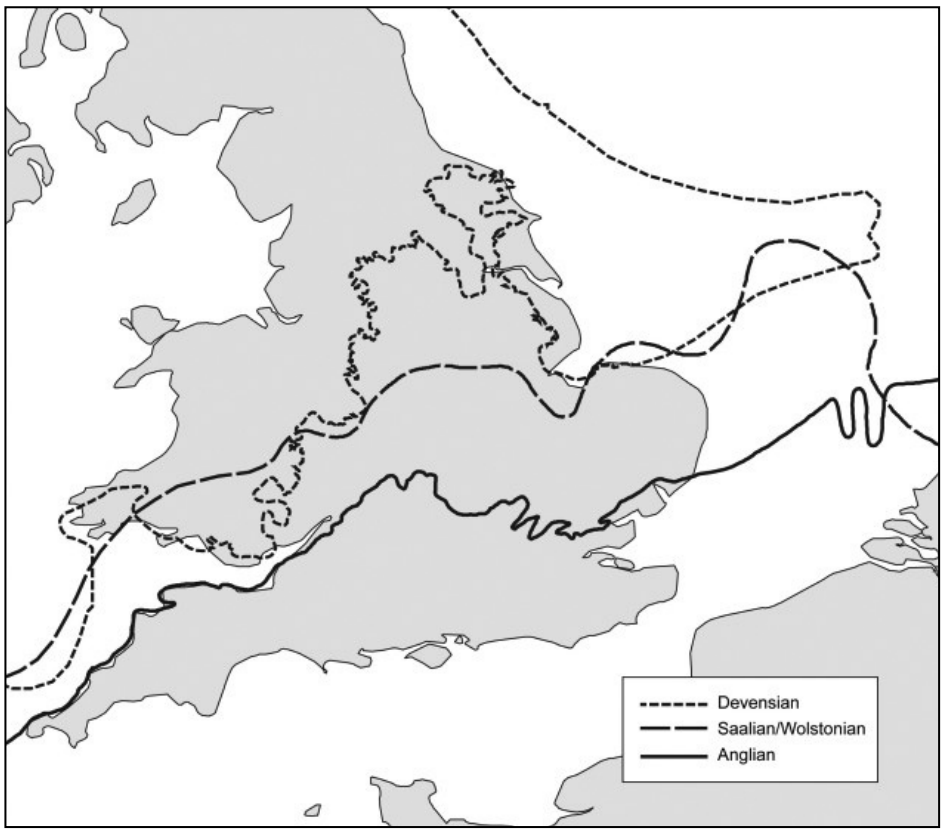

***Figure 5**. Glacial advance maximum limits of the 3 main post-Cromerian glaciations of England and Wales. These are not definitive!*

Suffolk (Beck *et al.* 1972), it was given the name 'Pre-Ludhamian', and this became the oldest British Pleistocene stage. Of particular importance were the stratigraphical constraints of the three major glaciations during the last 0.5 Ma – their possible distribution is shown in Fig. 5.

The 'Wolstonian' conundrum

In the mid-1960s the established stage name for the penultimate cold stage was 'Gippingian' (after the River Gipping) and the one before that was termed 'Lowestoftian' (a coastal cliff at Corton just north of Lowestoft), both being in the East Anglian county of Suffolk. In the new scheme these were substituted by 'Wolstonian' (Warwickshire) and 'Anglian', respectively based on the defined type sites of Wolston and Corton. The foremost factor in delaying the publication of Geological Society Special Report No 4 (Mitchell *et al*. 1973), was a radical reappraisal of the East Anglian glacial stratigraphy undertaken by Roger Bristow and Frank Cox of the Institute of Geological Sciences (now British Geological Survey). Essentially, they rejected Baden Powell's (1948) two chalky-till model of a Lowestoft Till overlain, after an intervening interglacial, by a later Gipping Till, and argued that the field evidence indicated just a single glaciation event. This paper was read at a packed meeting of the Geological Society in late 1971 and the published version was accepted in early 1972 (Bristow & Cox 1973). A clue to the paper's reception is illustrated by the printed discussion which at 19 pages exceeded the length of the original paper. Bristow and Cox were not mavericks, since by implication the other nine members of the IGS East Anglian field staff at that time agreed with their interpretation. They proposed that the Gipping Till was a weathering phenomenon, an artefact resulting from subaerial weathering of the Lowestoft Till.

This 'monoglaciation' hypothesis was not a unique revelation, as other workers having assessed the field evidence had come to the same conclusion, including, it might be added, members of the annual Quaternary geology field class to East Anglia from the University of Reading from 1966 onwards! Bristow and Cox accepted that the Lowestoft Till pre-dated the Hoxnian Interglacial Stage but also claimed that a post-Hoxnian glaciation event was unproven. Contrary to the established wisdom, they asserted that the Hoxnian and Ipswichian Interglacials were 'closer in time than has been thought hitherto', i.e. they were parts of a *single* interglacial stage but probably separated by a cold oscillation. It was this vision which enabled them to claim that the Lowestoft Till was the product of the penultimate glaciation of Britain, which in the north European terminology, was Saalian in age. Their minority dissenting report was incorporated into the Eastern England section of Special Report No 4, compiled by Charles Turner. In contrast, the authors of the main report endorsed an Anglian Stage (pre-Hoxnian) age for the glaciation in question, an interpretation which remains the established wisdom (Mitchell *et al*. 1973).

Birth of the Wolstonian

Following this débâcle, it became even more imperative that a suitable type site for the immediate post-Hoxnian glaciation should be located outside the limits of East Anglia where, incidentally, all the previous stages had been defined. The English Midlands had been the focus of Quaternary research for many decades and had become a specialism of the Department of Geology at the University of Birmingham. Successively, occupants of the Chair of Geology – Charles Lapworth, William Boulton, Jack Wills and Fred Shotton – had given leadership to this work for almost a century.

In the 1950s, just north of the Birmingham city centre at Nechells, a rich biogenic deposit had been identified from borehole cores, and several studies of the flora and biota within these had led to the conclusion that the sequence (latterly the Quinton Peat Formation) was coeval with the interglacial deposits at Hoxne. Further, it appeared to be associated with a hollow (? kettle hole) in fluvioglacial sediments overlain by glaciolacustrine clays (now the Nurseries Glacigenic Formation) which in turn was overlain by a complex of tills, lake clays and outwash (now the Ridgacre Formation). Later, in 1974, the Geological Survey identified another similar sequence at Quinton just west of the city centre. This evidence clearly indicated that the region had been glaciated twice, the first being pre Hoxnian and the second after that interglacial but earlier than the Devensian (Last Glacial Stage) deposits which lay north of Birmingham (see later). An indication of the age of these glacial events came from the observation that the present-day landscape and related erosional drainage network ante-dated the entire Pleistocene sequence. Until the promulgation of the Wolstonian Stage, publications from the Department of Geology at Birmingham tended to favour the north European Saalian glacial stage as its equivalent.

