March 2009

London's foundations

protecting the geodiversity of the capital

The London Plan (Spatial Development Strategy for Greater London)
London Plan Implementation Report

MAYOR OF LONDON

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LONDON GEODIVERSITY PARTNERSHIP

GREATER**LONDON**AUTHORITY

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British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

NATURAL ENGLAND

Contents

Mayor's foreword

Our city's development is intimately bound to its geodiversity – to the variety of natural materials and processes that have shaped it over the millenia and continue to do so.

It was London's bountiful supply of gravel and brick clay that helped transform it from a tiny hamlet in to our capital city. It was the relative ease with which the Victorians could excavate London's soil that enabled them to construct the extensive underground tunnel network that we still rely on today.

When we piece together the geological jigsaw puzzle we gain insights in to our past. But crucially this also helps us to understand our present and future. We need this knowledge to safeguard our environment, our heritage, and our wildlife, but also in order to most effectively harness our resources and develop our city's economy and infrastructure in a sustainable way.

London's Foundations will help us to protect and value geodiversity. It identifies and records features of geological value and provides a foundation for developing a Greater London Geodiversity Action Plan that will go even further towards ensuring geological conservation in the decades to come.

Boris Johnson
Mayor of London

Summary

This report describes a geodiversity audit of London commissioned by a partnership led by the Greater London Authority (GLA), which includes the British Geological Survey (BGS), Natural England, Government Office for London, London Biodiversity Partnership, London Borough of Lambeth, Harrow and Hillingdon Geological Society, South London London RIGS Groups, Hanson UK and Queen Mary College, University of London. The project was funded by an Aggregates Levy Sustainability Fund grant from Natural England plus additional support from the GLA, BGS and Natural England London Region.

The audit began with a review of the available geodiversity documentation for London including: BGS field maps, databases and publications; Regional Important Geological Sites (RIGS) Group information; Natural England Sites of Special Scientific Interest (SSSI) and Geological Conservation Review (GCR) documentation; and documentation and data from the GLA and London Boroughs. An initial list of around 470 sites with potential for geodiversity value was compiled from this information. This list was then narrowed down to 100 for further assessment by exporting site locations to a GIS and cross-checking against digital aerial photography backed up by BGS staff local geological expertise.

Using the procedure set out in this report field auditing was carried out by BGS staff and the South London RIGS Group between November 2007 and April 2008. From the list of 100 sites, 35 sites were found to be suitable for detailed auditing. Harrow and Hillingdon Geological Society audited a further site in November 2008, bringing the total to 36 sites.

Using the criteria set out in this report 14 of the 36 sites are recommended for designation as Regionally Important Geological/geomorphological Sites (RIGS) in borough Local Development Documents. Of the 33 London boroughs, RIGS are recommended in eight, with five in Bromley, three in Croydon and one each in Lewisham, Ealing, Greenwich, Harrow, Hillingdon and Bexley.

Using the criteria set out in this report 15 of the 36 sites have the potential to be designated as Locally Important Geological Sites (LIGS). These sites are located in nine boroughs, three in Waltham Forest, two in Bromley, two in Islington and one each in Barnet, Lewisham, Redbridge, Wandsworth, Southwark and Sutton.

Planning proposals should have regard to geodiversity in order to implement strategic and local policies. Sites should be protected, managed and enhanced and, where appropriate, new development should provide improvements to the geodiversity value of a site. This can include measures that promote public access, study, interpretation and appreciation of geodiversity.

In addition to individual sites of geodiversity interest, Greater London has distinctive natural landscapes shaped by geological processes, such as undulating chalk downlands with dry valleys in south London, and river terraces forming long flat areas separated by steeper areas of terrace front slopes. This natural topographic geodiversity underlying London should be understood, respected and only altered in that knowledge with full knowledge of it origin and form. Planners are encouraged to use authentic contouring in restoration work and new landscaping schemes, maintain the contributions of natural topography, rock outcrops, landscape features, and to maintain soil quality, quantity and function.

1 Introduction

1.1 The London Plan (Consolidated with Alterations since 2004) published in February 2008, hereafter referred to as the London Plan, aims to protect and promote geodiversity in London, stating that the Mayor will work with partners to identify Regionally Important Geological/ geomorphological Sites (RIGS) that should be protected. These sites, along with the designated national sites, would be of strategic importance for geodiversity across London. This report identifies suitable RIGS and provides guidance to enable the boroughs to identify Locally Important Geological Sites (LIGS), which would represent additional sites of local value.

1.2 This Implementation Report provides advice that shows how the London Plan policy can be achieved. It is intended for all those interested in the geodiversity of the Greater London area and seeks to address geodiversity in its very broadest sense. Although dealing with a varied, and sometimes complex, range of issues relating to geodiversity, it is not targeted solely at practitioners in earth science, but is intended as a source of information and guidance for a wide range of planning, management, conservation and interpretation interests.

1.3 The report and associated GIS information will help to provide a strong environmental evidence base for adoption of good practice in the planning system. The Mayor looks to the boroughs to use this information to inform the protection of important sites and the promotion of geodiversity in their local development documents and in the exercise of their planning powers. Land managers and owners are also encouraged to consider ways of managing sites to improve access to and understanding of geodiversity.

1.4 It does not seek to offer a detailed geological description of the area, or provide detailed technical advice, but introduces those aspects of the geology that are essential to appreciating their importance in London. The use of technical language has been kept to a minimum, though the use of some geological terms is unavoidable. To assist readers unfamiliar with such terms a glossary is provided.

1.5 The report has been produced by a partnership led by the Greater London Authority (GLA), which includes the British Geological Survey (BGS), Natural England, Government Office for London, London Biodiversity Partnership, London Borough of Lambeth, South London RIGS Group, Harrow and Hillingdon Geological Society, Hanson UK and Queen Mary, University of London. It is funded by an Aggregates Levy Sustainability Fund grant from Natural England and funding from the GLA, BGS and Natural England London Region. On behalf of the partnership, BGS has undertaken the survey work and has provided technical expertise in the selection of sites and preparation of this report.

Aims

1.6 The principal aim of this report is to achieve more effective geoconservation by helping to ensure that the requirements of *Planning Policy Statement 9: Biodiversity and Geological Conservation* (PPS9) (August, 2005) and of the London Plan policy on Geological Conservation are met. It also seeks to identify and record features of geological and geomorphological value, including identification and assessment of potential RIGS. The project is the first to address regional scale geoconservation in a largely urban area in response to the recommendations in PPS9. As the first comprehensive plan for such a densely populated area it is intended to serve as an example of good practice for cities and other urban areas in the UK.

1.7 To achieve these aims, the report:

- reviews existing guidance and criteria for geodiversity assessment
- undertakes a geodiversity audit of London, including: a regional geodiversity overview; a description of methods and criteria used for the audit; a map and description of each recommended RIGS; good practice guidance on geoconservation for the London Boroughs
- outlines further actions needed to facilitate the future development of a Geodiversity Action Plan (GAP) for London.

1.8 Geological conservation can be viewed as a four-part process:

- audit and selection
- site designation using a hierarchical approach that reflects the importance of the sites, from statutory Sites of Special Scientific Interest to non-statutory Regional and Locally Important Geological Sites
- site protection, proactive management and promotion
- valuing geological interests in the wider landscape.

1.9 This process is not a linear progression, but cyclical as there is an ongoing need to ensure that the site coverage remains up-to-date both from a scientific perspective and because some sites may lose their original value through damage or loss of interest of certain features. This report represents the start of this process and develops thinking for taking forward an Action Plan.

2. Understanding geodiversity

What is geodiversity and why is it important?

2.1 The European Landscape Convention defines landscape as 'an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors' (ELC, Article 1). Geodiversity is concerned with both the natural and human aspects of landscape, but is primarily focused on the rocks, sediments, soils, the landscape topography and the processes that act on the landscape. Geodiversity can be defined as:

> *'the variety of rocks, fossils, minerals, landforms, soils and natural processes, such as weathering, erosion and sedimentation, that underlie and determine the character of our natural landscape and environment' (London Plan)*

2.2 Geodiversity is a fundamental natural resource – all raw materials that cannot be grown and all energy that cannot be generated by renewables have to be won from the Earth's crust using geological science. It is the source of much of our prosperity, a key factor in our cultural identity, and will play a fundamental role in our nation's future development. Understanding of geology is also vital to the design and location of buildings and infrastructure as well as to the safe disposal of waste, and the identification and management of a wide range of natural and man-made hazards. All are aspects of geodiversity.

2.3 An awareness of geodiversity helps us to understand our environment and predict environmental change in the future. Geoscience research demonstrates that surface environments are continually evolving through natural self-regulating systems involving the Earth's crust and mantle, oceans, atmospheric processes and life forms. Human activity imposes further pressures and changes to these natural cycles, which pose great challenges to modern society. Global climate change from rising levels of greenhouse gases and exhaustion of finite resources such as fossil fuel are two of the most pressing. Studying the geological record can play a vital role predicting the Earth's response to these changing conditions. Recognition of geodiversity can help maintain this record for future study.

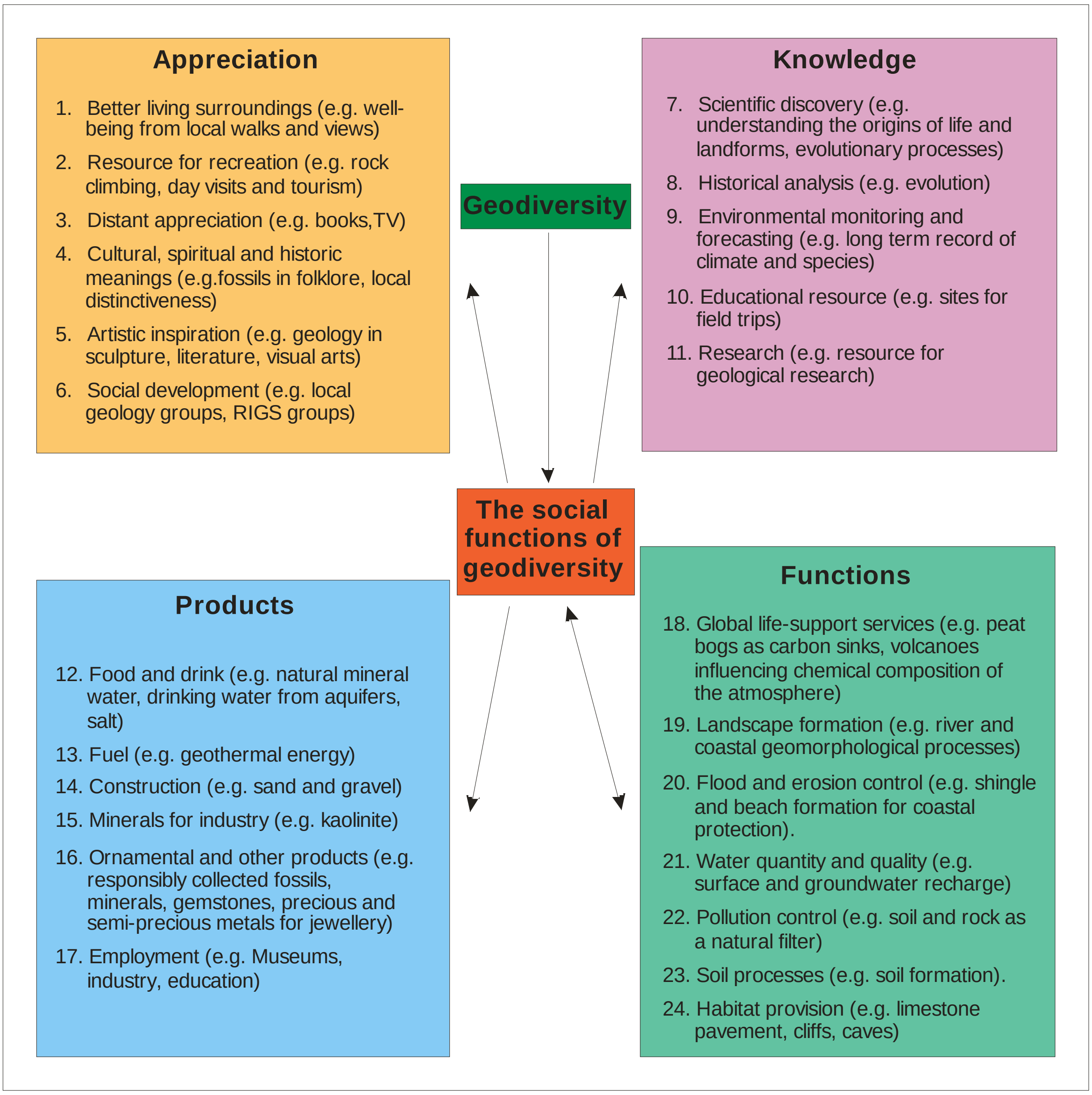
2.4 Geology is fundamentally a field-based discipline and the existence of well-exposed geological features is critical for scientific study, educational use and recreational enjoyment. If advances in geoscience and the educational and the recreational study and enjoyment of geology are to continue, important sites need to be identified and managed. Geoscientists need sites on which to undertake their research. Teachers and students need sites on which to demonstrate the principles of geology and landscape evolution processes. In order to locate and utilise the Earth's resources and to give advice on the management of natural hazards, trained earth scientists are needed. Such training requires access to high-quality geodiversity sites to provide field-based experience. Consequently, it is necessary to audit, conserve and manage our geological heritage so that it remains available for future scientific, educational and recreational use (Prosser et al., 2006).

2.5 The recognition of natural and cultural heritage features and their sustainable management are today accepted as important functions within a modern society. The geodiversity of any area is an equally important part of its natural heritage as its biodiversity. Conservation, sustainable management, educational use and interpretation of geodiversity are thus as important as that of biodiversity or archaeology.

2.6 However, geodiversity is not, or should not be regarded merely as concerned with conservation of Earth heritage sites or features – it has a vital place in all aspects of natural heritage and impacts in fields as varied as economic development (for example, supporting the development of geotourism in the European Geopark Network), building stone resource development, education and lifelong learning, archaeology, art and wildlife.

2.7 The intrinsic, cultural, aesthetic, economic, functional and research value of geodiversity has been evaluated by Murray Gray in his book 'Geodiversity: valuing and conserving abiotic nature' (Gray, 2004). Webber et al. (2006) reviewed the social and economic value of geodiversity and summarized the four main geodiversity value classes (Figure 1).

Figure 1 The social functions of geodiversity (from Webber et al., 2006)



2.8 An essential starting point in understanding an area's geodiversity is an appreciation of the most up-to-date available knowledge of its geological features, together with the processes that have formed them and continue to influence them.

2.9 An area's geodiversity includes:

- the broad geological and geomorphological character of the area
- key natural systems and processes within the area, such as pedological, fluvial or coastal processes
- main topographic features, including those which, due to their linear or continuous nature, are important habitats and conduits for the migration, dispersal and genetic exchanges of plants and animals

- sites or features where representative examples of the area's geological strata and features may be seen
- sites or features which are deemed worthy of some form of designation or protection for the quality of the Earth heritage features displayed
- the location and nature of past and present working of minerals
- sites and features currently employed in interpreting geodiversity
- the influence of geology in shaping the man-made environment, urban landscapes and architectural heritage
- the inter-relationship between Earth heritage and other interests, for example biodiversity, archaeology, history.

2.10 Documentation of an area's geodiversity may include:

- materials collections and site and other records such as borehole logs
- published literature and maps
- the historical legacy of research within the area.

Relationship with biodiversity

2.11 Geodiversity is of fundamental importance in controlling the topography, altitude, aspect and the physical substrates which provide the habitats that underpin biodiversity. At the physical level, geological processes such as glacial erosion and properties such as the relative resistance to erosion of different rock types produce varying landforms and relief features within a landscape. These landscape features in turn provide diversity in physical conditions that support plant and animal communities, at all scales from small outcrops through to mountain ranges.

2.12 At the larger scale, tectonic processes (e.g. continental break-up and collision) create pronounced relief which has a direct influence on regional and local climate, and in turn, on the ecosystems that develop. This also works at smaller scales, for example, microclimate differences between the top and base of a cliff. Landscape variety is continually modified by geomorphological processes acting at a variety of scales. Glacial, periglacial, fluvial and other processes such as slope failure produce new habitats that promote ecological succession and cyclicity and increase overall biodiversity.

2.13 In locations where climate, relief and human management are constant, the variation in rock type can strongly influence vegetation distribution. The way in which a rock weathers and acts as parent material for soil development is the most obvious mechanism for influencing floral characteristics. The main factors that rock type influences are soil chemistry, grain size, texture, porosity and permeability. Differences in pH have a major impact on the uptake of various minerals by plants – this is probably the key factor in differentiating the floras from calcareous and non-calcareous rocks. Specific plant-rock associations do occur with rocks of a very distinct chemistry such as serpentinite (for example Calaminarian grasslands of the *Violetalia calaminariae)*. Rock type also influences chemistry of both ground and surface waters which give rise to differing aquatic communities.

2.14 In summary, the very diversity of rock types and geomorphological processes creates and leads to further diversity in their interaction with other processes. Ultimately biodiversity is a direct function of geological form and process.

Geodiversity and spatial planning

Sustainable development policies

2.15 At the Rio Earth Summit in 1992, governments around the world committed to the principles of sustainable development contained within the Rio Declaration on Environment and Development. The UK Government produced its national strategy in 1994, and since 1999 progress has been measured every year against the indicators set out in the 1999 sustainable development delivery document *A Better Quality of Life*. *Planning Policy Statement 1: Delivering sustainable Development* (PPS1) (January, 2005) set out the overarching policies on the delivery of sustainable development through the planning system in England. For the environment, PPS1 states:

> *'Planning policies should seek to protect and enhance the quality, character and amenity value of the countryside and urban areas as a whole. A high level of protection should be given to most valued townscapes and landscapes, wildlife habitats and natural resources. Those with national and international designations should receive the highest level of protection.'*
> *Plan policies and planning decisions should be based on:*
> - *up-to-date information about the environmental characteristics of an area.*
> - *the potential impacts, positive as well as negative, on the environment of development proposals (whether direct, indirect, cumulative, long-term or short-term); and,*
> - *recognition of the limits of the environment to accept further development without irreversible damage.' (PPS1)*

2.16 Since the transposition of the Strategic Environmental Assessment (SEA) Directive (EC Directive 2001/42 EC) into UK law in 2004, Regional Planning Bodies (RPBs) and Local Planning Authorities (LPAs) must prepare an SEA as an integral part of the preparation of Regional Spatial Strategies and Local Development Documents. Included in the preparation of these documents is the need to collect and present baseline environmental information, which includes geological, soil and landscape information. As well as the current state of this baseline, the likely significant effects on the environment of implementing the plan need to be identified, described and evaluated.

2.17 Also at the Rio Earth Summit, international acceptance of the need to conserve biodiversity led to the UN Convention Biological Diversity and the subsequent signing by over 200 countries. Since the UK government published 'Meeting the Rio Challenge' in 1995, most local authorities or regions in the UK have prepared and implemented Biodiversity Action Plans (BAPs) for their areas, and biodiversity is now accepted as an essential element in sustainable development planning and management strategies. The GLA published its Biodiversity Strategy in 2002 (GLA, 2002). Until relatively recently the parallel concept of geodiversity had attracted little interest from planners, despite its fundamental importance in underpinning biodiversity, though recent developments, particularly the introduction in 2005 of PPS9, are beginning to address this.

Planning policy

2.18 The 1949 National Parks and Access to the Countryside Act established the legal framework for nature conservation, including geological conservation. Since then geodiversity, alongside wildlife interests, has been an important part of the planning process.

