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Identify the key reference and data resources that you use in your specialism to ensure that your work is properly informed, and critically evaluate their accessibility, currency, reliability, and relevance. (40%, 3500 words or equivalent).

The practice of geoarchaeology is fundamental to understanding the formation processes on a site. In everyday commercial practice, we need to recognise how different sediments travel over time and how soil formation functions to know how this affects anthropogenic deposits. The consequences of incorrectly speculating on site geology can have a detrimental impact on evaluations and subsequent excavations, which cascade an initial project's budget and might involve a significant amount of extra unplanned mitigation.

Comparatively, we can recognise an established and well-trodden path in other areas of archaeological specialist practice, such as pottery studies, environmental archaeology, and osteology. Conventionally, these areas have been recognised in commercial practice as essential to interpreting site data in post-excavation. This is perhaps outwardly reflected in well-structured postgraduate programs, CIFA and independent special interest groups and debatably the overall volume of guidance material and reports produced by Historic England. Therefore, in terms of identifying key reference material and data sources within geoarchaeology, a proactive approach is necessary because this area has been interpreted as something on the periphery and could be more geological than archaeological.

Part of this incorrect interpretation is based on the misconception that palaeolithic archaeology rarely exists within the UK pre-Holocene, and what commercial units interpret as the 'natural' geology often overlays earlier anthropogenic deposits formed in the Holocene. Commercial archaeology has yet to explore the potential for this type of research, with detailed deposit modelling inputs from geoarchaeologists on site formation processes, which can inform a project's successful development. However, regionally in the UK, there have been differing levels of engagement with geoarchaeology, larger nationwide units having the resources to employ full-time specialists and a more consistent focus regionally in the Southeast of England to engage with geoarchaeology methodologies for the palaeolithic. Nevertheless, there is still a need for more protection via statutory mechanisms when pre-Holocene deposits are encountered, and a practitioner's experience, knowledge and skills are required.

To identify the fundamental references and data sources that a geo-archaeologist uses in practice, it is, therefore, necessary to consider the process sequentially in broad terms of how we understand and physically explore stratigraphy, model data, and interpret with phased data sequences or utilise cross-discipline skills to better inform research based on regional or subject area frameworks. We can also structure specialist practice into four key areas: Geomorphology, which is the study on a larger scale of landforms and the effects on buried sites and artefacts post-disposition. Sedimentology, the effects of weathering, erosion, transportation, deposition, and diagenesis of sediments. Paleogeography combines

geomorphology and sedimentology data to produce interactive maps and deposit modelling to inform understanding of site formation processes and improve project resource targeting. And finally, at a smaller scale Soil Micromorphology is a lab-based excavation of sampled material under a microscope to differentiate human activity from natural phenomena.

Geoarchaeologists need to understand time from a deeper perspective, as geological processes can extend for millions of years. Reference models enable specialists to communicate how climate has changed overtime periods, enabling a better understanding of how climate has influenced topographical landforms and bathymetric variables of geomorphology. Understanding paleoclimatic change is a fundamental resource enabling geoarchaeologists to interpret periods with the Marine Oxygen Isotopes Record. A valuable and accessible schematic reference guide to the Pleistocene epoch has recently been produced by Historic England (HE, 2023), which comparatively assimilates data around isotope stages and periods, stage names, dating techniques, hominids, and predominant technology (Appendix A). Although this is only one facet of the guidance, it establishes a shared vocabulary and understanding of geomorphological time between specialists and non-specialists.

To be clear, palaeolithic geoarchaeology is a distinct specialism from Holocene geoarchaeology, but understanding geological and archaeological processes in a deeper context of time is an essential knowledge base. Demonstrably, 2023 HE guidance is weighted towards non-specialists that do not have first-hand experience of the palaeolithic, and it covers the basics very well in Part B, describing the palaeolithic occupation of Britain, geomorphological processes and evidenced case studies which makes the narrative extremely relatable and accessible to all professionals. Importantly, this up-to-date and relevant reference guide includes a glossary of terms; the language used in earth sciences can be exacting and a significant barrier to comprehension. The guidance also signposts further information sources and regional contact details, enabling non-specialists to access detailed information. Being a Historic England Reference guide, it is highly accessible regarding downloading, re-use, and digital rights management.