Fred Shotton, as chair of the Quaternary sub-committee, proposed that a suitable stratotype locality for the second (penultimate cold stage) glaciation be sought in the Birmingham region although no alternative appears to have been considered. In justification, he summarised the issue 'After this warm period [Hoxnian] it was considered expedient to move to the Midlands for the next stage, mainly because the Gipping Till which is claimed to overlie the Hoxnian is poorly represented in East Anglia and even claimed by some not to exist' (Shotton 1973a, p. 4). Four years later he declared, 'It appears that the Wolstonian was climatically a glacial period during which no till was deposited in East Anglia' (Shotton *et al.* 1977, p. 273), see Fig. 6. Also, this was seen as justifying the retention of the Wolston sequence as the stratotype for the penultimate glaciation.

Arguably, Fred Shotton's most inspirational investigation started in 1945 with field mapping of the Pleistocene succession in his home area, a *c.* 300 km² block of country spanning the River Avon valley south-east of Coventry (Shotton 1953), see Fig. 7. This work produced two spectacular discoveries. First, the identification of a total drainage reversal, with the former headwaters of a 'preglacial' proto-Soar, during or after deglacierisation, being incorporated into the south-westward draining Avon, thereby switching from the North Sea to a Bristol Channel outfall. This event involved the displacement of the central watershed

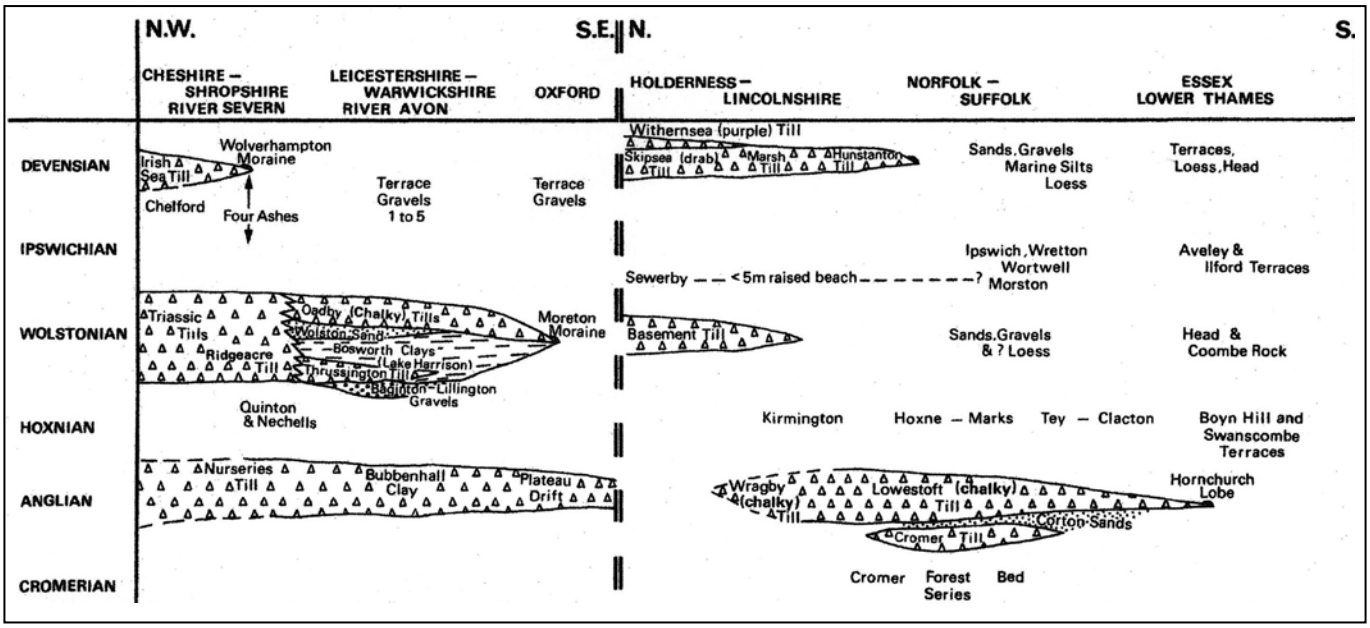

***Figure 6**. Correlation diagram for the Midlands (left) with the 'Wolston Series' and eastern England (right), without any equivalent glacial deposits, after Shotton et al. 1977, Fig.19.3. Note that Allan Straw's Wragby (chalky) Till) in Lincolnshire is shown as being coeval with the Anglian Lowestoft Till. He dissented from this, believing that it was Wolstonian in age and still, 2022, subscribes to this view.*

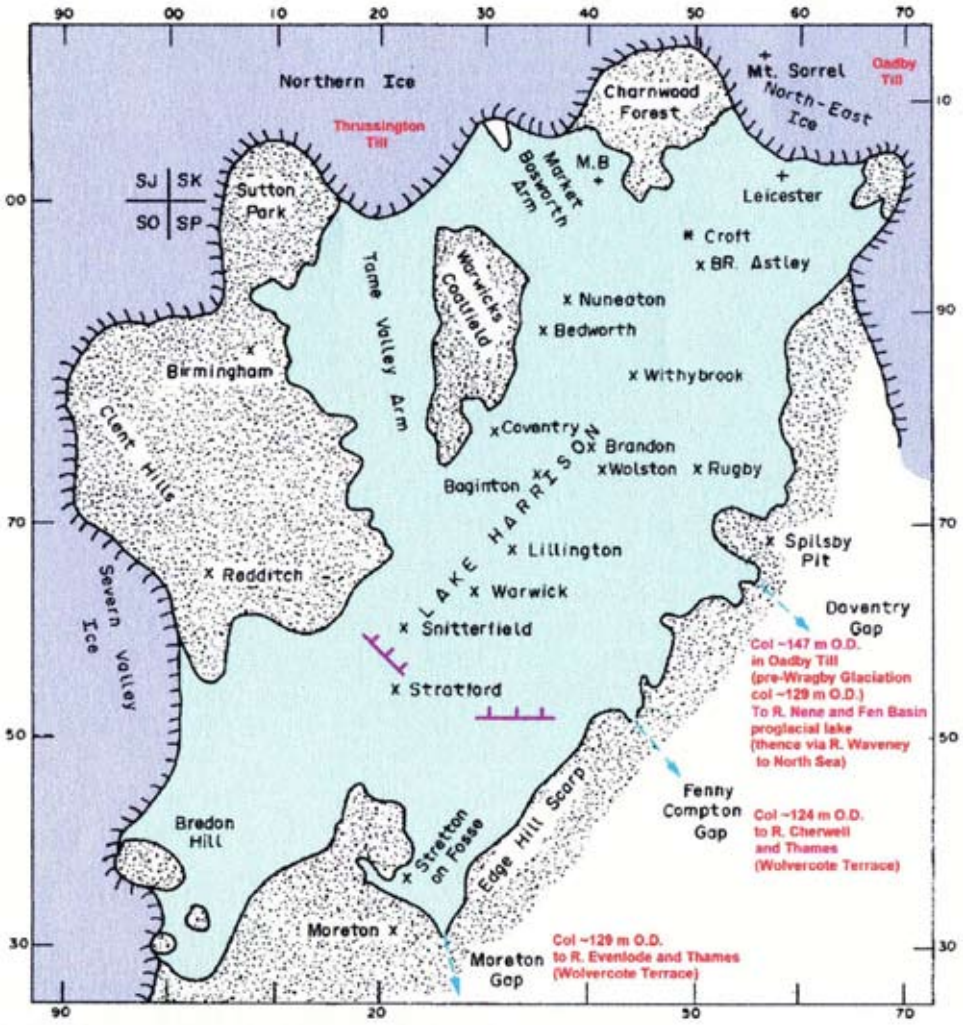

***Figure** 7. Shotton's Glacial Lake Harrison at its maximum extent and the controlling thresholds (from Westaway 2021). Throughout its existence, it is unlikely that the lake was a continuous open water body devoid of detached masses of glacial ice.*