2.19 PPS9 is explicit about the significance of geological conservation in relation to the planning process and associated policy development. It clearly states that both Regional Spatial

Strategies and Local Development Documents must have regard to the national guidance on geodiversity set out in PPS9. The key principles of PPS 9 are:

(i) Development plan policies and planning decisions should be based upon up-to-date information about the environmental characteristics of their areas. These characteristics should include the relevant biodiversity and geological resources of the area. In reviewing environmental characteristics local authorities should assess the potential to sustain and enhance those resources.
(ii) Plan policies and planning decisions should aim to maintain, and enhance, restore or add to biodiversity and geological conservation interests. In taking decisions, local planning authorities should ensure that appropriate weight is attached to designated sites of international, national and local importance; protected species; and to biodiversity and geological interests within the wider environment.
(iii) Plan policies on the form and location of development should take a strategic approach to the conservation, enhancement and restoration of biodiversity and geology, and recognise the contributions that sites, areas and features, both individually and in combination, make to conserving these resources.
(iv) Plan policies should promote opportunities for the incorporation of beneficial biodiversity and geological features within the design of development.
(v) Development proposals where the principal objective is to conserve or enhance biodiversity and geological conservation interests should be permitted.
(vi) The aim of planning decisions should be to prevent harm to biodiversity and geological conservation interests. Where granting planning permission would result in significant harm to those interests, local planning authorities will need to be satisfied that the development cannot reasonably be located on any alternative sites that would result in less or no harm. In the absence of any such alternatives, local planning authorities should ensure that, before planning permission is granted, adequate mitigation measures are put in place. Where a planning decision would result in significant harm to biodiversity and geological interests which cannot be prevented or adequately mitigated against, appropriate compensation measures should be sought. If that significant harm cannot be prevented, adequately mitigated against, or compensated for, then planning permission should be refused.

2.20 These key principles require that planning policies and decisions not only avoid, mitigate or compensate for harm, but seek ways to enhance and restore biodiversity and geodiversity.

2.21 Complementary to PPS 9, *Planning for Biodiversity and Geological Conservation - A Guide to Practice* (March,2006) provides good practice guidance, via case studies and examples, on the ways in which regional planning bodies and local planning authorities can help deliver the national policies in PPS9 and comply with legal requirements.

2.22 PPS9 has informed the development of Policy 3D.16 in the London Plan, the Mayor's Spatial Development Strategy (Figure 2). The policy underlines the need to protect and promote London's geodiversity and sets the strategic context for local planning decisions and policies in the Development Plan Documents (DPDs) prepared by the London boroughs. Chapter 8 of this report sets out advice on incorporating geodiversity into local level planning.

Figure 2 London Plan extract

London Plan Policy 3D.16 Geological Conservation

The Mayor will work with partners to ensure the protection and promotion of geodiversity. Boroughs should:

- *accord the highest protection to nationally designated sites (SSSIs) in accordance with Government guidance*
- *give strong protection in their DPDs to Regionally Important Geological Sites (RIGS) which, in addition to nationally designated sites, includes sites of strategic importance for geodiversity across London*
- *identify additional sites which are of value at the local level and should accord them a level of protection commensurate with their local significance.*

3.320 The planning of new development and regeneration should have regard to the conservation of geological features and opportunities should be taken to achieve positive gains for conservation through the form and design of development. Where development is proposed which would affect an identified geological site the approach should be to seek to avoid adverse impact on the geological interest, and if this is not possible, to minimise such impact and seek mitigation of any residual impacts.

3.321 The Mayor will work with Natural England, British Geological Survey and RIGS groups to identify RIGS based on the UKRIGS criteria and prepare a methodology that will enable boroughs to identify Locally Important Geological Sites (LIGS).

3.322 Measures to enhance study and appreciation can include provision for permanent geological sections, access and interpretation. Where only temporary sections are available opportunities should be provided for geological recording and sampling during development.

3. Geological conservation

Statutory designations

Sites of Special Scientific Interest (SSSIs)

3.1 A representative sample of the best of the UK's wildlife and geological sites enjoy legal protection through their designation as SSSIs. The designation was introduced as one of the provisions of the 1949 National Parks & Access to the Countryside Act and has been maintained through subsequent legislation. The term SSSI is used today to denote an area of land notified as being of special nature conservation interest under the Wildlife and Countryside Act 1981. The Countryside and Rights of Way (CRoW) Act 2000 greatly strengthened the legislation relating to the conservation of geology and wildlife in England and Wales by placing emphasis on management rather than just conservation of SSSIs. It requires that all public bodies should conserve and enhance SSSIs. The CRoW Act also makes it an offence for anyone to knowingly or recklessly damage an SSSI, including by irresponsible mineral or fossil collecting. The network of SSSIs in England is the responsibility of Natural England. Designation as an SSSI does not imply any right of access for third parties. Neither does it follow that the site is necessarily appropriate for public interpretation. There are seven SSSIs designated for their geological interest in Greater London area (Figures 3 and 4).

Figure 3 Geological Sites of Special Scientific Interest in Greater London

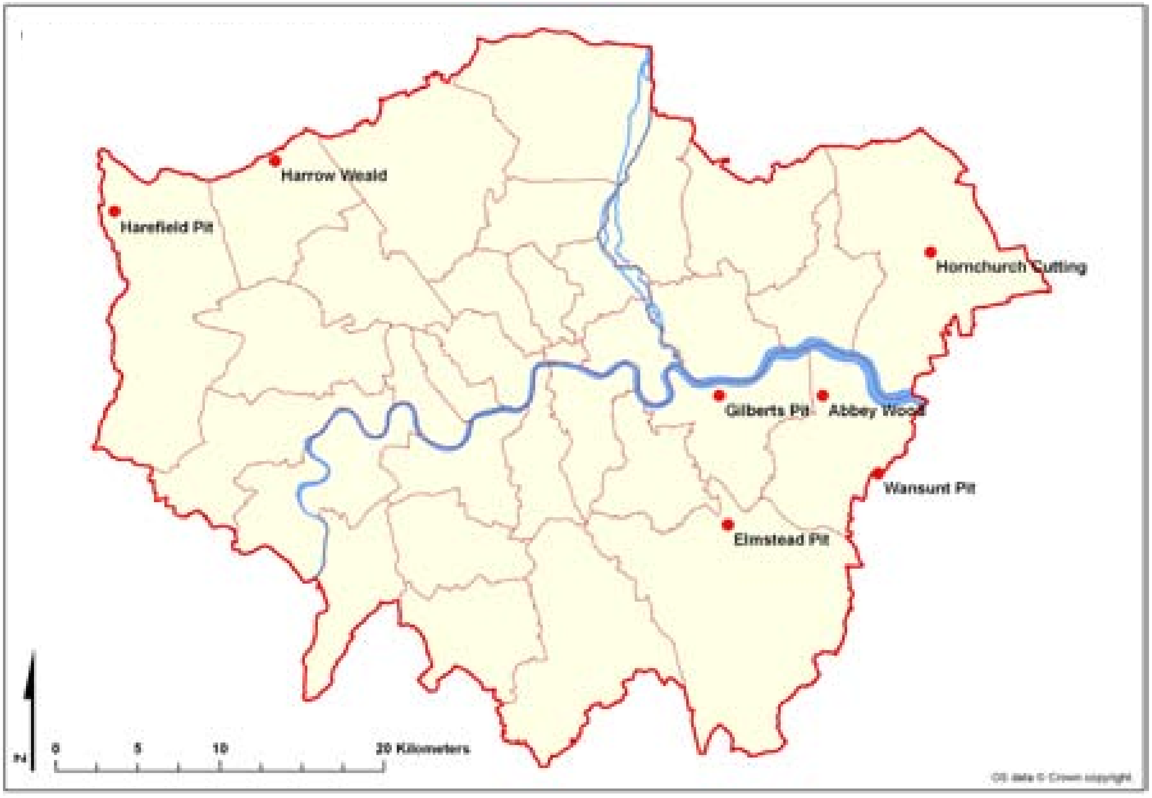


Figure 4 Geological SSSIs in Greater London

Site Name Site No.	Location Grid ref Area (ha)	Condition Ownership	Comments and stratigraphy
Abbey Wood GLA 1	Bexley TQ 480 786 6.89	Favourable London Borough of Bexley	Abbey Wood contains some of the most fossiliferous deposits in the Greater London area providing remains of a diverse mammal assemblage of earlyEocene age. The deposits are also important for studies in the evolution of bird faunas. The deposits occur in the topmost part of the Lambeth Group or in an outlier of the Harwich Formation (previously referred to the Blackheath Beds, or Blackheath Formation), in the 'Lesnes Shell Bed'.It is also suggested as a local sandy lateral variation of the Upper Shelly Clay of the Lambeth Group (Ellison et al., 2004).
Wansunt Pit GLA 35	Bexley TQ 515 738 1.94	Favourable Private landowner, but site managed by London Wildlife Trust	This site provides exposures in the Dartford Heath Gravel, a deposit that has been the subject of considerable controversy since the turn of the century. Current geological maps indicate the deposit is part of the Boyn Hill Gravel, of equivalent age to the terrace deposit at Swanscombe, but it has also been attributed to the Black Park Gravel, an older terrace deposit (Ellison et al., 2004).
Elmstead Pit GLA 33	Bromley TQ 4232 7066 0.05	Favourable Private landowner	Elmstead Pit provides a nationally important exposure of the Harwich Formation (Blackheath Beds) through a section containing an unusually rich fossil fauna (Daley, 1999a).
Gilbert's Pit GLA 14	Greenwich TQ 418 786 5.35	Unfavourable London Borough of Greenwich	Gilbert's Pit provides one of the most complete sections through the Early Palaeogene beds in the Greater London area. It forms a key Palaeogene site for stratigraphic studies and is particularly important for a palaeogeographic reconstruction of the Lambeth Group. It exposes the Woolwich Formation and the Harwich Formation (Blackheath Beds) but former exposures of the Thanset Sand and Chalk are now buried by war-time rubble and scree (Daley, 1999a).
Harefield Pit GLA 34	Hillingdon TQ 049 898 1.61	Unfavourable Private landowner	Harefield Pit provides a key section in the London Basin for a sequence through the Upper Chalk, Lambeth Group and London Clay. It is also the only known site for calcareous floral remains in the Reading Formation. As discussed by Daley (1999b), the stratigraphy of the Harefield Pit has been described in various ways. It includes representatives of the Upnor Formation (resting on a burrowed Chalk surface), the Reading Formation, Harwich Formation and the sandy basal part of the London Clay.
Harrow Weald GLA 18	Harrow TQ 147 929 3.52	Favourable London Borough of Harrow	Harrow Weald is a small but important geological site which exhibits the most complete exposure of the Stanmore Gravel, overlying the Claygate Member.
Hornchurch Cutting GLA 19	Havering TQ 547 874 1.57	Favourable Network Rail	Hornchurch Cutting provides unique sections through a series of deposits which are of great stratigraphical importance for studies of the Pleistocene. In particular the site is of considerable significance for correlating the formation of the Thames terrace sequence with the glacial stratigraphy of southern Britain. The sections expose a channel within London Clay bedrock infilled by Anglian till (the 'Hornchurch till'). This till is overlain by river terrace deposits currently assigned to the Black Park Gravel (although a correlation with the Boyn Hill Gravel has also been suggested).

Geological Conservation Review (GCR) Sites

3.2 The Geological Conservation Review (GCR) was initiated by the Nature Conservancy Council in 1977 to identify, assess, document and eventually publish accounts of the most important parts of Great Britain's rich and varied geological heritage. In general, only one site was selected as the best example of each aspect of geology under consideration. GCR sites were selected on the basis of their scientific value rather than their educational or historical importance. Three criteria were applied in selecting the GCR sites:

- sites of international geological importance
- sites that are scientifically important because they contain exceptional features

- sites that are nationally important because they are representative of a geological feature, event or process which is fundamental to understanding Britain's geological history.

3.3 Once selected, a GCR site was then proposed as a potential SSSI. All the GCR sites in Greater London area are designated as SSSIs (Figure 5). For further detail of the Geological Conservation Review, see http://www.jncc.gov.uk/page-2947

Figure 5 GCR Sites and Blocks

Site Name and Grid ref	Site Code	GCR Block
Abbey Wood(s) - TQ 480 786	2903	Mesozoic-Tertiary Fish/Amphibia
	1248	Tertiary Mammalia
	582	Aves
Harefield - TQ 049 898	762	Tertiary Palaeobotany
	519	Palaeogene
Charlton Sand Pit (Gilberts Pit) - TQ 419 786	520	Palaeogene
Elmstead Rock Pit - TQ 423 706	521	Palaeogene
Hornchurch - TQ 547 873	893	Quaternary of the Thames
Wansunt Pit - TQ 514 737	846	Quaternary of the Thames
Harrow Weald Common - TQ 147 929	1170	Quaternary of the Thames

Non-statutory designations

Regionally Important Geological/geomorphological Sites (RIGS)

3.4 RIGS were established in 1990 by the Nature Conservancy Council (NCC) (predecessor of English Nature and Natural England). They have support from Natural England and other national agencies, and are increasingly recognised by local planning authorities. RIGS complement the SSSI coverage. To date RIG Sites have been selected by voluntary groups (known as RIGS groups), which are generally formed by county or by unitary authority area in England. There are more than 50 local groups in the UK, though not all are active. There are two active RIGS groups in London, South London RIGS and North West London RIGS, but to date no RIGS have been formally designated in Greater London.

3.5 RIGS are currently the most important designated places for geology and geomorphology outside statutorily protected land such as SSSIs. The designation of RIGS is one way of recognising and protecting important geodiversity and landscape features for future generations to enjoy.

3.6 Guidance on RIGS is available on the UKRIGS website (www.ukrigs.org.uk). They are important as an educational, historical and recreational resource. Sites are selected according to:

- the value for educational purposes in life-long learning
- the value for study both by professional and amateur earth scientists
- the historical value in terms of important advances in Earth science knowledge, events or human exploitation
- the aesthetic value in the landscape, particularly in relation to promoting public awareness and appreciation of geodiversity.

3.7 In London RIGS are sites that are considered worthy of protection for their geodiversity importance at the London-wide level. They can be viewed as equivalent to Sites of Metropolitan Importance for Nature Conservation (SMIs), which include land of strategic importance for nature conservation and biodiversity across London. Chapter 7 of this report identifies sites that meet the criteria for London RIGS and are recommended that they be designated in the DPDs prepared by the London boroughs. These sites should be protected as set out in Policy 3D.16 of the London Plan.

Locally Important Geological Sites (LIGS)

3.8 The London boroughs may designate certain areas as being of local conservation (including geological) interest. The criteria for inclusion, and the level of protection provided, should reflect the local level of importance in the hierarchy of sites.

3.9 LIGS are equivalent to Sites of Borough or Local Importance for nature conservation, which are accorded a level of protection commensurate with their borough or local significance. Local site networks provide a comprehensive rather than a representative suite of sites. Defra have recently published detailed guidance on identification, selection and management of local sites (DEFRA, 2006).

3.10 These sites are designated in the DPDs prepared under the Town and Country Planning system by the London boroughs and are a material consideration when planning applications are being determined. Chapter 7 of this report identifies potential LIGS that may be designated in DPDs by the London boroughs.

Potential conflict of interest

3.11 Sites or features selected for any form of protection can rarely, if ever, be satisfactorily regarded as 'single interest' sites. Statutory designation of sites, as SSSIs or Scheduled Ancient Monuments (SAMs), offers a powerful means of protecting the most important sites and features, though even here failure to take account of other interests can lead to misunderstandings and potential conflict. In some instances scheduling without adequate multi-disciplinary consultation may result in these related interests being put at risk. Non-statutory designations, whilst offering no legal protection, may nevertheless be extremely useful in highlighting a site's importance.

3.12 In some instances the legal restrictions associated with SAMs may be detrimental to the conservation and use of the site's geodiversity interest. For example, a mine or quarry site selected for conservation and restoration of its archaeological interest may also include extremely important geological features. Failure to take these into account may result in them being compromised or even destroyed. Similarly, an abandoned quarry which displays extremely important geological sections may also support interesting or important plant communities, may be a bat roost, or may be associated with historically interesting buildings. Thus, there is a need to resolve the potential for conflict of conservation interests and it is hoped that this report will help to identify such conflicts and opportunities to combine interests.

3.13 A multi-disciplinary approach to conservation of all features is not only highly desirable, but offers enormous potential to enhance the value and interest of many individual sites. Whereas this may seem obvious, often the underlying principle seems to have been overlooked, or even ignored, in many previous conservation initiatives. More recently, integrated approaches are increasingly being encouraged and adopted, for example through the development of integrated management plans and conservation objectives.

4. London's geological heritage

Evolution

4.1 This chapter sets the geological scene for a discussion of the geodiversity of Greater London, summarising the geological evolution and development of the landscape.

Geological time

4.2 Geological time is divided into Eons, Eras, Periods and Epochs (Figure 6). Although the Earth is almost 4600 million years old, events from only the last 100 million years or so are represented in the surface geology of London. The coloured bands in Figure 6 indicate those periods of geological time represented in the district's rocks, from the mid-Cretaceous to the present, with their age in millions of years. Also indicated are events that occurred during the long periods of time for which no record remains; their presence has been inferred from evidence in adjoining areas.

4.3 The extent of geological time may be appreciated by considering the whole of Earth history as a single day. On this scale, the oldest rocks in the London area formed around 11.30 pm, and the London Clay that underlies most of the metropolis about 11.45 pm. The Quaternary ice ages began less than one minute before midnight and human-like creatures first strolled by the River Thames at less than one second to midnight.

Palaeozoic and older

4.4 To understand the surface geology, however, it is also necessary to consider the older rocks that form the local geological basement. In much of the district these lie between only 250 and 400 metres below the surface, but in the south they are much deeper, at more than a kilometre (Figures 7 and 8). The London district lies at the junction of two deep-seated geological terranes within the pre-Mesozoic basement. A third terrane lies just to the east (Pharaoh et al., 1993). These can be seen on the Bouguer gravity anomaly map of the region Figure 9).

4.5 The north and west of the district is underlain by the Midlands Microcraton, an area where Proterozoic and Palaeozoic rocks occur at relatively shallow depths. Structural trends are complex. The Midlands Microcraton extends west as far as Worcestershire and north beneath Leicestershire. It formed part of the Early Palaeozoic continent of Avalonia. In mid-Silurian times, when it lay at a latitude of about 30° south, the northern edge of Avalonia was driven at a shallow angle beneath Laurentia, during the Caledonian Orogeny. Since then, the Midlands Microcraton has been relatively tectonically stable. The terrane to the east of London is part of a Caledonide fold belt that underlies eastern England.

4.6 Evidence from the English Midlands suggests that the Proterozoic strata beneath London include volcanic rocks between about 600 and 700 million years old. Deep boreholes in the region show that the Early Palaeozoic strata are dominated by mudstones and sandstones, with some limestones, laid down in shallow seas. Most of the Ordovician, however, was a period of non-deposition in this region.

4.7 During the Devonian, following the Caledonian Orogeny, the London region formed part of a broad low-lying area with mountains of the Anglo-Brabant Massif to the north and an ocean to the south. Devonian strata occur at depth throughout most of the region, although varying in thickness considerably. They are dominated by sandstones, with siltstones and mudstones, deposited in desert, lacustrine and fluvial environments.

