Glacial Geology of the Condover Area, South Shropshire

Peter Worsley

Abstract. Late glacial mammoth remains were discovered during the extension of the Norton Farm sand and gravel quarry at Condover. At the Last Glacial Maximum a northern derived ice sheet terminated 15 km south of the quarry site. Many large blocks of glacial ice were buried in the associated outwash and till. An advance of Welsh ice terminated at Shrewsbury, 5 km to the north. Following this, regional deglaciation occurred, and localised, complex, dead-ice terrain developed with many kettle holes. Ice marginal lakes progressively drained and the ancestors of the present river systems developed on the glacial deposits. The kettle holes acted as sedimentation sinks. In the early Windermere Interstadial, lush vegetation on the floor of the Norton Farm kettle attracted mammoths, which then became trapped in the unconsolidated fills. Subfossil mammoth bones were discovered in 1986 when a kettle fill at the Norton Farm quarry was excavated.

Condover rose into the national limelight in late 1986 after mammoth bones had been discovered by Mrs Eve Roberts on the evening of 27th September. They were found protruding from dumped overburden at an active sand and gravel quarry at Norton Farm. These were sensational finds. They formed the most complete adult male mammoth skeleton found in Britain so far, and their clearly late-glacial age pushed forward the mammoths' extinction by about 5000 years, to c12 ka BP, when relatively mild interstadial conditions prevailed.

The aggregate workings (at SJ494073) lie close to the village of Condover, 5 km south of Shrewsbury (Fig. 1). The site lies within an undulating lowland plain, which to the west, south and east is surrounded by higher ground on Precambrian and Palaeozoic bedrock. Northwards the lowlands are relatively unrestricted and extend beyond Shropshire through Cheshire to the shores of the Irish Sea. The River Severn crosses the south Shropshire lowlands from west to east, and passes 4 km north of Condover. Anomalously, the river fails to take advantage of a potential shorter low-ground route to the north, and cuts through the bordering rim of higher ground, via the Ironbridge Gorge, to eventually reach the Irish Sea by way of the Severn Estuary. This is probably the most spectacular glacial diversion of drainage of the Last Glaciation in Britain, and was first recognised by Charles Lapworth in the late 19th century. The last major right bank tributary to the Severn before the gorge is the Cound Brook, and this approaches to within 1 km of the mammoth site (Fig. 1).

Within the immediate surrounds of Condover the poorly exposed bedrock forms part of the Salop Formation, a sequence of Upper Carboniferous red sandstones and mudstones. They constitute part of the Leebotwood Basin succession, which is enclosed by major faults to the northwest and southeast, (Toghill 1990). Within the Cheshire-Shropshire lowlands, the youngest solid sequence is middle Jurassic, and a major hiatus separates it from the Quaternary cover succession. In south Shropshire, only the products of the latter part of the last major climatic cycle of the Quaternary are recognised at present. In formal stratigraphical terms the three climatic stages which contribute to the full cycle are the Ipswichian Interglacial (part), followed by the Devensian cold stage and then the Flandrian Interglacial that continues to the present time.

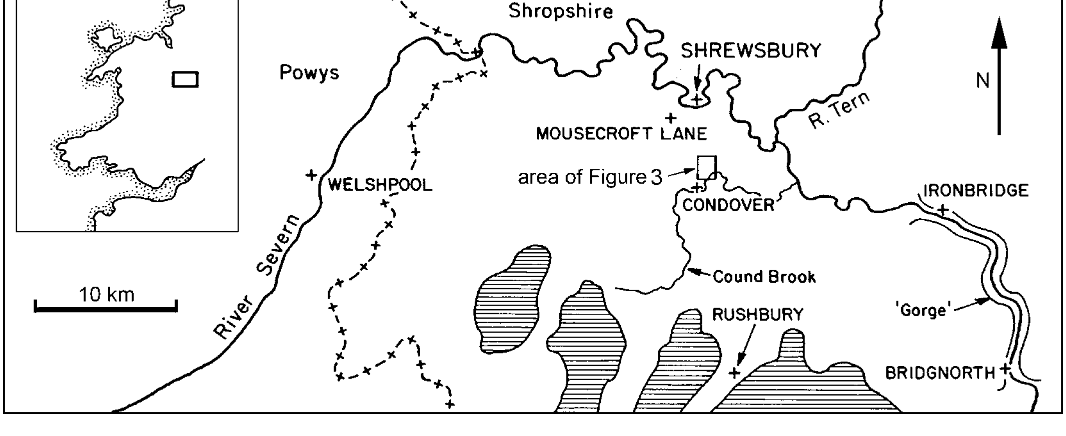

Figure 1. Location of Condover and related adjacent sites in southern Shropshire. The shaded areas along the southern borders of the map lie beyond the maximum extent of glaciation at the Last Glacial Maximum (the Late Devensian). Based on B.G.S. mapping.

