Long Paper

Advances in Archaeological Prospection

The Geoarchaeological Shift

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Abstract: This paper sets out some of the key challenges faced by archaeologists when they need to assess and evaluate large land parcels prior to development. It then outlines the application of a geoarchaeological 'landform element' technical approach to assessment and evaluation particularly in the light of current infrastructure developments. This approach grew out of more traditional geoarchaeological applications but has been modified directly to address the needs of large-scale construction and development projects where improved understanding of archaeological/palaeoenvironmental potential and significance is required due to the huge of scale of works being undertaken, often within a restricted timescale. The application of this approach using a real-world case study from Killerby Quarry is documented. This project delivered stunning archaeological preservation of Late Glacial – Early Holocene archaeological and paleoenvironmental remains that were able to be appropriately excavated and analysed leading to the discovery of the first preserved timber tepee-like structures associated with Early Mesolithic hunter-gatherer groups in northern Europe. The pre-determination evaluation works for this 200 ha site were able to be undertaken at between 25–50% of the typical cost of evaluation works for a project of this size and complexity. This meant that resources could be subsequently better targeted at the mitigation phase to maximise knowledge gain, and ultimately, public benefit.

Keywords: *Geoarchaeology—Archaeological—Mesolithic—Evaluation—Development*

CHNT Reference: Waddington, C. and Passmore, D.G. (2025). 'Advances in Archaeological Prospection: The Geoarchaeological Shift', *Proceedings of the 26th International Conference on Cultural Heritage and New Technologies*, Vienna and online, November 2021. Heidelberg: Propylaeum. doi: 10.11588/propylaeum.1449.c20750.

Understanding the Problem

Finding rapid, cost-efficient ways to effectively evaluate large land parcels for archaeological and palaeoenvironmental remains in advance of development, and particularly large construction and infrastructure schemes, forms a key challenge for archaeologists. It is widely accepted that no single archaeological prospection technique can provide the answers we need, despite an over-reliance on geophysical survey in some cases. Rather, a spectrum of techniques is required to assess the seen and 'unseen' potential of any given landscape. This means deploying the most appropriate techniques, in the most appropriate way, and in the most appropriate phasing so that the data sets can be assessed iteratively so as to enable identification and targeting of areas of interest and ultimately delimit and characterise significant archaeological and palaeoenvironmental remains present. Many non- or minimally intrusive techniques are now available to us that can be used to provide a powerful battery of analytical methods, often providing independent data sets, that can be combined to test different aspects of the landscape. These include, but are not restricted to:

- Remote sensing (aerial photographs, multi-spectral, satellite and thermal imaging),
- High resolution topographic survey (Lidar, SfM photogrammetry),
- Geophysical survey,
- Geochemical survey,
- Fieldwalking,
- Test pits,

typically followed by evaluation trenching.

In order to get the best out of these techniques and to know where and when each technique can contribute effectively to the analysis of any given study area or landscape unit within it, a 'way in' to the landscape is required. The starting point is some form of sampling, and it is self-evident that the effectiveness of a sampling strategy is directly related to the distribution of that which is being sampled. The archaeologist is therefore faced with a dilemma: the distribution of that which is being sampled remains unknown until it is sampled. This is the 'sampling paradox' referred to by Mueller (1975, p. 37). So how do we overcome the burden of the 'onerous sampling strategy', and structure the investigation of landscape and the application of archaeological techniques? It all starts with understanding the mosaic of landforms that form any given study area and through geoarchaeological mapping, sediment sampling and characterisation a scheme of landforms or 'landform elements' can be produced that encompass the full variation of landscape facies constituting the study area (see Passmore and Waddington, 2009; 2012; Brightman and Waddington, 2010; Howard and Macklin, 1999; Howard et al., 2008; Jackson et al., 2013; Carey et al., 2017).