of the English Midlands by *c.* 75 km. Second, that during the glaciation an extensive glacial meltwater lake (Lake Harrison) occupied the central Midlands dammed by glaciers on all sides except the escarpment of the Cotswolds to the south (Fig. 8). Within this area of inundation, a sand and gravel pit close to the small village of Wolston exposed a cold climate-related succession representative of the area. He explained that the logic of selecting this pit as the 'Wolstonian Stage' type site was that 'it had a number of stratigraphical units, regularly disposed and mapped over a large area, which cover the cycle from protoglacial, through full glacial to a period of ice retreat. From its lowest member, the Baginton-Lillington Gravel, have come a significant number of climatically useful fossils – land mammals, fishes, insects and plants' (Shotton 1973, p. 4). The implicit *assumption* was that this glaciation was the same as that which had occurred *after* the Hoxnian interglacial deposits at Nechells. However, Fred Shotton did recognise that the absence of any known Hoxnian interglacial deposits directly beneath the cold climate cycle sequence in the proto-Soar valley was a significant shortcoming. For the reasons outlined above, the recent assertion by White *et al*. (2017) that the Wolstonian Stage was a late substitute for 'Gippingian' in Report No 4 (Mitchell *et al.* 1973) is incorrect.

The Wolston type site (SP 411 747)

Fred Shotton (1953) identified a 'Wolston Series', consisting of the following members:

Dunsmore Gravel
Wolston Series
  Upper Wolston Clay
  Wolston Sand
  Lower Wolston Clay
Baginton Sand
Baginton–Lillington Gravel
long time interval
Bubbenhall clay

He had doubts about the status of the basal clay unit, stating: 'It is not clear whether any of the Bubbenhall clay is a true till' (p 213). Omitting the dubious Bubbenhall clay, the type Wolstonian succession consists of the sediments above the base of the Baginton–Lillington gravel (now known as the Baginton Formation).

In 1963, Fred Shotton approached the Geology and Physiography section of the former Nature Conservancy Council (NCC), to recommend that the Wolston pit be designated a Site of Special Scientific Interest (SSSI) and a decade later, in 1974, this was agreed (the wheels of government bureaucracy turn slowly!). Planning

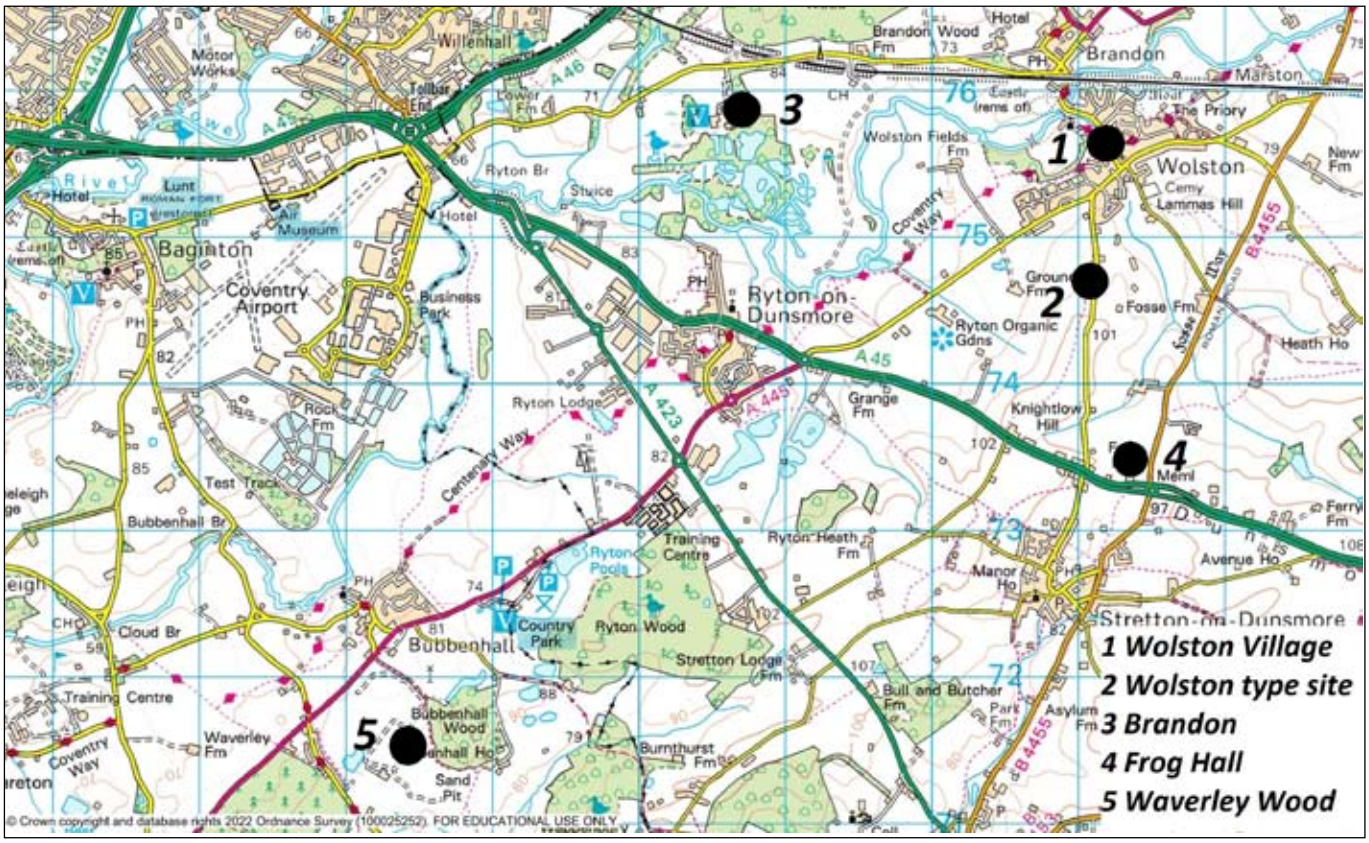

***Figure 8**. Location of the main sites in the Wolston area discussed in the text (after Digimap OGL)*

permission in 1972 had permitted the former pit to be used for waste disposal, but a condition was that a strip of land adjacent to the southern face had to be kept clear for scientific inspection. A Public Enquiry in 1974 saw Fred Shotton acting as an expert witness on behalf of the NCC since the site owners (who had already disposed of cyanide drums) wanted to bury the SSSI site with refuse. Two appeals followed and finally in 1984 the Secretary of State determined that the SSSI must be protected. Fortunately, a change in ownership occurred in 1990 and this proved beneficial since the new owners proved to be supportive of the need to maintain access to the SSSI.