Figure 6 A timescale and summary geological history for the Greater London area

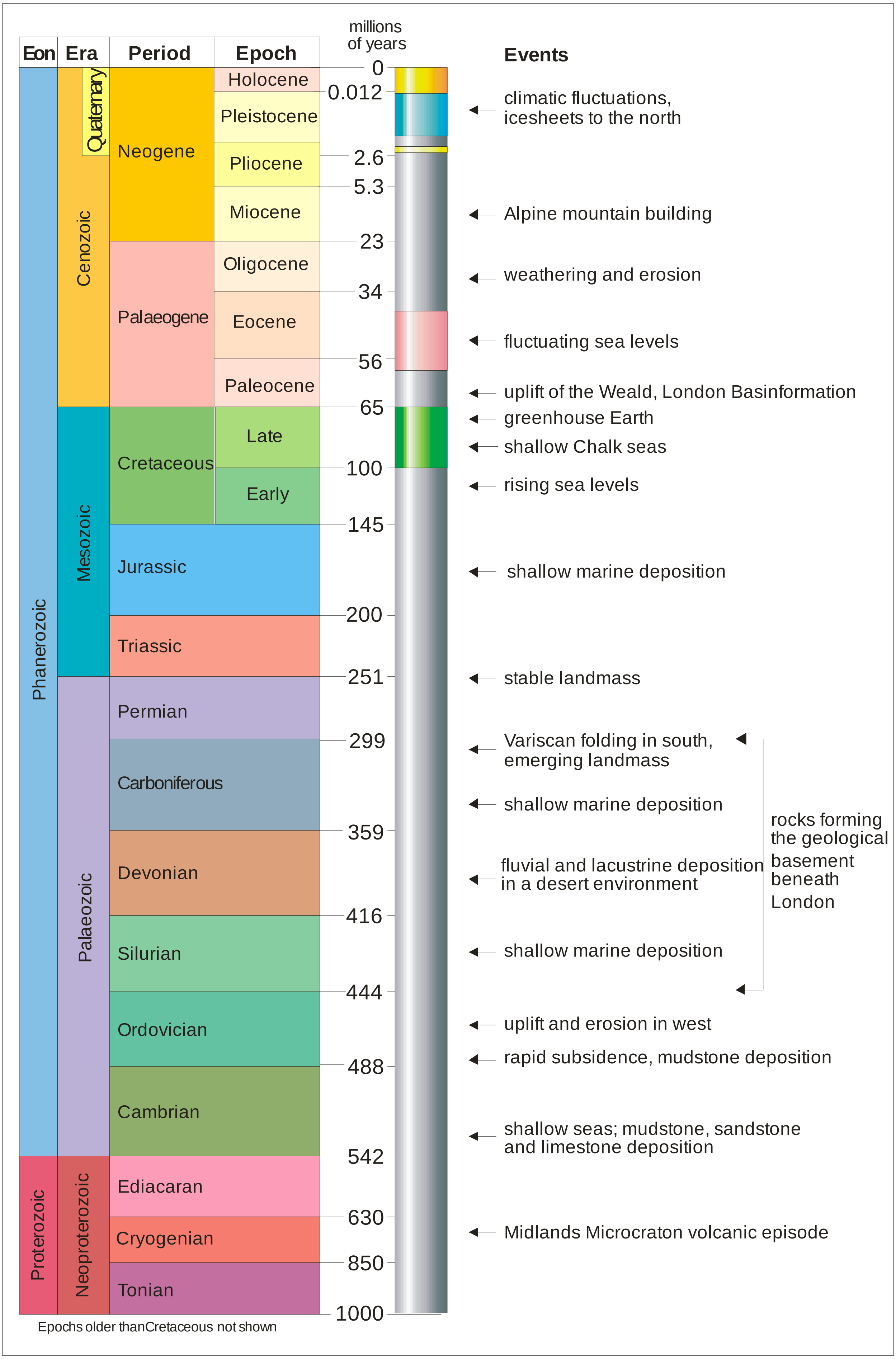


Figure 7 Palaeozoic basement of the Greater London (from Ellison, 2004)

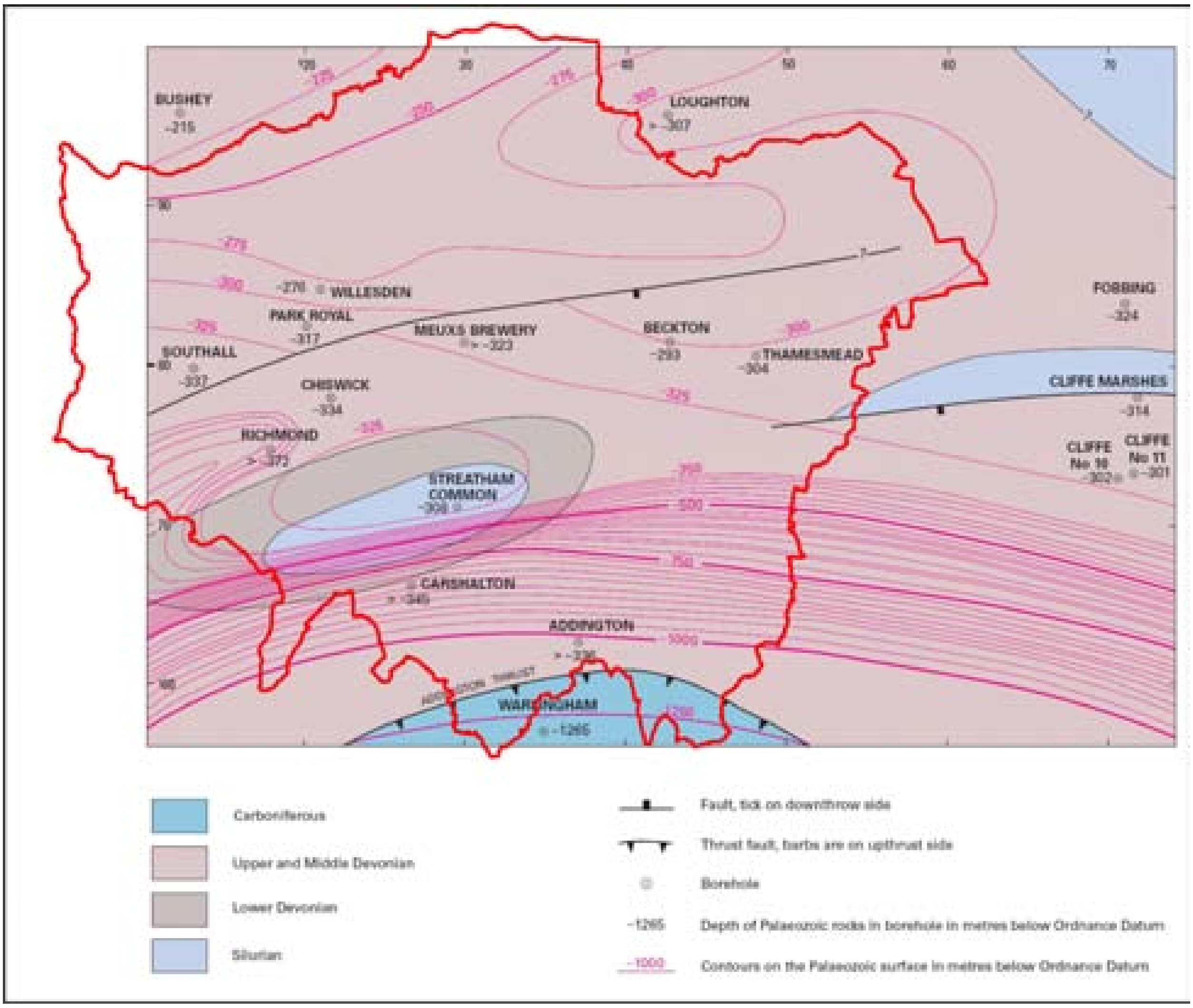


Figure 8 Geological section showing the London Basin syncline (from Sumbler, 1996)

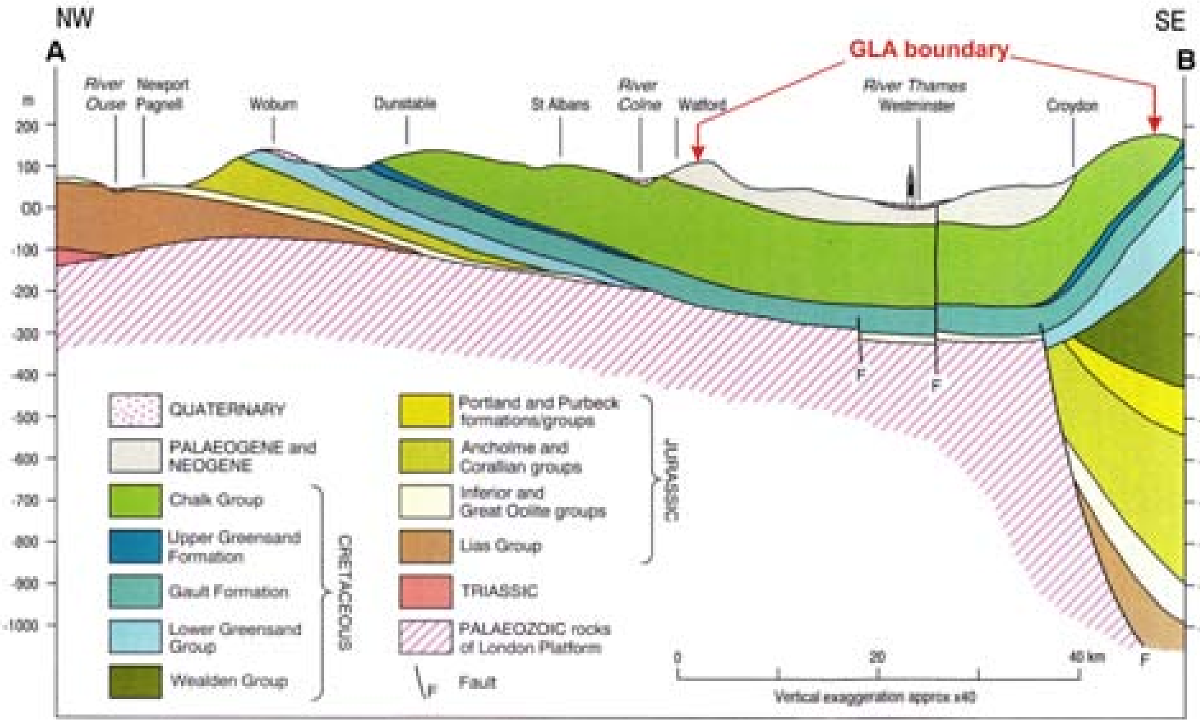
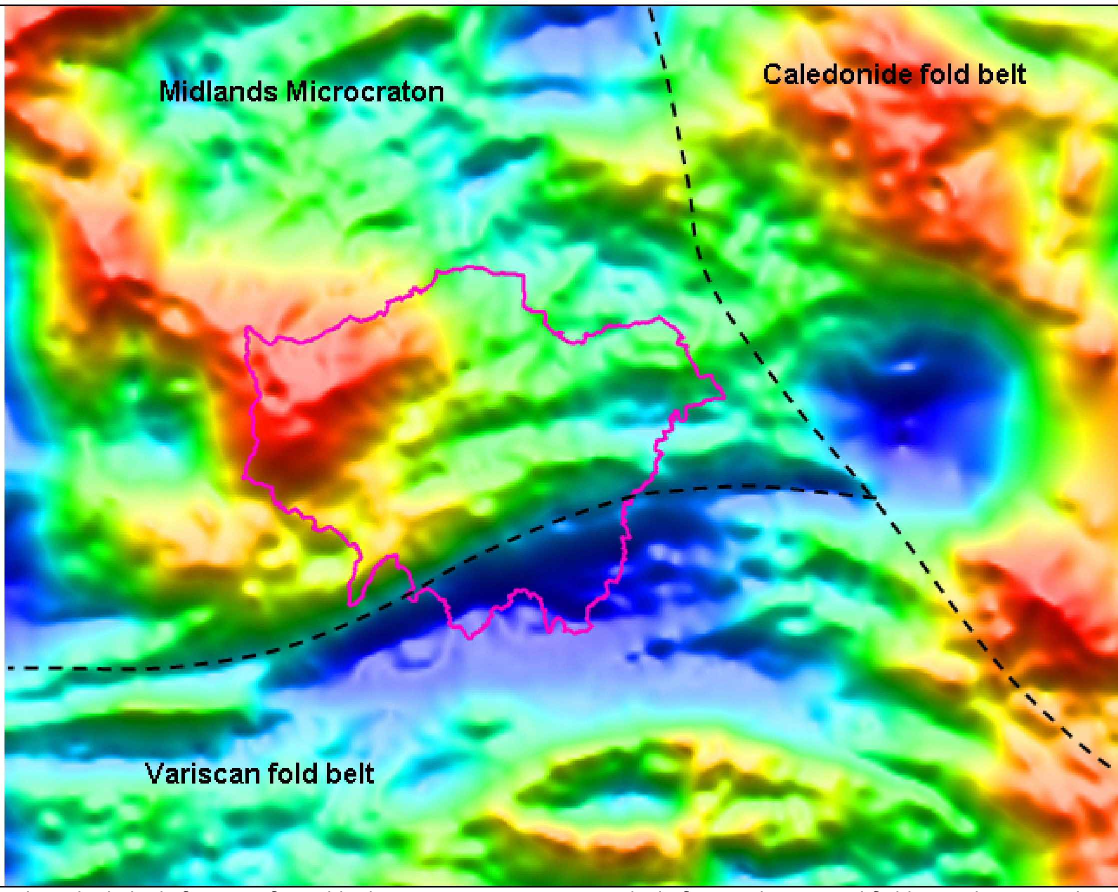


Figure 9 Gravity map of London and surrounding area



Colour shaded relief image of variable density Bouguer gravity residual of upward continued field to 10 km. Dotted lines indicate the approximate boundaries of the regional basement terranes: the 'deep geological structure'. Red: gravity 'high' (mass of underlying rock is greater than average); Blue: gravity 'low' (mass of underlying rock is less than average). Outline of the GLA in magenta.

4.8 The southern part of the area includes the northern margin of a Variscan fold belt, formed towards the end of the Carboniferous and in early Permian times during the Hercynian Orogeny, a mountain-building event that can be traced across southern Europe. This terrane is represented by arcuate structural trends, oriented approximately east-west, as seen in the Bouguer anomaly map. In the usual interpretation, the Variscan Front (the northern limit of the main fold belt) is locally marked by the Addington Thrust, a major fault detected by seismic reflection at more than a kilometre deep beneath the South Downs. To the south of this thrust, a borehole at Warlingham, Surrey, found early Carboniferous limestones and shales. Rocks of Carboniferous age have not so far been proved in the London district to the north of the Addington Thrust.

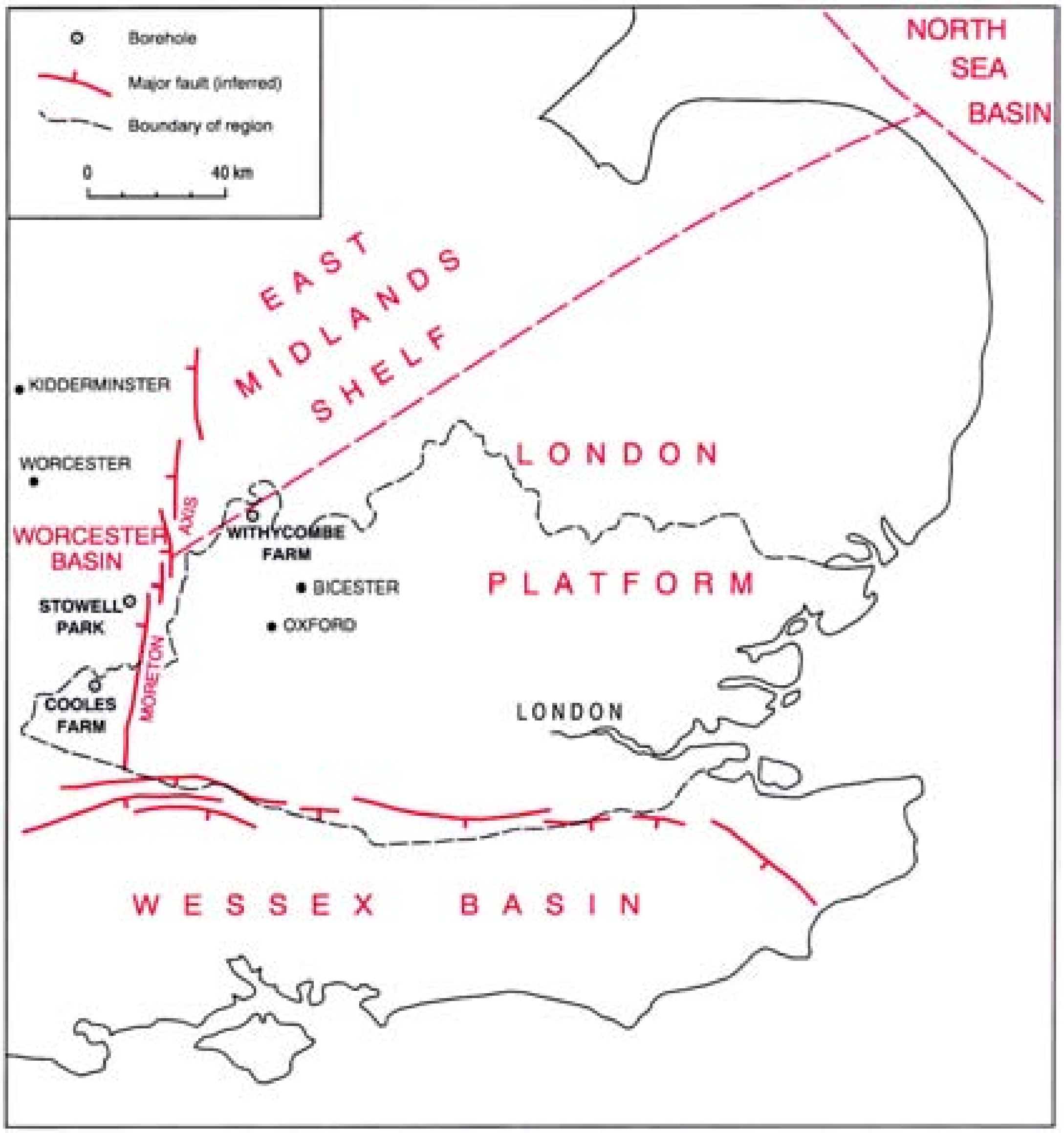
4.9 The presence of a thick wedge of folded Late Palaeozoic sedimentary rocks (probably Devonian in age), deep beneath south London, is shown by a large negative Bouguer gravity anomaly. This wedge may also be part of the Variscan fold belt. It is faulted against the older, denser rocks of the Midlands Microcraton, as shown by the curvilinear traces in the gravity map, extending from the south-west in a north-eastwards and then eastwards direction. These curvilinear fault traces represent a northwards splay from the main Variscan fold belt. This fault zone is likely to be quite complex at depth, becoming simpler upwards. Faults and folds seen in the bedrock under south-west and south London (the Wimbledon to Greenwich tectonic zone) formed by later movement in this structural zone.

Mesozoic and Cenozoic

4.10 The Variscan fold belt was the site of basin subsidence during the Mesozoic and basin inversion during the Cenozoic. During that time, the Midlands Microcraton and the Caledonide fold belt of eastern England remained relatively stable, together forming the

London Platform (Figure 10). No beds of Permian or Triassic age are known in the London area.

Figure 10 Mesozoic structural setting (from Sumbler, 1996)



4.11 The northern edge of the Weald Basin occurs in the south of the London district. Movement on major faults bounding this basin controlled the distribution and thickness of Jurassic strata. For example, about 1050 m of Jurassic mudstones with interbedded limestone and sandstone occur at Warlingham, but only 12 m occur in a borehole at Streatham Common, just 15 km to the north. In general, younger Jurassic formations overlap further onto the London Platform. Some may have extended right across it but were removed by erosion during periods of low sea level, and uplift in the late Jurassic or early Cretaceous associated with the opening of the North Atlantic Ocean. The London area appears to have been dry land during this time, with no deposition.

4.12 In mid-Cretaceous times, however, about 120 million years ago, rising sea levels began to flood the London Platform and by about 105 million years ago, deep water marine mudstone of the Upper Gault were being deposited throughout the area. Beneath London, the Gault is typically between about 50 and 70 m in thickness. In most of the London area, the Gault passes upwards into the Upper Greensand, composed of glauconitic fine-grained sandstone and siltstone and less than about 15 m thick. It is absent in the north-west of the district, passing laterally into the Gault or having been removed by erosion.