The local Devensian sedimentary record is dominated by glaciogenic deposits associated with the Last Glacial Maximum ice advance and its subsequent retreat. This reached an advance limit around 15 km south of Condover (Fig. 1) (Greig *et al*. 1968), and probably culminated about 20 ka BP. Traditionally this is known as the Newer Drift limit, since within it, constructional glacial landforms are common and the amount of post-deglaciation erosion is limited; this contrasts with the Older Drift beyond, which is normally heavily dissected and devoid of constructional glacial morphology (Worsley, 2005). This outer area, beyond the ice advance limit was subject to prolonged periglaciation during the glacial stage; not all of it has older glaciogenic sediments and much of the higher ground in south Shropshire is directly underlain by bedrock. Effects of periglacial processes are the tors, stone polygons and allied stripes that formed on the Ordovician quartzites of the Stiperstones (Goudie & Piggott, 1981).

Sedimentary evidence for constraining the timing of the Last Glacial Maximum event in Britain is provided by the sequence that defines the Devensian Stage. Fortuitously this is located only 40 km east of Condover, at Four Ashes in Staffordshire. There the glacial sediments overlie locally derived gravels that ante-date the ice advance and the contained organics have yielded a minimum radiocarbon date of some 30 ka BP. Nearby, an organic-rich sequence post-dating the glacial advance at Stafford has yielded a radiocarbon date giving a youngest age to the ice withdrawal of 13.5 ka BP (Bartley & Morgan, 1990).

Glacial research in the Shropshire Lowlands

Undoubtedly the most valuable and detailed regional study of the Shrewsbury area glaciogenic sediments arose as part of the 1:10,560 geological mapping by the Geological Survey, which led to publication of the 1:63,360 Shrewsbury drift sheet 152, plus an accompanying memoir (Pocock *et al*, 1938). Although the field mapping was undertaken between 1914 and 1929, this work remains the benchmark study. Its value was enhanced by the geologists involved clearly having a personal interest in the interpretation of the glacial sediments and landforms.

Subsequently, Shaw (1971, 1972a, 1972b) made valuable contributions to understanding the glacial sedimentology in the context of an evolving appreciation of the complex nature of contemporary glacial depositional environments. An appraisal of sand and gravel resources by the Geological Survey (Cannell, 1982) covered two adjacent 1:25,000 sheets centred on Shrewsbury, and documented a large borehole data base. However, this did not extend as far south as Condover. This deficiency was largely rectified by a similar resource survey by the Engineering Geology Unit of Liverpool University (Crimes, 1985). The latter study covered an irregularly shaped area including Condover, but a tantalising strip, 2 km wide and aligned east-west, separated the two investigations. Although both Cannell (1982) and Crimes (1985) attempted some interpretation of their data, their brief was only to assess the bulk mineral resources. Nevertheless, in comparison with many areas of Britain there is a rich archive of sub-surface information pertaining to the glacial sediments of the Condover district.

Outline glacial history

The glacial stratigraphy has been interpreted in terms of two different ice advance events within a single glaciation (Pocock et al, 1938). The first was thought to have moved essentially southwards from out of the Irish Sea Basin, bringing with it erratic material derived from the granite and volcaniclastic outcrops in the Lake District and south west Scotland, with abundant sediment from the relatively soft Carboniferous and especially the Permo-Triassic of the Irish Sea borderlands. The resultant glaciogenic materials are red-brown in colour. A very minor but significant fraction also consists of a derived Pleistocene marine fauna from the bed of the Irish Sea (Thompson & Worsley, 1966). There are two radiocarbon assays on marine shells in the Condover vicinity, >38 ka (Birm-60) from Great Ryton and 32 ka (I-2939) from Buildwas. Both of these are consistent with the regional chronological picture. The second glacial advance was surmised to have originated within the Welsh Uplands and moved generally eastward through the borderlands, bringing

stage or sub-stage	event	sediments	beds in kettle hole	years BP
Flandrian Interglacial	Post-glacial		f & g	10,000
Loch Lomond Stadial			e	11,000
Windermere Interstadial			c (*with mammoth*) & d	*12,500*
Dimlington Stadial	Last Glacial Maximum	Shrewsbury Formation Stockport Formation	a & b	13,500 26,000
Middle and Early Devensian Glacials and Ipswichian Interglacial				

Table 1. *Correlation of events and sediments in the Condover area.*

with it various Palaeozoic lithologies (lavas, tuffs, limestones, sandstones and slates) that impart an overall grey colour to its till and outwash lithologies.