Renfrew has observed (1976, p. 2): "because archaeology recovers almost all its basic data by excavation, every archaeological problem starts as a problem in geoarchaeology"

These words are considered broadly correct because by applying any of the archaeological prospection techniques blindly across large landscape parcels without consideration of the geoarchaeological context has the potential to yield inherently flawed data. This is because different landforms have formed in different ways at different times, have been subjected to varying forms of landscape taphonomy, have different preservational properties, different susceptibilities to different archaeological prospection techniques and different histories of human land use.

A geoarchaeologically-driven solution

For those areas where there is little pre-existing remote sensing data or which have geologies/soils/ground conditions unfavourable to crop or soil mark formation, and/or have restricted scope for geophysical survey, other approaches to drive evaluation of these areas need to be found. Following an in-depth study in the Till-Tweed basin (Passmore and Waddington, 2009; 2012) a geoarchaeological methodology was devised, termed the 'Landform Element' approach, whereby the evaluation of a given land parcel is initially geoarchaeologically mapped, cored/trenched and surveyed in order to partition the landscape of interest into a series of discrete landforms. For each of these landforms their geological character is ascribed, together with the dominant geomorphic activity, together with known archaeological associations and implications for the types of methods most appropriate to their evaluation (see Table 1 for an example).

Table 1. Example of a landform element initial classification chart for Killerby Quarry (© Passmore and Waddington 2009, 267, Figure 6.1).

Landform element		Geology/Sediment type	Holocene geomorphic activity	Archaeological associations
1a	Undifferentiated Late Devensian glacial and glaciofluvial drift	Till, sand and gravel, some poorly-sorted slope deposits	Generally stable, some localised colluvial activity	Mixed age cropmarks, earthworks and artefacts. Can occur as upstanding features, features in underlying deposits or as artefacts in ploughsoils
1b	Late Devensian ice-contact Glaciofluvial deposits	Sand and gravel, some localised thin till deposits	Generally stable, some localised colluvial activity	Mixed age cropmarks, earthworks and artefacts. Can occur as upstanding features, features in underlying deposits or as artefacts in ploughsoils. Particularly common are Mesolithic flint scatters, Neolithic pits and ceremonial monuments and Early Bronze Age and Anglo-Saxon settlement sites
1c	Late Devensian glaciofluvial and river terraces	Sand and gravel, some localised sand, silt and clay	Generally stable, some localised colluvial action	Mixed age cropmarks, earthworks and artefacts. Can occur as upstanding features, features in underlying deposits or as artefacts in ploughsoils. Particularly common are Mesolithic flint scatters, Neolithic pits and ceremonial monuments and Early Bronze Age and Anglo-Saxon settlement sites
1d	Late Devensian kettle holes inset within 1b, 1c and 1d	Peat, organic-rich and inorganic fine sediment	High probability for Lateglacial and Holocene sedimentation	As (1b), but with high probability for burial of Lateglacial and Holocene landsurfaces and(or) organic deposits
1e	Late Devensian and(or) Holocene palaeochannel deposits and enclosed basins inset within 1b, 1c and 1d	Sand and gravel, variable depth of fine sediment overburden	Generally stable, but possibility of local sediment accumulation	As (1b), but with potential for burial of late-glacial and Holocene landsurfaces, sediments and archaeological remains
2a	Holocene alluvial terraces and floodplain deposits (pre-nineteenth century)	Mainly sand and silt overlying sandy gravel	Alluviation and local fluvial erosion	Mixed age cropmarks (rare), earthworks (rare) and artefacts within ploughzone, high potential for buried *in-situ* Holocene landsurfaces and organic deposits, local reworking and truncation of older Holocene surfaces
2b	Holocene alluvial palaeochannels and floodbasins developed on 2a surfaces	Alluvial sand, silt and clay with variable organic content, peat	Alluviation and local fluvial erosion	Limited or no surface archaeology, but proven (or high probability of) buried *in-situ* landsurfaces and organic deposits
2c	Holocene colluvial spreads	Mainly soil, sand and silt overlying palaeosols or sands and gravels	Colluviation and localised erosion from upper slopes with accumulation burial of deposits on lower slope	Potential for buried in-situ soils, land surfaces and archaeological features below the colluvial spreads. Reverse stratigraphy of artefacts possible when comparing upper colluvial layers with lower in-situ layers due to erosion and transportation of older material from upslope being re-deposited on top of younger material in-situ positioned in a stable setting downslope.
2d	Holocene peat bogs	Peat, some less-organic inwash	Accumulation of peat and organic-rich deposits	Limited or no surface archaeology, but proven (or high probability of) buried *in-situ* landsurfaces and organic deposits
3	Modern ponds / reservoirs and quarry workings	n/a		Archaeological material in secondary (reworked) contexts only where disturbed by quarrying.