4.13 The Late Cretaceous, from about 100 million to 65 million years ago, was a period of 'greenhouse Earth', with a much warmer global climate than at the present, and globally very high sea levels, possibly the highest of the past 500 million years. A warm epicontinental sea extended across Europe, and at least as far east as Kazakhstan. The gradual accumulation of the calcareous, siliceous and phosphatic remains of marine organisms of many kinds led to the formation of the Chalk. With nearby areas of dry land diminishing and ultimately confined to the highlands of Wales and Scotland (and possibly even further afield), and the onset of a predominantly arid climate, input of terrigenous sediment was minimal, although occasional clouds of volcanic ash were blown across the region, probably from volcanoes to the west of Britain. Although this was a period of tectonic stability in the region, limited earth movements led to some localised compositional variations in the Chalk.

4.14 Greater, more widespread earth movements in the latest Cretaceous and early Palaeogene, associated with the early phases of the Alpine Orogeny of southern Europe, caused the onset of basin inversion and uplift of the Weald. There was gentle folding and some erosion of the Chalk, and the formation of a broad basin of Palaeogene deposition that extended from Berkshire eastwards into the North Sea and across Europe. The portion now preserved in England is known as the London Basin.

4.15 The Palaeogene sediments of the London area, which lie across the centre of the London Basin, were deposited in shallow marine, coastal and fluvial environments between about 58 million and roughly 50 million years ago. At this time, Britain lay at about 40° N, and 'greenhouse' global climate conditions continued. Generally high, but fluctuating sea levels, driven by global sea level changes coupled with local tectonic movements, brought a series of cyclical marine transgressions and retreats. To begin with, this generated a varied and in places rather complex sedimentary sequence with evidence of erosion between some of the formations. The prevailing climate was generally warmer than at present, with evidence of mangrove swamps and tropical-style weathering and soil formation on emergent coastal plains. However, the greater part of the Palaeogene deposits in the London area belongs to the London Clay, which was laid down in fully marine conditions.

4.16 The youngest Palaeogene sedimentation in the London area is represented by the Bagshot Formation, sands deposited in a shallower sea than the London Clay, or possibly a coastal environment.

4.17 The main period of Alpine earth movements occurred in the mid-Miocene, when further basin inversion caused uplift of the Weald, and concomitant down-warping of the London Syncline, in which the London Basin is preserved. The London Syncline extends from east-north-east to west-south-west between the Chiltern Hills in the north-west and the North Downs in the south: its axis passes through central London. Smaller folds, notably the Greenwich and the Millwall anticlines, were caused by more localised 'up-to-the-south' movements on deep-seated faults amongst those bounding the Midlands Microcraton. Some of these folds have faulted axial zones, within a zone of faulting extending from Wimbledon north-eastwards across the Thames near Greenwich, and beyond towards Essex.

4.18 For most of the period since the late Eocene, the London district has been land, and the existing deposits have been gradually weathered and eroded. Sparse remnants of coastal gravel deposits on the highest ground suggest that the sea covered the area relatively briefly in the Pliocene.

Quaternary

4.19 In the early Quaternary, rivers flowed across the London area from the south and south-west towards the 'proto-Thames', a river larger than the modern Thames that flowed out of Wales, through the Midlands and southern East Anglia, into the North Sea (Figure 11). The Quaternary saw the onset of a series of extreme climatic fluctuations, with glacial periods much colder than at present alternating with interglacial periods that were in general somewhat warmer. During the Anglian glaciation, about 450 000 years ago, the ice sheets that covered northern Britain reached their most southerly extent, in the north of the London district (Figure 12). This caused a diversion of the River Thames to its present-day valley. In the north of the district, where tributaries of the Thames had once flowed north, they now flowed south.

Figure 11 Reconstruction of the pre-Anglian drainage system (from Sumbler 1996)

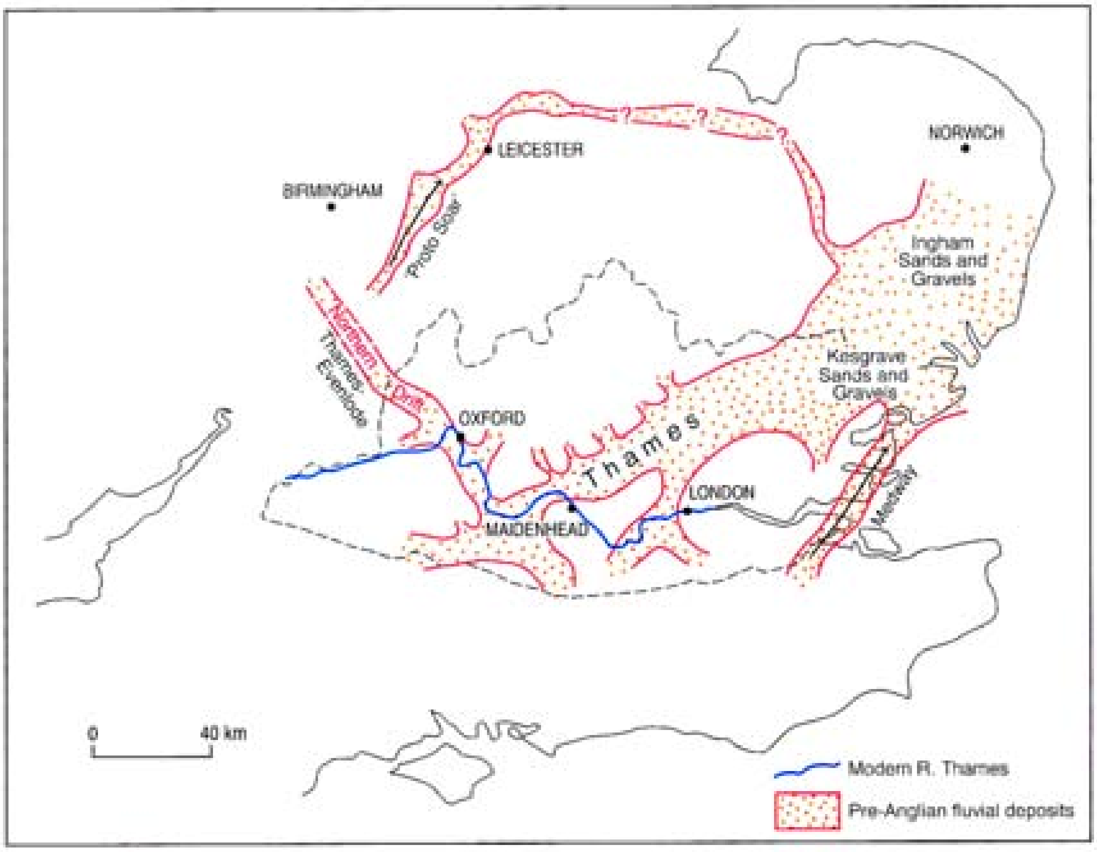
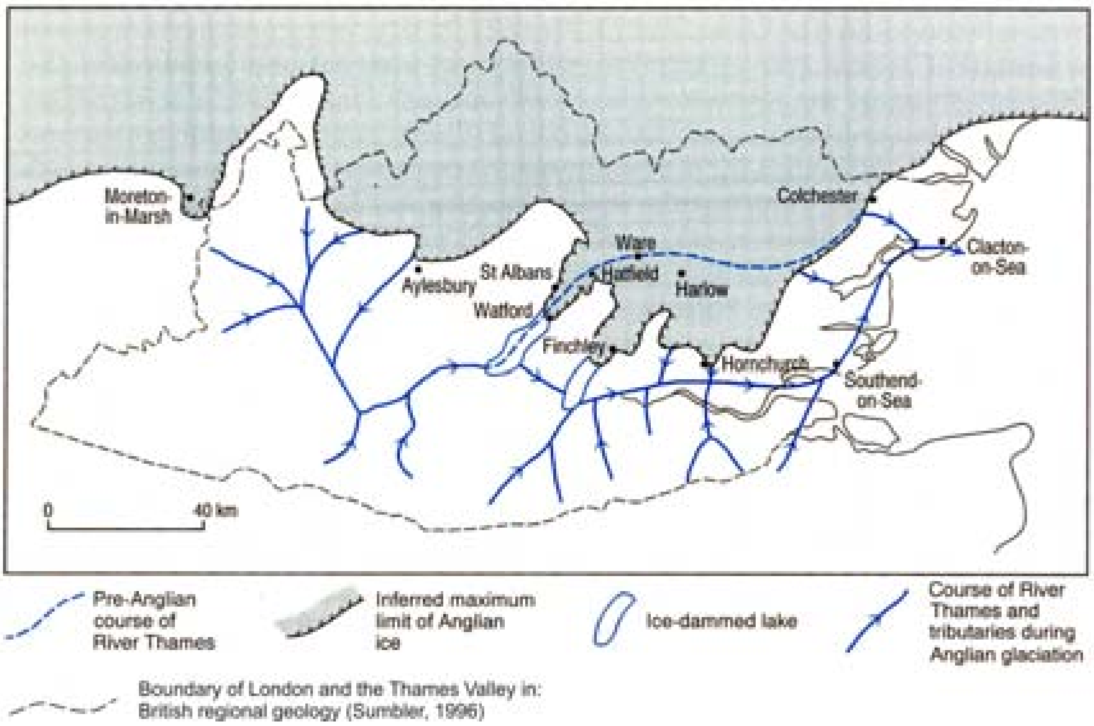


Figure 12 The extent of the Anglian glaciation in the Thames Valley (from Sumbler 1996)



4.20 Cyclical deposition and downcutting by the Thames, chiefly following changes in sea level caused by climatic change and crustal adjustments to glaciation, has left a complex series of river terrace deposits. These form a discontinuous and rather irregular 'staircase' down the valley sides. They are dominated by gravels and sands laid down under cold climate conditions by large braided river systems, overlain in many places around London by fine-grained 'brickearths', whose major component is wind-blown silt, or loess. Pockets of interglacial deposits also exist, typically at the 'back edge' of a river terrace. These deposits mark periods of warm climate, when the Thames would have followed a single meandering channel with a broad flood plain much as at present, although at times with much more lush vegetation and a fauna with some exotic elements reminiscent of modern Africa. Interglacial deposits dating from about 400 000 years ago, overlying the Boyn Hill Terrace at Swanscombe (just east of the London district), include the remains of one of the oldest hominids found in Britain.

4.21 During the coldest part of the last glacial stage, the Devensian, between about 25 000 and 13 000 years ago, ice-sheets covered northern Britain, reaching as far south as north Norfolk. The London area was subject to frigid, periglacial conditions. Peat with plant remains indicating the severity of the climate has been found close to the River Lea at Ponders End, in the north-east of the district. With enormous volumes of water captured within ice, global sea level was considerably lower than at present. Down-cutting in the Lower Thames, which then extended far into what is now the offshore area, created a deep channel. As the climate ameliorated and sea level rose once more, this channel was then infilled with gravels and sands. These deposits now form a 'buried channel' beneath the river alluvium, peat, salt-marsh and estuarine sediments, which have been lain down within the past 10 000 years or so, since the end of the last glacial period.

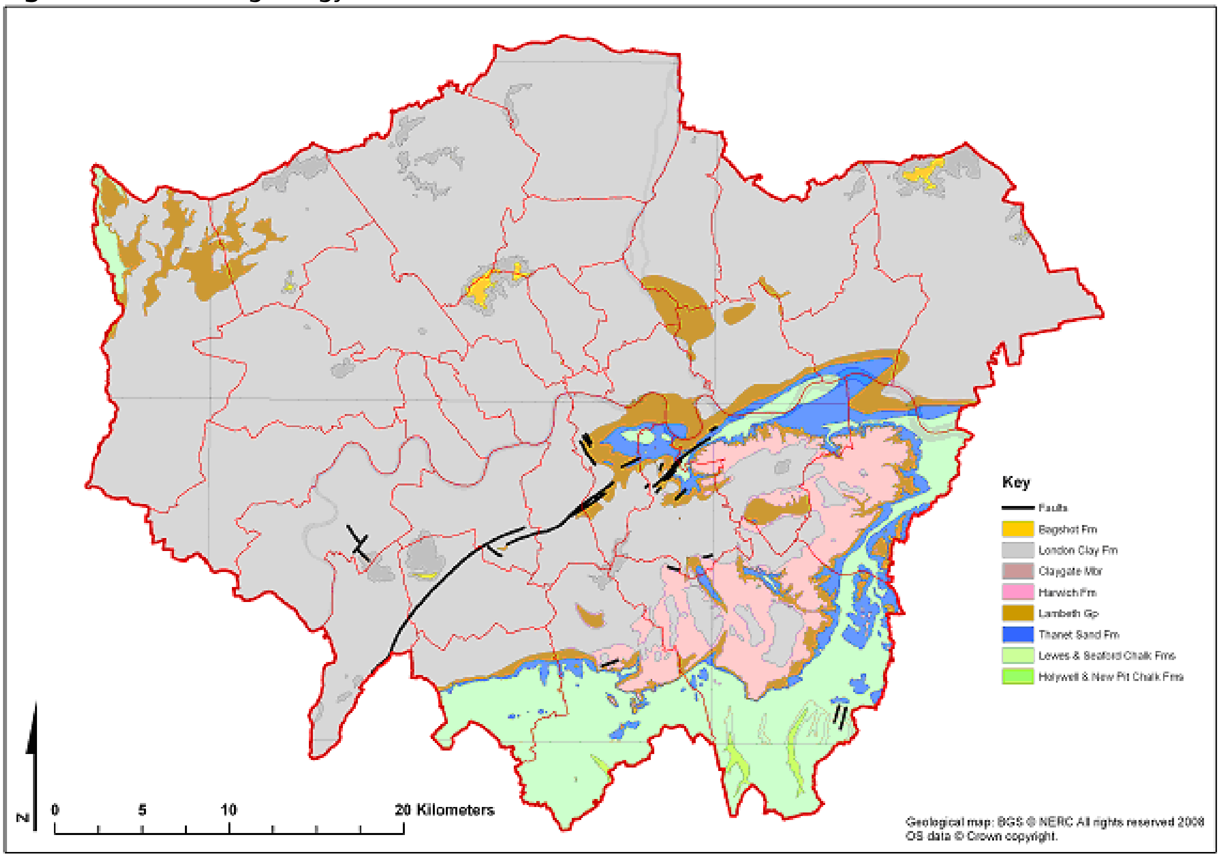
4.22 Upstream of its confluence with the River Lea, the width of the Thames flood plain decreases abruptly, so creating the most natural place to found a crossing point and settlement. The rest, as they say, is history (!).

Bedrock geology

4.23 Bedrock formations predate the Quaternary Sub-Era: they define the local geological structure (Figure 13). The bedrock may be overlain by natural superficial deposits, by artificial deposits, or by both; or it may crop out at the surface, perhaps covered only by soil. Parts of the bedrock close to the surface have generally suffered the effects of weathering; they are then typically weaker and more oxidised compared with fresh, unweathered material from the same formation, and are commonly of a different colour.

4.24 The exposed geological succession is described in order of formation age, from the oldest to youngest. The Chalk represents the youngest part of the Mesozoic. The rest of the bedrock sequence dates from the Palaeogene Period. The Palaeogene and the succeeding Neogene together used to be known as the 'Tertiary' period. The Tertiary and Quaternary periods are now referred to as the Cenozoic Era (Figure 6). Quaternary and possible Neogene deposits are described in later in this chapter. A summary of the geological strata of London is given in Figure 14.

Figure 13 Bedrock geology of Greater London



Chalk Group

4.25 The Chalk, of Late Cretaceous age (100 to 65 million years ago), is the oldest bedrock unit seen at outcrop in the district, and underlies the whole area at depth. The Chalk is a very widely occurring geological unit, extending across southern England, East Anglia and northwards into Lincolnshire and Yorkshire. It also occurs widely outside the UK, reflecting the remarkable continuity of depositional conditions produced by the exceptionally high sea levels in the Late Cretaceous. The UK Chalk succession was deposited in a few hundred metres of water, and probably blanketed much of the British Isles. Chalk deposition largely ceased at the end of the Cretaceous when there was a major fall in sea level that transformed much of the UK into land and exposed the newly-formed Chalk to erosion.

4.26 In the London area the Chalk crops out in the Chiltern Hills and in the North Downs, and also in the core of the Greenwich Anticline and related fold structures. Its maximum preserved thickness is about 200 m, which is quite small compared to the c. 400 m present in the Hampshire – Sussex area. This contrast partly reflects deeper erosion of the Chalk in the London area prior to deposition of Cenozoic sediments, and partly differences in tectonic environment. The relatively shallow occurrence of ancient basement rocks in the London area may have influenced the extent of this erosion as well as limiting the space available for Chalk accumulation.

Lithology

4.27 In southern England, the Chalk is typically a very fine-grained, relatively soft, white limestone, predominantly composed of the disaggregated skeletal remains of tiny planktonic algae called coccolithophores. These flourished in the seas of the Late Cretaceous, and today remain an important source of biologically produced marine limestones. The Chalk is compositionally similar in northern England, but much harder due to greater cementation.

4.28 The lower part of the Chalk Group contains up to 30 per cent clay, and comprises a decimetre-scale alternating succession of hard limestones and soft mudstones. Individual limestones and mudstones are widely traceable across the UK and far beyond, and individual beds have been identified using an alphanumeric code. The rhythmic cycle of limestone and mudstone has been interpreted as reflecting regular climatic oscillations, with the limestones accumulating in warmer phases and the mudstones in colder periods. Estimates of the frequency of these changes, every 20 000 years or so, suggests that they correspond to Milankovitch Cycles, produced by regular changes in the Earth's attitude and orbit that in turn altered the amount and distribution of solar radiation.

4.29 The higher part of the Chalk Group is almost pure calcium carbonate in the form of low magnesian calcite, and is the typical white chalk with which most people are familiar. Flints are a conspicuous feature of this part of the succession, occurring as bands at regular intervals and giving an indication of the natural bedding. Flint is composed of silica, in the form of ultramicroscopic quartz crystals, derived from the dissolved skeletons of siliceous sponges and microfossils (radiolarians and diatoms) that inhabited the Chalk sea. The complex chemical process of flint formation occurred at some distance below the sea bed whilst the Chalk was still being deposited, often as replacements of burrow systems formed by organisms living in the seabed sediment (Clayton, 1986). Such flints typically have irregular nodular or elongate forms. Laterally continuous tabular flints are typical of homogeneous, well-bedded sediments in which burrows are either absent or poorly defined; lack of these preferred sites for silica replacement promoted the formation of more evenly developed flint horizons (Clayton, 1986). Some flint bands have a distinctive appearance and are geographically extensive, making them valuable for correlation. Locally, thin sheet-like flints, with a distinctive hollow centre, are found cross-cutting parts of the Chalk succession. These flints are inferred to have grown along fractures or shear-planes in semi-consolidated chalk.

4.30 The thin marls that are first seen in the lower part of the Chalk Group continue to occur at intervals through the higher part of the succession. These clay-rich horizons have higher water retention than the adjacent chalk, and are often preferentially vegetated in outcrops. Where visible in weathered exposures, marls may appear as shaly horizons and can be preferentially eroded, but in fresh exposures their darker colour is usually their key distinguishing feature.

4.31 Some aspects of the formation of the marl seams in the higher part of the Chalk remain unknown, but some have been interpreted as decomposed volcanic ashes and others as the result of an enhanced influx of land-derived sediment (Wray and Wood, 1995; Wray, 1999). Many marl seams are geographically extensive marker beds and are important for correlation.

