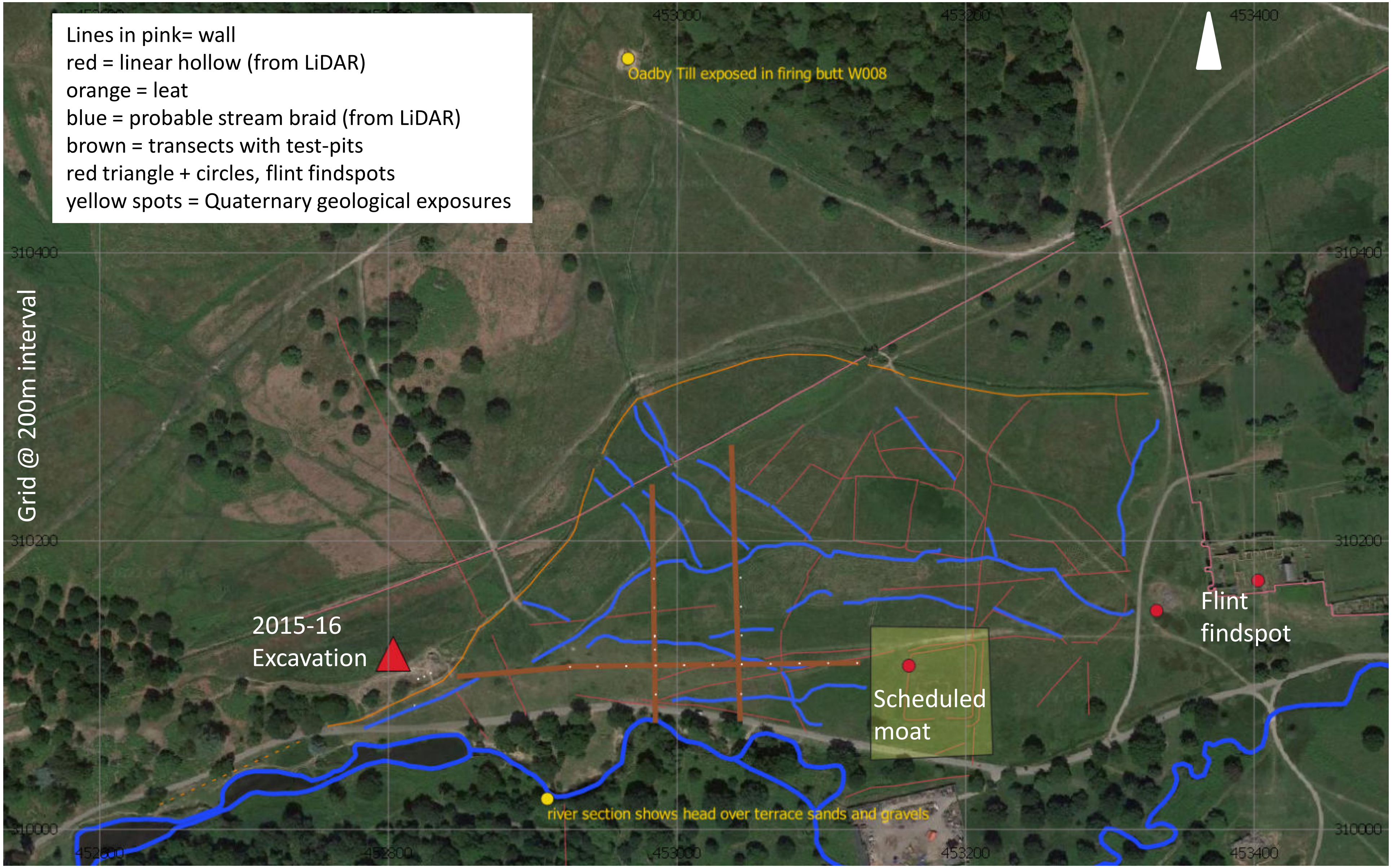
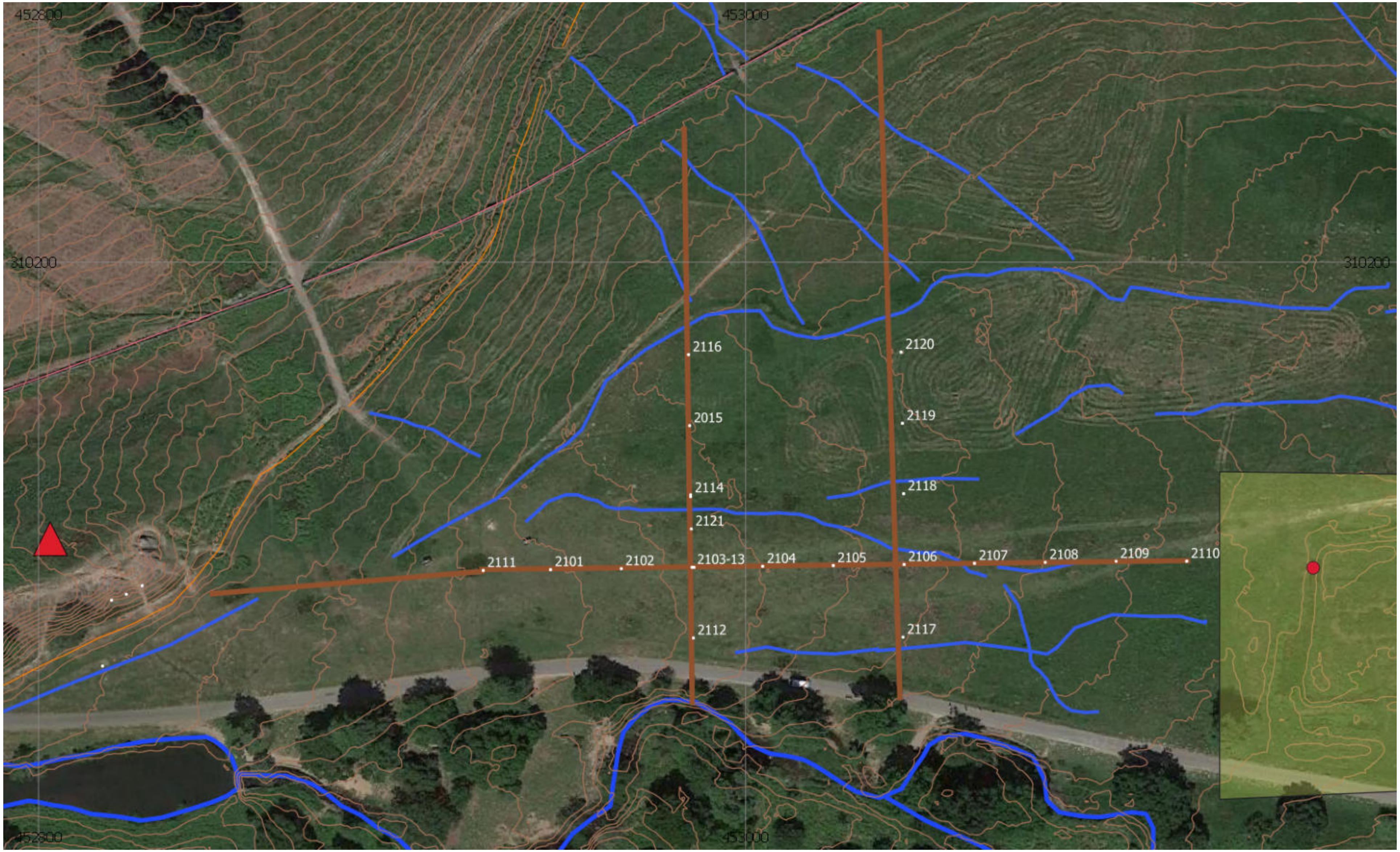
Google Earth