Case study: Killerby Quarry

Fig. 1. Location map showing Killerby Quarry, UK (© Archaeological Research Services Ltd).

This paper outlines a real-world application of this approach to a new 'super quarry' that was deployed from its earliest planning stages, through Environmental Impact Assessment, determination, construction and now its operation. The site is called Killerby Quarry and it is located in North Yorkshire, UK, and lies immediately east of the A1M motorway (see Figure 1). Together with the adjoining Ellerton extension the site extends over c. 200 ha. The site straddles a range of landforms including the so-called 'Leeming moraine' which is characterised by a variety tills and deglaciation features such as kettle holes, enclosed basins and a palsa bog which form an undulating landscape of low lying wetland basins surrounded by steep bluffs and ridges formed from glaciofluvial sands and gravels with organic sediments, peats and paleosols surviving in the wetlands and kettle hole fills, as well as sealed below colluvium at the base of the bluffs. The flatter or gently sloping tops of the bluffs and ridges are free draining and have much lighter, tractable soils than those covering the enclosed basins which tend to be more peaty, much wetter and heavier. The soils on the ridges currently support cultivation and cereal production while the soils in the low-lying wetlands support pasture, primarily for sheep. The eastern part of the site is younger in age, being the Holocene alluvial valley floor which has a series of palaeochannels preserved across its surface, albeit buried by the topsoil, and which in turn is flanked to the east by the current course of the river Swale.