4.32 Decimetre-scale beds of characteristic hard, nodular chalk occur at some levels in the Chalk. These have a distinctive knobbly appearance produced by preferential removal by weathering of the softer chalk that surrounds the harder nodules. Thinner horizons of very hard chalk, known as hardgrounds, also sometimes occur. These beds, generally less than a metre thick, have typically been bored and encrusted by marine organisms and stained orange, green or brown with iron and phosphate minerals. Both nodular chalk and hardgrounds reflect primary hardening of chalk caused by enhanced sea floor cementation associated with periods of non-deposition (Hancock, 1989). Cementation occurred just below the sea floor, initially producing nodules of harder chalk in softer sediment (Gale, 2000). Local exposure by sea floor erosion facilitated further cementation, and allowed the hard chalk pavement to become bored into and encrusted by marine fauna. The formation of nodular chalks and hardgrounds has been related to reductions in sedimentation rate by current-winnowing across submerged massifs, in proximity to basin margins, or associated with eustatic fall in sea level (Hancock, 1989).

Figure 14 Summary of the geological strata of London (adapted from Ellison, 2004)

Period		Group	Formation	Thickness (m)
Palaeogene			**Bagshot Formation:** sand, fine-grained with thin clay beds	10 – 25
		Thames	**London Clay Formation:** clay, silty; fine-grained sand and clay at base. **Claygate Member:** interbedded sand and clay at top	90 – 130
			Harwich Formation: sand, clayey fine-grained sand and pebble beds	0 – 10
		Lambeth	**Reading, Woolwich, & Upnor Formations:** clay mottled with fine-grained sand, laminated clay, flint pebble beds and shelly clay	10 – 20
			Thanet Sand Formation: sand, fine-grained	0 – 30
Cretaceous		Chalk	Undivided mainly **Seaford Chalk Formation:** chalk, soft, white with flint courses	Up to 70
			Lewes Chalk Formation: chalk, white with hard, nodular beds	25 – 35
			New Pit Chalk Formation: chalk, white to grey with few flints	30 – 40
			Holywell Chalk Formation: chalk, white to grey, shelly, hard and nodular	13 – 18
	Concealed strata		**Undivided Zig Zag Chalk Formation** and **West Melbury Marly Chalk Formation** (formerly Lower Chalk): chalk, pale grey with thin marls; glauconitic at the base	65 – 70
			Upper Greensand Formation: sand, fine-grained, glauconitic	Up to 17
			Gault Formation: mudstone	50 – 70
		Lower Greensand	**Folkestone Formation:** sandstone, fine- to medium-grained	60
			Sandgate, Hythe & Atherfield Clay Formations: sandstone and mudstone	34
		Wealden	**Weald Clay Formation:** mudstone **Hastings Beds:** sandstone and mudstone	Up to 150
Jurassic			Limestone and mudstone	0 – c.750
Silurian & Devonian			Sandstone and siltstone	

Stratigraphy

4.33 Traditionally, a three-fold classification was applied to the Chalk Group everywhere in the UK. This simple subdivision into Lower, Middle and Upper Chalk was based on the development of beds of hard chalk which, through their topographic expression, could be traced across chalk downlands. In the last 20 years, research has shown that there is much greater variation within the Chalk than is suggested by the traditional classification. Separate modern classifications are given to the Chalk of north-eastern England and southern England, based on differences in the character of the chalk and distribution of flint and marl. Between these two areas is a region, extending from the London area across most of East Anglia, where classification of the chalk becomes less straightforward because of subtle changes in its character (Mortimore et al., 2001). Investigations of the outcropping succession around Dartford and buried successions seen in boreholes suggest that in general, the southern England classification can be applied to the Chalk of the London area. The southern England scheme follows Rawson et al. (2001); it recognises two subgroups and up to nine formations within the Chalk Group.

4.34 The two major subdivisions are the Grey Chalk Subgroup and White Chalk Subgroup. The boundary between them is an erosion surface at the base of a clay-rich unit named the Plenus Marls Member. The top of the Plenus Marls marks the top of the traditional Lower Chalk, but in the new scheme this unit marks the base of the White Chalk Subgroup.

4.35 In the London area, where Cenozoic erosion has removed part of the succession, a maximum of seven formations can be recognised.

Grey Chalk Subgroup

4.36 The Grey Chalk Subgroup is typically 60 – 70 m thick in the London area, and generally comprises less pure, more clay-rich chalk than the White Chalk Subgroup. Unlike the latter, it does not contain flint. The two formations that make up the Grey Chalk Subgroup, the *West Melbury Marly Chalk Formation* and overlying *Zig Zag Chalk Formation*, are not seen at outcrop in the London district, although they are penetrated by boreholes. These boreholes, and outcrops in quarries south of London, show that the base of the West Melbury Marly Chalk, as elsewhere in southern England, comprises a sandy clay, rich in the green-coloured iron mineral glauconite, named the *Glauconitic Marl Member*. Above this are regularly alternating hard limestones and mudstones, each typically a few tens of centimetres thick. This interval was traditionally referred to as the Chalk Marl. Alternating limestones and mudstones continue up into the lower part of the Zig Zag Chalk, but eventually these give way to thick beds of creamy grey chalk with thin interbeds of marl, traditionally known as the Grey Chalk. The base of the Zig Zag Chalk is marked by a silty chalk horizon, named the *Cast Bed*, within the upper part of the Chalk Marl of the traditional scheme. The West Melbury Marly Chalk is unusually thin in the Fetcham Mill Borehole [TQ 1581 5650] at Leatherhead, where it is less than 20 m thick, but it shows evidence of thickening to perhaps 30 m or more elsewhere within the region. The Zig Zag Chalk is more uniform, at about 40 m thickness.

White Chalk Subgroup

4.37 The change to the much purer chalks that characterise the White Chalk is thought to be related to a major sea level rise, following the short-lived sea level fall that led to the erosion surface at the base of the Plenus Marls. This sea level rise curtailed the supply of detrital material from land areas and probably fundamentally changed the circulation pattern on the drowned continental margins, allowing the low-nutrient oceanic water favoured by coccolithophores to flood across these areas.

4.38 Five formations are recognisable in the London area, namely (from oldest to youngest) the Holywell Nodular Chalk, the New Pit Chalk, the Lewes Nodular Chalk, the Seaford Chalk and the Newhaven Chalk. The lowest three of these are seldom seen at outcrop in the London area, except where exposed in deep quarry or mine workings. The Seaford Chalk has the greatest surface exposure and underlies most of the Cenozoic sediments. The Newhaven Chalk has a restricted occurrence along parts of the southern margin of the London area.

4.39 The *Holywell Nodular Chalk Formation* is hard, nodular, and distinctively shell-rich in the upper part. It is typically 14 to 18 m thick in the London area, and contains regularly developed thin beds of marl throughout and an interval with several beds of greenish-grey marl at the base, up to several metres thick, named the Plenus Marls Member. Much research has focussed on the Plenus Marls and immediately overlying strata in recent years, since evidence from their carbon and oxygen isotope geochemistry points to a series of major environmental perturbations at this level, including oxygen-starvation of the Late Cretaceous oceans and a major change from global climatic warming to global cooling. The base of the traditional Middle Chalk Formation was mapped using a hard bed of chalk that immediately overlies the Plenus Marls, named the Melbourn Rock.

4.40 The *New Pit Chalk Formation* is firm, smooth-textured chalk, 40 to 46 m thick where recognised in boreholes in central London. It lacks the nodularity and abundant shell remains of the Holywell Nodular Chalk, and in its upper part, bands of nodular flint appear. Marls continue to occur in the succession, and are generally slightly more noticeable than in the Holywell Chalk. Several thick marl beds, more than 0.1 m thick, occur in the upper part of the New Pit Chalk.

4.41 The *Lewes Nodular Chalk Formation*, up to 40 m thick, marks a return to hard, nodular chalk, but unlike the underlying Holywell Chalk, flint occurs fairly regularly throughout the formation. Some of the flints are very distinctive, such as the Lewes Tubular Flints, which can be traced across southern England and northern France. Hardgrounds are relatively common, with at least four major intervals containing closely spaced hardground surfaces. In some parts of the London area the top of the Lewes Chalk is marked by the Rochester Hardground, but elsewhere this is replaced by a pair of marl seams separated by sponge-rich chalk. Marls occur at intervals through most of the succession. They include important marker horizons such as the distinctively thick (about 0.1 m) and plastic-textured Southerham Marl 1, which chemical analysis has shown to be a decomposed volcanic ash. The base of the traditional Upper Chalk falls within the lower part of the Lewes Chalk, but in the London area the beds that define this boundary are not well developed.

4.42 The *Seaford Chalk Formation i*s typically soft, smooth-textured chalk, with shell-rich beds and common horizons of nodular and tabular flints. Some flints are widespread marker beds in the Chalk of southern England, such as the Seven Sisters Flint in the lower part of the succession, and Bedwell's Columnar Flint and Whittaker's 3-inch Flint in the higher part of the Seaford Chalk. Marls are restricted to the lower part of the formation, and in the higher part of the succession is an interval of iron-stained chalk with common sponge remains (Barrois Sponge Bed) or a hardground (Clandon Hardground). Over most of the area the preserved thickness is affected by the depth of Early Palaeogene erosion (where overlain by Palaeogene rocks) and Quaternary erosion (where exposed). The complete thickness of Seaford Chalk is proved in the Fetcham Mill Borehole at Leatherhead, but the c.33 m there assigned to the formation is probably atypical because part of that succession shows unusual local thinning.

4.43 The *Newhaven Chalk Formation* is very soft, smooth-textured chalk with marl seams, and less abundant flint than the underlying Seaford Chalk. Only the lower and middle parts of the formation are preserved locally, mainly on the southern and south-western fringes of the London district. The thickest development is probably in the Fetcham Mill Borehole at Leatherhead, just south-east of the London district, where nearly 20 m of Newhaven Chalk were proved. Sparsely flinty chalk belonging to this formation also occurs around Croydon, Purley, Ewell and Beddington.

Landscape

4.44 Where it crops out, Chalk produces attractive undulating downlands, seen in the North Downs to the south of London, and the Chiltern Hills to the north-west. The undulating character is controlled by geological structure and by the different character of each of the formational subdivisions of the Chalk. Where not overlain by younger strata, the gentle dip of the Chalk produces a broad tract of outcrop, successively revealing each of the different formations to the effects of surface weathering.

4.45 Both ancient and modern weathering has shaped the Chalk landscape. In the Quaternary, the development of permafrost during glacial epochs and/or the presence of an elevated water table, allowed streams to flow across the normally permeable Chalk and develop valley systems. These are now visible as networks of dry valleys. Weathering of the Chalk has also been affected, and continues to be influenced, by the unique combination of physical features that characterise each of the formational subdivisions. These features include the presence or absence and relative abundance of flint, marl, nodular chalk and hardgrounds, as well as variable chalk composition, cementation and style of fracturing. Differences in these characters between formations subtly alter the way each weathers, which in turn produces changes in slope profiles. It is this feature that has allowed the new Chalk Group stratigraphy to be mapped out across often poorly exposed terrains.

Economic Importance

4.46 Water supply and cement manufacture are the two most important economic uses of the Chalk. In the past chalk was also exploited in small workings as a source of agricultural lime, and has been mined extensively in several places in south-east London as a raw material for brick manufacture, or for flint.

4.47 The Chalk is crucially important for water supply, being one of the UK's major aquifers. Boreholes drilled into the Chalk are a source of water for large parts of south-east England, including the London area. The dense urban development that covers much of the exposed Chalk in south-east England also means that this aquifer is vulnerable to contamination from surface pollutants. Often a considerable interval of Chalk occurs above the water table (the 'unsaturated zone'), where pollutants may build up over many years, and then be rapidly distributed into the aquifer by a rise in the water table. In recent years there has also been concern about maintaining supplies of ground water during prolonged droughts; mitigating the negative effects of excessive groundwater abstraction on chalk streams and wetlands, and assessing the risks of flooding due to sudden rises in the water table. Consequently much recent work has focussed on understanding pathways of ground water movement in the Chalk, and how this is influenced by stratigraphical variation and geological structure.

4.48 Chalk is an important source of raw material in the manufacture of cement, and has been extensively worked in quarries close to the London area, especially along the Chalk outcrop flanking the Thames estuary. Some of these quarries have a long history of development and have furnished important geological data that has greatly contributed to our understanding of the Chalk of the London area. Some of the older quarries, especially those adjacent to built-up areas, were extended underground by driving adits from the faces.

4.49 Chalk mines are found in places in the south-east of the London district, and at Pinner in the north-west. The oldest and smallest types of mine are the 'dene hole' and related forms of hand-dug mine used to win agricultural lime in areas of acidic or clay-rich soils. Some may be of pre-Roman age but most seem to date from the 13th to the 19th centuries. They typically consist of a shaft of about 1 m in diameter sunk through a cover deposit of Thanet Sand or of clay-with-flints, plus enough Chalk to make a safe roof. Chalk was excavated by expanding the shaft, commonly along adits of various patterns and lengths, over a radius up to about 12 m. Dene holes can occur singly or in groups of up to 70, or more. They are common in parts of the Cray valley in south-east London (see also paragraphs 5.9-5.10).

4.50 Pillar and stall chalk mines mostly date from the 19th century, with some earlier or later. Their passages are typically 2 to 5 m wide and can be up to 9 m high, generally narrowing upwards for stability. They can extend more than 100 m from the access point. Some of the largest were dug within brick works, as a source of chalk to be added to the brick clay prior to firing. The Pinner chalk mine, dug through the Lambeth Group in north-west London, is one of the deepest, at about 35 m. Most other examples are in south-east London, around Woolwich and Erith, or in south London, most notably at Chislehurst.

Wider Geological Importance

4.51 The Late Cretaceous is thought to have had a 'super greenhouse' climate, produced by large amounts of submarine and continental volcanic activity that pumped huge volumes of carbon dioxide into the atmosphere. Consequently there has been considerable interest in studying the Chalk in order to gain insights into how biological systems responded to this environment, and what the implications might be for modern global warming. There has been particular focus on the strata at the base of the White Chalk Subgroup, represented by the Plenus Marls and immediately overlying succession of the lower Holywell Nodular Chalk. This interval appears to show evidence of a period of global oceanic oxygen starvation that is broadly coincident with a sudden climatic reversal, from global warming to global cooling.

4.52 Milankovitch cycles are regular climatic fluctuations produced by cyclical changes in the Earth's orbital parameters. Evidence of the presence and impact of these changes has been gained by studying the sediments of the Grey Chalk Subgroup, and it has been suggested that some aspects of the flint distribution in the White Chalk Subgroup might be a response to environmental changes produced by these cycles.

4.53 The details of the Chalk succession in the London area, particularly the nature of any local variations, are likely to be pertinent to an understanding of the relationship between sedimentation and structure during the Late Cretaceous, particularly the timing of tectonic movement at the southern margin of the London Platform and along the Wimbledon – Greenwich tectonic zone.

4.54 Exposures of the local Chalk will aid understanding of its behaviour in engineering and hydrogeological contexts, including (for example) the likely pathways taken by pollutants in the groundwater system.

Palaeogene strata

4.55 Most of the London district is underlain by an intricate succession of Palaeogene strata within the London Basin. This was laid down during a series of cyclical fluctuations in sea level between about 58 and 50 million years ago, and represents deposition in environments ranging from terrestrial to fully marine.

4.56 Four major divisions are present. The oldest, the Thanet Sand Formation, is overlain in turn by the Lambeth Group (with 3 formations), the Thames Group (with 2 formations) and the Bracklesham Group, of which the Bagshot Formation is the only representative in the London district. The Lambeth Group comprises the Upnor Formation, overlain by the Reading Formation in the west, the Woolwich Formation in the east, and by a complex interdigitation of both in the centre of the district. The Thames Group consists mostly of the London Clay Formation, which is by far the most widespread single bedrock formation in the London district, with the Harwich Formation, previously known as the 'London Clay basement bed'.

Thanet Sand Formation

4.57 The Thanet Sand is the oldest Palaeogene formation in Essex and Kent, with London marking its north-western extent. It forms a fairly narrow outcrop along the west side of the Cray valley and westwards at the foot of the North Downs, with a few broad outliers just to the east of the Cray at the south-eastern boundary of the district and some narrow inliers in south-east London. It also crops out around the Greenwich and Millwall anticlines but is there almost entirely covered by superficial deposits. The Thanet Sand and the Lambeth Group were together previously known as the 'Lower London Tertiaries'.

4.58 The Thanet Sand was deposited in a shallow marine environment, following a global rise in sea level after about 58 million years ago in the late Paleocene (the earliest series of the Palaeogene). It rests unconformably on the Chalk, on what was originally an approximately planar erosion surface, although that surface is now folded, and typically highly convoluted on a small scale following dissolution of the Chalk. The unconformity surface is attributed to erosion and reworking during two or more depositional cycles. Where it is more fully developed to the east, up to nine onlapping sequences have been recognised in the Thanet Sand but the bulk of the deposits (and perhaps all) in the London area represent only one. Deposition of the Thanet Sand was followed by further cycles of falling and rising sea level prior to the deposition of the succeeding Lambeth Group, which overlaps the Thanet Sand towards the west. Consequently, the Thanet Sand has been truncated, diminishing in thickness from about 22 m in east and south-east London to where it is cut out almost completely along a line between Hillingdon and Borehamwood. To the west of this line, sparse remnants that occur in some solution cavities in the Chalk demonstrate the greater original extent.

4.59 In the London district, the Thanet Sand Formation consists predominantly of a coarsening-upwards sequence of fine-grained sands which is clayey and silty, particularly in the lower part. The proportion of fine-grained sand varies from about 10 per cent at the base, to about 60 per cent at the top. The unweathered strata are pale grey to brownish-grey, and weather to a yellowish-grey. They are often intensely bioturbated, shown by wisps of relatively dark silt and clay, but few primary sedimentary structures remain. The sands may locally contain irregular masses of much harder siliceous sandstone known as 'doggers'.

4.60 At the base of the Thanet Sand Formation there is typically a distinctive unit up to 0.5 m thick called the Bullhead Bed. This is usually a conglomerate with flints ranging in size from small well-rounded pebbles to large unworn flint nodules (the 'bull heads'). The flints typically have a distinctive green coating of glauconite and are set in a matrix of dark greenish-grey clayey, fine- to coarse-grained sand containing glauconite pellets. Some fossils derived from the underlying Chalk are present.

Lambeth Group

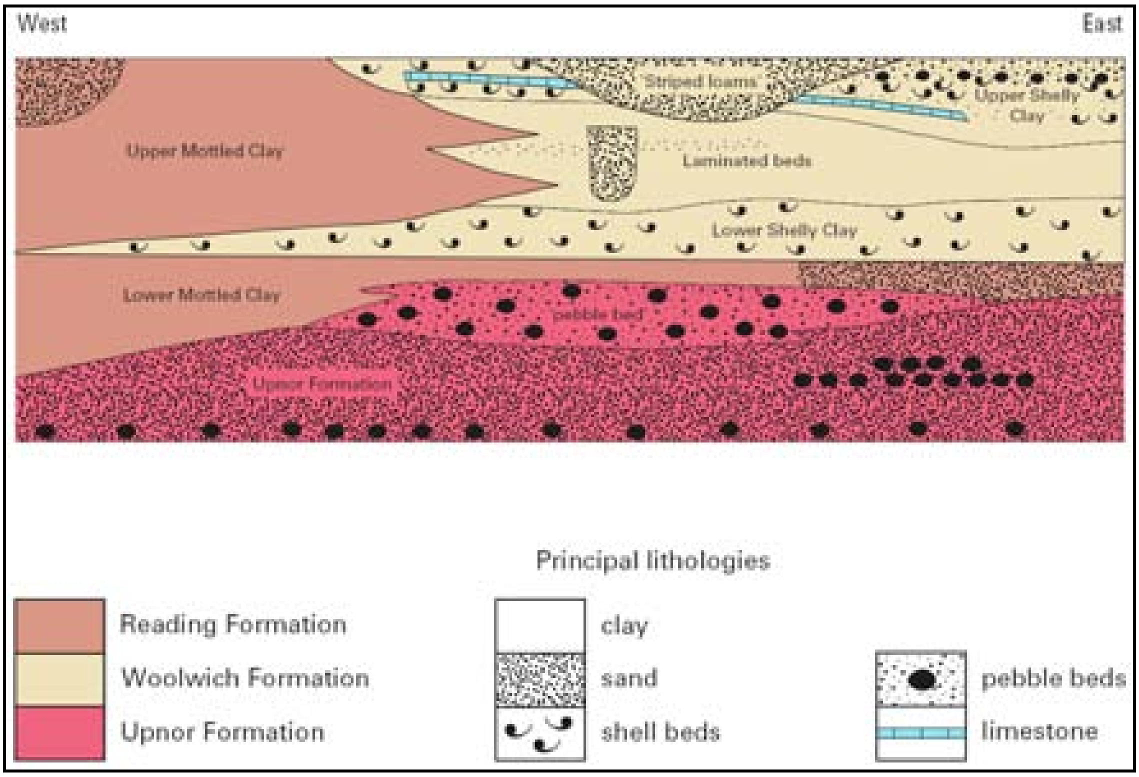
4.61 The Lambeth Group (formerly known as the 'Woolwich and Reading Beds') succeeds the Thanet Sand, overlapping it to rest on the Chalk in the north-west of the district. Like the Thanet Sand, it forms a narrow outcrop on the south-east side of the London Basin, but with only a few small outliers. It likewise delineates the Greenwich and Millwall anticlines and forms scattered inliers, where it is mostly covered by superficial deposits. Some of the inliers have arisen through incision in the Ravensbourne River and its tributaries, but others (such as those in the Lower Lea Valley and nearby) are probably controlled by a local geological structure. Unlike the Thanet Sand, the Lambeth Group also crops out at the north-western edge of the London Basin, in north-west London.