Comprehension and acquiring foundational knowledge in the earth sciences is also significant barrier to the accessibility of any reference material or data sources. It is essential to recognise how geomorphological processes work, to interpret and understand how landscapes change and where to locate evidence of anthropogenic activity.

At the intermediate level, published textbooks can offer a valuable reference source for early career geoarchaeologists and academic researchers. Although it should be noted that textbooks are not vigorously peer-reviewed, the information content can become quickly outdated as the publication process can take years. Therefore, reliability and currency decrease with time. Another significant barrier to accessibility is expenditure; textbooks can be expensive due to their bulky size, photographic and figure colouration charges, and relatively small distribution cycle. Open-access publishing has impacted textbook publishing differently than monographs and journal articles, so the material is often paper-based. If published digitally, textbooks can be prohibitively expensive to purchase with restricted single-user licences. Notably, the format is not usually accessible for people with disabilities such as visual impairments because textbooks have traditionally been manufactured around

normative assumptions of the ability of the average readership, therefore maximising profitable returns to this exclusive publication model.

However, academic textbooks are often published by leading experts in a specialist field of study, with sometimes decades of teaching and research experience. For this reason, they can be key reference material that collates empirical evidence and signposts large volumes of peer-reviewed research, enabling further access to essential data resources through accurate bibliographic referencing. Peter Toghill, *The Geology of Britain An Introduction* (Toghill, 2000) is a well-written, illustrative textbook. In terms of grasping the fundamentals of earth sciences, it is an authoritative source which enables an overview of the last 200 million years of geomorphology in the British Isles. It is best described as an aid to understanding key processes; less than two hundred pages, it covers the lay of the land but needs to be written specifically for geoarchaeology and references are kept to a minimum of one page. It is an excellent introductory learning resource. In its fifth edition, Richard Huggett's and Emma Shuttlesworth's *Fundamentals of Geomorphology* (Huggett, et al 2023) is a large expansive volume of material that focuses in depth on key geomorphological process, including human activity as a critical geomorphic agent. It combines the necessary information to make it a good learning resource and a good reference source linking to contemporary bibliographic research references. The authors are UK-based academics from the University of Manchester, which adds currency and reliability to the resource and debatably makes the material more relevant to a UK-based specialist.

Peer-reviewed Journals are an essential and trusted source for reference material, but increasingly also sources of primary datasets used in research to increase validity and transparency. Over the last decade, there has been expansion by publishers to include the sets of data used in studies, often published alongside the finalised research paper, or linked to a third-party provider. Journal publishing websites have debatably become a type of data repository, containing many formats detailing calibration data used in experiments, 3D models, computer code and algorithms (Elsevier, 2023a).

The Journal *Geoarchaeology: An International Journal* is published by Wiley six times a year. (Wiley Online, 2023). The Journal contains a significant amount of content on geomorphology and links in references, related material, research funding information, and citation data in a PDF format, which is not accessible for readers with specific impairments using Optical Character Recognition (OCR) software. Critically, when checked against an accessibility checker online, the web content for the Journal scored 48% compliance (Accessibility-Checker, 2023). Therefore, it does not meet the basic web accessibility standards for online content (WSI, 2023). This is problematic regarding equality, fairness, and inclusiveness if the journals' extensive data resources and references are to be used by all geoarchaeologists, including those with disabilities.

From a geomorphology perspective, Elsevier publishes *The Geomorphology Journal* (Elsevier, 2023b); although not specifically targeted towards geoarchaeology, the Journal does contain cross-disciplinary content, which can produce significant research and data that departs from the narrow perspective occasionally found within journals that use a strict criteria output. As a resource, it can communicate across a broad audience with a high citation score and impact factor.

However, international journals tend to use a hybrid open-access model, meaning that most of the content is non-accessible behind a paywall. A practitioner that is not part of a large institution, such as a university with multiple subscriptions to large journal packages would struggle to access the content, therefore unable to ensure that practice is correctly informed by current research and theory.