A detailed description of the surviving exposures has been given by Glasser & Lewis (1994; Fig. 9). They emphasise that like all soft rock sites, face degradation has meant that excavation is necessary in order to view the sediments. More recently the

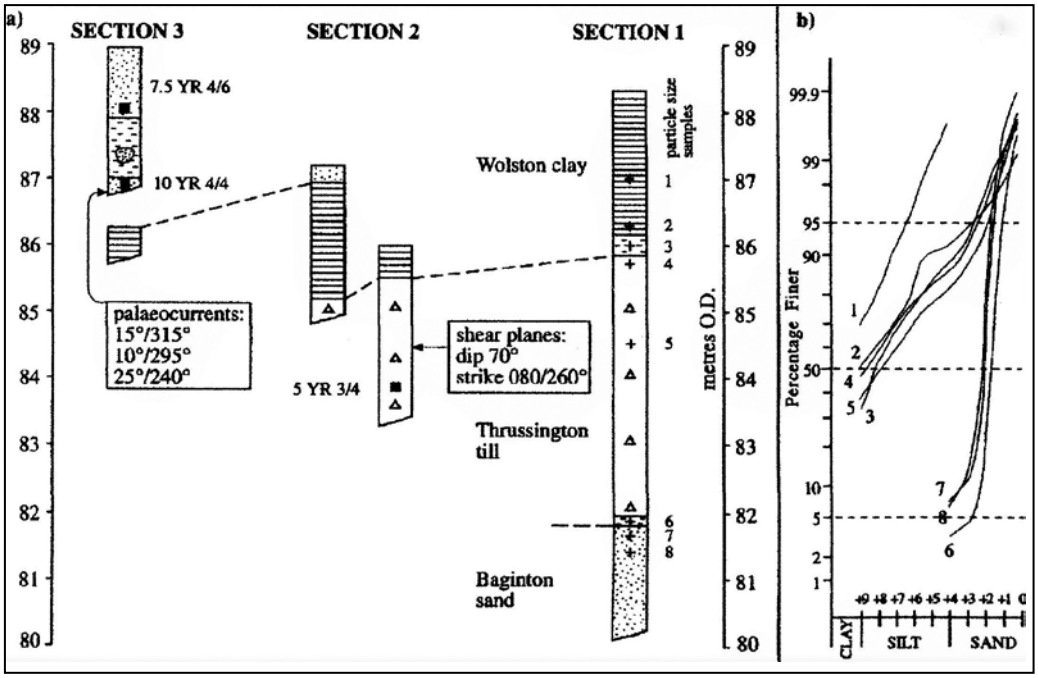

***Figure 9**. Sedimentary logs and particle size distributions (<2 mm) from the Wolston type site (after Glasser & Lewis 1994).*

***Figure 10**. The Warwickshire Geological Conservation Group's interpretation panel 'Did you know that Wolston is an important place because of its connection with the Ice Age in the Midlands?' at Wolston village being inaugurated in 2007 by Mrs Ann Black, daughter of Fred Shotton. Paradoxically this assumes that the Wolstonian sequence is of Anglian age!*

Warwickshire Geological Conservation Group has taken an active interest and within Wolston village a display board gives an explanation of the significance of the SSSI (Fig. 10). In a thoughtful gesture, Fred Shotton's daughter Ann was invited to inaugurate the display (Ellis & Fenwick 2007; Fenwick 2009). Ironically, the contextual chronology used in the description would not have met with Fred Shotton's approval: for example, the portrayal of a Heidelberg man at Wolston rather than a Neanderthal reflects the belief that the Wolston succession was related to the earlier Anglian Stage (see below).

Doubts over validity of 'Wolstonian Stage'

Following the publication of Geological Society Special Report No 4, reservations about the wisdom of adopting the Wolston sequence per se for defining the penultimate cold period, and hence Wolstonian Stage, began to emerge. The notion that the Chalky Till (Boulder Clay) of East Anglia is probably the lateral equivalent of indistinguishable East Midlands till lithologies was possibly first suggested in print by Bristow and Cox (1973) and Cox (1980). Concurrently, a regional study of the heavy minerals, grain size and carbonate content in the greater East Anglian region by Perrin *et al*. (1973, 1979), concluded that the chalky-rich tills of East Anglia and the Midlands were of the same age, and this included the glacigenic sequence at Wolston. Also, Gallois (1978) supported this conclusion after mapping much of the critical transitional region. By fortunate coincidence, between 1976 and 1979, the British Geological Survey remapped the Warwick 1:50,000 scale sheet 184 and parts of adjacent sheets including the Wolston stratotype locality. In addition, a sand and gravel resource evaluation by the BGS Industrial Mineral Assessment Unit followed in 1980–81 yielding new borehole data (Crofts 1982).

On the basis of field mapping, Mike Sumbler, a member of the BGS team, made the radical proposal that there was no evidence to sustain a differentiation of the deposits assigned to either the Anglian or the Wolstonian stages (Sumbler 1983a, b). The Quaternary chapter of the Warwick memoir (Old *et al.* 1987, p 49), states 'Within the main outcrop of the glacial deposits there is a clear stratigraphy which was first recognised by Fred Shotton (1953) and has been largely confirmed by the present survey' but also professed 'the present authors prefer to regard the glacial drift of the Warwick district as Anglian, though recognising that this correlation is as tenuous as the conventional one'. This judgement was also endorsed by Jim Rose (1987), who proposed that the Baginton Sand and Gravel Formation (based in the Baginton–Lillington Sand and Gravel) could be traced eastwards into East Anglia where its downstream equivalent, the Ingham Sands and Gravels, unambiguously lay beneath Anglian Stage tills. On the evidence of a similar lithological content, these separate fluvial formations, were correlated and interpreted as part of an integrated river system which ultimately discharged into the North Sea basin. He named it the 'Bytham River'.

Jim Rose was also a co-author of a wide-ranging review (Bowen *et al.* 1986) which concluded (p 309) that 'The only satisfactory evidence for glaciation between the Hoxnian and Ipswichian Interglacial Stages is the Welton/Basement/Warren House Tills of northeastern England'. This opinion led him to disqualify and hence omit the Wolstonian Stage from his review of British stadial (cold) type successions (Rose 1989). He asserted that 'the stratotype at Wolston must give preference to the more adequately defined stratotype at Corton' where the Anglian Stage has its type site. He continued 'the Wolstonian glaciation of the east and west Midlands must be considered as part of the Lowestoft Stadial' i.e., be of Anglian age. In linking the East Anglian glacial stratigraphy to that of the Midlands it was necessary to *assume* that the fluvial succession which constitutes the first upstream outcrop in west Norfolk at Shouldham Thorpe was part of an integrated Bytham River system draining the Midlands. This necessitated making a correlation from Thurlby, on the western margin of Fenland, across a 50 km gap to Shouldham Thorpe, without any intervening supportive sedimentary evidence (the Fen basin was created by later glacial erosion) but nevertheless this idea became the accepted wisdom.