Bradgate Park Lawns- supplementary information/notes on the geology and sediments

Daryl Garton, Colin Baker, Lynden Cooper and Richard Tyndall

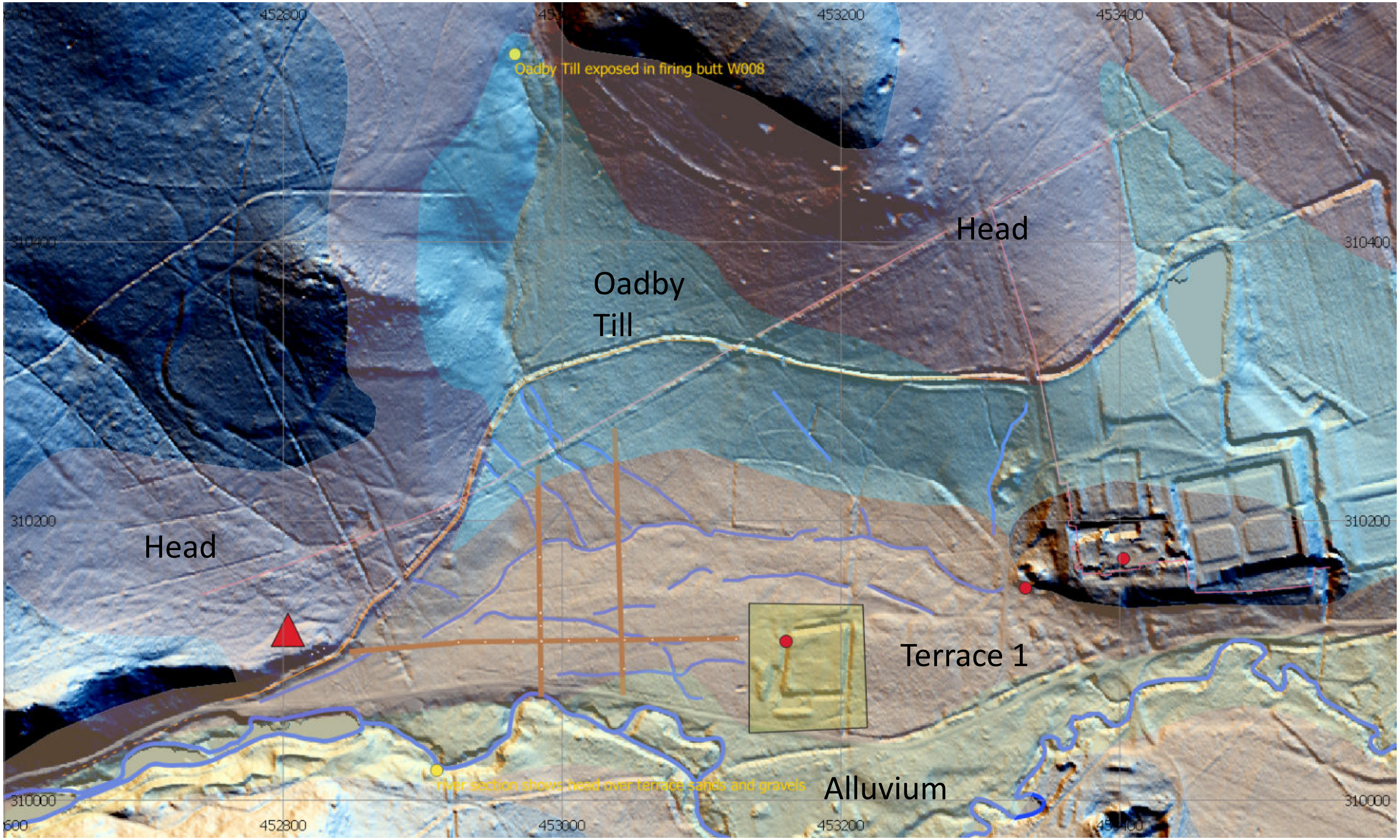


Test pit locations, contours from 1m DTM LiDAR at 0.5m vi

Topography

Test pits were set out in a H shape across the Lawns (p.1,2), between the Scheduled Moated site (buff) and the aquaduct [orange line] E of the 2015-16 excavated LUP campsite (Red triangle). The Lawn lies within a bowl with rising ground to W, N and E, and is slightly higher than the floodplain of the current River Lin to the S. Contours at 0.5m vertical interval (brown, generated from 1m DTM Environment Agency LiDAR) and GPS ground survey of two N-S transects (brown lines) show that the ground is very slightly convex N-S, and slopes gently down from W to E. The N edge of the bowl is marked by lower ground within which is a continuous stream hollow (mid-blue line north of test-pits 2116/2120) running to the E; other short stretches of linear hollows/probable streams (mid-blue lines) between this stream and the River Lin can be identified in the LiDAR processed for multi-hillshade indicating probable braided streams across the floodplain.

