

A palaeoenvironmental reconstruction of the Late Devensian sediments at Bromfield Quarry, Shropshire

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TROMANS, D.¹ (2017). A palaeoenvironmental reconstruction of the Late Devensian sediments at Bromfield Quarry, Shropshire. *Proceedings of the Shropshire Geological Society*, **18**, 53–60. Bromfield Sand and Gravel is a working quarry extracting a series of Devensian glacial outwash sediments. This study provides an insight into the origin, transportation and depositional environments of these glacial outwash sediments. It is believed that the sediments at Bromfield were derived from the Welsh and Irish Glacial Ice Sheets, from the west and north respectively, transported through the Onny and Stretton valleys via high energy glacial meltwater river systems, to be deposited at Bromfield.

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INTRODUCTION

Bromfield Sand and Gravel quarry in South Shropshire exposes fluvioglacial sediments. During the Late Devensian the area would have experienced the effects of glaciation by the Welsh and Irish Sea Ice Sheets, deposits of which now cover the county between Shrewsbury and Ellesmere (Chiverrell & Thomas, 2010). Furthermore, Shropshire experienced the impact of two independent ice masses: the Irish Sea Glacier and the Welsh Ice Cap (Thomas, 1989). Shropshire in terms of palaeoglaciology and Quaternary sediments hosts potentially some of the clearest evidence for these events in the UK.

The study area at Bromfield is the new excavation alongside the A49, started in 2007 (Figure 1). Observations within the older parts of the quarry have been previously carried out by Rosenbaum *et al.* (2006; 2007). Their work provides much of the background for this paper, detailing observations and providing interpretations of the late glacial evolution at Bromfield.

Three sampling sites were selected within the new quarry (Figure 1).



Figure 1. Location of the three study sites (numbered 1, 2 and 3) at Bromfield Sand and Gravel quarry (based on Google Earth imagery, 2016). The A49 trunk road is located to the lower left of the view.

Site 1: 52°23'31.45" N, 2°46'23.86" W – Grid Reference: SO 47459 77400

Site 2: 52°23'32.21" N, 2°46'24.12" W – Grid Reference: SO 47474 77427

Site 3: 52°23'30.43" N, 2°46'21.83" W – Grid Reference: SO 47514 77362

GEOLOGICAL SETTING

The Superficial deposits at the Bromfield Sand and Gravel Quarry are underlain by Bedrock comprising the Raglan Mudstone Formation [423–419 Ma], an Upper Silurian stratum of Downtonian age within the Přídolí Stage (BGS, 2000). The Raglan Mudstone Formation is comprised of a series of sandstones and siltstones that are derived from a fluvial channel environment. Above this lie the Superficial deposits comprising fluvial sands and gravels which are of Late Devensian age. The origin of these clastic sediments is believed to have been from the Onny Valley to the North West, having been transported by glacial meltwater in channels fed by the Welsh Ice Cap.

The Late Devensian extends from 28 Ka to 18 Ka, with the maximum extent of the British-Irish Ice Sheet taking place during this period. During this time the Welsh and Irish Ice Sheets extended as far as North Shropshire where the ice stagnated, notably in the vicinity of Shrewsbury. Subsequent melting (“retreat”) occurred to such an extent that the area was not re-glaciated during the Windermere Interstadial c. 11 Ka (Toghill, 2006). Glacial ice did not extend further south, but to the south and west of Ludlow two glacially dammed lakes have been recognised: Wigmore and Orleton (Hodgson, 1972; Rosenbaum, 2006). This supports the hypothesis that the quarry deposits are a consequence of glacio-fluvial action. However whether this was from the south or north is to be determined.

The two hypotheses for the depositional environment of the sands and gravels infer similar modes of transportation. However, different origins of the sediment are invoked. The Church Stretton and Onny Valley meltwater channels flowed south and south eastwards respectively, originating from the Irish Sea and Welsh Ice sheets (Figure 2). These sediments contain erratics from as far as North Wales and Scotland: fragments of granite and rhyolite (Toghill, 2006) (Figure 3).