Fred Shotton's defence

Throughout the period 1953–1990, Fred Shotton was unwavering in his conviction that the penultimate cold stage and allied glaciation, i.e. the Wolstonian *sensu stricto*, was as he had postulated and certainly not Anglian in age. Progressively he 'amplified' his understanding of the Wolstonian sequence after examining new sections created by the construction of the M45/M1 motorways (Shotton 1963) and M69

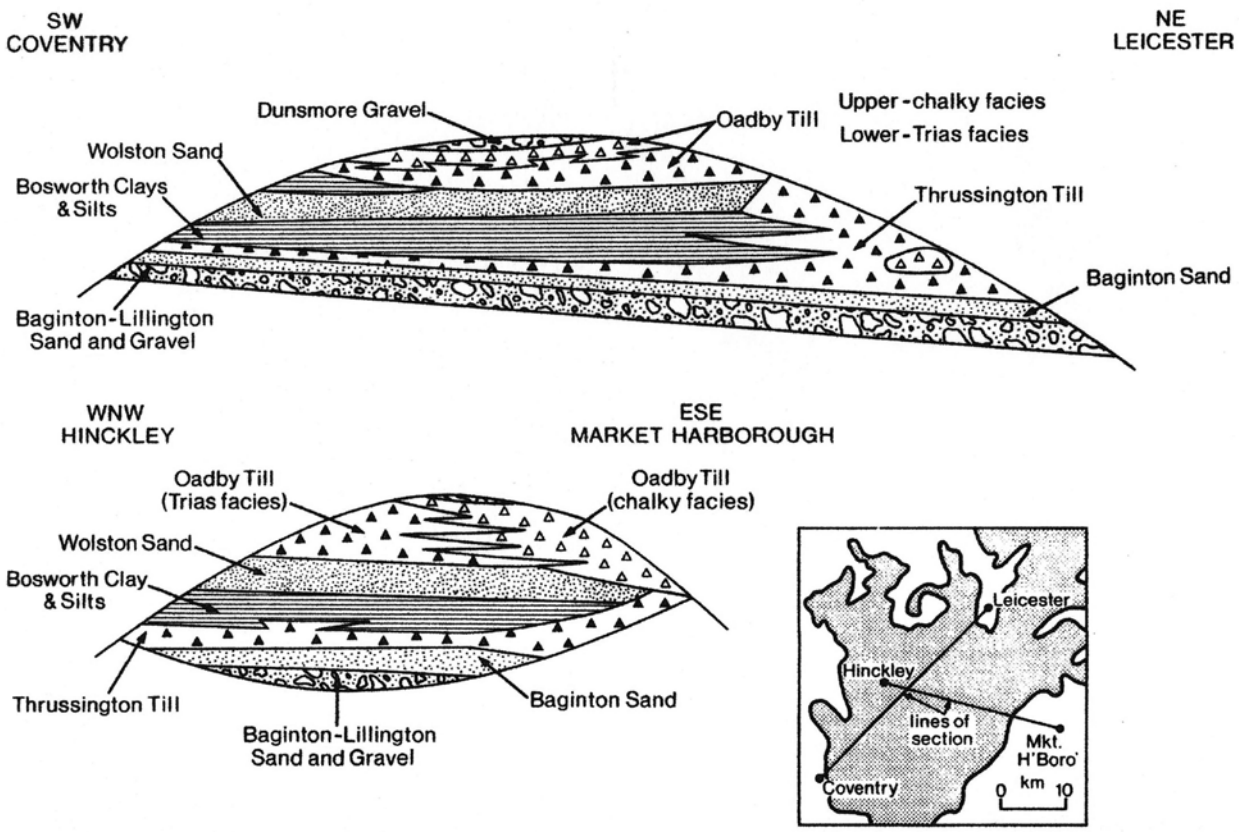

Figure 11. *A model of the Wolstonian succession in the Coventry – Leicester area of the Midlands which synthesises the work of Birmingham and Leicester workers (after Rice & Douglas 1991).*

motorway between Coventry and Leicester (Shotton 1976). He also incorporated the conclusions of work undertaken independently in the greater Leicester area lying to the north, by John Rice and Terry Douglas, which were in accord with his pioneering mapping. A synthesis of the Shotton/Rice & Douglas stratigraphy is illustrated by Fig. 11 (Rice & Douglas 1991). At the Wolston Pit itself, he revised his interpretation of the Lower Wolston Clay as a glaciolacustrine deposit (related to glacial Lake Harrison) and reinterpreted this unit as a till, adopting the terminology of John Rice by calling it Thrussington Till (this till is characterised by a high Carboniferous/Triassic content and hence considered to be of a northerly/northwesterly derivation). I can recall that during the 1964 QRA visit, the 'Lower Wolston Clay' had many of the attributes of a till although this was not the official line at the time (Fig. 12).

During the last 15 years of his life he wrote a series of papers robustly defending his views (Shotton 1976, 1983a, b, 1989). However, during this period his critics outnumbered his supporters, and apart from his immediate Midlands-based research collaborators, John Rice and Terry Douglas of Leicester University, the most prominent advocate favouring his view over many years was Allan Straw of Sheffield/Exeter University, e.g. Straw (1983). To mark the 25th anniversary of first QFSG/QRA field meeting in 1989, the QRA again met at Birmingham University with the main objective of discussing the ongoing Wolstonian controversy. At that time, evidence hinting at additional intra Hoxnian-Ipswichian interglacials was emerging. Sadly, Fred was unable to fully participate in the anticipated debate, but nevertheless he was able to be present when the new Waverley Wood Farm pit exposures were visited. Finally, local interglacial deposits beneath the 'Wolstonian Series' had been identified. At the end of the meeting the majority consensus was still that the Wolstonian was actually Anglian in age.

Post-1990 research

In the decade following Fred Shotton's death, the stratigraphy of three important sites very close to Wolston was published.

First, Waverley Wood: Shotton *et al.* (1993). Earlier, at a QRA discussion meeting in 1986, Fred Shotton was able, despite declining health, to report 'Since the channel sediments (containing a rich assemblage of plant and animal fossils) are directly overlain by the standard Wolstonian succession the age of the deposits is of considerable significance'. The long sought-after but hitherto elusive temperate organics *beneath* the glacial sequence, had been found at Waverley Wood Pit only 6 km west of Wolston. Further, in-situ Acheulian hand axes were reported by Shotton & Wymer [1990]

***Figure 12**. Wolston pit. The interface of the Lower Wolston clay [Thrussington till] over the Baginton Sand as seen in 1964 during the QRA visit.*

and the presence of these must have given Fred Shotton as much joy as did the associated organic- rich sediments. An investigation of these deposits formed the basis of this posthumously published paper of 1993 and making Fred as the first author was a commendable gesture. David Keen had marshalled a multidisciplinary team of contributors, but alas, the abstract gave undue emphasis to an appendix on amino-acid geochronology by D. Q. Bowen and G. A. Sykes. It declared 'an age within the Cromerian Complex Stage for the channels'. The paper's introduction mused: 'It seems probable on palaeontological grounds that the Waverley Wood channel deposits relate to a ...'Cromerian Complex' temperate event'. By applying the principle of Occam's razor, this conclusion supported an Anglian age for the overlying glacigenic succession, but close examination of the paper reveals that this is not reflected by the age-related inferences of all the team members, and it is suggested here that this might be a case of 'the eye seeing what the mind looks for' by Keen. Indeed, this seems likely since over a decade later, Keen *et al*. (2006) have 'Cromerian (MIS 13)' in the title of their paper discussing the Waverley Wood hand axes associated with the basal sediments despite having commented earlier that 'the biostratigraphic indicators are not conclusive as to age' (Keen 1999, p 164).