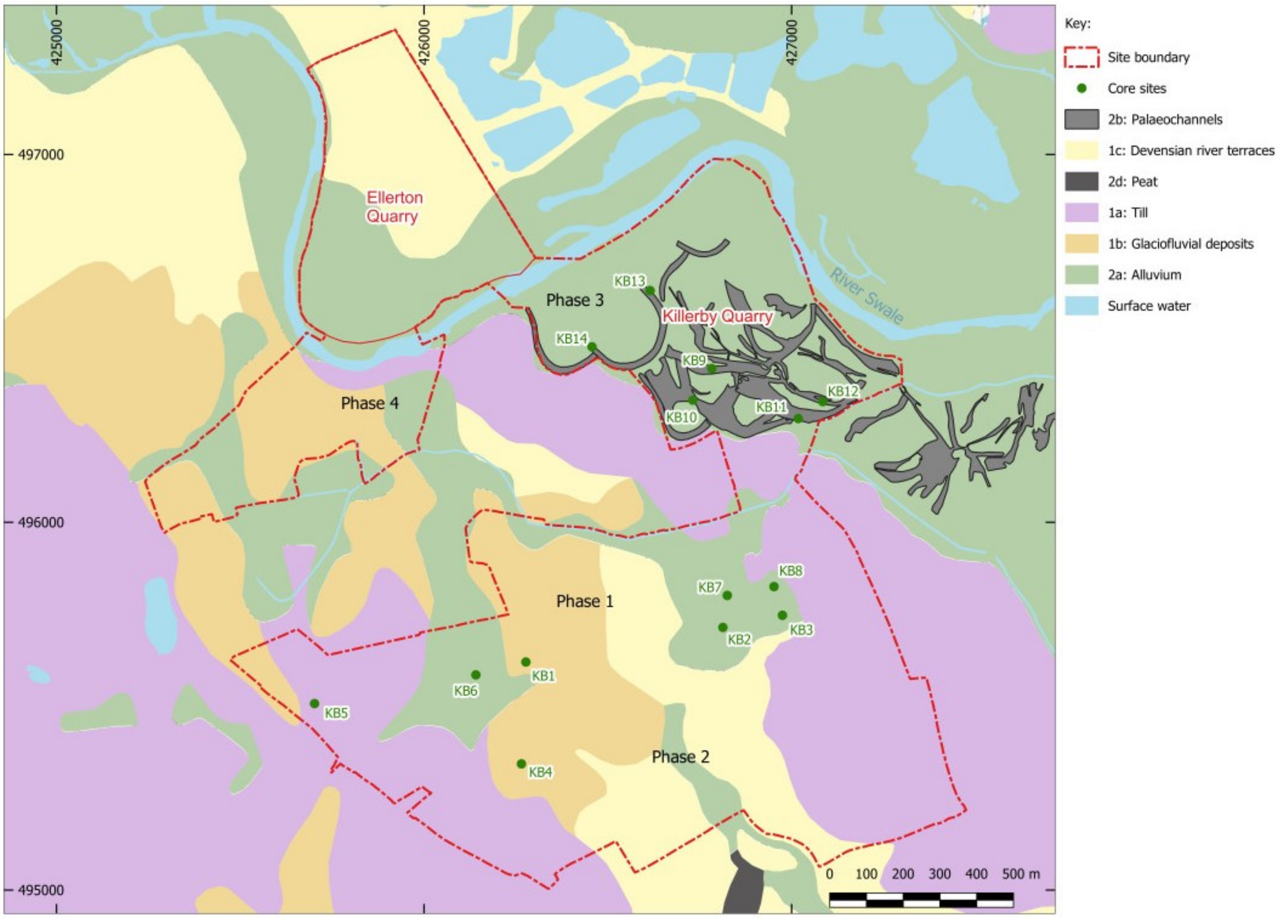

Fig. 2. Initial landform element map of the Killerby Quarry area used to drive the fieldwork evaluation strategy (© Archaeological Research Services Ltd).

The first stage of work was to undertake a highly detailed desk-based assessment that included a detailed geoarchaeological landform map (see Figure 2) and which was set up in the project's GIS and which included the currently available lidar data and detailed analysis and digital transcription from aerial photographs to understand the morphology, identification and extent of landforms and any observable archaeological associations. This was followed by a phased programme of evaluation that included targeted sediment coring, range finder dating and assessment of palaeoenvironmental proxies on a range of deglaciation features that included enclosed basins and kettle holes, as well as palaeochannels on the Holocene floodplain. An extensive fieldwalking survey was then undertaken at close-spaced intervals to maximise finds recovery with a particular emphasis on chipped stone artefact recovery. Following on from these studies highly targeted geophysical survey and evaluation trenching was undertaken. Once this site received planning permission archaeological mitigation took place based around a scalable watching brief through to strip, map and sample condition, together with the targeted sample excavation of specific kettle hole and enclosed wetland basin features (see Figure 3) – one of the first times any such features had been targeted for archaeological excavation as opposed to just palaeoenvironmental sampling in British commercial archaeology.

This approach was selected for use on this project as it provided an appropriate method for rapidly and accurately assessing a large land parcel in advance of large-scale development that required a high level of digital information to inform the planning decision and to give confidence to the developer of the scale and cost of the post-permission mitigation that might be required. The approach allowed what was considered to be significant about this previously unknown and unstudied landscape and the type of archaeological and geoarchaeological records it contained to be targeted from the outset, whilst avoiding the need for digging several hundred evaluation trenches across this landscape and which would almost certainly have failed to identify the most significant archaeology surviving in this study area. This meant that there was virtually no impact on surviving sub-surface archaeology during the evaluation phase, large scars in the field surface were avoided, speed of work was high, the quality of the archaeological information to inform decision-making and to understand this landscape was considered superior to that which would have resulted from typical geophysical survey followed by trenching, and the cost of the works was considerably less than a typical geophysical survey-evaluation trenching approach. This geoarchaeologically-driven and digital approach to evaluation was therefore considered by all parties to be good value for money. This meant that the greater bulk of the financial resource could be spent on creating new and significant information during mitigation rather than expending large amounts during pre-determination landscape reconnaissance and evaluation that would in turn reduce the resource available to create value and new information during mitigation.