The lithologies of the fluvio-glacial sediments are varied, clasts including: siltstone, sandstone, limestone, quartz and shale. Field work carried out by Rosenbaum (2006) identified more clasts: conglomerate, quartzite, dolerite, rhyolite, andesite, vein quartz and granite. The presence of these clasts and their likely origin indicate a heterogeneous mix, which would support the

hypothesis of transportation by glacial meltwater channels from the North West.

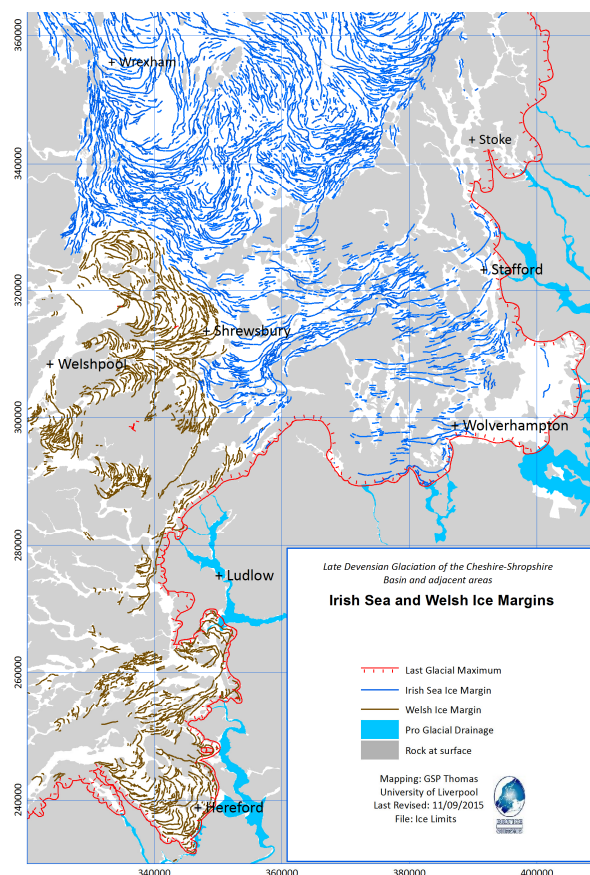


Figure 2. Irish and Welsh Ice margins in Shropshire (Thomas, 2015).

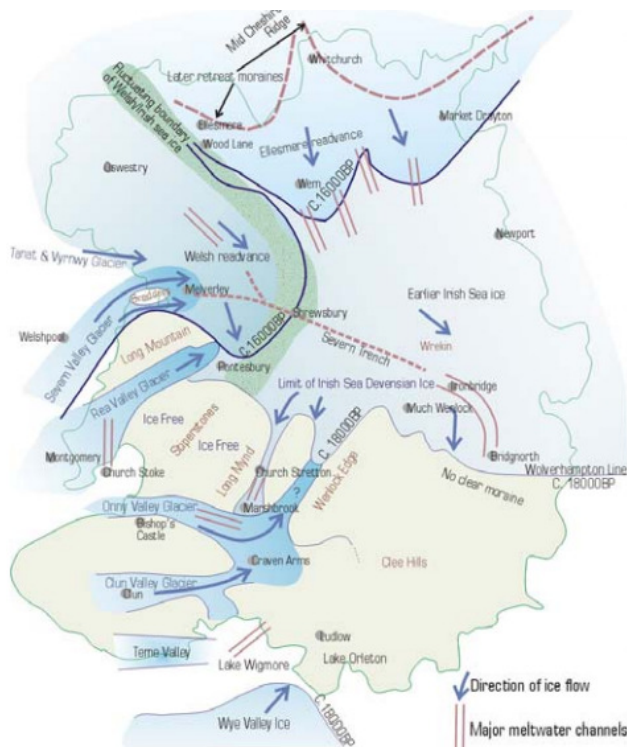


Figure 3. Ice margins and flow regimes of meltwater channels in Shropshire (Toghill, 2006).