Three lines of test pits were excavated, all (0.5x0.5 to 0.5m deep) with most at 20m intervals.   Once turf removed, all sediments sieved through a 10-11mm sieve mesh, and all stone collected together - photo'd to show approx quantity and range. N face of each pit also photo'd and drawn at 1:10. Despite heavy rain the day prior to opening any test pits, the sediments were very dry.



BGS digimap of superficial deposits (https://geologyviewer.bgs.ac.uk/)
over LiDAR (1m DTM processed with Relief Visualisation Toolbox multi-hillshade, x5vi)

Local Quaternary geology
For overall geology see Carney 2010 and Worssam and Old 1988. For a chronological table (compiled by Colin Baker), see p.6.

In the Lawns area, the limits of the Terrace deposits mapped by BGS follow the surface morphology (p.4). The Terrace runs from the roadway atop the slight break in slope just N of the River Lin to beyond the N stream-braid [mid blue line] where the ground slopes up more steeply to the north. This represents a high energy flow when the river was swollen by periglacial meltwater during or at end of MIS2 glaciation (LGM), debouching from the mouth of the Little Matlock Gorge into the bowl within the Precambrian/Triassic bedrock.

The River Lin is a tributary of the Soar, joining it at Quorn, and feeding the Cropston and Swithland Reservoirs downstream of our testpits. BGS [2010: Coalville 155] map the River Terrace deposits within Bradgate Park as Terrace 1. 'The first Terrace generally lies 1 to 1.5m above the floodplain of each stream, and is probably late Devensian to early Flandrian in age' [Worssam and Old 1988, 102]. The river section described below (p.7-8) suggests that this 1st Terrace (and the overlying Head) was deposited during the LGM.

In the Soar the sequence of Upper Pleistocene terrace deposits are mapped as Knighton, Birstall, Wanlip, Syston (Bridgland et al. 2014, Fig. 2.15; Plate 2). Brown et al. (1994) dated samples from the Syston Terrace deposits at Pontylue (close to the Soar-Lin confluence) to 28,875±205 BP which calibrates to 33,387±368 cal BP (Westaway et al 2015, fig. 6) suggesting that this was deposited as a cold river terrace towards the end of MIS 3 (MIS 2 commencing at 29 ka). The Syston Terrace is usually attributed to MIS2 and correlated with the Holme Pierrepont Terrace of the Trent (Bridgland et al. 2014, 90-91; Cooper 1997, table 2) – see p.7.

	MIS stages (Lorraine Lisiecki website)	Marine Isotope Stages (BGS)	British substages		Start date (ka)- warm and cold phases	Greenland stadials (GS) and interstadials (GI) (Rasmussen et al 2014)	4 phases of periglacial activity in East Anglia (Bateman et al2014)	Bradgate sequence	Soar and Trent terraces
Holocene	MIS 1	MIS 1		Holocene	11.7				Quorn and Hemington
Late or Upper Pleistocene			Late Devensian	Younger Dryas	12.9	GS-1	11-12ka ●	Periglacial activity Solifluction (head) Wind processes?	HPSG-B
	14*	14*		Windermere Interstadial	14.7	GI-1		LUP activity	
	MIS 2	MIS 2		Dimlington Stadial or LGM		GS-2a (17.5)	20-22ka ●	Periglacial activity Solifluction (head) Wind processes? River terrace 1	Syston and HPSG-A
						GS-2b (21.0)			
					23.0	GS-2c (23.0)			
		24			23.5	GI-2			
					27.5	GS-3			
	29			29	29.0	GS-4			
	MIS 3	MIS 3	Middle Devensian	Upton Warren Interstadial (29-40)	32.0	GS-5	31-35ka ●		
					32.5	GI-5			
					33.5	GS-6			
					34.0	GI-6			
					35.0	GS-7			
					35.5	GI-7			
					37.0	GS-8			
					38.0	GI-8			
					41.0	GS-9/10			
					41.5	GI-10			
					42.5	GS-11			
					43.5	GI-11			
	57	59	59		etc		55-60ka ●		

- *Some disagreement over the exact start of MIS 1 (Railsback et al 2015). The Younger Dryas is an unusual meltwater-forced cooling event that does not show up in marine cores. Hence the disparity. Informally MIS 2 should include the cold Younger Dryas in the Pleistocene, and MIS 1 should mark the Holocene warming at 11.7ka rather than the Windermere Interstadial at 14.7ka.*

The Quaternary geology is exposed in two places (p.8, located on p.1):

- In the shooting butt to the north of the Lawns SK5296-1053 – with flint and quartzite pebbles, and mapped as Oadby Member diamicton/till by BGS
- To the south of the Lawns in the Lin riverbank section at SK 5921-1002