Second, Brandon: Maddy *et al*. (1994). This locality was a major gravel pit working the Baginton Formation only 2 km north west of the Wolston type site. Exposures there, yielding a flora and coleoptera fauna, had been originally investigated by members of the Birmingham Department of Geology in the 1960s (Shotton 1968). A palaeontological analysis of two newly discovered biogenic- rich lenses associated with the deposits encouraged a correlation with similar sediments at the nearby Waverley Wood. This led to the *assumption* that the latter locality related to MOIS 15 (marine oxygen isotope stage) and the new Brandon material to the MOIS 15-14 transition and the assertion that the overlying type Wolston sequence could be correlated with MOIS 12, i.e. Anglian in age.

Third, Frog Hall: Keen *et al.* (1997). In the late 1980s in a sand and gravel pit just 1 km SSE of the Wolstonian type site, Mike Sumbler in the course of BGS mapping discovered a palaeochannel infilled by a sand and gravel body < 300 m wide and < 11.9 m maximum thickness overlying either Triassic Mercia Mudstone or the glacigenic Wolston Clay (Sumbler 1989). Within the main channel was a sub-channel infilled by interbedded organic rich muds with a rich biota including pollen, plant macrofossils, insects, ostracods, and molluscs. After detailed study, the palaeontology suggested a temperate (interglacial) environment. However, the seven investigators concluded (p 206): 'Whatever the age of the organic sediment, it is now established *beyond reasonable doubt* that the underlying glacial deposits [Wolstonian] cannot be either contemporary with the Saalian, or equated with [Marine] Oxygen Isotope Stage 6 as proposed by Shotton (1953, 1983), since in their type area they are at least as old as [Marine] Oxygen Isotope Stage 10'.

Collectively these three studies of biogenic-rich deposits, all in remarkably close proximity to Wolston, involved no less than 14 investigators and most of these appear to support the belief that the type Wolstonian was likely to be of Anglian age. Again, the numeric values derived from work on the amino-acid ratios appear to have been influential in their judgment, specifically the paper by Bowen *et al*. (1989) which outlined an amino-acid geochronology based on non-marine bivalves and gastropods from midland and southern England. This claimed that the ratios of *Bithynia troscheli* and *Trichia hispeda* from Waverley Wood could be ascribed to MOIS Stage 15. The accuracy of these data appears not to have been questioned.

Broader classification issues

In general, from *c*. 1990 onwards, workers have tended to become rather obsessed by correlations to the oceanic sequence of marine oxygen isotope ratios. This can be justified by their frustration that the British terrestrial record is so fragmented and devoid of undisputable evidence for correlation. There is a refreshing low-key emphasis on such correlations in the text of what is still probably the best overview of the Pleistocene of the British Isles (Jones and Keen 1993). This contrasts with the Geological Society revised Quaternary correlation (Special Report no 23) which appeared six years later (Bowen 1999), which heavily promoted the use of marine oxygen isotope stages. Apart from maintaining that the stratotype Wolston is of Anglian age, this special report disappointingly failed to resolve the 'Wolstonian Stage' problem despite undisputed evidence that two significant cold stages occur between the Hoxnian and the Ipswichian stage interglacials, with an intervening more temperate interval. Indeed, the trace of oxygen isotopic variation, a proxy of former global ice volumes, convincingly showed this was likely to be the case. Unfortunately, we frankly have the unsustainable situation that 'in the absence of formally defined British equivalents of MI[O]S 10-6, the name [Wolstonian] is retained here for the period of complex change (Catt *et al.* 2006, p 447). A factor influencing this was that unlike when the 1973 report was compiled, the 1999 report was not preceded by an open public discussion, even the former Joint Association for Quaternary Research (Geological Society/QRA) was circumvented entirely (the writer was chair at the time). Indeed, the statement that 'it was the majority view of the contributors to this report that it was premature to designate additional stages as they were defined in the first edition', if true, requires substantiation (Bowen 1999, p 6).

Currently there appears to be a continued reluctance by the British terrestrial Quaternary community to urgently 'grasp the nettle' and define *agreed* new stages to bridge the Hoxnian–Ipswich interval. Astonishingly, a working group to consider the 'Interglacials after the Hoxnian in Britain', was established by the Royal Society with Fred Shotton as Chairman (Shotton 1983a). A little later the Quaternary Research Association sponsored a discussion meeting in 1987 with the theme 'additional stages in the British Pleistocene' (abstracts were published in the Quaternary Newsletter no 50). These initiatives were between 35 and 40 years ago, yet despite the problem being evident then, nothing effective has emerged since. As a result, even today workers persist in using the term 'Wolstonian' for this complex interval as there is a lack of an agreed alternative despite general agreement that several stages of cold (glacial)/ temperate (interglacial) status are contained within the Wolstonian 'dustbin'. For example, Penkman *et al*. (2011) using more refined amino acid racemisation data, demonstrated 'the existence of four interglacial stages between the Anglian (MIS 12) and the Holocene in terrestrial successions'. In an attempt to address the problem, a figure accompanying the field report by Straw & Worsley (2016) informally adopted Purfleet and Aveley interglacial stages separated by a Wragby Glaciation within the intra Hoxnian–Ipswichian 'Wolstonian' period.

Over the last decade the reality of the palaeo-Bytham River formerly extending across the area now occupied by the Fens into West Norfolk and Suffolk has come into question. Following detailed work, Gibbard *et al*. (2012) concluded that the first outcrop alleged of palaeo-Bytham river sediments on the east side of Fenland at Shouldham Thorpe *overlies* Anglian chalky till and furthermore, Gibbard *et al.* (2021) reported new luminescence dating results supporting a MOIS Stage 6 age for the same sediments. If valid, these findings demolish the integrity of the Bytham river and its role in linking the East Anglian and Midlands glacial successions.

Towards a new consensus

If the Anglian advocates are set aside, currently, two conflicting views prevail on the extent of Midlands glaciation per se during the 'Wolstonian interval'. These opinions will be termed the 'Cambridge model' which promotes a MOIS 6 age for a *Tottenhill* glaciation (e.g. Gibbard & West 2020) and the 'East Midlands model' which argues for a MOIS 8 age for a *Wragby* glaciation (the latter being the product of an alliance of former Trent Valley Palaeolithic Project workers and Allan Straw (White *et al*. 2017). Rose *et al*. (2021) have given tentative support to this latter interpretation but stress the difficulties of resolving the problem. A common feature of the reconstructions of both groups is the variation in the mapped ice advance limits between their successive publications, a reflection of the difficulty in establishing unequivocal field evidence for them. Gibbard & West place the type Wolston deposits and their underlying temperate biogenic sediments associated with the Baginton Formation within their ice limit. They consider the Wolstonian (Tottenhill) glaciation to be a MOIS 6 event. In contrast, the White *et al*. consortium and Rose *et al*. place a maximum advance limit based on the distribution of the chalk-rich Oadby Till less than 20 km east of Wolston and appear reluctant to extend this any further westward. They both assign a MOIS 8 age to the Wragby glaciation and unlike the Cambridge view, they retain an Anglian age for the Wolston succession.