Conversely, there is an alternative hypothesis, that the sediments may have originated from the South as a result of Lake Orleton overflowing through Ludlow northwards, potentially reaching as far as Bromfield and at its greatest extent as far as Onibury, suggests that there may have been flow in the opposite direction (mentioned in Rosenbaum & Wilkinson, 2006). The plausibility of this second theory is supported by the presence of varved lacustrine clays at the base of the sands and gravels within the old quarry. This basal bed of clay is approximately 0.1 m thick, possibly deposited by Glacial Lake Orleton. Equally likely is that the presence of varved clays may have been deposited in small pools or even relict oxbow lakes.

The fieldwork noted the presence of large boulders in the matrix of the fluvioglacial sediments; one of these boulders was composed of Wenlock Limestone (Rosenbaum, 2006). This would suggest an origin from the North-West, North or North-East, but the fluvial energy to transport them would have had to be much more than the present-day river could sustain. One possibility is flow of fluvioglacial water through Corve Dale, fed by periglacial movement down the valley sides (Rosenbaum, 2006).

LITHOLOGY OF CLASTS

The research has not revealed many detailed sedimentological studies of clasts in South Shropshire, despite extensive examination of the stratigraphy (Cook, 2010). The most thorough study was undertaken by Peter Cross, including Bromfield quarry next to the now closed Bromfield railway station (Cross, 1971).

At each of the three sampling sites (Figure 1), 90 clasts in total were analysed, 30 from each site and 10 from every other metre in the section. The observations on the clasts were: clast roundness, orientation, sorting and shape.

Initially 10 clasts from a metre section of the 6 m long section at each site were analysed. Their orientation was determined *in situ* using a compass clinometer measuring the dip and strike of each clast. This enabled determination of the trends in the clast orientation. The outcome of this study helped to determine a North Eastern trend for the clasts, which would support an origin of the large Wenlock Limestone boulders from the direction of Corve Dale (Figure 7).

After the orientation had been determined the clasts were then removed from the section and measured in their axial planes: a, b and c. These planes are representative of length, width and depth in order of: a, b and c. The shape of the clast helped to identify the possible flow regime that deposited the sediment.

Clast shapes were determined using the method suggested by Sneed and Folk (1958), using tri-plot diagrams to determine one of four shapes: compact, platy, bladed and elongate. These shapes were then matched to the standardised names for clasts as published by Tucker (2001).

For ease of comparison between the Sneed and Folk classifications, and the standardised names for clasts, the names are given again on the following page.

Site 1 Sedimentary Logs

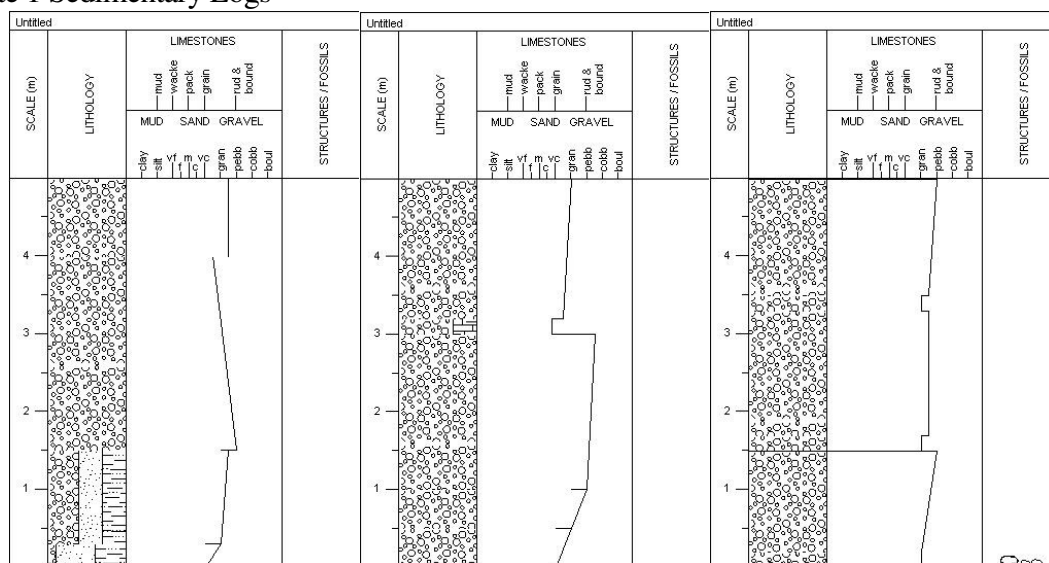


Figure 4. Logs of the three individual metre sections at Site 1.