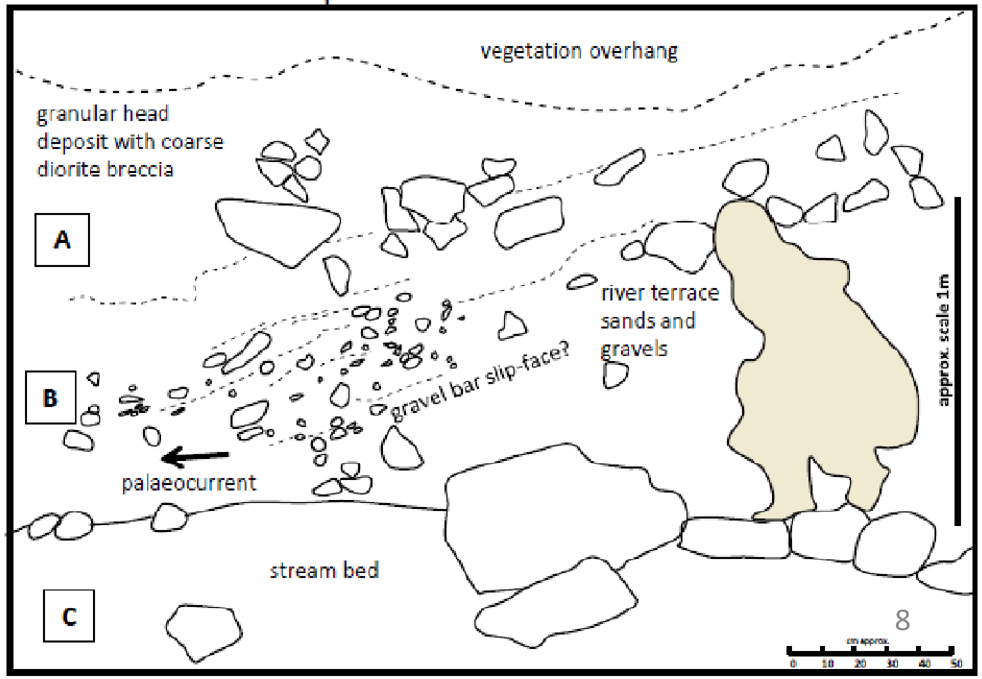
The riverbank section (as exposed, no cleaning) shows gravels some 0.3-0.4m thick overlain by some 0.8m of coarse, granular, head.
(A) overlying coarse granular head: with angular and sub-angular diorite cobbles and boulders (clasts 8-40cm) in red sandy Mercia Mudstone matrix.
(C) residual angular/sub-angular boulders of diorite fallen into stream bed (clasts 25-75cm)
(B) current-bedded terrace sands and gravels: rounded, sub-rounded and sub-angular coarse gravel (clasts 5-12cm) in sandy matrix; coarse clasts are mixed and loosely clustered, including rounded quartz (and diorite?) pebbles and elongate sub-angular stones (Bradgate Formation slate?). Elongate stones appear to run parallel to bedding planes, suggesting a slip-face at the front of a gravel bar advancing right to left (west to east) in keeping with the most likely palaeocurrent through the Little Matlock Gorge.

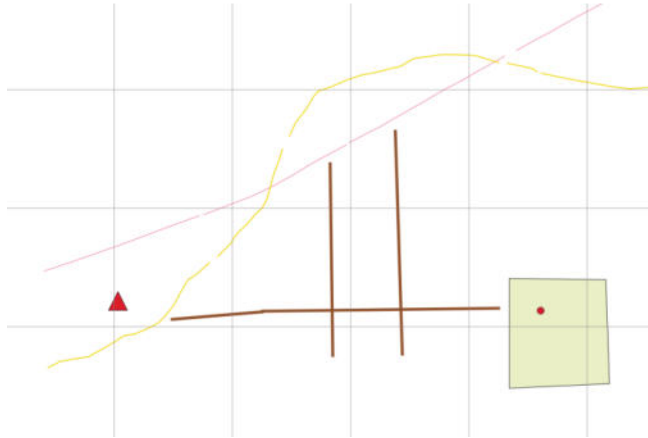
Further E along the river, and high in the sequence/just below the surface, deposits of a sandy loam with small-medium pebbles could be seen in patches – the sand component was coarser than that seen in most of our test pits. This horizon is assumed to be Holocene alluvium.

Oadby Member (diamicton/till exposure in shooting butt at SK5296-1053

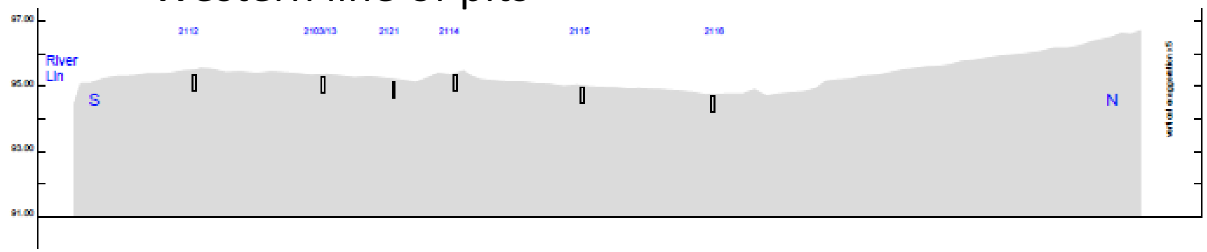
River Lin river bank GR 45291, 31002

Interpretation of the section

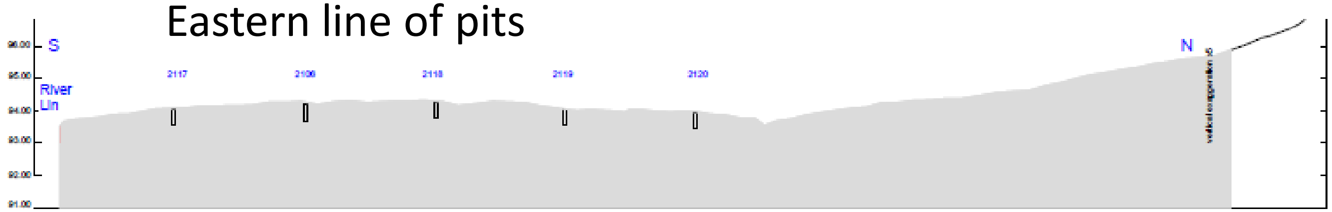




Western line of pits

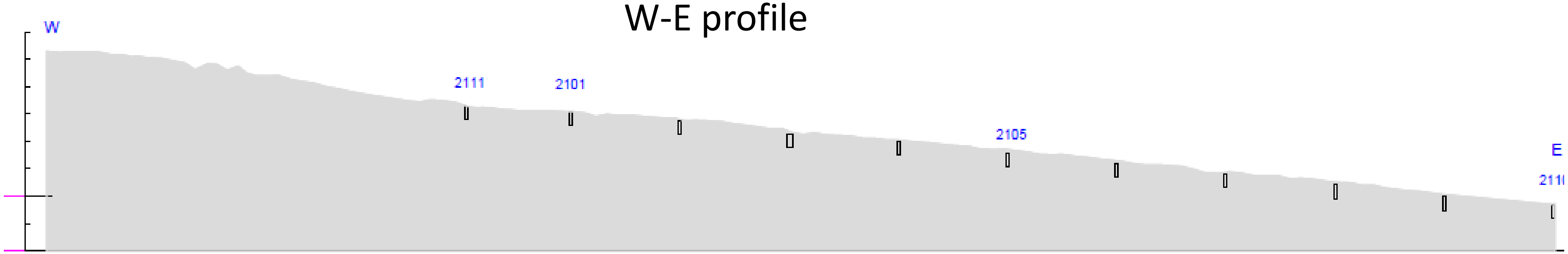


Eastern line of pits



Height exaggeration x5

W-E profile



Profiles with locations of test pits

Table summarizing features of the sediment horizons

Horizon	Dominant features with that horizon	Test pit numbers
Topsoil	Biologically sorted	2101-2105
	Pebbly/disturbed	2112, 2119, 2121
	Clay inwashing?	2111, 2116
Subsoil	Unsorted colluvium/head	All bar 2121
	Silt layer (sorted)	2121
	Breccia dominated	2106?, 2114, 2115, 2116
Terrace	Sandy gravel	2112