The application of a geoarchaeological approach from the outset to drive all subsequent prospection and mitigation resulted in a coherent programme of work resulting in notoriously ‘hard to find’ archaeology being identified and recovered. The works were undertaken using the following sequence:

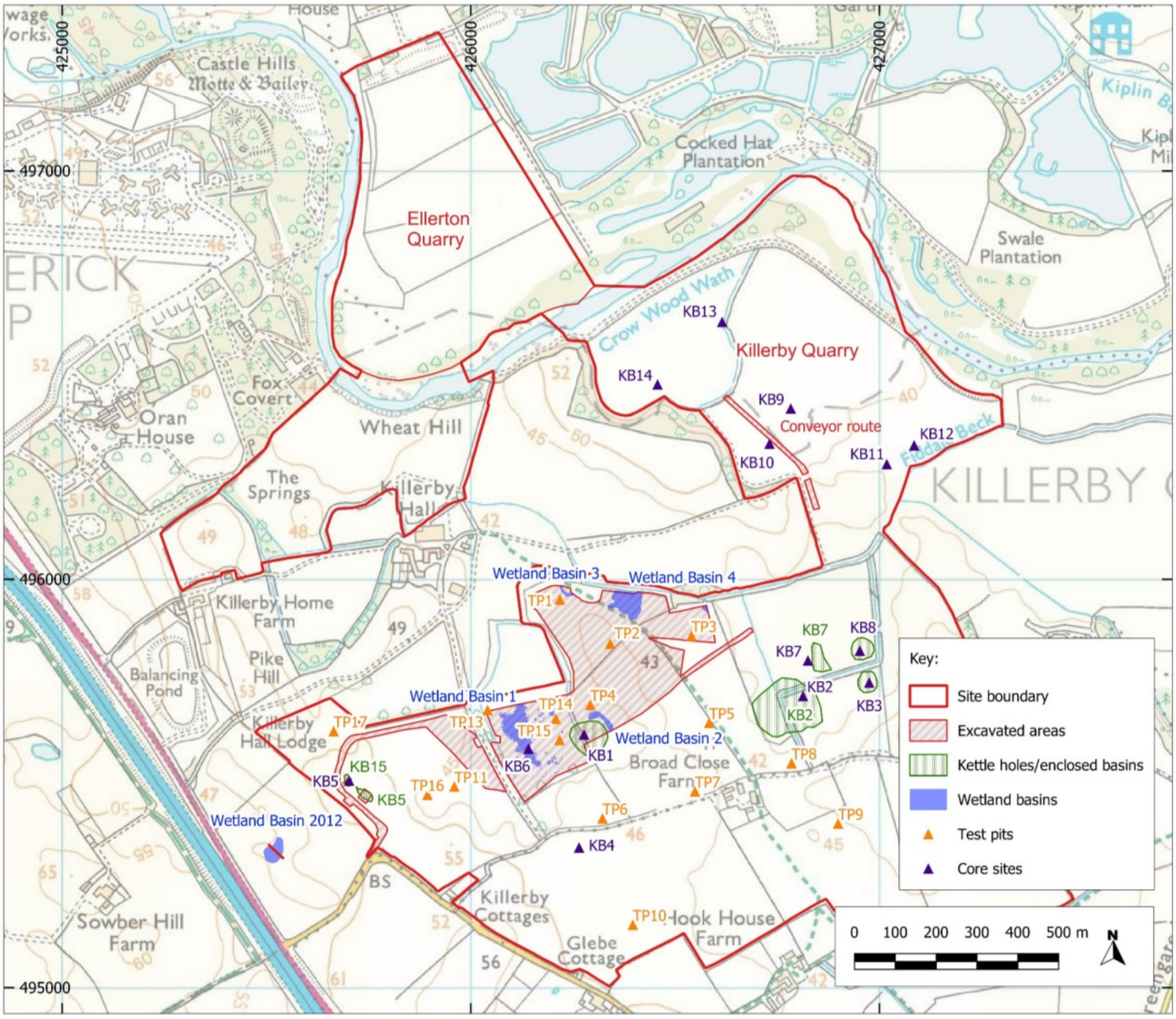

Fig. 3. Map showing detail of archaeological works within Killerby Quarry (© Archaeological Research Services Ltd).