The relationship between these two ice advances in south Shropshire was excellently exposed in a former aggregate quarry at Mousecroft Lane in the southwest suburbs of Shrewsbury during the 1960-70s. Outcrop evidence showed that the ice derived from the northerly Irish Sea arrived first, and that the Welsh ice advanced after the Irish Sea ice had retreated from the site. The succession was first described by Poole and Whiteman (1961) although their specific interpretation found little support by other workers. A note by Shotton (1962) described a deep borehole adjacent to the quarry and Worsley (1991) included a log of a sequence 19 m thick exposed in 1964 beneath a kettle hole that had been cross-sectioned by the advancing quarry face (Fig. 2); this succession is dominated by fluvial facies. Shaw (1971, 1972a) elaborated on the sedimentology, and Worsley (1977) provided the last stratigraphic account prior to abandonment of the site. Two key relationships revealed at Mousecroft Lane were that ice blocks must have been entombed within the outwash sediments of the first (Irish Sea) ice advance, and that the bulk of the deformation and subsidence arising from the later melt-out of these blocks took place after the retreat of the second (Welsh) advance.

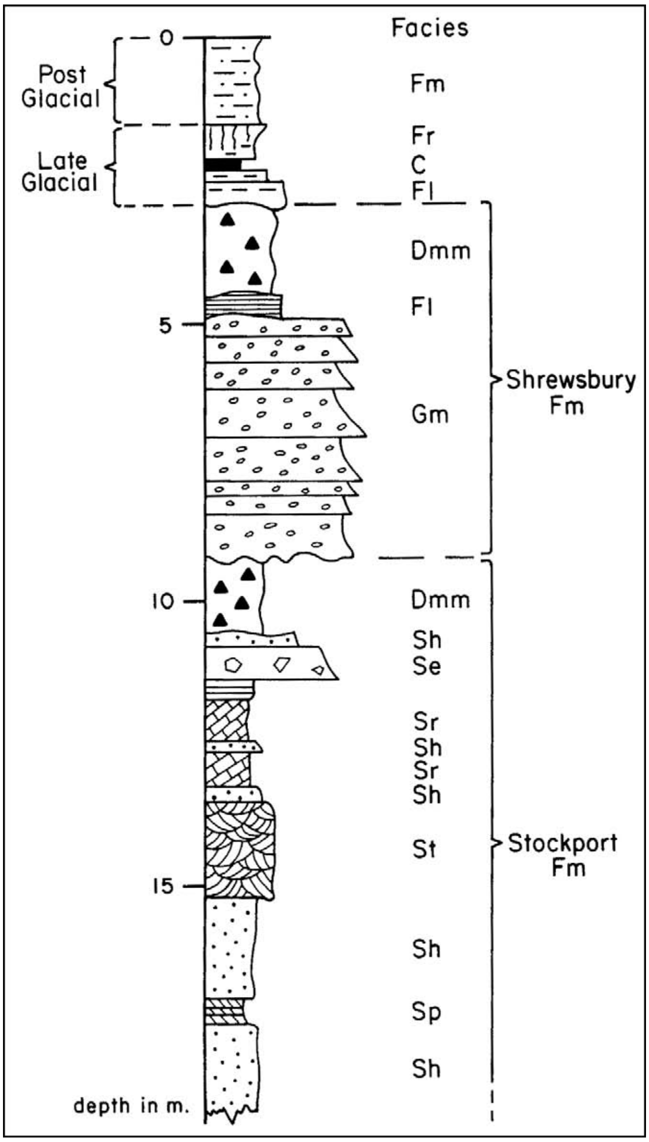

Figure 2. *Sedimentological log of the succession exposed at SJ 478109 in the Mousecroft Lane Quarry, Shrewsbury in 1964. The Stockport Formation consists of the products of the earlier ice advance from the north, whereas the Shrewsbury Formation represents the sediments introduced by a later ice advance from the west. Since this log lies directly beneath a kettle hole, the Shrewsbury Formation is overlain by kettle hole infill sediments of late and post glacial age. Lithofacies codes:- C = clay; F = fine silt: S = sand: D = diamict; c = angular clasts of sand; h = horizontally stratified; m = massive, matrix supported; p = planar; r = rippled; rs = roots; t = trough-bedded.*

More recently, Worsley (1991, 1999) has proposed that, since the earlier sequence derived from the Irish Sea can now be confidently regarded as the lateral equivalent of the Stockport Formation, it should be named as such, whereas the later succession of a till overlying its sandur is the Shrewsbury Formation.