The sediment in most of the pits was consistently assessed in hand sample as an uncohesive silt to fine sand [which flowed freely through the sieves] and which formed the uppermost deposit and the matrix around the variable amounts of clasts. In pits 2118-2120, it was the dominant constituent, and, in 2119, was proved by augering up to 1m deep.

Only in pit 2121 was the silty sediment described as 'stone-free' (0.09m exposed at the base of the pit). This pit lay close to a mapped stream braid and possibly indicates some superficial sorting of sediment. It was at the top of this 'stone-free' silt that a struck flint was recovered.

Test-pit 2112 had unsorted colluvial/head deposits in a silt matrix overlying coarser-sand gravels. A similar sequence was observed in the River Lin some 105m to the SW (p.8); though there, the overlying colluvium/head was thicker, and included angular, rather than sub-angular, clasts – presumably reflecting differences in the country rock on the S side of the gorge.

Clasts

Rock types include :

•Flint - frost fractured and with variable surface condition, mostly below 2-3cm max dimension, largest piece some 8cm long from 2106.

•Black chert – all rolled/rounded and small [<4cm]

•Rounded pebbles of quartz and pebbles and cobbles of quartzites [max. dimension 10cm] – probably ultimately from Triassic deposits. No cobbles with indications of wear/batter noted.

• Sandstones and 'Skerry' [tabular, sub-rounded fragments of green banded siltstones, probably from Mercia Mudstones]

•Igneous rocks with sub-angular to angular arretes (presumed South Charnwood diorites and/or Bradgate/Beacon Hill volcaniclastic-siltstone [max dimension exposed rock was some 35 cm in 2107, >50cm in 2112]. Most common rock type, and could be recovered as dense accumulations.

•Kaolinite-like lumps, soft and easily squashed (<5cm, recognised in sieved deposits only) = deeply weathered igneous (cf. Ford 1967, 8-9).

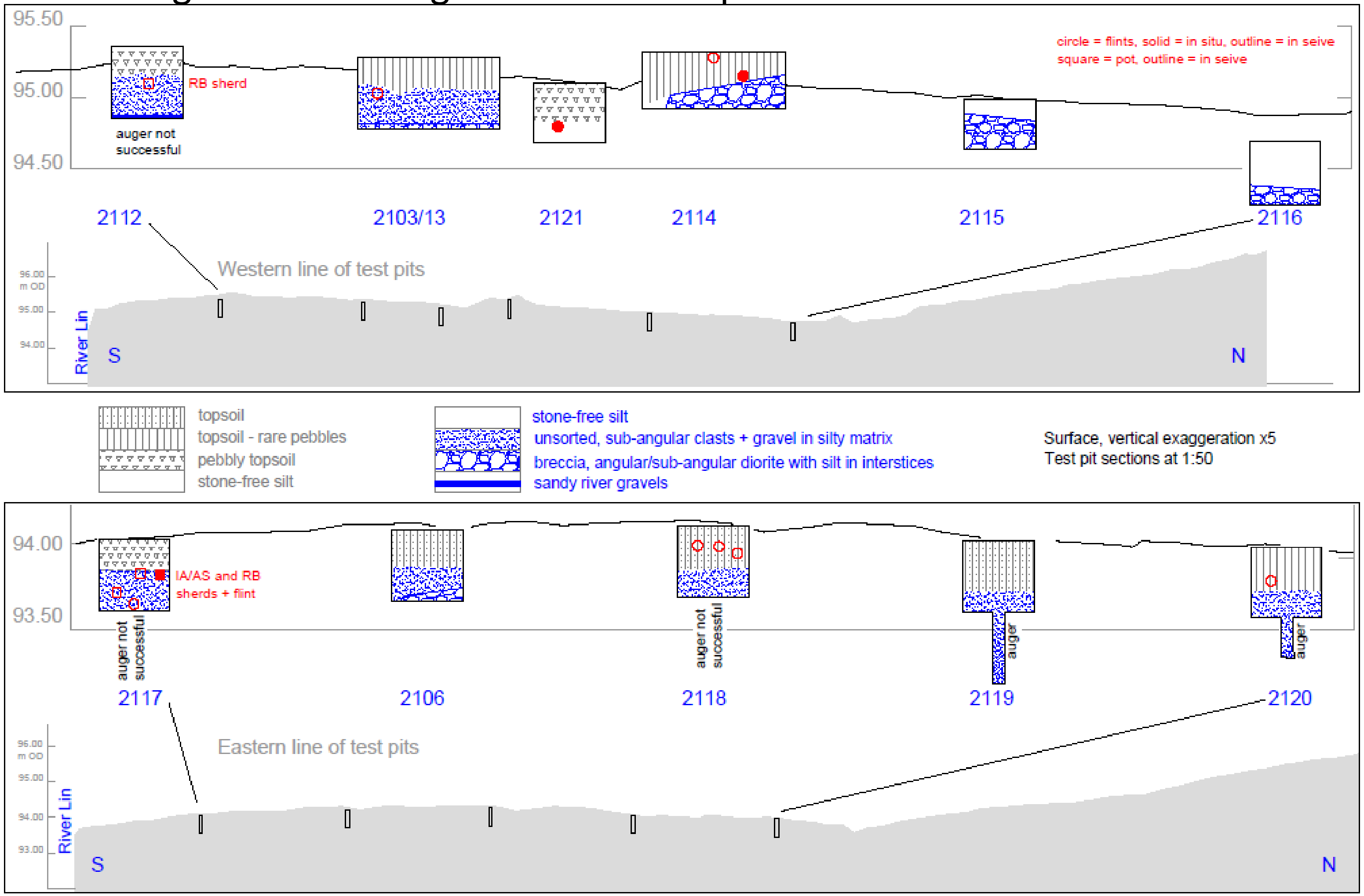
The quartzites, sandstones/skerry and flint/chert were mostly only common in the uppermost deposits of the pits.