Just over three decades after his passing, Fred Shotton's original vision of a Wolstonian Stage might be on the cusp of being widely validated. Sadly, in what was probably his last publication before his untimely death, Rob Westaway (2021) perceptively endorsed the concept of an Oadby/Wragby Glaciation during a Wolstonian cold stage between the Ipswichian and Hoxnian Stage Interglacials as originally envisaged in the 1953 paper. However, he maintained his opinion that

the Baginton Formation was part of the hypothesised greater Bytham River system rather than just the proto-Soar. His map of Lake Harrison adapted from Fred Shotton's reconstruction, shows an ice limit trending NW–SE just north of Stratford-on-Avon implying an ice advance from the north east which encompassed the glaciogenic Wolston type sequence (Fig. 7). He declared 'The Wragby Glaciation [MOIS 8] palaeo-environment was essentially as envisaged decades ago (e.g. Shotton, 1953, 1983; Bishop 1958) during the Late Middle Pleistocene…Glaciation, providing a remarkable instance of scientific ideas turning full circle'.

Most recently, Gibson *et al*. (2022) report on new stratigraphical observations from five sites in the West Midlands along with newly acquired luminescence ages, supplemented by cosmogenic ^{36}Cl exposure dating of erratic boulders. They interpret this data to suggest an ice advance across the west Midlands south to the Morton-in-Marsh glacial limit constrained to between 199 ± 5 and 147 ± 2.5 ka, i.e. late Saalian Stage, MOIS Stage 6. Critically, they assign this age to the type Wolstonian succession and erect a new substage late in the 'Wolstonian' which they name the 'Moreton Stadial'. Unfortunately, in the opinion of the writer, this retains a view that the Wolstonian Stage embraces all the MOIS stages/substages 11b–7, rather than admit that such a long and complex-time span embracing several MOIS stages as simply 'Wolstonian' defies logic.

The Devensian type site at Four Ashes, Staffordshire (SJ 916082)

When the proposed 'Stratigraphical table of the British Quaternary' was discussed at an open meeting of the Geological Society in June 1969 (Proceedings no 1660, 377–392), the introduction of a uniquely British name for the Last Cold Stage – the 'Devensian' – was criticised on the grounds that since the stage could be confidently correlated with the Weichselian of north Europe, a new name was unnecessary (an early Brexit moment?). Further, by the late 1960s numerous radiocarbon age estimates had become available all of which supported this linkage.

The term Devensian was coined solely by Fred and claimed to be derived from Latin *Devenses* – people living by the River Deva (Dee). Although the Dee drains an undoubted classical region for last-glaciation deposits, there is no credible historical support for a tribe with that name. Indeed, Chelford was not even in the Dee catchment (it was in that of the River Weaver, a tributary of the Mersey). When the Four Ashes site was discovered (see below), it was quickly adopted as the new type site and as we have seen above, Chelford, was dropped. This change in location had even greater implications for the appropriateness of the name 'Devensian' since Four Ashes was not even in the Dee–Mersey catchment discharging into the Irish Sea (it was in that of the Trent which reaches the North Sea). However, no change was made although I recall that when demonstrating Four Ashes to overseas geologists during the 1977 INQUA Birmingham Congress, they were amused by the British maintaining the early Victorian practice of coining terms derived from ancient Celtic tribes.

In Mitchell *et al*. (1973) the Devensian cold stage was uniquely defined by radiocarbon data (years BP) and subdivided into three elements:

Early – pre 50 ka

Middle – 50–26 ka

Late – 26 ka to end of pollen biozone III (Loch Lomond Stadial)

The logic of selecting a middle/late boundary age of precisely 26 ka was not given although Coope & Sands (1966) was given as a reference. Following a query, Richard West (pers. comm.) has explained that at the time of compilation, figure 2 of the cited paper (see Fig. 13), a reconstructed temperature curve extending over the last 70 ka had just been published which showed that at 26 ka BP there was a steep

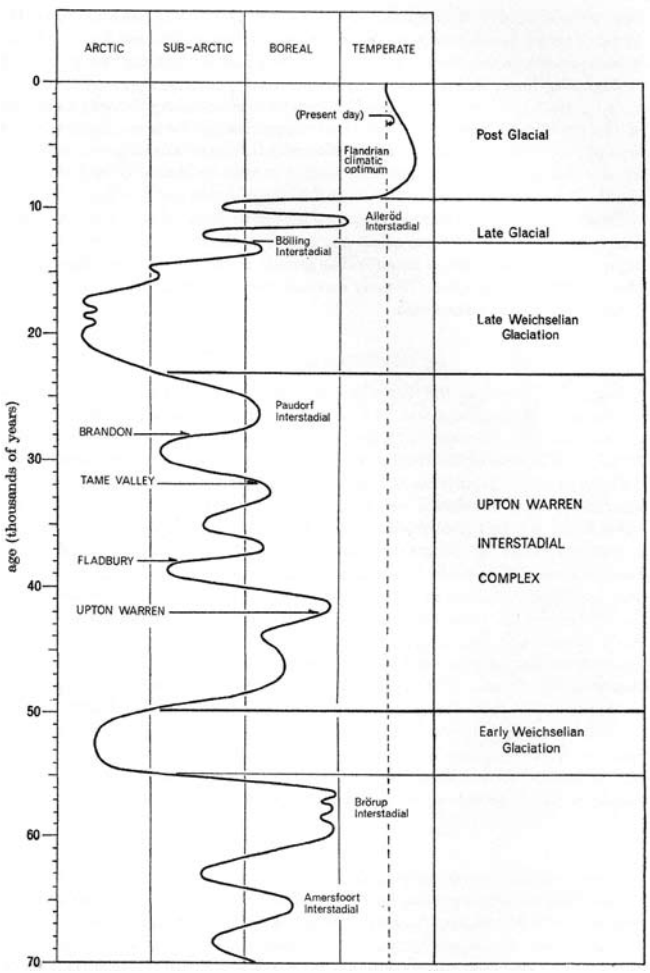

Figure 13. *The reconstructed Last Glacial/Flandrian palaeotemperature curve from Coope & Sands (1966) fig. 2, showing the hypothetical early glaciation (Irish Sea ice) and the radiocarbon age of the Middle Devensian (end of Upton Warren interstadial complex)-Late Devensian boundary. The Brörup (Chelford) Interstadial is now known to be c.100 ka.*

temperature fall from boreal to arctic temperatures at the end of the 'Upton Warren Interstadial Complex'. Accordingly, this was adopted as the date of the Late/Middle sub-stage boundary, and it still stands. The original table of 1968 noted that a definition of the base is necessary 'and awaits the study of a suitable site'. A fuller discussion of this problem was included in Fred's 'holistic' account of the Devensian Stage (Shotton 1977b) but with the conclusion 'this cannot be done in a satisfactory manner' – the wait continues until a full succession spanning the transition from the Ipswichian to the Devensian is identified in Britain. What tends to be overlooked is the fact that a cold stage embraces a specific time span and in the case of the Devensian this approximates to 100 ka. It is only within this interlude that time limited glaciation events – stadials – occur, otherwise the environmental state oscillates between periglacial treeless and short periods of boreal forest (interstadial) vegetation.