Commercial archaeology units are unlikely to have the resources to pay for these types of subscriptions; the alternative is to use resources such as the Directory of Open Access Journals (DOAJ) to locate information (DOAJ, 2003). However, this can be challenging; open-access journals can have a low citation and impact rating, with a slow overturn of content. No specific open-access journals exist for geoarchaeology within the DOAJ. However, relevant journals, such as *the Journal of Lithic Studies* published by the University of Edinburgh (JLS, 2023), are valuable and free resources that can help reference lithic identification, for example, from test pitting exercises.

It is essential to distinguish between sediments, a generalised term for naturally occurring geological particles that vary in a single sedimentary unit, characterised by variables such as angularity, colour and structure. And soils, a specific term for sediments that have been transformed through several internal horizons, such as topsoil and subsoil biological activity over the constant of time. A process called soil paedogenesis. Sedimentology is important as it provides an empirical marker for anthropogenic activity during a site's formation process, which can enable geoarchaeologists to interpret environments from primary sedimentary deposit structures, such as longshore drift wave action along a coastline, to secondary structures that modify sediment deposits once in situ, for example, natural frost damage or a trampled floor in an occupation layer.

The Historic England Reference Guide for *Geoarchaeology* (HE, 2015) provides a conduit between specialists framing essential information and non-specialists that need a rapid overview. Part 1 provides a basic overview of site formation processes and how sedimentary deposits form from natural processes such as colluvium, alluvium, aeolian and fluvial motion. Part 2 introduces field methods, such as auguring and sampling profiles, to build up datasets for modelling.

The guidance is an accessible document that pulls together relevant information to explore how analytical methods can be utilised in various techniques, such as Loss on Ignition to track sediment accretion or mineralogy to identify specific sediments in stratigraphic sequence (Appendix B). It also looks further at the type of questions a specialist would typically try to answer and the methodologies they would use to gain answers (Appendix C). This makes the guidance very relevant to planning a geoarchaeological intervention, and Part 3 discusses logistics in the project planning process.

However, the information is descriptive and needs to signpost further information, for example, on field techniques such as obtaining sedimentary samples for analysis. There is an overall need for more information within this area. Of course, there are practical reasons, as it involves a multitude of complex mechanical machinery, which should only be operated by trained professionals and used in compliance with specific manufacturers' guidance and

health and safety regulations. However, trying to simply fathom what is involved in a borehole survey and other geoarchaeological interventions requires searching database resources to find relatable real-world examples in published grey literature.

The Archaeological Data Service (ADS) provides an invaluable, accessible, and extensive resource to contextualise interventions using geoarchaeological techniques (ADS, 2023). As an information tool, ADS is overlooked because it is mainly used as means to find specific data, usually based on geospatial coordinates, rather than searching around keywords and phrases such as 'Magnetic Susceptibility' or 'Borehole Survey' to proactively understand and inform best practice, with the relevant background challenges and written by practising specialists in the field. However, regarding reliability, it should always be remembered that grey literature is not peer reviewed and should therefore be critically reviewed and comparatively analysed.

Reliability is also problematic regarding research frameworks, which only sometimes update and change over time as new research becomes available. For example, from a palaeolithic perspective, isolating relevant research questions at a national level is challenging because the overall research volume of palaeolithic sites is relatively rare, concentrated in the Southeast of England, and, when discovered, can fundamentally change previous interpretations. The *Research and Conservation Framework for British Palaeolithic* (HE, 2008) was a positive enterprise that brought together experts and consolidated research questions on the 1999 framework (Prehistoric Society, 1999). However, the 2008 framework has been fifteen years since its first publication and must be reviewed as a credible resource. In contrast, *the Early Palaeolithic in the Southeast* (SERF, 2019) offers a much more up-to-date approach. It discusses the geomorphology and sedimentology background data in detail and then focuses on specific research questions and objectives. Given the variability of localised geology in the UK, a regionalist approach is the best approach to frame research. It needs to be expanded to other regions of the UK to improve the validity of this neglected area of research.