All our test pits included a heterogeneous mixture of clast types and sizes, ranging from angular to rounded within a fine-sand silt matrix. No bedding structures or obvious grading of sediment size was recognised. The unsorted nature of this deposit suggests a colluvial or head deposit from periglacial conditions. The non-durable kaolinised diorite pebbles in our samples, locally-derived from contact with Mercia Mudstone (Ford 1967, 8-9), are indicative of short-distance transport, perhaps unlikely to have survived as river gravel.

The igneous clasts in our test pits were mostly sub-angular, so had been moved/weathered from their original site of fragmentation. The density of clasts in pits 2114-2115 – some with fresh, angular, edges – may be in situ frost-fractured breccia from a buried large boulder or represent a high point on an undulating diorite surface (not detected in BGS mapping – or possibly part of Ford's [1968, 354] 'boulder fields' noted below).

All our test pits also included rounded quartzite pebbles; wherever vegetation is broken, they can also be found on the southern ridge overlooking Little Matlock gorge and the higher ground to the south, even where no till is mapped by BGS.

Diagram illustrating character of deposits and finds locations



Sandy gravels underlie the unsorted colluvial deposit in one pit [2112]; it is possible that our pits were not deep enough to encounter gravels elsewhere. However given the height of its surface [94.87m OD], and that this distinctive deposit was not encountered in the lowest pit on that transect (2116 investigated to 94.25), or the deepest pit (2119 investigated to 93.12m OD), this suggests that sandy gravels may be deeply buried or not very extensive to the north of the current river-line or too difficult to recognize in augering.

Test pit 2103/2113

Sediments
A c. 2.5 litre sample from the unsorted deposit removed from the section of 2113 [at 25-30cm depth] and 2118 [at 25-35cm depth] was sieved through 11mm and 6mm sieves; the clast component formed ~one third and ~one quarter respectively of the volume and weight (p.16). Both contained the full range of stone types found on the site; the igneous and (rare) flint fragments were sharp or sub-angular, all the other types were rounded or sub-rounded. Both samples included a fair proportion (c. 8-16% by weight) of small gravel-sized pebbles.

To characterise this sediment, and help to determine the nature of its deposition, a sediment sample from 2113 was also submitted to Matt Kirkham at BGS, who kindly conducted a Particle Size Assessment *pro bono* (p.15).

Particle size distributions reflect the textural characteristics of the original geological source material, the changes arising from any depositional processes, and, in some cases, post-depositional effects and soil formation. Particle size analysis is therefore valuable for looking at sediment source areas, and some aspects of sedimentary or pedological processes, such as sorting and clay translocation (Historic England 2015, 37).

The Particle Size Distribution showed nearly equal quantities (~40% by weight) of silt and sand – best illustrated by the histogram of the data on p.16 prepared by Colin Baker which clearly shows its bimodal character. The histogram shows peaks in medium silt and medium sand (with intermediate coarse silt/very fine sand hollowed out); there also might be a third peak in the granule range. Bimodal distributions are typical of colluvial and residual soils. The bimodal distribution might have resulted from either an admixture of sediment from two different sources or selective removal of the more mobile coarse silt/fine sand fraction by wind deflation (Mark Bateman, pers. comm.). There is however no supportive evidence for aeolian activity.

There are no sedimentary structures suggesting water flow, but the admixture probably had an alluvial input at some stage. The silt content is very clear. We might use the term "fluvio-aeolian" to imply that there is some windblown material, but with added fluvial input [the term favoured by BGS; McMillan and Powell 1999, 10].

Coarse fraction determined by sieving

Total Sample Weight 133.42 g
Retained Sample Weight 60.43 g **Passing 63µm Sieve** 72.99

Sieve Size (mm)	Sieve Size (ø)	Retained Weight (g)	Total (g) Retained	% Retained	% Passing
8.000	-3.0	0.00	0.00	0.0	100.0
4.000	-2.0	2.02	2.02	1.5	98.5
2.000	-1.0	6.76	8.78	6.6	93.4
1.400	-0.5	3.59	12.37	9.3	90.7
1.000	0.0	2.16	14.53	10.9	89.1
0.710	0.5	2.11	16.64	12.5	87.5
0.500	1.0	2.84	19.48	14.6	85.4
0.425	1.2	2.28	21.76	16.3	83.7
0.355	1.5	4.44	26.20	19.6	80.4
0.250	2.0	11.01	37.21	27.9	72.1
0.180	2.5	8.89	46.10	34.6	65.4
0.125	3.0	5.51	51.61	38.7	61.3
0.090	3.5	3.95	55.56	41.6	58.4
0.063	4.0	4.87	60.43	45.3	54.7