The Norton Farm area

The area adjacent north and northeast of Norton Farm displays some of the most spectacular hummocky glacial terrain in England. It is not easy to describe the landform assemblage since specific forms grade into one another resulting in complex terrain. In general hummocks (kames) and linear features (eskers) are interspersed by hollows (kettles) on varying scales. The latter are generally interpreted as the sites of former buried glacier ice, and between and over them the glacial sediments (mainly outwash) accumulated. Later with climatic amelioration the ice melted to leave the kettle holes as elements of the present day relief. Many of these remain to be integrated into the modern fluvial drainage network. Northeast of the quarry, a major esker-like linear ridge of sand and gravels extends from Sharpstone Hill in the north west for about 1500 m, before it is cut by the valley of the Cound Brook. This ridge is bordered by linear depressions one of which is occupied by Bomere Pool, south of the farm (Fig. 3). The quarry is cut into a large, complex kame-like landform, the southeast portion of which still survives. Prior to its opening and the attendant destruction, it was reported that, at Norton Farm, *a hill of sand and gravel, with a very moundy surface, rises steeply from the fluvioglacial terrace on the north and north-west but gently from the boulder clay (till) area on the east* (Pocock *et al*, 1938).

Sharpstone Hill is a low ridge of Longmyndian grit that protrudes through the glacial cover. During the official geological survey, Pocock reported 'well marked striae' on freshly exposed surfaces, indicative of a north-south ice movement during a phase of net erosion associated with basal sliding. Eastwards, the sub-drift surface forms a broad shallow valley with an axis falling from southwest to northeast. Condover village lies over the valley axis, and Norton Farm Quarry is located over the northwest flank, where bedrock lies at around 65 m OD, whereas the present day land surface at the site averages 90 m OD. The degree to which the bedrock surface is modified by glacial erosion is unknown, but the valley morphology has nothing to suggest that the low ground was greatly influenced by ice erosion, in marked contrast to the resistant ridge of Sharpstone Hill.

The original operators of the Norton Farm Quarry (ARC Western) commissioned 70 exploration boreholes to establish the magnitude of the sand and gravel resource. Although these remain confidential, the compilers of the sand and gravel isopachyte maps and cross sections (Crimes, 1985: Figs. 14, 11 and 16) had access to them. That survey commissioned an additional six new boreholes, and the logs of these are in the public domain. An adapted version of the borehole data can be presented as a series of cross

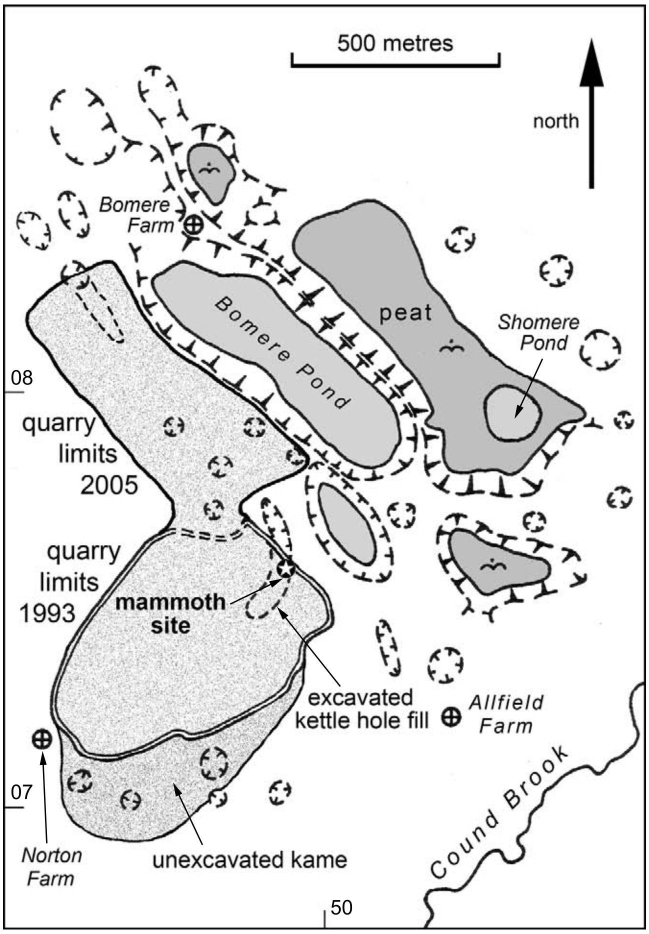

Figure 3. *Glacial geomorphology of the area adjacent to the Norton Farm Quarry, Condover, to show the extent of the kettle holes and associated ice-contact features.*

sections (Fig. 4). Thus stratigraphic data for the area around Norton Farm Quarry are unusually good.