4.62 The Lambeth Group is of rather more uniform thickness than the Thanet Sand. It is generally thickest in south-west London and reaches as much as 30 m at Southwell, but in most of the district it is between 10 and 20 m thick. It is least in south-east London, in large part due to erosion prior to the deposition of the Harwich Formation, and in places east of the Cray valley, near Swanley, it has been removed entirely.

4.63 The Lambeth Group typically comprises interbedded colour-mottled clays and fine silty sands, with occasional shell beds, thin limestones and some beds of sandy gravel containing black, very well-rounded flint pebbles. The colour-mottling is a consequence of weathering under conditions of a warm climate with a distinct dry season. It is associated with duricrust formation and soil formation.

4.64 Three formations are present in the Lambeth Group, each of which varies significantly in composition both laterally and vertically. They together make up four depositional sequences separated by unconformities (Knox, 1996). The basal Upnor Formation occurs throughout the area. In the west of the London Basin it is overlain by the Reading Formation, and in the east by the Woolwich Formation. In the centre of the London area, both the Reading and Woolwich formations are present in a complex interbedded relationship, in which a number of informal subdivisions have been recognised (Figure 15). These divisions are described in more detail in the London Memoir (Ellison et al., 2004).

Figure 15 Relationship of Lambeth Group informal lithological units in central London



4.65 The Lambeth Group was deposited during the youngest part of the Paleocene and the oldest part of the Eocene (Collinson et al., 2003; King, 2006). The Upnor Formation is of marine origin, and rests unconformably on a erosion surface. Deposition of the upper part of the Upnor Formation followed a lowering of sea level that may have led to the removal or reworking of earlier deposits. The Upnor Formation as a whole was followed by a further fall in sea level. Emergence of the Upnor Formation is indicated by the local presence of silcretised sediments (some as clasts in the pebble beds at the top of the formation) typical of 'Hertfordshire puddingstone' and 'sarsen stone'.

4.66 The succeeding Reading Formation represents deposition in an area of marshy coastal plains crossed by rivers, and the Woolwich Formation in estuarine, lagoonal or nearshore marine conditions. These two formations are divided by a sequence boundary, marking a period of sea level fall, emergence of the lower part of the Lambeth Group and their consequent weathering and local erosion. This boundary marks onset of the 'Paleocene-Eocene Thermal Maximum', a relatively short-lived period of global warming (King, 2006). The corresponding stratigraphic surface (which seems to disappear westwards within the Reading Formation) has been named the 'mid-Lambeth Group hiatus' (Hight et al., 2004). This is commonly characterised by pedogenic effects such as calcrete formation in the underlying strata, which may be part of the Reading Formation or the Upnor Formation, and by lignite deposits.

Upnor formation

4.67 This formation comprises fine- to medium-grained sand with variable glauconite, beds and stringers of flint pebbles and minor thin clay interbeds or intraclasts. It may be bioturbated, or well-bedded or laminated. Oyster shells occur. Rare fragments of carbonaceous material occur also. It is mainly dark grey to greenish-grey in colour, but the highest part (and locally the whole thickness) has been oxidised to brown, orange, red, and purple-brown. It tends to be made up of slightly coarser sand than the Thanet Sand, and the lower beds may be gritty. A basal bed of rounded flint pebbles up to 1 m thick is usually present, but is not persistent. Where the Thanet Sand is absent, the Upnor Formation rests directly on the Chalk and can contain unworn flint nodules, as found in the Bullhead Bed. At the base, burrows extend as much as 2 m below the contact.

4.68 The pebbles that occur throughout the formation are generally less than 30 mm in diameter but may exceptionally reach 200 mm. They are typically well-rounded and elongate, spheroidal to flattened spheroidal. Many have small surface crescentic percussion marks. Pebble-dominated beds occur principally at the base and top of the unit: in central and south-east London, there is a persistent pebble bed up to 3 m thick at the top of the formation.

4.69 The Upnor Formation was previously treated as the 'basal bed' of either the Woolwich Formation or the Reading Formation, respectively. It underlies the mid-Lambeth Group hiatus and so is of Paleocene age.

4.70 Harefield Pit SSSI, Hillingdon, exposes the Upnor Formation overlying the Chalk (Figure 4).

Lower Mottled Clay (Reading Formation)

4.71 The Lower Mottled Clay generally consists of purple, red, green, blue-grey and brown mottled clays, with some silty or sandy, and fine- to medium-grained sands. The clays are generally unbedded. The sands tend to be brown. Lenticular bodies of cross-bedded, medium-grained sand (commonly containing layers of mud flakes) are interpreted as the deposits in river channels.

4.72 The Lower Mottled Clay is present throughout the Lambeth Group in the London district, but is thin or absent in the north-east. In the west of the district, it has not been differentiated from the Upper Mottled Clay (if that is present). The Reading Formation as a whole is as much as 20 m thick in the south-east of London, decreasing eastwards where it interfingers with the Woolwich Formation.

4.73 Harefield Pit SSSI, Hillingdon, exposes the whole of the Reading Formation (Figure 4).

Lower Shelly Clay (Woolwich Formation)

4.74 This is a very uniform unit composed of dark grey to black organic clay with shells. Some brownish grey clay, partly cemented with siderite, can be present, especially in the upper part. Sand or shell beds can be present, especially in the north-east of the district. Lignite is commonly seen at the base of the unit, especially in the south-east, where it marks the mid-Lambeth Group hiatus. The thickest such lignite bed (up to 2 m) occurs at Shorne, in Kent.

4.75 In general this unit thickens from central London towards the south-east, reaching as much as 6 m. It is absent in the west of the district.

4.76 The Lower Shelly Clay overlies the mid-Lambeth Group Hiatus and so is of Eocene age.

4.77 The Lower Shelly Clay is exposed in Gilberts Pit SSSI, Greenwich (Figure 4).

Laminated Beds (Woolwich Formation)

4.78 The Laminated Beds are mostly composed of fine- to medium-grained, laminated sands, silts and clays, which can contain shells. These sediments are typically pale greenish grey to brown in colour.

4.79 The Laminated Beds generally rest conformably on the Lower Shelly Clay and have a similar distribution. The unit reaches as much as 5 m thickness in east London.

4.80 A second unit of similar composition occurs higher in the sequence (above the Upper Shelly Clay) in places, notably in south-east London. This has been called the 'Striped Loams'.

4.81 The Laminated Beds (there also known as the 'Leaf-Bed of Lewisham') are exposed in Gilberts Pit SSSI, Greenwich (Figure 4).

Upper Mottled Clay (Reading Formation)

4.82 This unit comprises clay and sands, very occasionally with gravel. It is typically grey-brown in colour. It is generally less variable than the Lower Mottled Clay, and can be difficult to differentiate from the Harwich Formation. In places it is known to interdigitate with the Laminated Beds.

4.83 The Upper Mottled Clay is only known to occur between Walthamstow and Merton. To the east its distribution is limited by non-deposition or erosion before the deposition of the Harwich Formation, whereas to the west (where the Woolwich Formation is absent) it is not differentiated from the Lower Mottled Clay.

Upper Shelly Clay (Woolwich Formation)

4.84 This comprises grey shelly clay, with thinly interbedded grey-brown silt and very fine-grained sand with glauconite grains. Lignite is locally present. The unit is lithologically the same as the Lower Shelly Clay, but the shelly fauna can be more diverse. It can include 'Paludina' freshwater biogenic limestone, especially in south London.

4.85 The base of the unit is generally sharp and rests on the Upper Mottled Clay, the Laminated Beds or, probably, the Lower Shelly Clay.

4.86 It is up to about 3 m thick, but tends to have a patchy development, and is inferred to be preserved in depressions below the erosion surface at the base of the Thames Group.

Thames Group

4.87 The Thames Group underlies the large majority of the London district. The basal unit, the Harwich Formation, is present throughout, but is mostly too thin to show separately on geological maps. Only in south-east London, where it attains as much as 12 m in thickness, has its outcrop been delineated from the London Clay. The London Clay is up to 130 m thick.

4.88 The Thames Group is entirely of marine origin, and was deposited during the Early Eocene, between about 55 and 51.5 million years ago. It everywhere overlies the Lambeth Group on an erosion surface. In places considerable portions of the Lambeth Group have been removed prior to the deposition of the Harwich Formation.

4.89 Several subdivisions of the London Clay can be recognised in borehole core but only the topmost, the Claygate Member, can be mapped on the ground.

Harwich Formation

4.90 This is typically composed of glauconitic fine-grained sand with beds of rounded black flint pebbles. The proportion of pebbles varies considerably. Broken fossil shells occur in places. The formation is locally cemented. This type of deposit was previously known as the Blackheath Beds where it is thickest in south-east London. Elsewhere, the Harwich Formation was previously known as the 'basement bed' of the London Clay.

4.91 A sandy shelly bed at Abbey Wood SSSI, Bexley, is part of the Harwich Formation (Figure 4). The Harwich Formation is exposed in Elmstead Pit SSSI, Bromley, Gilberts Pit SSSI, Greenwich and Harefield Pit SSSI, Hillingdon (Figure 4).

London Clay Formation

4.92 The London Clay typically comprises bioturbated or poorly laminated, slightly calcareous, silty to very silty clay. It commonly contains thin courses of carbonate concretions ('cementstone nodules') and disseminated pyrite. At depth, where fresh, it is grey, blue-grey or grey-brown in colour. Near the surface the uppermost metre or few metres typically weathers to clay with a distinctive brown colour produced by the oxidation of pyrite. The London Clay may contain thin beds of shells, and fine sand partings or pockets of sand, which commonly increase towards the base and towards the top of the formation. Glauconite can be present in the sands and in some clay beds. White mica grains may be present. At the base, and at some other levels, there may be a thin bed of black well-rounded flint pebbles.

4.93 Five sedimentary cycles have been recognised in the London Clay, each recording an initial sea level rise and marine transgression, followed by gradual shallowing of the sea (King, 1981). The base of each cycle of deposition is typically marked by a sparse pebble bed. This is covered by thick clays, which become progressively more silty and sandy upwards. An alternative scheme of subdivision has been recognised in the London area, from the study of borehole core (Ellison et al., 2004).

4.94 The *Claygate Member* is the uppermost part of the London Clay Formation, and corresponds to the upper part of the last of the five sedimentary cycles. It typically comprises interbedded fine-grained sands, and silty clays and silts. The proportion of sand tends to increase upwards. The clays are generally blue-grey where fresh, and brown where weathered.

4.95 The Claygate Member deposits are of tidal marine origin, and represent a transition to the overlying Bagshot Formation. They occur only as scattered outliers, throughout the Thames Group outcrop.

4.96 The sandy basal beds of the London Clay, there known with the Harwich Formation as the Harefield Member, are exposed at Harefield Pit SSSI, Hillingdon (Figure 4) (Daley, 1999b).

Bracklesham Group

4.97 Only the oldest part of the Bracklesham Group, the Bagshot Formation, is represented in the London district. It occurs only as a few scattered outliers, forming high ground (most notably Hampstead Heath). It is much more extensive to the north-east in Essex and to the south-west in Surrey. The maximum thickness in the outliers in London ranges up to about 18 m. Local erosion at the base has removed the top part of the Claygate Member.

Bagshot Formation

4.98 The Bagshot Formation is the lowest part of the Bracklesham Group in the London Basin, and the only part to occur within the London area. It is typically composed of brown to white-coloured quartzose sands, with occasional thin beds of clay, and some pebbly layers. A coarse iron-cemented flint gravel is commonly found at the base.

4.99 The Bagshot Formation was deposited in a shallow marine and estuarine environment.

Landscape

4.100 In southern and south-west London, the older Palaeogene strata form a gentle escarpment rising up to about 20 m from the Chalk dip slope of the North Downs, or (from Erith westwards) up to about 35 m from the river terraces adjacent to the River Thames. The Palaeogene outliers to the south and east tend to form low, well-drained hills with convex slopes. The inliers tend to occur in the floors of shallow valleys.

4.101 The main outcrop of the Thanet Sand lies at the foot of gently rising ground formed by the Lambeth Group, or is covered by superficial deposits. No distinctive landforms are associated with the Lambeth Group, which crops out in concavo-convex slopes or locally on hill-tops in some outliers. Minor springs occur at the top of clay-rich units, particularly the Lower Shelly Clay.

4.102 The London Clay gives rise to a broad swathe of low-lying, subdued topography in the Thames Valley. Even where dissection has been most pronounced (as between Stanmore and Hampstead) only gently rolling ground with convex slopes of generally less than 4° is found.

4.103 The Bagshot Formation underlies the prominent hills of Hampstead Heath and Highgate in north London, Harrow On The Hill in the north-west, and Havering-atte-Bower in the north-east. It gives rise to relatively steep convex slopes up to 12°. It is characteristically free-draining and in a natural or semi-natural state supports typical heathland vegetation. The base of the formation is commonly marked by a spring line.

4.104 There are few natural exposures of the Palaeogene formations in the London district, where it is usually studied in borehole samples or in temporary excavations, especially those associated with construction projects. Some exposures occur in nearby parts of Essex and Kent (Ellison et al., 2004, pp.24, 26). Publications of the Geologists' Association and of local societies such as the Croydon Natural History Society contain a wealth of description of pits and cuttings that are no longer available for study.

Economic significance

4.105 Regionally, the clays of the Reading Formation and of the London Clay have been important historical sources for the local production of bricks and tiles. Local examples include those on the Woolwich side of Plumstead Common. Sand and gravel for construction purposes has also been taken from the Palaeogene formations in places.

4.106 Fragments of silcrete and ferricrete from the Lambeth Group have been used locally as building stone.

4.107 The variability of the Palaeogene deposits, and in particular the presence of poorly cemented sand bodies (some of irregular and unpredictable shape and distribution), have important implications for the ground conditions experienced by the construction industry. Exposures of the Lambeth Group are of great potential value to its understanding by the engineering geology community, through which the information provided by ground investigation boreholes can be better appreciated. On the other hand, the London Clay is an excellent medium in which to drive tunnels: this has greatly facilitated the development of the metropolis.

4.108 However, the Palaeogene clay deposits, especially the London Clay, are known for a relatively high content of the clay mineral smectite. This is especially prone to change volume with moisture content. The resulting ground movement is a common cause of structural damage in the London district. Steep slopes in the London Clay are prone to landslide. This has occurred particularly in places in north and north-east London that were once adjacent to the Anglian ice sheet.

Wider geological significance

4.109 Parts of equivalent Palaeogene successions offshore beneath the North Sea are up to 2 km thick and include sands that are important hydrocarbons reservoirs. Study of their onshore correlatives in the London Basin has helped understand these strata.

4.110 The Palaeogene is particularly relevant to studies of global climate. It contains a variety of fossil indicators of environment and climate, and encompasses a variety of climatic conditions, including a short thermal maximum at the Paleocene-Eocene boundary, and a longer period of climatic warming in the early Eocene (King, 2006).

Geological Structures

4.111 The axis of the London syncline runs in an east-north-east to west-south-west direction across the middle of the London area, from the vicinity of Romford in the north-east to Surbiton in the south-west.

4.112 North-west of that axis, the bedrock dips gently south or south-east at less than about 2°, decreasing to near horizontal in the middle of the basin. To the south-east of the axis, the bedrock generally dips north-west at 2° or less (and in general somewhat more steeply than to the north-west), but this regional pattern is distorted by a series of elongated periclinal folds. The largest of these is the Greenwich Anticline. Some of these subsidiary folds are asymmetrical, with steeper north-facing limbs, in which dips are generally up to about 7°.

4.113 A belt of faults, extending from Wimbledon to Greenwich, lies parallel to the axes of these periclinal folds, some cases breaching the fold noses. Close to these faults, the dip of the strata may increase and in some places is vertical. The largest faults have displacements of as much as about 30 m.

4.114 Structure contours on the Palaeogene basal unconformity (Ellison et al., 2004) show that the patterns of folding and of faulting are significantly more complex than shown by the geological map. Although not all structures present at the base of the Palaeogene necessarily extend to the surface, some probably do so within the outcrop of the London Clay, where a lack of lithological contrast renders such structures unmappable.

Future Earth science research potential

4.115 The Chalk of the London area probably has a much more complex structure (folds and faults) than has previously been assumed. The more refined modern stratigraphy of the Chalk offers the potential to resolve previously unrecognised structures. Future understanding of the structure and related fracturing in the Chalk offers great benefits for major engineering works that impact on the Chalk and understanding the hydrogeology of the Chalk.

4.116 There are changes in the thickness of formational subdivisions in the Chalk across the London area. Future studies need to focus on the extent to which these relate to the effects of long-lived geological structures and the architecture of the sedimentary basin in which the Chalk was deposited.

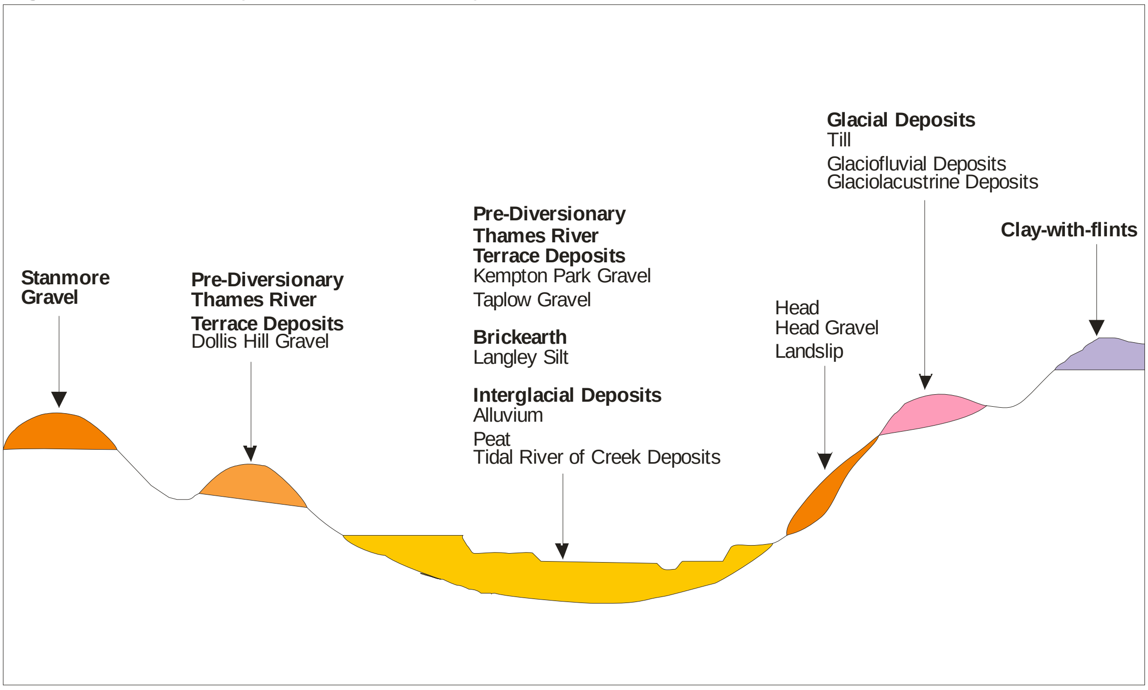
4.117 The very large chalk quarries in the London area provide almost unparalleled opportunities for examination and sampling of inland chalk successions. This is important for wider Chalk studies, particularly those concerned with understanding the nature of the Late Cretaceous greenhouse climate and Chalk depositional environment. Many of these studies rely on examination of coastal successions, but these are not always ideal in terms of stratigraphical development and accessibility. The absence of saline water intrusion in inland Chalk successions is an advantage for geochemical studies.