Site 2 Sedimentary Logs

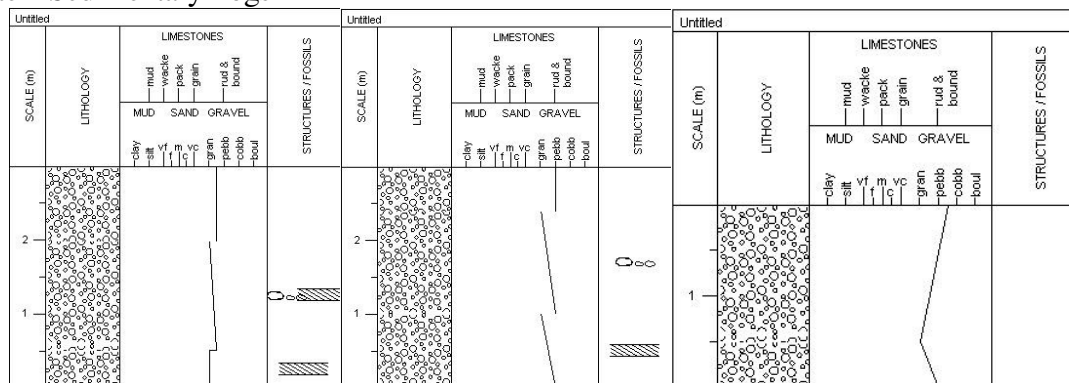


Figure 5. Logs of the three individual metre sections at Site 2.

Site 3 Sedimentary Logs

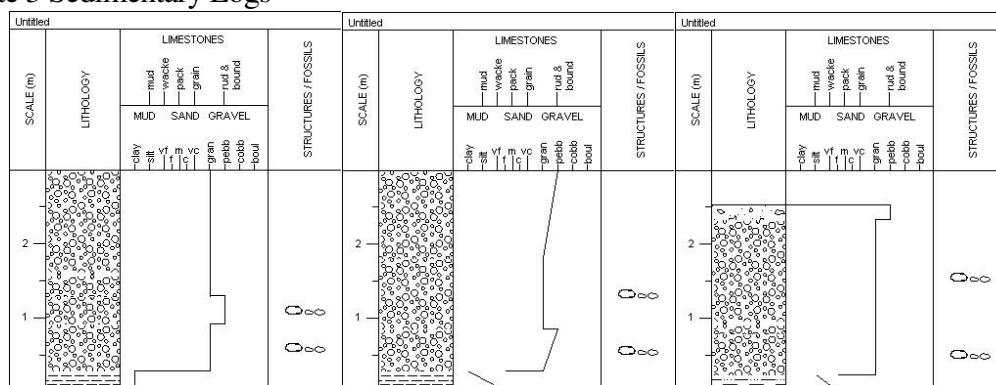


Figure 6. Logs of the three individual metre sections at Site 3.

Key:  Imbrication  Cross Bedding

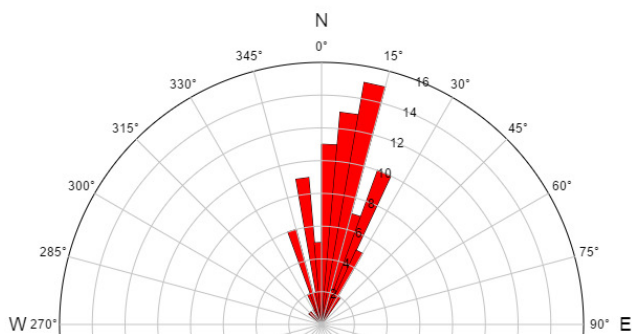


Figure 7. Clast orientation comparison for all three sites, showing a dominant NNE trend.