Above the bedrock surface at Norton Farm, the glacial litho-stratigraphy is relatively simple, consisting of a lower till smeared over the solid such that its upper surface tends to mimic the rockhead profile. Above this, a major body of sand and gravel body is generally over 20 m thick, but is confined laterally by steep margins, giving the impression that it is set into the till beneath. In plan form this sediment unit is funnel-shaped, with the apex at Condover village and a long axis towards the northeast (Fig. 4). In places the sands and gravels crop out at the surface, usually as kame landforms. Associated with the kame areas are relatively thin till sheets which pass laterally into a much thicker till unit at the margins of the sand and gravel.

The initial quarry exposures were discussed by Shaw (1972b), based upon observations in the late 1960s. He described a complex sedimentary association with an upper unit consisting of a central gravel-dominated zone passing laterally into mainly horizontally stratified sands. These relationships, along with the occurrence of widespread faulting, encouraged him to suggest that initially the glacial meltwater depositional environment was constrained by glacier ice walls, then, upon melting, the removal of lateral support led to collapse in the ice-contact zone. A lower unit was interpreted as part of a deltaic sequence, with a longitudinal section of classical delta foresets dipping 30º to 210º. Levelling of the truncated top established that the water body into which the delta was prograding stood at a minimum of 81.4 m OD. Such a vertical change in sedimentary facies well illustrates the dynamic nature of the ice marginal environment with, in this case, ponded water deposition abruptly giving way to torrential river sedimentation.

Surface mapping of the distribution of enclosed hollows shows that they occur on a wide range of scales (Fig. 3). When their locations are superimposed upon the extent of the sand and gravel unit revealed by the boreholes, the virtual correspondence suggests a genetic link between the two. Significantly, this same relationship could be identified in the Mousecroft Lane area, in Shrewsbury. Hence, it appears that the sedimentological environments associated with the accumulation of the thick sand and gravel units were conducive to the burial of detached blocks of ice derived from the glacier; these were later to melt-out, and induce subsidence of their cover sediments.

All the available stratigraphic data suggest that the Shrewsbury Formation is absent in the immediate Condover area and that the glacial sediments *per se* all belong to the slightly earlier Stockport Formation. The latter corresponds to the Last Glacial Maximum, and this major glacial ice advance culminated at about 20 ka. The Shrewsbury Formation post-dates the maximum ice advance in south Shropshire; although the time differential is unknown, relationships indicate that there was no climatic warming between the two ice advances. The probability is that they were within a millennium of each other, and farther north along the Welsh border they were coeval. No local evidence is known to support the assignment of the deeper glaciogenic sediments to a pre-Devensian age, although this possibility should not be excluded.

‘Flood-gravels’ and glacial lakes

The Geological Survey officers' interest in glacial geology probably accounts for the adoption of a classification recognising two separate kinds of glacial meltwater deposits, 'glacial sand and gravel' and 'fluvio-glacial flood-gravels' on the Shrewsbury map sheet. The discrimination of the latter is not usual Survey practice. According to T.H. Whitehead (in Pocock *et al*, 1938, and pers. comm., 1965), the flood gravels were envisaged as being produced by 'torrents of water, perhaps derived from the melting of snow on the hills' washing coarse detritus to form valley trains and extensive flats above features mapped as conventional river terraces marginal to the modern drainage net. Therefore direct run-off from a wasting glacier was not involved, though glacial ice may have persisted in the region. Major spreads of periglacial 'flood-gravels' were mapped in the Condover area (and confirmed by Crimes, 1985). Indeed, the western limits of the Norton Farm kame abut onto a flood-gravel surface which descends northwards to a gap in the Precambrian ridge. Kettle holes are not associated with the flood-gravels, suggesting that any melt-out that may have occurred had been completed prior to their final aggradation.

The glacial geological mapping of the Shrewsbury sheet was undertaken at a time when there was considerable interest in the concept of an ice-dammed lake in the lowlands. To an extent therefore, the fieldwork was a test of the lake hypothesis. This idea had been given coherence by Wills (1924), who argued that the Ironbridge Gorge of the River Severn was a glacial diversion of drainage initiated through overspill of a small, high-level, ice-dammed lake; with progressive glacial retreat, this became more extensive and of lower elevation as its outlet sill was lowered by the overflowing meltwater. He envisaged that the glacial lake stabilised for a time at an altitude of about 300 feet (90 m), and at this stage the feature was called Lake Lapworth. Subsequently, it lowered further and eventually drained, allowing the River Severn to establish its present day course. Accordingly, critical attention was paid to the nature of the landforms and sediments within the potential shoreline zone.