4.118 Each of the Palaeogene formations, especially those of the Lambeth Group, will continue to be the subject of studies for regional stratigraphic correlation and palaeoenvironment analysis. These topics are relevant both to scientific research, for example in sequence stratigraphy and climatic variation, and to applied studies, for example in geotechnical engineering.

Quaternary deposits

4.119 The Quaternary deposits of London provide a fascinating insight into the capital's Ice Age past. They overlie the bedrock of the area and were deposited during the Quaternary Period, between 2.6 million years ago and present day (Figures 16 and 17). They are collectively known as 'superficial deposits' or, in older literature, as 'drift' or 'drift deposits' (Figure 18).

Figure 16 Summary of the Quaternary strata of London



4.120 The superficial deposits are thickest and most extensive within a few kilometres of the River Thames, especially on its north bank, and along its main northern tributary, the River Lea. Less extensive Quaternary deposits occur in the valley floors of the other tributaries. By contrast, the older deposits are confined to interfluve areas and tend to have relatively restricted distribution on the higher ground. Large areas of ground, of intermediate elevation, are shown by the geological map to have no cover of superficial deposits, especially in the north-west and the south, but even here there is likely to be a thin discontinuous cover of head deposits (paragraphs 4.157-158).

4.121 The oldest superficial deposits in the London district probably date from the Neogene (Figure 6). In the south they are the clay-with-flints, a residual deposit derived mainly from a past cover of the Palaeogene, and in the extreme north-west the Stanmore Gravel of unknown but probable marine origin. At lower levels, the interfluve deposits also include a series of river terrace deposits laid down by southern tributaries of an ancestral River Thames. During the Anglian Glaciation, approximately half a million years ago, an ice-sheet extended southwards, diverting the river system and laying down glacial deposits in the north of the district. When the climate warmed and the glacier retreated, the River Thames and its tributaries had been established in approximately their modern positions. Subsequently, the superficial deposits were largely confined to valley floor areas: they include extensive representatives of cold climate deposition (river terrace deposits and 'brickearths') and restricted occurrences of warm climate interglacial deposits. The latter, however, arguably include the alluvium (the extensive deposits of the modern floodplain) and estuarine deposits. The mass movement deposits of the intermediate slopes (head deposits and landslides) formed mainly during periods of cold climate, albeit with some development at other times. This stratigraphy provides a remarkable record of climate change in the region, recording the oscillations between glacial and interglacial periods.

Figure 17 Chronology of the main Quaternary deposits of London (from Ellison, 2004)

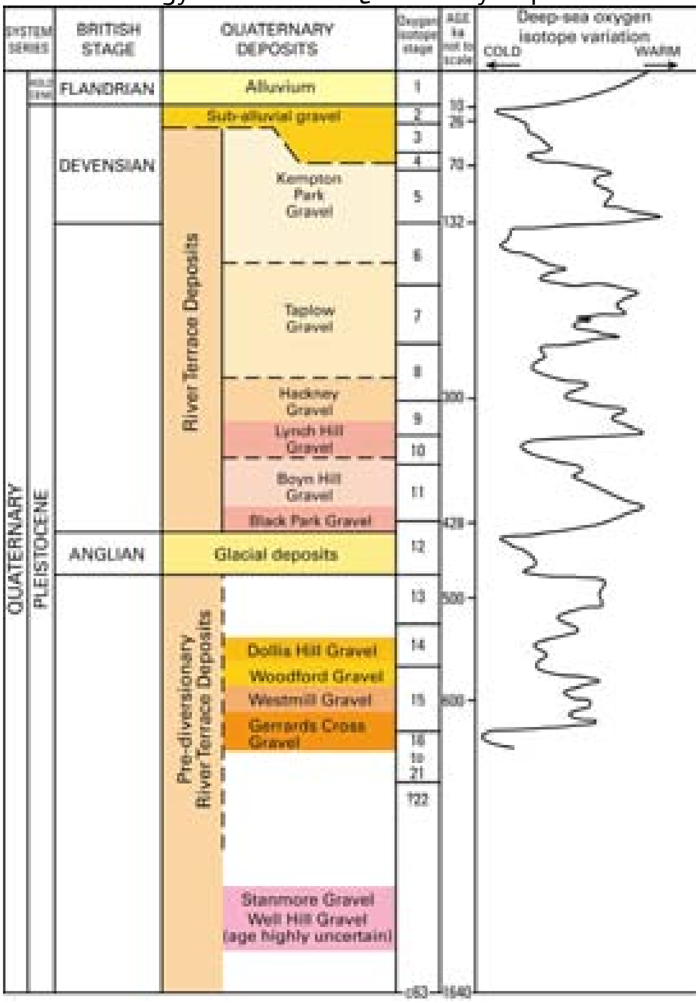
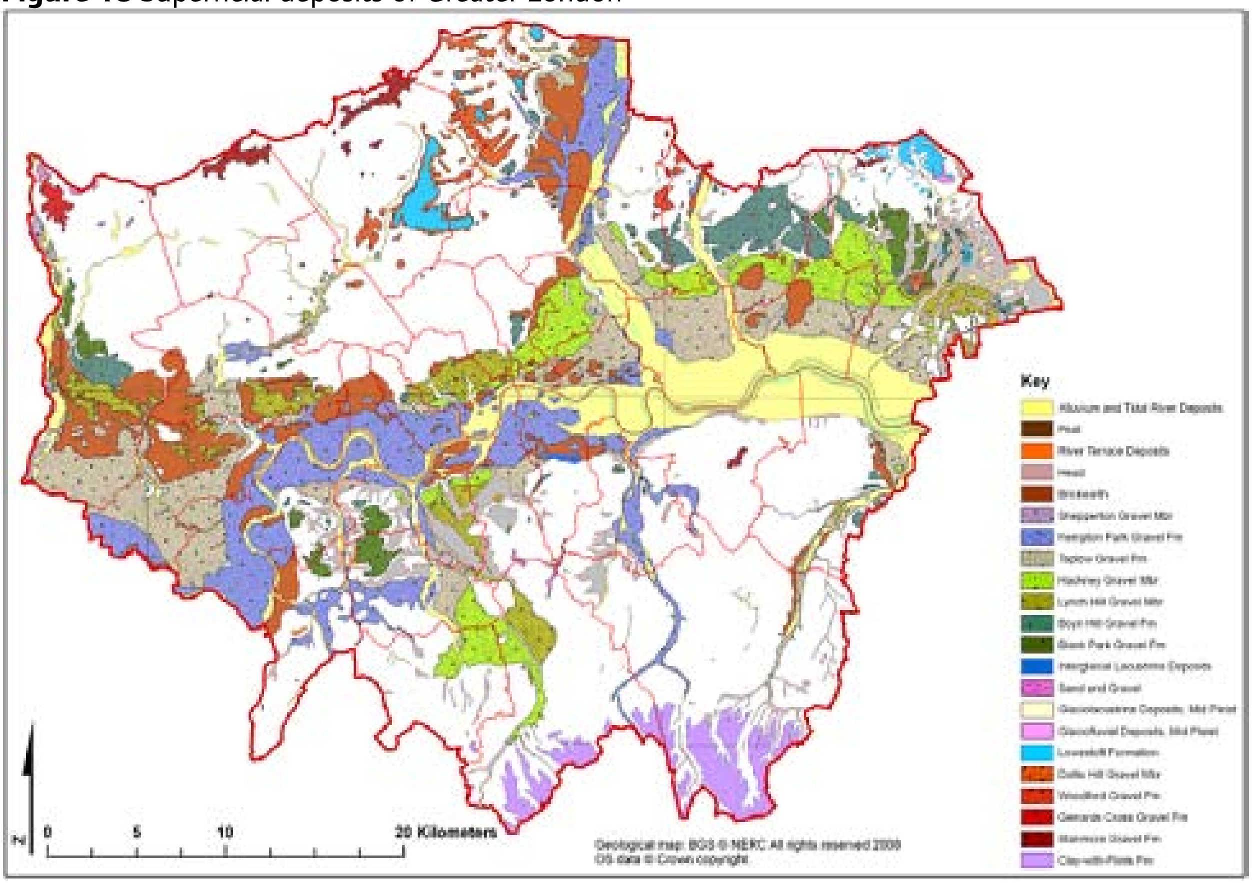


Figure 18 Superficial deposits of Greater London



4.122 There are very few natural exposures of any of the superficial deposits.

Clay-with-flints

4.123 The clay-with-flints is a rather variable deposit that occurs on the highest interfluves of the chalk downlands in the extreme south of the district. Typically, it comprises an orange or reddish brown clay or sandy clay, with abundant matrix-supported flint nodules and pebbles. In places, however, it can comprise clean sand or gravel. The lower surface of the deposit is generally irregular, often infilling deep, steep-sided solution pipes and fissures in the underlying Chalk. The thickness of the deposit is thus very variable. In general it forms a blanket up to about 5 m thick, locally greater, but can abruptly increase to several tens of metres in a solution pipe.

4.124 The clay-with-flints is a residual deposit formed by weathering, cryoturbation and solifluction of the original cover of Palaeogene, Neogene and early Quaternary deposits, together with the insoluble components left after dissolution of the Chalk. This process of weathering probably started during Neogene times, continuing into the Quaternary.

4.125 The clay-with-flints is very widespread on the Chalk of southern England. The occurrences in the London district appear to have no special significance, other than as local representatives of this deposit.

Stanmore Gravel

4.126 Hilltop occurrences of gravel at between 130 and 150 m OD in the extreme north-west of the London district have been named the Stanmore Gravel. This typically contains well-rounded pebbles of flint, with lesser proportions of quartz pebbles, subangular to nodular flint, quartzitic sandstone, and some other types. These are set in a clayey, sandy matrix, with some pockets of coarse sand. The deposit is up to about 5 m in thickness.

4.127 The Stanmore Gravel is of uncertain age and origin. It has been proposed as river deposits from south bank tributaries of the proto-Thames, rather like the older of the Thames terraces. However, its distribution suggests that it is a westwards correlative of the Red Crag of East Anglia, and that it therefore comprises marine deposits of latest Pliocene to earliest Pleistocene age (Ellison et al., 2004, p. 52).

4.128 As such, it could yield significant information about the early Quaternary palaeogeography and climate, and about the long term rates and patterns of vertical crustal movement in the London region.

4.129 The Stanmore Gravel, overlying the Claygate Member, is exposed at Harrow Weald SSSI, Harrow (Figure 4).

Glacial deposits and landforms

Till

4.130 In the north of the district, particularly around Finchley, and in the north-east at Upminster, glacial till overlies the proto-Thames river terrace deposits. The till (part of the Lowestoft Formation) was deposited during the Anglian Glaciation, about half a million years ago, when an ice-sheet extended into the region from the north. The deposits in north-east London mark the most southern ice margin in eastern England (Figure 12).

4.131 The Anglian till of eastern England was traditionally known as 'chalky boulder clay', reflecting its most obvious lithological characteristics. It is a heterogeneous deposit typically consisting of variably sandy, silty clay with pebbles, cobbles and boulders. The clayey matrix is derived mainly from Jurassic mudstones. The clasts are mostly of flint or chalk but commonly include Jurassic and Carboniferous sandstones and mudstones (and fossils derived from them, such as the Jurassic oyster *Gryphaea*), Triassic quartzite, as well as other rarer erratic material such as dolerite or granite. The till is composed essentially of the material eroded, transported and subsequently deposited by the ice-sheet.

4.132 The Lowestoft Till (locally known as the 'Hornchurch Till') is exposed below river terrace deposits in Hornchurch Cutting SSSI (Figure 4).

Glaciofluvial sands and gravels

4.133 Glaciofluvial sands and gravels form lenses and sheets in close association with the till, locally underlying it. They were deposited by meltwater streams flowing from the ice-sheet. Their composition is thus similar to that of the coarser components of the till, chiefly flint and chalk pebbles with variably clayey sand.

Glaciolacustrine deposits

4.134 Small outcrops of glaciolacustrine deposits also occur near Upminster, in the north-east of the district. They consist of thinly bedded sand, clayey sand and silty clay laid down in proglacial lakes at, or close to the front of the ice-sheet. As with glaciofluvial deposits, in the GLA area, these occur only in very small areas in the north and extreme north-east.

Wider geological significance

4.135 The glacial deposits mostly occur on what is now high ground, on the interfluves. Although they were therefore once more extensive, their distribution provides important information on the maximum extent of the Anglian ice-sheet.

4.136 There are also sporadic occurrences of till found in boreholes at relatively low levels in the Lea Valley, near Edmonton and Waltham Cross (Cheshire, 1981). These provide evidence about the contemporary topography, and the pre-glacial river systems.

4.137 Their relationship to some of the older river terrace deposits is an important constraint on the age and stratigraphy of those deposits.

Fluvial deposits

Thames river terrace deposits

4.138 The Thames has left a record of its former courses in the form of a series of fluvial deposits, which together make up the most widespread suite of superficial deposits in the London area (Figure 19).

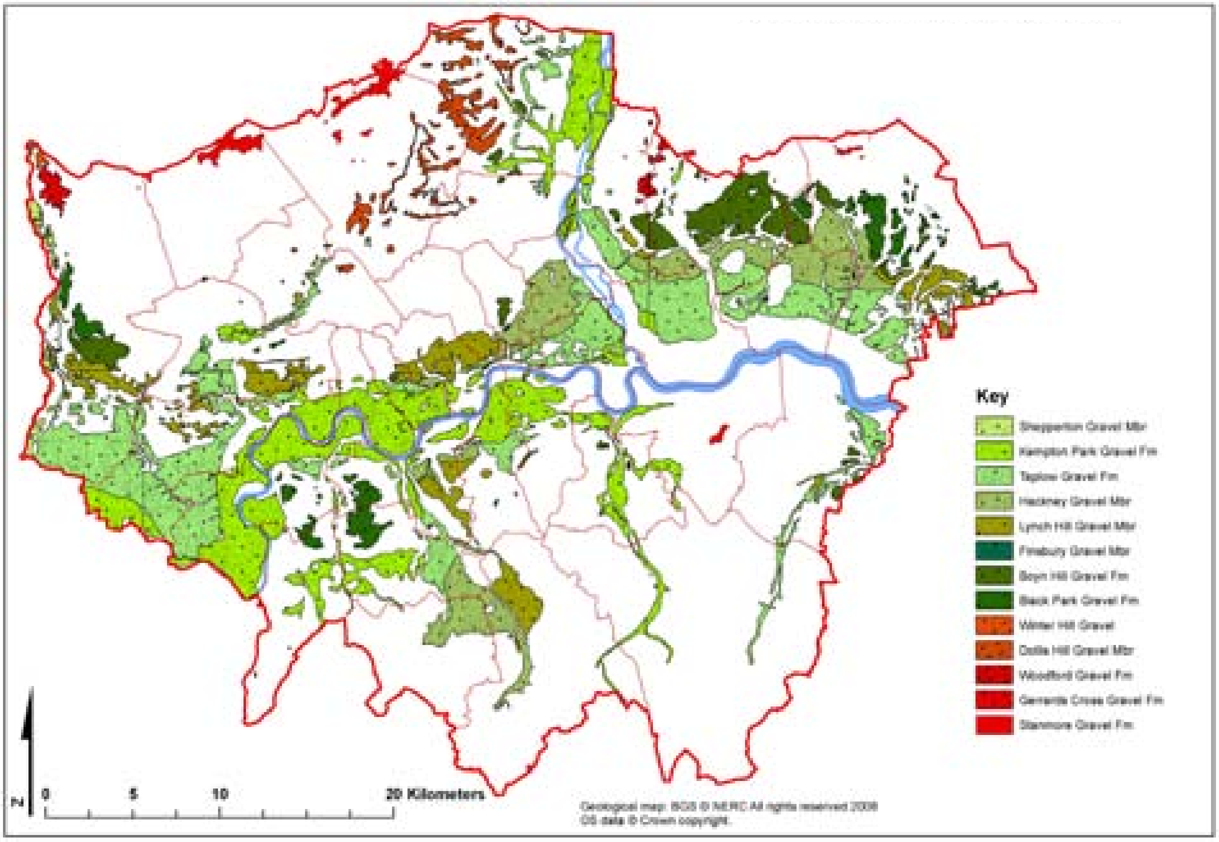
4.139 The river terrace deposits consist primarily of sand and gravel in varying proportions, most usually comprising flint gravel in a matrix of medium- to coarse-grained sand or clayey sand. Beds or lenses of sand, some clayey or silty, occur locally and there are rare lenses of clayey silt, silty clay or peat.

4.140 Each of the terraces was originally deposited on the contemporary valley floor, typically overlying bedrock. They mostly represent deposition under cold climate conditions, when vegetation was sparse, freeze-thaw weathering was active, and seasonal run-off was great. Consequently, large braided rivers carried voluminous sediment, which accumulated relatively rapidly. Subsequent uplift and erosion left portions of each deposit some distance above the modern river, with the older terraces at greater altitude. Together the Thames river terraces thus take the form of a disjointed 'staircase' which range from some ridge-tops down to beneath the floor of the main valleys, where they are overlain by alluvium and peat. Some terraces are preferentially preserved on one side of the valley; and the older terraces have been more extensively dissected by subsequent erosion.

4.141 Each terrace deposit is typically a few metres thick, lying on a step-like surface eroded into the underlying bedrock. Greater thicknesses of the terrace deposits occur locally associated with either channels or closed hollows in the underlying bedrock. In their undisturbed state, each river terrace forms areas of almost level ground which slope gently downstream at a similar gradient to that of the modern river. The importance of this is that it gives the London landscape part of its topographic character of long flat areas, e.g. underlying Heathrow airport or Hyde Park, separated by steeper areas of terrace front slopes, e.g. leading from the Strand to Temple tube.

4.142 The river terrace deposits in the London district can be separated into two systems (Figures 18 and 19). The older terraces pre-date the Anglian glaciation. They mark north-eastwards-flowing tributaries of an ancestral River Thames, which at that time flowed through what is now Hertfordshire and Essex on its way to the North Sea. The advance of the Anglian ice-sheet diverted the Thames southwards to approximately its present course. The younger system of river terraces follows the course of the post-diversionary Thames and its tributaries. For example, in the London Borough of Enfield, the Dollis Hill Gravel was deposited by a pre-diversionary tributary of the Thames, flowing towards the north-north-east, whereas the nearby portions of the post-diversionary Taplow Gravel and Kempton Park Gravel were deposited by the southwards-flowing River Lea.