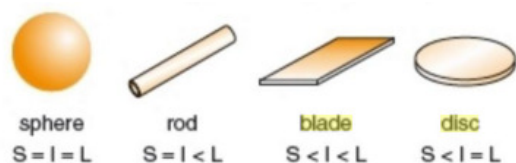


Figure 8. Clast shapes as they would appear in a Sneed and Folk tri-plot (Tucker, 2001).

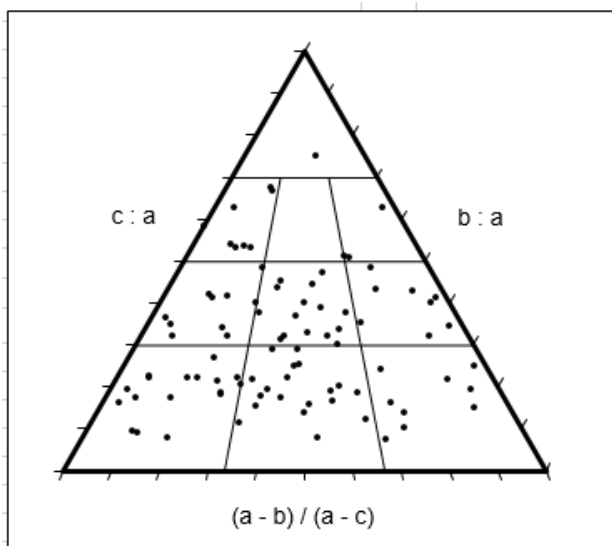


Figure 9. Triangle plot for 90 clasts sampled across the three sites.

Table 1. Sneed and Folk Classes for 90 clasts with bladed and platy dominant clasts present.

Sneed & Folk classes		
	Count	Percent
Compact	1	1.11
Compact-Platy	8	8.89
Compact-Bladed	1	1.11
Compact-Elongate	2	2.22
Platy	10	11.11
Bladed	15	16.67
Elongate	8	8.89
Very-Platy	17	18.89
Very-Bladed	19	21.11
Very-Elongate	9	10.00

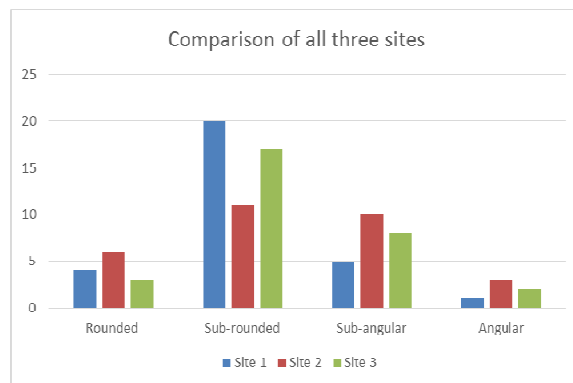


Figure 10. Clast roundness totals for each of the three sites, showing a sub-rounded majority.

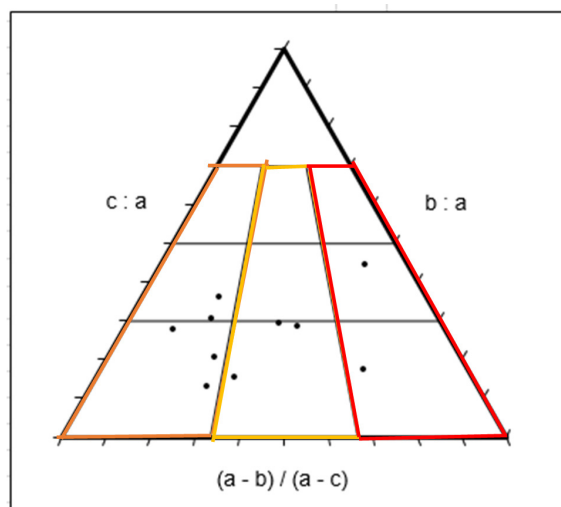


Figure 11. Tri-plot of the large *ex situ* boulders.