In the Shrewsbury memoir, Pocock *et al* (1938) were generally in favour of the glacial lake hypothesis; they postulated a number of small local lakes during the ice advance and retreat, and also subscribed to the Lake Lapworth reconstruction. In particular, the flood-gravels were interpreted as being graded to one or more glacial lakes. Having re-examined the terraces in the valley of the River Tern (Fig. 1) and east of Shrewsbury, Worsley (1975, 1976) concluded that there were field relationships, in the form of abruptly terminating glacial outwash terraces that were best explained as relict deltas aggraded into glacial lakes. At Shrewsbury, the eastern limit of the Shrewsbury Formation (till and outwash from the Welsh ice) lies near Fox Farm, 3 km northeast of Norton Farm Quarry, and this was interpreted as a former delta related to a lake at an altitude of 66 m. At Mousecroft Lane, the landform-sediment relationship shows that deformation of the Shrewsbury Formation post-dates its deposition, and originated in melt-out of residual glacial ice blocks buried within the underlying Stockport Formation. By analogy, it appears likely that the Condover kettle holes were also generated by melt-out processes after the Welsh ice advance event. At that time any residual glacial lakes would have drained via the developing River Severn drainage system to below the 65 m level.

The kettle hole with the mammoths

Although site of the mammoth find was interpreted as the fill of a former kettle hole (Coope & Lister, 1987), its morphological expression was subdued in

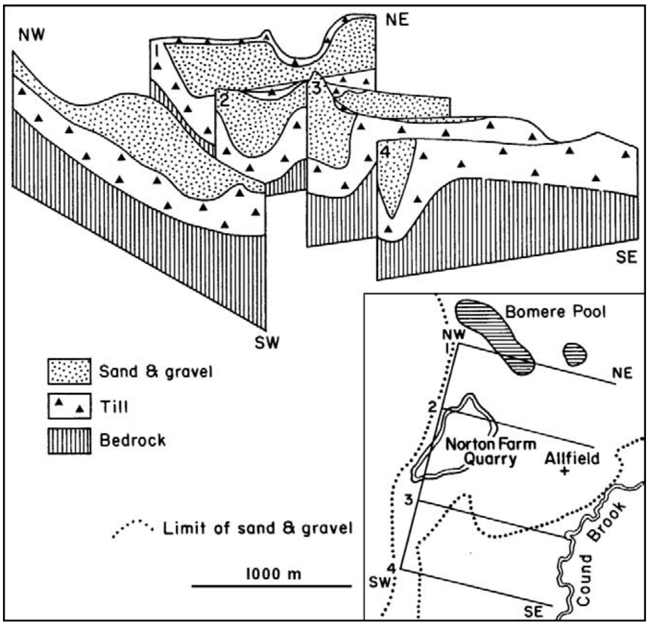

Figure 4. Fence sections of the glacial sand and gravel and the till near Norton Farm Quarry, Condover; the mainly sub-surface extent of the sand and gravel unit lies within the dotted line on the inset map (adapted from Figure 11 in Crimes, 1985).

comparison with many of the other kettle holes at Condover. The Liverpool geomophological map (Crimes 1985) did not show one at the find site. Fortunately, the original geomorphology can be examined on the Shropshire County Council air photographic survey of August 1983. These reveal an enclosed banana-shaped depression at the mammoth site. Comparison with the writer's field mapping (Fig. 3) shows that the northern end of this depression survives immediately beyond the margin of the quarry. The mammoth remains occurred midway along the axis of the depression which was around 300 m long.

Virtually all the recovered bone material was disturbed and had to be excavated from dumped overburden. Very few bones were found in situ. Nevertheless their stratigraphic status is not in doubt as the adhering matrix on the bones could be readily correlated with a specific bed in the surviving succession at outcrop. Seven units (**a-g**) were reported in the infill sequence that was about 10 m thick (Lister, 1993), and these are shown in the schematic section (Fig. 5). Field examination of the quarry in 1993 and 2005, showed that units a and b could still be identified in the north face adjacent to a lagoon on the quarry floor, with the remainder being obscured by vegetation and backfill. Beyond the quarry boundary in the field to the northeast, the continuation of the kettle feature could be identified; hence part of the infill succession survives as an important archive.

The first bed to accumulate in the kettle hole was the pink glacio-lacustrine clay (unit **a**) and this indicates standing water and an inflow with an abundant suspended load. The status of the following gravel (unit **b**) is less certain but might indicate collapse of the steep walls. Unit **c**, a dark grey silt about 1 m thick, lay in the middle of the infill; this is the key horizon, since it contained the mammoth bones together with pollen indicative of a treeless landscape dominated by grasses and sedges, the environment thought to be favoured by mammoths. This evidence, along with five radiocarbon assays on skeletal material giving a weighted mean uncalibrated age of about 12.5 ka BP, correlate with the first part of the Windermere Interstadial. Unit **d**, consisting of sedge peat, relates to the latter part of the same interstadial.