Desk-based assessment

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Geoarchaeological landform mapping (including analysis of aerial photographs, Lidar data, satellite imagery, GIS modelling) into discrete 'landform elements' and then assessing the potential of each landform element, the landscape as a whole and which techniques to deploy where.

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Targeted sediment coring was undertaken on what were thought to be both Late Glacial and Holocene features with range finder radiocarbon dates acquired for most sequences together with assessment of potential of the deposits to contain palaeoenvironmental proxies.

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Close spaced fieldwalking was undertaken over all parts of the site available for fieldwalking with the focus on chipped stone tools of the Stone Age.

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A small amount of geophysical survey was undertaken where aerial photographs suggested some anomalies could be present and which was followed up by very limited and targeted evaluation trenching.

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Planning application submitted with full Environmental Statement chapter for cultural heritage dealing with other issues such as impacts on 'setting', and crucially, with the full scheme of archaeological mitigation set out as part of the application.

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Planning permission given subject to usual conditions.

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Archaeological mitigation works undertaken as quarry construction and operation progressed including: targeted sample excavation of a kettle hole, targeted sample excavation of wetland basins, strip, map and sample excavation of non-wetland areas and targeted geoarchaeological sediment sampling and analysis.

The results have been stunning and have added genuinely new knowledge and data to our understanding of the Late Glacial and Early Holocene in northern Britain. The earliest evidence for human activity identified at Killerby was from palaeoenvironmental deposits in kettle hole (KB5) which produced extraordinarily high abundances of microcharcoal within a deeply stratified and sealed organic-rich clay silt radiocarbon dated to 10958–10764 cal BC (95.4% probability), or probably 10873–10794 cal BC (68.2% probability) (SUERC-79304 (GU79304)) (Hunter and Waddington, 2018) during the latest phase of the Younger Dryas. This proxy evidence is further supported by the chipped lithic evidence that include an unusual tanged point, a backed blade, as well as broad and heavily patinated blade implements recovered from both the fieldwalking and the excavations (Waddington et al. 2009, p. 5). More spectacular has been the discovery of three Early Mesolithic pond-side camps with the structural timbers of tepee-like dwellings (see Figures 4 and 5), one with an internal hearth, surviving in remarkable condition despite dating to the 91st century cal BC (see Figure 5).

These camps represent a behavioural practice that continued in this locale over several centuries whereby short-stay camps were made around a sheltered pond using locally available alder growing on the on the wetland margin. They appear to have been occupied for short stays and formed part of a wider pattern of hunter-gather mobility around the wider landscape comprising episodic use of this hummocky wetland area close to the routeway of the River Swale, possibly for resource acquisition that included lithic raw materials (e.g. the locally available chert), as well as riparian resources and the taking of animals watering and nesting around the various wetlands.

A substantial Late Mesolithic timber platform dating to c.5,500 cal BC was discovered extending out into a small pond inside the kettle hole KB5 (see Figures 6 and 7) and this had evidence for cattle teeth, chipped flints, a stone rubbing tool, as well as posts, postholes and other features that have led to its interpretation as a platform for processing animal skins and potentially curing hides in the pond. This site also had successive occupation in the Neolithic and Bronze Age stratified above the Mesolithic remains. In the cases of both the Early and Late Mesolithic archaeological structures these well-preserved remains also had preserved alongside them a continuous palaeoenvironmental sequence of deposits rich in environmental proxies that could be linked to landscape development and human activity in the immediate landscape surrounds (see Figures 8 and 9) as well as lithic material of various types (see Figure 10).

Fig. 4. Aerial view of Wetland Basin 1 (dark peat-filled basin) exposed after topsoil strip inset within a relict palsa bog (© Archaeological Research Services Ltd).