Table 2. Percentage distributions of *ex situ* boulders.

Sneed & Folk classes		
	Count	Percent
Compact	0	0.00
Compact-Platy	0	0.00
Compact-Bladed	0	0.00
Compact-Elongate	0	0.00
Platy	2	20.00
Bladed	0	0.00
Elongate	1	10.00
Very-Platy	3	30.00
Very-Bladed	3	30.00
Very-Elongate	1	10.00

Roundness of each clast was observed once measurements of the dimensions had been undertaken, placing them into four classes (Figure 10).

Roundness indicates the distance that the sediment has travelled from its origin. In addition it also indicates an erosional force acting on the sediment and what the source of that erosion might be. 61 out of the 90 clasts sampled are rounded to sub-rounded, indicating that these clasts were affected by fluvial forces, most likely glacial meltwater coming from the North or North-East.

Sieving of the sediment was undertaken after clast analysis, providing an indication of the degree of sediment sorting and the possible depositional processes. Three samples of sediment each of one Kg weight were collected from each one metre section of each site, providing 27 samples altogether. The sieving process involved using a set of sieves ranging from -4.0 to 3.0 phi. Each sieve was weighed whilst empty and then again after sieving had been conducted. The values were then subtracted from one another to provide a true weight of the sediment.

The values obtained by sieving were then analysed using 'Gradistat'. This software, developed by Blott and Pye (2001) of Royal Holloway University, provides a method for grain size analysis. It uses the Folk and Ward methods, similar to that for the grain shape, to determine descriptive names for sediment types.

The outcome of the Gradistat statistics shows that the sediment at Bromfield quarry is a poorly sorted homogenous mix of fine to coarse gravels. This is supported by further statistical analysis of the sediment as produced by Khan and Aziz (2015). Folk and Ward produced a series of statistics from the sieved sediment data, which can then be plotted and compared to boundaries for glacial sediments as determined by Khan and Aziz (2015). This showed that the sediments were consistent with being fluvioglacial, with a small trend towards fluvial.

LARGE BOULDERS

Large *ex situ* boulders were first mentioned by Rosenbaum (2006), observing them at the side of the excavation pit. While undertaking field work ten of these large *ex situ* boulders were measured using the same method as for the clasts. The dimensions were then input in the tri-plot to describe the shapes of these boulders. From this it

was then possible to infer a mode of transport and depositional environment for these boulders.

As can be seen (Figure 11 and Table 2) the majority of the large boulders are very platy or very bladed (60%). The other 4 samples (40%) were elongate or platy. The general trend suggests that these boulders were transported by fluvial action, while having travelled a considerable distance to create the more extenuated shape of the platy and bladed clasts.

These may originate from the Wenlock region, transported through the Onny Valley to the Bromfield site, possibly during a high energy flood event. The theory for ice rafting to transport the large Wenlock Limestone boulders would contradict the evidence that ice did not reach the region, the stratigraphy shows fluvial structures with cross bedding, imbrication and sub-rounded clasts. It may be noted that the geological map shows glacial till at Stanton Lacy (British Geological Survey, 2000), but perhaps this was deposited during an earlier glaciation (?Anglian) and not related to the outwash sediments exposed at Bromfield.

CLAY LAYER

Observed at Site 3 during field observations, at the base of the section, was a 3 m long clay layer. The position of this layer within the stratigraphy suggests an early deposit before the Late Devensian meltwater channels were formed.



Figure 12. Clay layer observed at Site 3; trowel for scale.

Figure 12 was taken facing South-West within the new excavation, at the base of Site 3. The layer measures approx. 0.28 m in height and 3 m in length.

Additionally, the nature of this clay layer suggests a low energy environment of deposition compared with the sands and gravels overlying this layer. Graded bedding is present within, from

a very fine sand down to clay at the top of the layer, supporting deposition under fluvial or lacustrine conditions, possibly a tributary or pool within the fluvio-glacial system.