There then followed the final cold phase of the Last Glacial, the Loch Lomond stadial, when the grey clay of unit **e** was deposited. Nationally, this sub-stage was one of very active geomorphological processes; at Church Stretton, 15 km to the south, intense fluvial activity is recorded (Rowlands & Shotton 1971). In the immediate Condover area, no stratigraphic record outside the kettle fills is known, but it is possible that some deposition of the flood gravels occurred at this time. The humified peat and ploughsoil (units **f** and **g**) are both products of the Flandrian (postglacial).

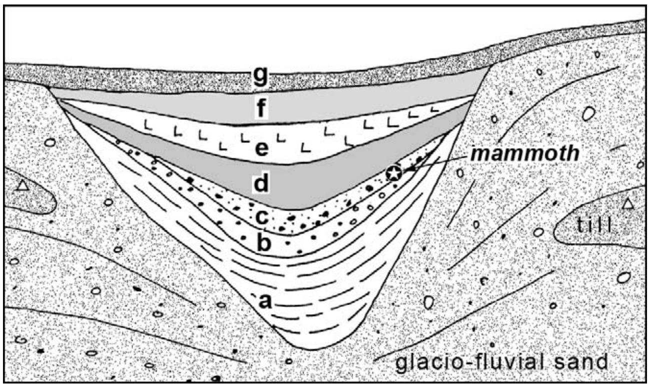

Figure 5. *Schematic profile through the kettle hole sediments; lithologies as in the text (after Lister 1993).*

The Condover mammoths

The preliminary report on the discovery of Mammuthus primigenius (Blumenbach) was by Coope and Lister (1987), along with a commentary from a North American perspective (Saunders, 1987). Subsequently, some details were amplified and modified as the analysis progressed (Lister, 1993; Lister & Bahn, 1995). About 400 disarticulated bone fragments were finally recovered from the dumped overburden debris. These represent the mainly complete bone kit of one adult male (without the skull, which was mysteriously missing; Fig. 6) and at least three youngsters - on the basis of three lower jaws. The adult male is estimated from size and wear of the lower teeth to have been close to 28 years of age, and the juveniles were between 3 and 6 years old. Since elephant siblings remain with their mother rather than their father, by analogy it appears likely that the mammoths at Condover were unrelated; this banishes romantic notions of a family group becoming stranded and perishing. The presence of fly and beetle fossils within the bone cavities, each signifying rotting fresh and dung, suggests that the carcasses were exposed for a period before sinking into the kettle fill.

Conclusion

At the maximum extent of glaciers during the Last Glacial Maximum, around 20,000 years ago, most of south Shropshire was covered by a major ice sheet. Initially this ice advanced from the north, and the generally red-brown colour of the Stockport Formation reflects the nature of the rocks over which the ice flowed. During the ice retreat a substantial thickness of till accumulated, along with outwash sands and gravels much of which was within ice-walled depositional sinks. Major blocks of glacial ice became buried in the outwash, and the overlying sedimentary cover retarded their wastage. In the Shrewsbury area, shortly after the loss of active northern ice, ice extending out of Wales (via the Upper

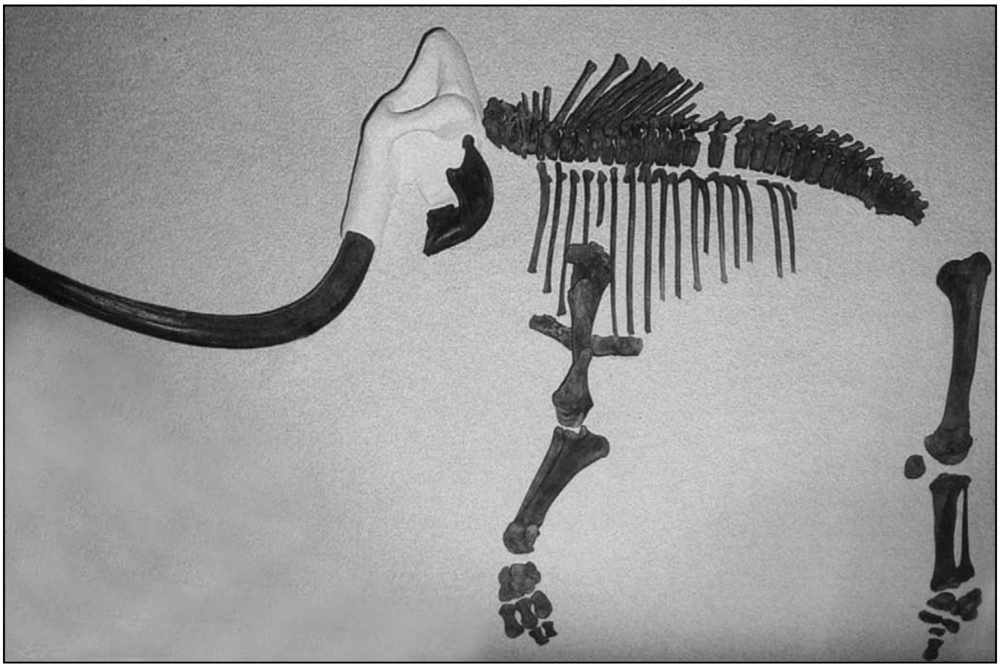

Figure 6. *The assembled left side skeleton of the adult mammoth; the white plaster represents the missing skull. The bones are now kept in the Ludlow Museum.*