This has meant that the cultural and environmental archives can be directly integrated to provide a much fuller and more accurate understanding of past human activity in this remote period of early human activity in this region (Hudson et al., 2023). Elsewhere on the site archaeological remains from the Neolithic, Bronze Age, Late Iron Age, Romano-British and early medieval periods was also discovered, although their significance is much less than the rare Stone Age archaeology.

Although other archaeological remains have been found as well, these are remarkable discoveries that have been found as a result of the application of a specific evaluation technique and innovative mitigation whereby palaeoenvironmental deposits were targeted for archaeological sampling and excavation. They were not found by chance. The Killerby project has ground-tested the approach in a real-world setting on a large scale and has proved effective in recovering what was significant about the archaeology of this area, as well as in directing the best-use of spend at the right times in the discharge of the planning process.

Fig. 5. View of one of the well-preserved Early Mesolithic camp structures with long poles for a tepee-like structure collapsed over the fireplace and radiocarbon dated to the 91st century cal BC, directly contemporary with the earliest phase at Star Carr, also in North Yorkshire (© Archaeological Research Services Ltd).

Fig. 6. Aerial view looking west of kettle hole KB5 (dark peat-filled egg-shape) exposed after topsoil strip with initial evaluation filled with water (© Archaeological Research Services Ltd).

Fig. 7. Late Mesolithic timber platform emerging during excavation in the fill of kettle hole KB5 under light snow conditions (© Archaeological Research Services Ltd).

Fig. 8. View of section through kettle Hole KB5 deposits showing the well-preserved and sealed stratigraphic sequence during recording and sampling of the deposits (© Archaeological Research Services Ltd).