The British Geological Survey (BGS) is a big data-driven organisation with over 400 operational databases (BGS, 2023); Not all the data on the BGS is relevant to geoarchaeology, and for this reason, it is possible to feel overwhelmed by the array of data and be distracted by all the different types of functionalities when using BGS geo-index mapping data and layering different datasets. It is, therefore, a complicated online tool that requires some expertise and familiarity to use competently, which can make accessibility an issue. However, the BGS Geology viewer is a more accessible tool that gives a good overview of UK geology, with precise catalogued entries describing the bedrock geology.

Primarily borehole data in the geo-index viewer is a rich source of data for geoarchaeologists that want to understand and use data to build up representative models of deposits. Undoubtedly this is a valuable resource; however, some restrictions affect currency, reliability, and relevance. Although abundant borehole data exists, it is only sometimes in the location of interest. When it is, it may not be accessible and free to view, it might not go down to an adequate depth, the record may be a low-quality scan difficult to read, and the descriptions used to describe deposits can be inaccurate for geoarchaeology. Although British Standards 5930:2015 has introduced a code of practice for ground

investigations, to uniformly categorise soils, sediments, and anthropogenic ground (BS, 2015).

Two essential functions that a geoarchaeologist performs are to firstly collate data from either existing sources or conduct new surveys in the field if the data is not available, and secondly, to produce the data into a model and report the findings, usually in 2D cross-section transects or 3D fence diagrams indicating the structure of deposits in a site's formation process. Within the introduction of Historic England guidance *Deposit Modelling and Archaeology* (HE, 2020), it should be noted that the keyword is model, and the model is only as good as its parts, i.e., the data that produces the output.

As discussed, existing BGS borehole data is a good, yet not perfect, data source. ADS also has many datasets contained within grey literature and embedded in Local Historic Environment Records (HERs). Some of this survey data can be extensive, for example, the *Medway Valley Palaeolithic Project* (Francis Webham-Smith, 2009), but the discoverability of the datasets is not intuitive, and it is also unlikely that previous borehole or test pitting data will exist for the same area of interest, potentially only around an approximate locality. This means that a sampling strategy in a deposit model can be skewed if it is only based on existing data sources, so additional data must be obtained to build a realistic deposit model.

New Borehole data is usually the gold standard in deposit modelling. However, other methods, such as test pitting, are a viable option to record deposits in stratigraphic sequences in areas such as riverine gravel terraces, where sampling is possible near the sub-surface.

It is advantageous for a professional geoarchaeologist to have an excellent working knowledge of geophysical data sources that can be included in a model to determine a strategic sampling method, especially when identifying features such as palaeolithic channels which might yield anthropogenic deposits. The Geophysical Survey Database (GSD), now hosted on ADS (ADS, 2023), uses the OASIS recording system to identify geophysical survey techniques. GSD is a valuable resource; the database is searchable on multiple variables, such as geophysical technique or land use; it also links back to ADS to find the associated grey literature from the original query. Comparatively, it would be beneficial in the future if ADS specifically hosted a geotechnical database to make all survey data more discoverable for deposit modelling.

Again, the Historic England Guidance for deposit modelling manages to strike a good balance in making information accessible and reliable for non-professionals. It has the currency to make it a useful baseline reference source for practising professionals. However, at a more sophisticated level, the edited monograph produced from the associated 2016 workshop held in London, UK, between academics and commercial geoarchaeologists that use deposit models has proven to be a very valuable resource to inform good practice (Carey, 2018). It contains approximately twenty case studies of real-life deposit modelling scenarios based on differing circumstances, which provide a good range of detail. Notably, at the end of each case study is the best practice workflow used in the study, allowing quick references between studies and a comparative analysis of the results. The monograph is,

therefore, a useful and up-to-date tool that enables flexible application for a practising specialist that needs to contextualise and plan a current project.