DISCUSSION

The supporting evidence from the clast orientation, roundness and sorting suggests that the sediments at Bromfield are derived from the Welsh Ice Sheet, having been transported by a high energy fluvial system. A flood event is possible to explain the large boulders observed. Unfortunately none of the large boulders were observed *in situ* and it remains to be determined how they fit within the stratigraphy.

Evidence for transportation under fluvial action comes from the imbrication of the sediment clasts. Cross bedding provides additional evidence of fluvial action, along with the sub-rounded nature and platy/ bladed shapes of the clasts. The shape of the clasts appears to be the result of planar weathering from a uni-modal fluvial regime, in this instance the glacial meltwater flowing from the Onny Valley. The cross bedding in particular stretches across 3 m of site 2, suggesting a large current change during deposition of the sediment; this may also account for the poor sorting.

Lithology of the clasts supports a Welsh Ice Sheet origin. However; the large boulders of Wenlock Limestone are more likely to have been derived from a North-Easterly direction. The far-travelled clasts of rhyolite and granite suggest that the sediments at Bromfield have been re-worked during transportation, which would support initial transport by glaciers and then along meltwater channels.

CONCLUSIONS

In conclusion it is suggested that the North/North-Easterly orientation of the clasts provides evidence for an Onny Valley origin of the sediment at Bromfield Quarry. However, there remain unanswered questions regarding the provenance of the erratics, especially the large boulders.

ACKNOWLEDGEMENTS

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REFERENCES

- Blott, S.J. and Pye, K. (2001). GRADISTAT: A grain size distribution and statistics package for the analysis of unconsolidated sediments. *Earth Surface Processes and Landforms*, **26** (11), 1237–1248.
- British Geological Survey (2000). *Geological Map at a scale of 1: 50,000 for Geological Sheet 181 (Ludlow)*. HMSO.
- Chiverrell, R.C. and Thomas, G.S.P. (2010). Extent and timing of the Last Glacial Maximum (LGM) in Britain and Ireland: a review. *Journal of Quaternary Science*, **25**, 535–549.
- Cook, S.J. (2010). The glacial geology of Shropshire: insights from modern glaciology. *Proceeding of the Shropshire Geological Society*, **15**, 20–27.
- Cross, P. (1971). *Glacial and proglacial deposits, landforms and river diversions in the Teme Valley near Ludlow, Shropshire*. unpublished PhD thesis; University of London (University College), 407 pp.
- Google Earth (2016). Google [online] available at <<https://www.google.com/earth/>>
- Hodgson, J.M. (1972). *Memoir and accompanying map for one-inch Soil Survey Sheet 181 (Ludlow)*. HMSO. 139 pp.
- Khan, A.A. and Aziz, M. (2015). A critical analysis of statistical parameters of the Quaternary deposit of Homonid locality, Hathnora, Narmada Valley, District Sehore (m.p). India. *Journal of Agriculture, Forestry and Environmental Science*, **1**, 17–29.
- Rosenbaum, M.S. (2006). Field Meeting Report: Bromfield Sand and Gravel Pit, nr Ludlow, Shropshire, led by Ed Webb, 22nd April 2005. *Proceedings of the Shropshire Geological Society*, **11**, 12–17.

- Rosenbaum, M.S. & Wilkinson, W.B. (2006). A Geological Trail for Titterstone Clee and Clee Hill. *Proceedings of the Shropshire Geological Society*, **12**, 18–48.
- Rosenbaum, M. S. (2007). A geological trail in front of the last glacier in South Shropshire. *Proceedings of the Shropshire Geological Society*, **12**, 56–69.
- Sneed, E.D. and Folk, R.L. (1958). Pebbles in the lower Colorado River, Texas, a study of particle morphogenesis. *Journal of Geology*, **66**, 114–150.
- Thomas, G.S.P. (1989). The Late Devensian glaciation along the western margin of the Cheshire-Shropshire lowland. *Journal of Quaternary Science*, **4**, 167–181.
- Toghill, P. (2006). *Geology of Shropshire*. 2nd edn. The Crowood Press: Marlborough.
- Tucker, E.M. (2001). *Sedimentary Petrology*. 3rd edn. Blackwell Science Limited, Oxford.