Whilst on consulting work, in early March 1967, Alan Wright (ironically a hard rock geologist!), found organic deposits within the working aggregate quarry at Four Ashes. By coincidence he was a member of Fred's academic staff in the Birmingham Department of Geology and naturally Fred took an immediate interest and following a field visit on 13 March he concluded that the peat lenses were in a gravel terrace *above* till. The site discovery coincided with the arrival in Birmingham of Alan Morgan as a prospective research student. Following a reconnaissance field visit by the latter, he concluded that the till was *overlying* the gravels (contra to his superior!). The stratigraphic position of the till was subject to a vigorous debate in Birmingham during the following three months. Russell Coope (pers. comm.) related how Fred Shotton was so disturbed by the apparent Four Ashes stratigraphy that he received more than one evening telephone call from him seeking his assurance that a true in-situ till blanketed the gravel succession. A field visit in June by Fred, in the company of Aleksis Dreimanis (1914–2011), a visiting eminent Canadian glacial geologist who specialised in till lithologies, finally convinced him both that the till was genuine and that its stratigraphic position was as Alan had reported (Alan Morgan pers. comm.). To establish a numeric age for the till (and glaciation of the site), priority was given to undertaking two radiocarbon assays in the newly established Birmingham radiocarbon laboratory within the Department of Geology. A 'seismic' shock occurred when results gave radiocarbon age estimates of 30 and 36 ka (Birm. 24 & 25) from organic samples close to the till base, demonstrating unequivocally that the overlying till was 'Late Devensian' in age. This finding prompted Fred to submit a short note to the journal *Nature* accompanied by a declaration that his previous assignment of an *early Devensian* age for the Wolverhampton line was incorrect (Shotton 1967). Inexplicably, Fred Shotton used the alpine term 'Würm' rather than Weichselian in this paper (this might have been an editorial demand). Previously the Last Glacial Maximum limit had been generally accepted as lying some 25 km to the north (Boulton & Worsley 1965). Later, when a further six assays antedating 30 ka were available, he stated, 'This conclusively places the Irish Sea Till of the north Midlands as Upper Devensian and not *lower Devensian* as I once thought before these dates were available' (Shotton 1971, p 527).

Fred tasked his new research students Alan and Anne Morgan to investigate the Four Ashes stratigraphy and fauna since it promised to throw a more comprehensive light on the entire cold stage than was possible with the Chelford evidence (Morgan, A. 1973: stratigraphy; Morgan, A.V. 1973: fauna). Despite a gravel thickness typically less than 3 m, numerous organic lenses (*c*. 50) occurred, each with coleopteran faunas which were ecologically conformable. They were located either within or below the gravel succession, and all were overlain by a relatively thin till (Figs. 14 & 15). Unfortunately, because of the scattered nature of the various organic lenses, a clear-cut biostratigraphical succession could not be established. Lithologically, the sequence was divisible into five units:

Figure 14. *A section exposed at the Four Ashes quarry during the QRA short field meeting September 1968. Fred Shotton (left) is discussing the stratigraphy with John Shaw (centre).*

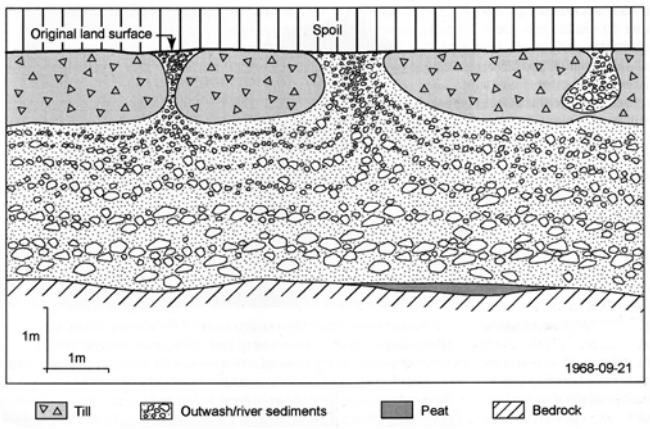

Figure 15. *Drawn section of the Four Ashes exposure in 1968 (Worsley 2006). This was more typical of the site than the schematic diagram in Morgan (1973).*

1. Sands;
2. Till (Stockport Formation) of Irish Sea provenance (< 2.75 m);
3. Sands and gravels with peat and organic silt lenses (0.5-4.5 m);
4. Locality 44 with fen peat containing an interglacial flora (Ipswichian);
5. Triassic (Sherwood Sandstone Group) bedrock.

The Early Devensian ice maximum concept was based on the belief that the river terrace sequence at the Upton Warren interstadial site in Worcestershire could be directly correlated (misguidedly) with the River Severn Main Terrace, an outwash valley sandur originating within the glacial advance limit. Upton Warren had yielded two mid-Devensian radiocarbon age estimates and it was assumed that these supported a pre-LGM age to the sandur (Coope *et al.* 1961; Worsley 1976). Figure 1 well illustrates this ice advance chronology featuring an early Devensian glaciation into the Midlands region; significantly both the authors, Coope and Sands (1966), were members of the Department of Geology at Birmingham.

Conclusion

Reflecting on some sixty years of progress in understanding British Middle and Late Pleistocene geology it is unfortunate that after the principles of stratigraphy had been democratically agreed by *c.* 1970, the initial impetus has not been maintained. The revised Special Report No 23 (Bowen 1999) was a missed opportunity to tackle the Wolstonian Stage dilemma. One factor could be the reduction in the number of academic Quaternary geologists. Despite the objectives of the 1980s national rationalisation of geology, the intended strengthening of Quaternary geology in the earth sciences failed, exemplified by the disbanding of the world class Cambridge Subdepartment of Quaternary Research. Similarly, the new University of Reading Institute for Sedimentology did not survive for long.

Many workers in what has become Quaternary Science have become mesmerised by newly developed dating techniques at the expense of classical stratigraphy. Reference has already been made to the deleterious influence of amino-acid racemisation 'numbers' on interpretations and the same can be said of MOIS stages. Currently there is a danger of luminescence data being taken as gospel. Earlier there was a period of radiocarbon dating abuse (Shotton 1973b). The phrase 'radiometric dates are good servants but poor masters' comes to mind. Fred Shotton had built in his department two proportional gas counter systems enabling in-house radiocarbon measurements. When operational, he was a daily visitor to it and was personally involved in the calculation of age estimates, famously on the back of one of his many cigarette packets (Roger Williams pers. comm.). He made sure that all users understood the physics and statistics of the measurements by issuing the reports under his name.

Throughout the Wolstonian debate in his lifetime, Fred Shotton stuck to his geological principles. His legacy has now been vindicated after several decades when his judgement was challenged. Whilst recognising that post 1979 politically driven academic transformation was inevitable, it is poignant to note that the Quaternary geological power house at Birmingham led by Fred Shotton did not survive the aftermath of the former University Grants Committee's Earth Science Review.

This paper is dedicated to the memory of George W. Radge, BSc (1930), MSc Birmingham, my geology mentor at Grimsby Winteringham Grammar School, 1951–58. His MSc thesis was on the Glacial Geology of North Cleveland (Radge 1939).

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