Severn valley) deposited grey glacial till and outwash (Shrewsbury Formation) over the earlier till and outwash sediments.

Following Welsh ice retreat, the climate improved and the buried blocks of northern ice melted out to create the kettle holes and other ice-contact features that characterise the Condover landscape today. Concurrently sub-aerial drainage, some originating beyond the glaciated area, extended across the progressively draining lake basins. The flood-gravels mark the courses of these early periglacial rivers. Since these gravels are not pitted by kettle holes, it is surmised that the buried glacial ice had largely if not entirely disappeared before the flood gravels were deposited. Many of the kettle holes initially contained lakes, and these have subsequently become repositories of infill sequences containing records of environmental change, many of which extend through to the present day. Only the larger kettles have remained flooded until the present day, the remainder having been largely infilled and converted to swampy ground. At Norton Farm, one of these infills of late glacial age contained the remains of mammoths and it is possible that others remain to be discovered.

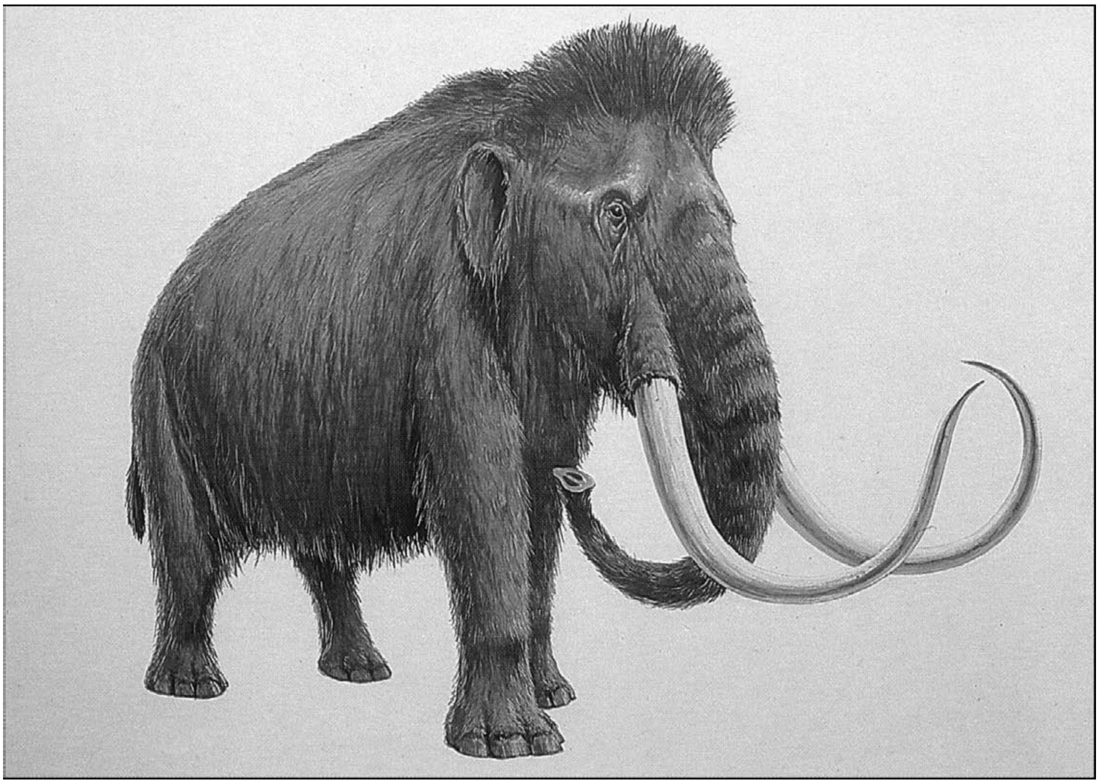

Figure 7. *Reconstruction of the adult mammoth. The original model is now at the Discovery Centre, in Craven Arms.*

Acknowledgements

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Peter Worsley
Oxford University Centre for the Environment
South Parks Road, Oxford OX1 3QY
peter.worsley@ouce.ox.ac.uk