Technical expertise and competence are also needed for data management and to present data in a communicable format to project stakeholders. Rockworks is a computer program often used by geologists in the energy industry (RockWare, 2023). It is complex and expensive software, making it not very accessible in terms of the time and learning curve required to be proficient. However, in terms of currency, it is a program that practising geoarchaeologists are now expected to have some skills and experience in using. However, data can be visually modelled and mapped in Computer-Aided Design (CAD) technologies and shareware Graphical Information Systems (GIS) software, such as QGIS (QGIS, 2023). In terms of developing the required IT skills, it is realistic to start by learning shareware CAD and GIS programs before investing resources and time into more sophisticated modelling software.

Following on from the above discussion, it is evident that there is a plethora of different types of reference material and data sources that a geoarchaeologist can use in specialist practice to varying degrees of accessibility, reliability, currency, and relevance to inform workflows. Within the broader scope, it should be noted that there is a lot more that could be added to this assignment in terms of scientific knowledge and skills to enable a geoarchaeologist in practice to communicate with other professionals, although perhaps not explicitly being the specialist, yet obtaining an excellent professional working knowledge of key source material.

For example, soil micromorphology is an extensive and nuanced subject area from key texts such as *Applied Soils and Micromorphology in Archaeology* (Macphail, et al. 2018.) The ground-breaking 1981 publication on Environmental Archaeology by Elizabeth Reitz, updated in 2012 with co-author Myra Shackley (Reitz, et al. 2012), provides a succinct overview of research design, field methods, research questions and explanatory chapters on a range of study material from biomolecules to starch grains. Especially important in the field of geoarchaeology is dating, which is an expeditious subject area that uses many sub-disciplines, such as dendrochronology, radiocarbon dating, and luminescence dating, to mention just a few methodologies. The peer-reviewed *Journal of Archaeological Science* published by Elsevier (Elsevier, 2023c) is an authoritative resource to keep up to date with new research in these areas.

A geoarchaeologist, therefore, needs to have a wide-ranging set of skills, knowledge and experience in geomorphology, sedimentology, paleogeography, and soil micromorphology. In addition to having the practical hands-on skills of a field archaeologist, the ability to model complex data, understand sophisticated geospatial programs and potentially technical engineering equipment such as percussion drills.

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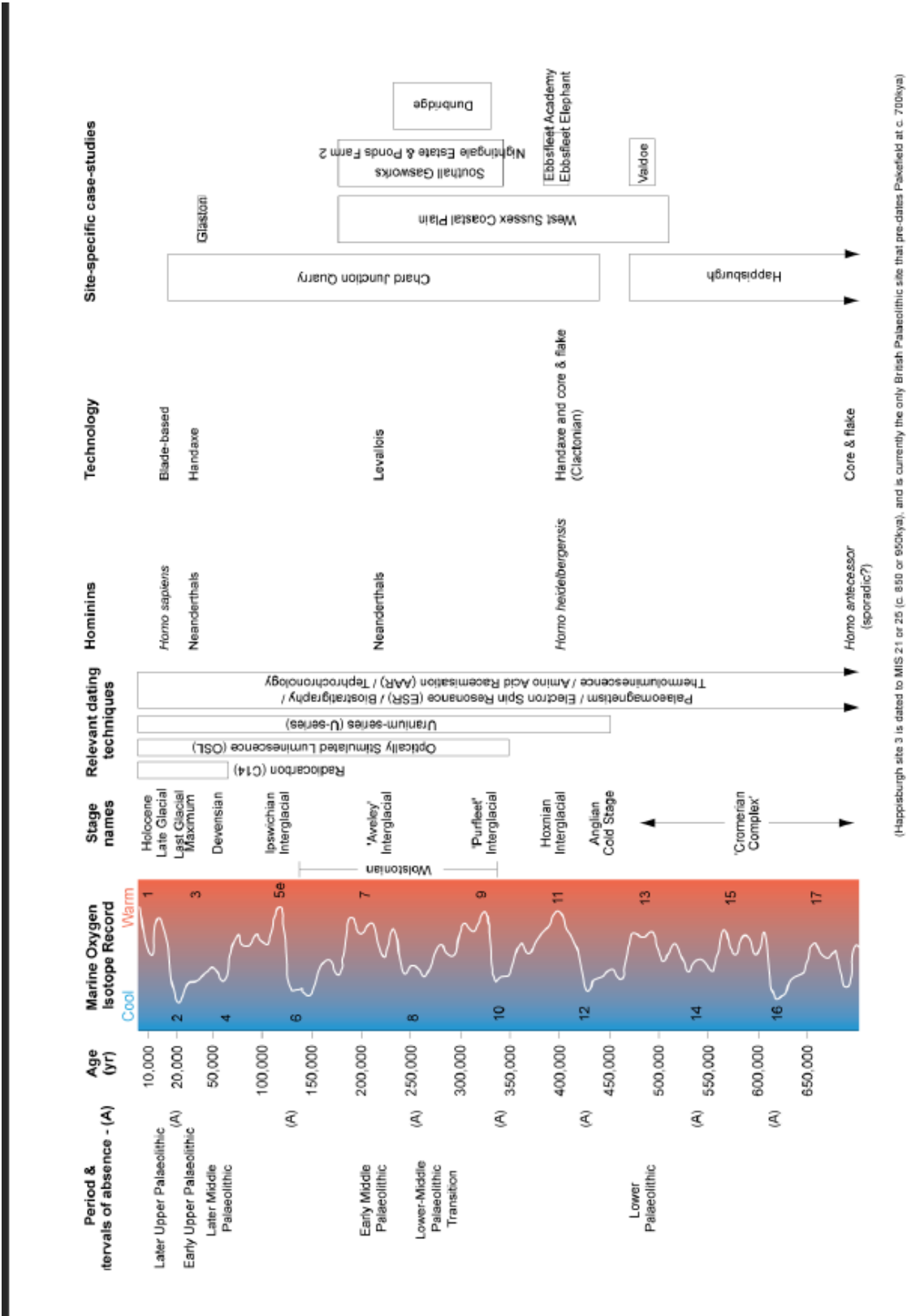
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Appendices:

A. Marine Oxygen Isotope Model.



Source: Historic England, Curating the Palaeolithic 2023.

B. Analytical Methods.

Table 10: Summary of analytical methods and their archaeological applications			
Analytical method	Scale of investigation	Sample type	Archaeological applications
Particle size analysis	Site specific and regional scale	Bulk samples	■ Identification of sediment source areas ■ Understanding of sedimentary and pedological processes
Loss on ignition	Site specific and occasionally regional scale	Bulk samples	■ Identifying soil development sequences ■ Tracking fluctuations between sediment accretion and peat growth in sea-level studies
Magnetic susceptibility	Site and structure scale	Bulk samples	■ Geophysical prospection ■ Identification of human activity in weakly defined sequences
pH	Mainly site and structure scale; occasionally regional scale	Bulk samples	■ Understanding soil history ■ Taphonomy; artefact and ecofact preservation
Mineralogy	Site and regional scale	Bulk samples	■ Identification of sediment origins ■ Biominerals assist identification of soil or sediment use and history
X-radiography	Site scale	Intact blocks	■ Understanding of depositional phases and environments
Micromorphology	Site, structure or feature scale	Intact blocks	■ Wide ranging aid to archaeological interpretation of features, structures and sites
Multi-element survey	Regional, site, structure or feature scale	Bulk samples	■ Prospection and survey to identify and delimit sites ■ Determination of activity areas within settlements and sites ■ Interpretation of individual features and/or deposits
Phosphorus survey	Regional, site, structure or feature scale	Bulk samples	■ Prospection and survey to identify and delimit sites ■ Determination of activity area within settlements and sites ■ Information on past land-use practices ■ Interpretation of individual features and/or deposits

Source: Historic England, Geoarchaeology Guidance, 2015.