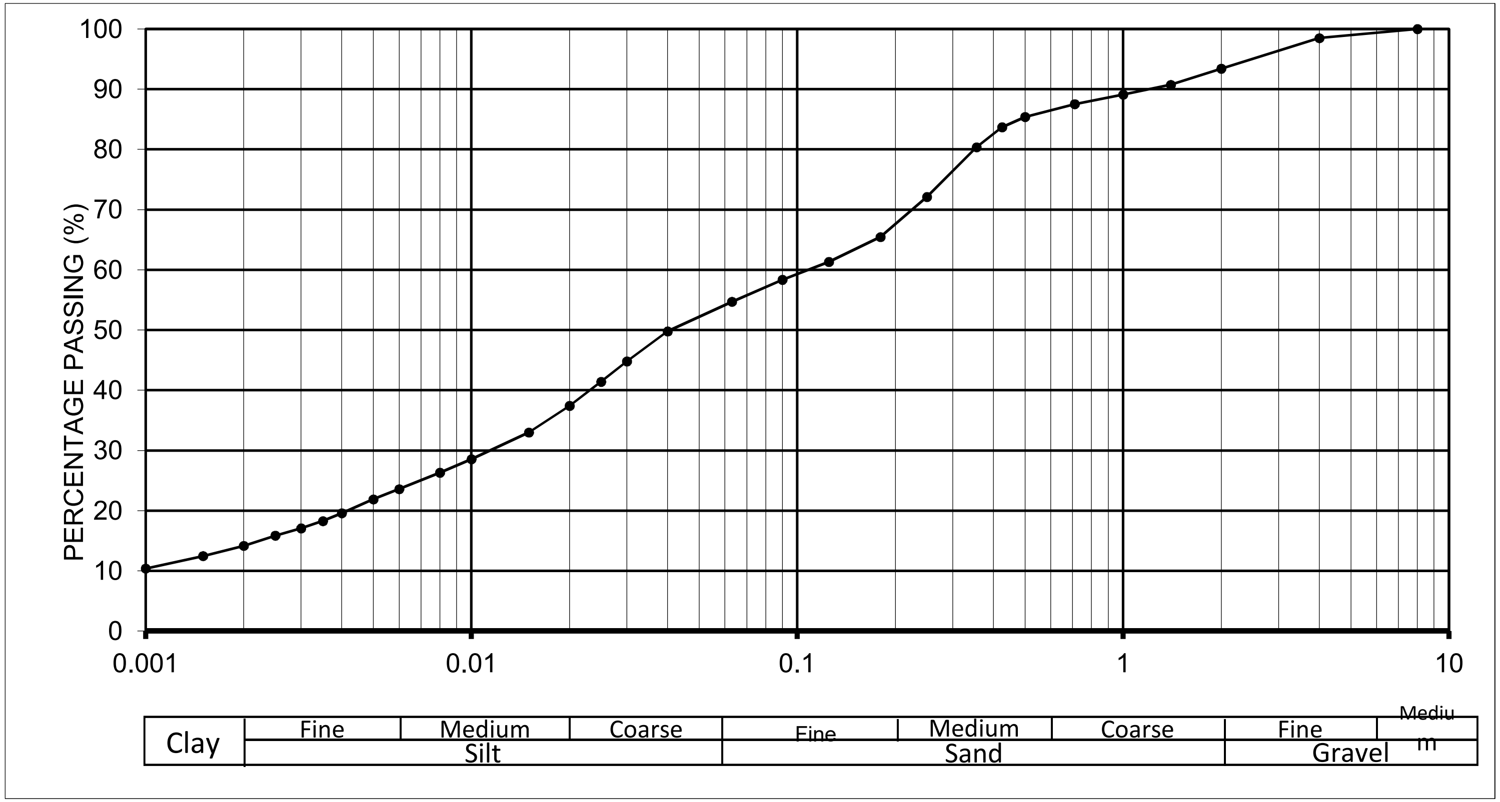
Fine fraction determined by X-ray sedigraph

Particle Size (mm)	% Passing	Actual %
0.0400	91.0	49.8
0.0300	81.9	44.8
0.0250	75.7	41.4
0.0200	68.4	37.4
0.0150	60.3	33.0
0.0100	52.2	28.6
0.0080	48.1	26.3
0.0060	43.1	23.6
0.0050	40.0	21.9
0.0040	35.8	19.6
0.0035	33.4	18.3
0.0030	31.2	17.1
0.0025	29.0	15.9
0.0020	25.9	14.2
0.0015	22.8	12.5
0.0010	19.0	10.4

Type	%
Gravel	6.6
Sand	38.7
Silt	40.5
Clay	14.2

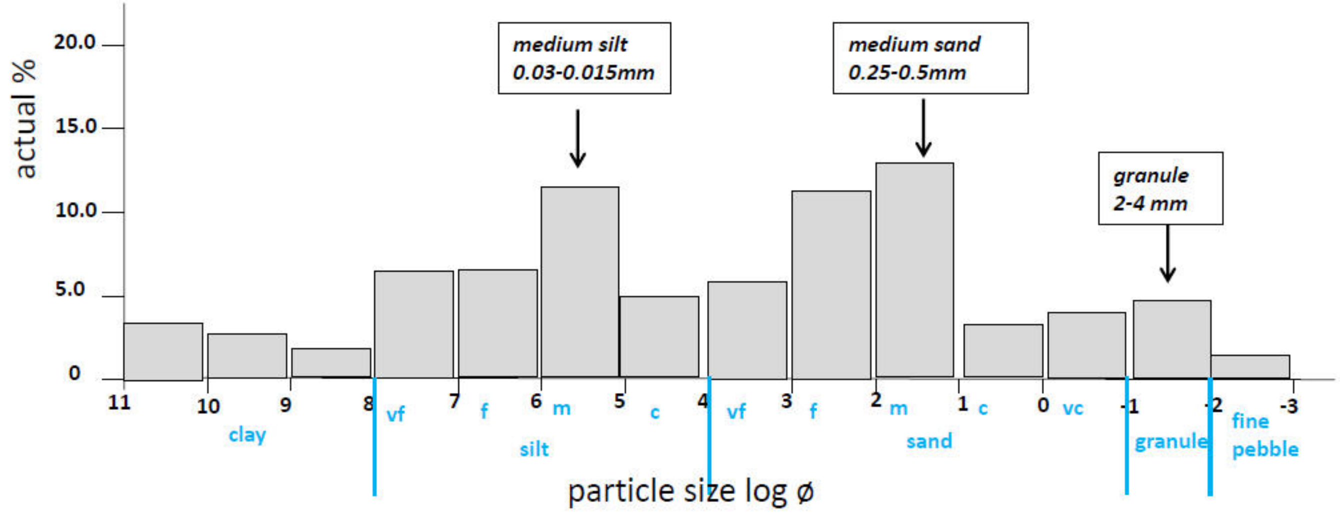
Container 175.15g
Wet 330.9g
Dry 308.57g
M.C (w/w) 16.74%

PSD by Matt Kirkham, BGS



2113 Particle Size Distribution of sediment <6mm

Type	%
Gravel	6.6
Sand	38.7
Silt	40.5
Clay	14.2



Sample 2113 @25-30 (*c.* 2.5litre): ~1/3rd stone > 6mm, 2/3rd silt

2113 sample at 25-30 cm deep	
11mm sieve	1020gm
6mm sieve	340
silt	3060
Silt + some fine sand – silt loam, no grit	10YR 4/6

Richard Tyndall supplied the following report on microscope examination of the sediments smaller than 6mm: (x20 for point counting and an overall sample description; x40 for detailed description of grains)

TP 2113

SILT grading to SAND, loose, very fine to rarely coarse, mode very fine to fine sand, poorly sorted, quartz, sub-round to round, rarely sub-angular, sub-spherical to rarely sub-elongate, generally colourless/ transparent, occasionally milky grains, occasional orange staining, no cementation, argillaceous matrix, very rare large well rounded igneous clasts, commonly micaceous, occasional fine carbonaceous or plant fragments.