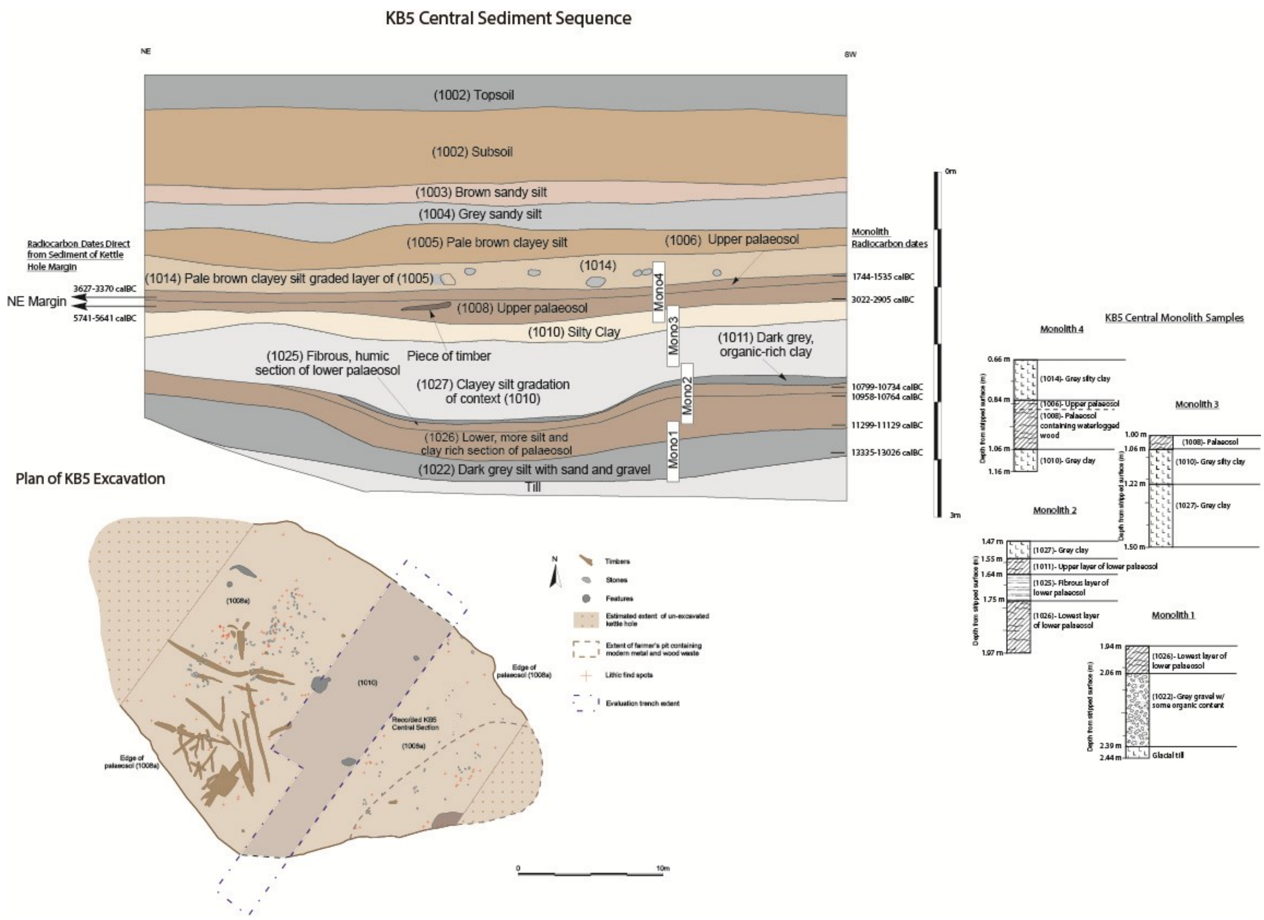

Fig. 9. Plan and section of archaeological remains and sedimentary sequence in kettle hole KB5 (© Archaeological Research Services Ltd).

Fig. 10. Heavily patinated flaked flint axehead found in the Mesolithic palaeosol around Wetland Basin 2 (© Archaeological Research Services Ltd).

Conclusions

The archaeological and geoarchaeological works undertaken at Killerby Quarry represent an innovative approach to both evaluation and mitigation, that have resulted in the recovery of stunning and rare discoveries that will inform future methodologies, as well as contributing significantly to understanding the Late Glacial and Early Holocene archaeology and palaeoenvironment in Britain and north-west Europe. On the basis of the application of the approach outlined here to a large-scale real-world case study the following conclusions can be drawn:

- The geoarchaeologically-driven approach allowed for what was archaeologically significant to be targeted from the outset and without recourse to digging up and disturbing soils and buried deposits across large tracts of landscape
- The evaluation phase was relatively swift and inexpensive with the evaluation works estimated as costing between 25%-50% of the typical costs associated with a geophysical survey and percentage-based evaluation trenching approach
- The archaeological result was considered better than a ‘normal’ approach reliant on geophysics and evaluation trenching, and which resulted in the discovery of very rare and highly informative archaeological and palaeoenvironmental remains
- The bulk of the archaeological expenditure was made in the post-permission mitigation phase linking it directly to the phase when most benefit was delivered (ie. knowledge gain, preservation by record, public visits and talks, dissemination of information, environmentally sensitive quarry construction and extraction and sustainable economic benefit in terms of local jobs)
- GIS was utilised from the outset as the key digital means by which data was stored, analysed and articulated and its ease of visual comprehension assisted the planning application itself as well as for easily comprehensible understanding of the archaeological and palaeoenvironmental potential of the site with non-archaeological specialists and planners.

Acknowledgements

The application of the archaeological approach documented here would not have been possible without the dedication and teamwork of a wide range of people, however the authors would like to express particular thanks to the following individuals for their varied contributions whether as part of the planning application approach and/or delivery of fieldwork, analysis and project reporting: David Atkinson, David Cockcroft, Alan Coe, Philippa Hunter, Jim Innes, Helen Kennedy, Luke Parker, Mark Potter, Peter Rowe, Mark Spenceley, Bob Sydes and Mike Young.

Funding

Funding for this entire project courtesy Tarmac.

Conflict of Interests Disclosure

There are no conflicts of interest.

Author Contributions

Conceptualization: Clive Waddington
Methodology: Clive Waddington, David Passmore
Writing – original draft: Clive Waddington, David Passmore
Writing – review & editing: Clive Waddington

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