C. Geoarchaeological Questions.

2.13 Typical geoarchaeological questions

Throughout this document, emphasis has been placed on a question-led approach to geoarchaeology. This should apply as much to higher level approaches as it does to more detailed site work. At the landscape scale, issues such as the broad archaeological potential of an area, its likely human use and the human impact on topography are all part of the geoarchaeological spectrum. This type of landscape analysis will tend to involve techniques, such as borehole surveys and air-photo interpretation, that inform at a suitable scale. Focussing in at the scale of individual deposits, geoarchaeological questions are commonly detailed points of stratigraphic distinction or site formation. Table 11 presents examples of typical site issues that geoarchaeologists are regularly asked to deal with. The methods suggested for answering them are restricted to those from geoarchaeology, when in reality a range of other environmental methods might contribute to resolving some of the issues (Campbell *et al* 2011). It is important to emphasise that field examination is the primary approach in most cases, with subsidiary tests employed only where they are needed.

Table 11:

Example question

Is this reddening due to burning?

Is the contact between these two layers representative of a natural depositional environment or has the upper layer been dumped?

Is this layer visually different due to soil processes or is it a different context?

This layer seems ashy. Was it originally ash?

Is the microstratigraphy intact or bioturbated?

Was this an animal pen?

Is this a buried soil?

Is this a whole soil profile or was it truncated prior to burial?

Were there stillstand phases in this stratigraphic build-up?

Was this a trampled layer or even a floor?

Could this layer have been formed by the washing out of fines from nearby (eg road-wash)?

Where did this silty layer come from?

Is this the natural?

Is this a water-laid deposit?

Common questions and possible geoarchaeological solutions	
Geoarchaeological techniques	Reference section
■ Macro-examination of section and field description ■ Magnetic susceptibility to look for enhancement ■ Possible micromorphology of boundary between reddened and normal soil to determine whether the colouration could result from redox-induced mottling, soil heated elsewhere and dumped, or soil heated <i>in situ</i>	■ Effects of burning
■ Close field inspection, possibly followed by micromorphology of the contact. Are there portions of the lower layer in the upper layer or vice versa? If so, is this due to bioturbation?	■ Boundary characteristics
■ Field description primarily, possibly followed up by micromorphology for examining matrix differences. Are they similar materials with, for example, iron movement having changed the visual properties?	■ Field description ■ Micromorphology
■ Micromorphology to show remains of ash (characteristic crystals and phytoliths) partly dissolved and not visible at the field scale	■ Micromorphology
■ X-radiography or micromorphology for burrow structures in sediments or faecal remains from soil fauna. Whole layers of soils are sometimes faecal material	■ X-radiography ■ Micromorphology
■ Examination of deposit subsoil interface ■ Phosphate survey of target area and surroundings ■ Micromorphology for calcium carbonate residues and faecal spherulites	■ Boundary characteristics ■ Soil phosphorus analysis ■ Micromorphology
■ Visual inspection of possible horizonation compared to local soils ■ Magnetic susceptibility and loss on ignition useful in some cases ■ Micromorphology to clarify some aspects of soil processes	■ Field description ■ Magnetic susceptibility ■ Loss on ignition ■ Micromorphology
■ Examination for comparison with expected profile in the area, possibly followed by micromorphology if translocations or accumulations (eg illuvial clay) are expected	■ Field description ■ Micromorphology
■ Field description, followed possibly by x-radiography, magnetic susceptibility ■ Micromorphology for evidence of humic materials, weathering, magnetic enhancement, faecal remains or biominerals	■ Field description ■ X-radiography ■ Magnetic susceptibility ■ Micromorphology
■ Micromorphology for compaction structures ■ Particle size for comparison if floor is suspected to be composed of imported material	■ Micromorphology ■ Particle size analysis
■ Particle size for comparison of the fine materials in each layer, and/or micromorphology of the contact	■ Particle size analysis ■ Micromorphology
■ Visual comparison with likely source materials from the surrounding landscape ■ Particle size and heavy mineral analysis of likely candidates	■ Field description ■ Particle size analysis ■ Mineralogy
■ Visual examination ■ Possibly particle size and mineralogy in difficult cases	■ Field description ■ Particle size analysis ■ Mineralogy
■ Visual examination for sorting and lamination ■ Micromorphology useful in some cases	■ Field description ■ Micromorphology

Source: Historic England, Geoarchaeology Guidance, 2015.