TP 2118

SILT grading to SAND, loose, very fine to rarely coarse, mode very fine to fine sand, poorly sorted, quartz, sub-round to round, rarely sub-angular, sub-spherical to rarely sub-elongate, generally colourless/ transparent, occasionally milky grains, occasional orange staining, no cementation, argillaceous matrix, rare large well rounded igneous clasts, commonly micaceous, common fine carbonaceous or plant fragments.

Discussion

The two samples are very similar to each other, consisting of poorly sorted but generally fine sediments with occasional larger grains and clasts. The only real difference between the two is in the amount of fine-grained carbonaceous material seen with larger amounts present in the TP 21.18 although this is not sufficiently different to be able to rule out random sampling differences.

The main feature of the samples is the poor degree of sorting present in both and particularly the presence of larger igneous clasts. In addition, these larger clasts, like the smaller sand grains, are relatively well-rounded indicating transport over a significant distance or in a high energy environment. These combined features would tend to indicate a fluvial depositional environment.

When asked the direct question – did any of the sand grains have the characteristics of blown sand? RT replied: Nothing that would obviously suggest wind blown i.e. rounded and with frosting of the grains - it isn’t there in the samples I have looked at, even after going back for another look. The relatively well rounded nature of the sand grains would indicate a fluvial environment rather than aeolian.

Discussion

Our expectation for the deposits that we would find was based on BGS mapping and the record from the University excavations in the moated site: our test pits, though small, suggest that the story of deposition by the River Lin in this bowl within the Precambrian/Triassic bedrock is more complex.

BGS map the Terrace deposits within Bradgate Park as Terrace 1 which may be equated to the Syston terrace attributed to MIS2/Dimlington Stadial/Late Glacial Maximum (LGM) – see p.6. In the two places we've identified sandy river gravels, they are overlain by unsorted deposits: the character of the upper deposit in the steam section – a coarse, angular, granular head – indicates a period of severe periglacial activity likely to be of LGM date. No cryoturbation structures were identified (remembering the very small size of our test-pit exposures), and no patterned ground is visible on Google Earth images, so this period attribution for the colluvium/head, though perhaps likely, cannot be certain. The date of any colluvium/head is critical when prospecting for Late Upper Palaeolithic activity in the Windermere Interstadial.

The common occurrence of rounded (Triassic) pebbles on the high ground above the Lawns suggest an extensive mantle of till/head/colluvium north of the River Lin, mostly too thin to be recorded in published BGS mapping (cf. Smith 2009). Colin Baker points out that the till exposure lay at the head of a gulley (between Elder Plantation and Bowling Green Spinney) that could be one source of the admixed material forming the 'terrace' surface to the south.

We have identified extensive head/colluvium forming a gently-sloping convex surface (p.2) mapped as Terrace by BGS – but what shaped it's form? Ford (1968, 35) noted that 'boulder fields are spread round most of the crags in the form of solifluction spreads' and Bridger (1981, 44), in describing the Charnwood tors, says that 'surface spreads of clitter are not always apparent, but sectional slopes have almost invariably exposed a layer of head running down-gradient from the sides of crags'. Giles *et al*. 2017 describe solifluction sheets as generally having little or no surface expression (3.11.2.1), and Murton and Ballantyne [2017] note that 'colluvial processes such as slopewash and solifluction dominated small tributary valleys that lacked streamflow for much of the year… such valleys lack distinctive fluvial landforms' (5.2.6.3). Murton & Ballantyne (2017) depict a transverse section through an idealised terrace in the middle reaches of a river in southern England (fig 5.23) with "brickearth" deposited as a veneer over terrace sands and gravels and interdigitating with hillslope head deposits: this might be a useful model for thinking about the Bradgate Lawns deposits.

So what does this tell us about the likely stratigraphic position of any LUP activity? If the head/colluvium is LGM, then any LUP flints should be on top of this deposit (or given evidence for topsoil sorting) just into this deposit - and this is the case for the *in situ* flake in 2114 (though the form of this flake is not diagnostic of date). Any fluvio-aeolian silt could be LGM or Younger Dryas: the latter would have implications for the potential recovery of lithics at the near surface.

Two flint flakes were found in the deposits below possibly disturbed topsoils (2117 and 2121). The flint in 2121 lay at the interface with a ?reworked/stone-free silt, indicating that some flints may have moved from their original context. Such re-working may be reflected in the S-N profile of the surface.

The IA/RB/AS sherds were both in pits (2112, 2117) near the river in horizons that could have been reworked or subject to biological activity: alongside other local finds, they indicate extensive Romano-British activity. The other Holocene activity was also in this zone close to the current river (2109, 2110 and Scheduled moat).

To predict the extent of likely deposits in which in situ LUP artefacts could exist, further intrusive investigation would be required. The stoniness of the deposits means that hand-auger sampling is not a feasible investigative method. The potential for geophysical techniques to map the near-surface breccia and stone-free deposits (and any surface features like stone-drains) could be considered alongside surface geochemical methods, though these would also pick up any Holocene activities (as demonstrated in our test pits), and their signatures might swamp those of the earlier activity we seek.

In any future test pitting on the Lawns, a bigger pit is recommended for at least some of the pits, both to get a better picture of any lateral variation of the deposits (e.g. cryoturbation, sorting or bedding), and enable a greater depth to be penetrated to investigate the underlying deposits. This would also allow a potentially larger sample of lithics to be collected.

Bibilography

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