Figure 19 River Terraces of Greater London (pre-diversionary terraces in red colours)



Wider geological significance

4.143 One of the main reasons the Thames river terrace deposits are so important to Quaternary scientists is their content of the remains of plants and animals. These can give an insight into the types of vegetation and habitats in the area at the time, potentially providing information of the climate and temperature during the time of deposition. For example, organic deposits associated with the Kempton Park Gravel beside the River Lea in the Enfield area contain plant and insect remains indicative of a sub-arctic, tundra environment. Some terraces contain evidence of early human activity in the area, such as bones and flint tools.

4.144 Another of the values of the Thames river terrace deposits is the continuity in their source, and the river basin geometry, over a considerable duration of time. The continuity provided by this stratigraphy is vital for building an understanding of long term Quaternary climate change. The Thames river terrace deposits are arguably one of the most complete sequences of Quaternary deposits in the UK, particularly rich in information on the cold stages represented by the gravels, evidence of which is scarce in other parts of the UK.

4.145 The Wansunt Pit SSSI, Bexley, exposes the Dartford Heath Gravel, part of the complex of Thames river terrace deposits (Figure 4).

Brickearth

4.146 The river terrace deposits (and some of the nearby bedrock outcrops) are widely overlain by 'brickearth', now assigned to the Langley Silt or other named formations on a geographical basis. The London brickearth is typically composed of very fine-grained sand, silt and clayey silt, ranging to silty clay, with some flint gravel. It is generally yellowish-brown in colour and poorly stratified.

4.147 The silt is thought to have originated as a wind-blown deposit, a loess, but the admixture of much sand and gravel in the local development of these deposits suggests they have been largely reworked by fluvial processes or solifluction (down-slope mass movement under cold climate conditions), or both.

4.148 In the past, the brickearths were extensively worked for brick manufacture. Large areas of London close to the Thames and its tributaries occupy former brickfields.

Interglacial deposits

4.149 There are a relatively few, small, but widely distributed examples of deposits from past interglacial periods, representing deposition in temperate climates, typically warmer than at present. These are associated with the river terrace deposits and the brickearths, typically towards the 'back' of the terraces, although the nature of the relationship is not everywhere clear.

4.150 They are mostly sandy to clayey in nature, representing fluvial or lacustrine deposition. Many have yielded significant fossil material, including in some cases the remains of large mammals now found in Africa, and so have a greater significance than their relative rarity might suggest.

4.151 The most well known of the Thames river terrace deposits are probably those evacuated from around Trafalgar Square. These were identified in the early 1700s, when remains of large vertebrates were first discovered. This river terrace deposit is from the Ipswichian (Last) interglacial, providing a detailed insight into the animals and habitats which would have been found living close to the Thames 125 000 years ago. Mammals found include present day hippo (*Hippopotamus amphibious)*, cave lion *(Panthera leo)* and straight-tusked elephant (*Palaeoloxodon antiguus*). Molluscs found in the deposit suggest full interglacial conditions, with a large slow flowing river containing plenty of aquatic vegetation (Preece, 1999).

4.152 The scientific importance of the interglacial deposits is quite disproportionate to their extent. The richness and variety of the contained flora and faunal assemblages provide detailed information about the prevailing climate and physical environment and in some cases can provide the basis for stratigraphic correlation from one site to another across northern Europe. For example, certain of the Pleistocene Mammal Assemblage Zones have been named after localities in the east of the London district and nearby Essex (Schreve, 2001). This stratigraphic value is enhanced by the close relationship with individual river terrace deposits, which can be traced over very wide areas.

Alluvium

4.153 Alluvium, composed of mainly silt and clay with rare seams of sand and gravel, forms the floodplains of the Thames and the other rivers in the region. Also found within the alluvium are peat beds, indicating periods of favourable conditions allowing vegetation growth. Mesolithic artefacts have been found in early Holocene alluvium, providing information on the activities of humans in the area. Also abundant in alluvium are fossil molluscs, insects, ostracods and mammals, providing yet more information on the habitats and climate during the Holocene. The Thames foreshore is a source of sites with Holocene alluvium, such as the submerged forest at Erith in east London.

4.154 In most parts of the London district, the floodplains are defended against inundation, and so alluvial deposition has there effectively ceased. Deposits below the level of high water, within the modern river channel, are generally referred to as tidal river or estuarine deposits.

Mass-movement deposits

Head

4.155 Head deposits are commonly present on slopes or on the floor of valleys. They formed mainly by gradual down-slope mass-movement (solifluction) under past conditions of cold climate, but can include the products of more recent soil creep or hill wash. Their composition reflects that of the local materials from which they were derived, either the bedrock or other types of superficial deposit, or both in combination. Head deposits typically are poorly stratified and poorly sorted, and can be variable in composition. Head deposits may be more extensive than shown on the geological map.

4.156 In some places head deposits may pass laterally into river terrace deposits or landslide deposits.

Landslide

4.157 In the London area, landslides are associated mainly with steep slopes on the London Clay. These occur in the Shooter's Hill area of Greenwich, in Richmond Park, and around Romford.

Superficial periglacial structures

4.158 Aside from the types of superficial deposit, the past occurrence of permafrost conditions can be demonstrated by the presence of certain superficial structures. The most common are cryoturbation structures, such as involutions. These occur in the glaciofluvial deposits and some river terrace deposits.

4.159 Pingo scars are thought to be present in a few places, notably at Blackwall. Aside from their scientific interest, these structures are an important element of the local groundwater systems, and place a major constraint on civil engineering works.

Holocene deposits and processes

4.160 After the end of the last glacial period, around 11,800 years ago, river alluvium, peat, salt-marsh and estuarine sediments were laid down and soils developed.

Soils

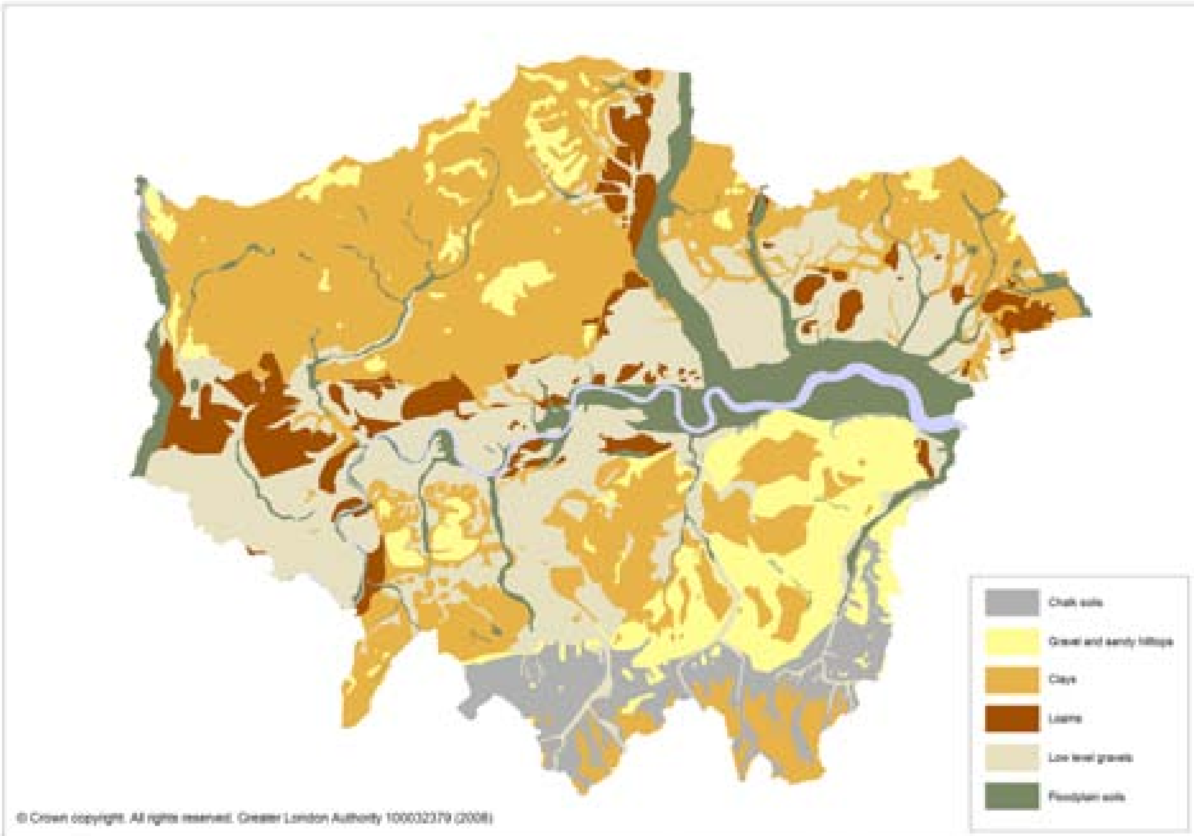
4.161 Soils link the underlying geology with surface habitats, biodiversity and land use. At any given location, soils reflect the interaction between soil parent material, climate, topography, vegetation and fauna. Soil biodiversity is known to be greater than above-ground biodiversity, but is poorly understood. London's soils, like all English soils, are young, but still represent more than 11,000 years of ecological processes and are thus irreplaceable (Figure 20). London's soils have also been extensively modified by urban development.

4.162 Chalk soils occur in a broad band across the south of London and include downland habitats of Down Bank, High Elms, Saltbox Hill, Riddlesdown, Farthing Down and Happy Valley biological SSSIs. In the east of London chalk soils are confined to small areas in Lewisham, Woolwich, Crayford and Abbey Wood. A small area occurs in the north-west of London.

4.163 Sand and gravel soils (on river terrace deposits and parts of the Lambeth Group) occur extensively on the hill slopes south of the Thames, in small areas to the north-east of London, on top of the clay in south London at Richmond Park and Wimbledon Common and in a band north of the chalk, which widens to the east. Sandy hilltops occur on top of the clay across the north and west of London. Acid grasslands and heathlands include:

- Richmond Park, Wimbledon Common, Croham Hurst, Keston and Hayes Commons SSSIs in south London
- Hadley Green, the western end of Monken Hadley Common and some of the northern and western outliers of Hampstead Heath in north London
- Stanmore and Little Commons, Stanmore Country Park and part of Bentley Priory in west London
- Epping Forest SSSI, Hainault Country Park, Bedfords Park and Lesnes Abbey Wood in east London.

Figure 20 Soils of Greater London



4.164 Low clay hills (London Clay Formation) occupy most of the north and west London and the north-eastern and south-eastern boundaries, now very largely occupied by built development, except in the Green Belt of the far north and west. In south London low clay hills occupy a band to the north of the chalk overlapping with the sands and gravels in the west. Many of London's surviving ancient woods are on the clay, including:

- Queen's Wood, much of Epping Forest biological SSSI and most of Highgate, Whitewebbs and Scratch woods in north London

- Ruislip woodlands National Nature Reserve and those on Stanmore Golf Course in west London
- Hainault Forest and all of the Oxleas Woodlands biological SSSIs in east London
- Sydenham Hill in central London.

4.165 Most grasslands tend to be damp, and this includes some of London's best 'mesotrophic' grasslands, which include:

- Totteridge Fields, Edgeware Way, Arrandene and Mill Hill in north London
- Richmond Park biological SSSI and Morden Cemetery in south London
- Bentley Priory biological SSSI, Fryent Country Park, Horsenden Hill, Yeading Brook Fields and Kensal Green Cemetery in west London.

4.166 In the north-east there is extensive agricultural land as at Fairlop plain.

4.167 Loams occur south of the clay in west London in a wide band, in a few small areas near the Thames and to the west of the Lea Valley. A scattering of loam soils is also found over the low level gravels largely north of the Thames. These soils are fertile, and in history were the focus of productive agriculture and horticulture for London's breadbasket.

4.168 Extensive low level gravels (river terrace deposits) occur near the Thames and also beside tributary rivers, particularly the Wandle, and are found either side of the Lea Valley. Acid grassland and heathland habitats are evident here, such as:

- Bushy Park, Home Park, Ham Lands, and Barnes and Mitcham Commons in south London
- the centre of Whitewebbs Wood in north London
- Wanstead Flats in east London
- Wandsworth Common in central London.

4.169 Narrow belts of floodplain (alluvium) soils occur around the Thames and also in valleys of the tributaries (including the lost rivers of central London). These would once have been managed as grazing marsh, but most have been displaced by development. The best surviving grasslands and remnant saline grazing marsh are at:

- the northern edge of Ham Lands, Wilderness Parkfield at the eastern edge of Hampton Court and beside the upper Wandle in south London
- Frays Farm Meadows and Syon Park biological SSSIs and in wet gravel pits in west London
- Rainham biological SSSI, Dartford and Bexley Marshes, and the best fresh water example at the Ingrebourne Marshes biological SSSI.

4.170 Woodland is naturally scarce but there are some valuable wet woodlands in the Ruxley Gravel Pits SSSI, in the Ingrebourne valley and areas associated with wet gravel workings in the Colne and Crane valleys. In places, previous use has left rubble, sand, etc, on top of the natural floodplain surface.

Artificially modified ground

4.171 Artificial deposits are those created by human activity. They comprise *Made Ground* (material deposited on an existing land surface) and *Infilled Ground* (material deposited in an excavation, typically a quarry or the like). For example, rubble from cleared World War II bombsites was used to fill gravel excavations on Blackheath and large quantities were used to raise Hackney Marshes above flood level to create playing fields. In some instances this distinction cannot be made clearly and so Made Ground and Infilled Ground can together be referred to as *Artificial Ground*. Geological maps typically also include *Worked Ground* (excavated areas) in the category of Artificial Deposits or Artificially Modified Ground. Artificial Deposits may overlie either superficial deposits or bedrock formations.

4.172 *Underground chalk workings* are present in some parts of London, notably at Pinner, Chislehurst, Sidcup, Blackheath and Woolwich. These are of a variety of ages and types. Some are very extensive (see paragraphs 4.46-4.50 and 5.9-5.10).

Natural processes

4.173 London's natural river system has largely been lost due to urban development. Most smaller streams have been built over and channelized, or altered by the quarrying of aggregate, for example, in the Lea Valley. However, over the last few years, efforts have been directed at reversing this loss. The Blue Ribbon Network policies in the London Plan aims to protect and improve London's semi-natural and man-made water systems. The policy takes into account that this network is a dynamic system and is subject to natural forces such as tides, erosion and floods. Restoration of rivers to a more natural form is encouraged and proposals to impound or partially impound rivers and development on functional flood plains are resisted. Proposals that include the removal of impounding structures in rivers are also welcomed.

4.174 Guidance on river restoration in London is available from: *River Restoration – A stepping stone to urban regeneration, highlighting the opportunities in South London* (Environment Agency, 2002) and *Bringing your rivers back to life - A strategy for restoring rivers in North London* (Environment Agency, 2006).

Future Earth science research potential

4.175 Many of the Quaternary (and in the case of the Stanmore Gravel, possible late Neogene) deposits, particularly the system of river terrace deposits and the associated interglacial deposits, preserve an important record of changes in sea level and palaeoenvironment, and so also of climate variation. Some of these deposits also yield significant archaeological information.

4.176 The details of the relationships between the river terrace deposits, interglacial deposits, and glacial deposits provide important controls on Quaternary stratigraphic correlation in southern England.

Fossils and palaeontology

Late Cretaceous

4.177 On an ultra-microscopic scale, the Chalk is literally made of fossils. The nanometre-sized fragmented skeletons of coccolithophores, only visible under a scanning electron microscope, are the major constituent of the Chalk, but microfossils visible using conventional optical microscopes, such as foraminifera, radiolaria and ostracods, also occur. Macrofossils, those visible with the naked eye, have been the traditional focus of Chalk palaeontological studies, and include a wide variety of forms, the most important being sponges, brachiopods, bivalves, ammonites, belemnites, crinoids and echinoids. At some levels macrofossil remains are so abundant that they are important rock-forming elements, such as the bivalve *Mytiloides* forming the shell-rich higher part of the Holywell Chalk, or the fragmented occurrence of the bivalve *Platyceramus* in the Seaford Chalk. Trace fossils, representing burrows made by animals in the sea bed sediment whilst the Chalk was being deposited, are also locally abundant and extensively developed at some levels.

4.178 The technique of biostratigraphy classifies the Chalk into intervals (biozones) on the basis of its fossil content. Historically this methodology offered a much more sophisticated way of subdividing up the Chalk than was possible using the traditional scheme based on rock composition. The standard zones of the Chalk are based on macrofossils, but there are also microfossil schemes. In Mesozoic rocks, ammonites are usually the best macrofossils for biostratigraphy, as they show rapid evolution, are widely distributed and are normally well preserved. The Chalk is unusual, however, in that ammonite remains are only common in the lower part of the Grey Chalk Subgroup, requiring reliance on a variety of other macrofossil groups for the biozonation of the higher part of the Group.

4.179 Biostratigraphy remains important for understanding the age distribution and correlation of the Chalk, but increasingly attention is being focussed on the microscopic fossils, as these may offer insights into fundamental environmental processes in the Late Cretaceous, such as ocean circulation and global climate change.

Palaeogene

4.180 Parts of the Palaeogene sequence in the London area, particularly but not exclusively the marine deposits, have a rich and varied fossil fauna and flora.

4.181 Bivalves and microfossils such as foraminifera and ostracods have long been used for stratigraphic correlation. More recently, nannoplankton and dinoflagellates have also been found to be of value. Fossil remains of many other groups of marine organisms can be commonly found, including sharks' teeth which in places have been concentrated by winnowing of the sea floor sediment.

4.182 The Palaeogene fossil mammal fauna is less important for correlation than the marine assemblages, but provides valuable insights into evolution following the large-scale extinctions (most notably of the dinosaurs) at the end of the Cretaceous.

4.183 The Thanet Sand is not conspicuously fossiliferous, containing sporadic, poorly preserved bivalves and gastropods, but microfossils are important. Calcareous nannoplankton and palynomorphs have been used for regional correlation. The foraminifera and other fauna indicate that the greater part of the formation was deposited in a shallow sea, less than 50 m deep, and that the prevailing climate was generally cool, turning warmer during deposition of the younger sediments. Irregular nodules of pyrite, less than 5 mm across, are presumed to have replaced fragments of wood. The Bullhead Bed includes a variety of fossils, including echinoid spines, bryozoa, pelecyod shells and fish vertebrae, derived from the Chalk.

4.184 The marine deposits in the Lambeth Group contain molluscs and sharks' teeth. The Woolwich Formation, especially the Shelly beds, commonly contains a limited mollusc fauna indicating brackish water conditions. However, the 'Paludina Limestone' of the Upper Shelly Clay contains the remains of freshwater molluscs, while the rest of the Upper Shelly Clay contains a generally more diverse fauna than the Lower Shelly Clay, including more marine-tolerant species. The Harwich Formation is locally shelly, as at Elmstead Pit (Section 4.3), and also yields sharks' teeth and fish scales.

4.185 As a non-marine deposit, the Reading Formation is relatively poor in fossils, but thin beds rich in leaf impressions and other plant remains occur in places. Clay beds with leaf impressions have been noted in the 'Striped Loams' of the Woolwich Formation. The lignite deposits at the Paleocene-Eocene boundary arose from vegetation dominated by angiospermous trees and herbs, with many ferns, which was subject to repeated fires. These fires may have been a response to climatic events associated with the Paleocene-Eocene thermal maximum (Collinson et al., 2003; King, 2006).

4.186 An important mammal fauna at Abbey Wood, Bexley, is in shelly sands, is in shelly sands of the Blackheath Beds.

4.187 The marine fossil fauna of the London Clay includes numerous types of bivalve, gastropods and some brachiopods, corals, echinoderms such as starfish and sea lilies, arthropods including crabs, lobsters and barnacles, cephalopods and a variety of sharks' teeth. Bones of fish and reptiles can also be found.

4.188 A variety of plant seeds and fruits, some quite large, also occur in the London Clay.

Crystal Palace dinosaurs

4.189 The Crystal Palace was originally built in Hyde Park as part of the Great Exhibition of 1851; it was relocated to its current position once the exhibition was over. As part of the relocation and development of the grounds, Benjamin Waterhouse Hawkins was commissioned to build life-size models of extinct animals. With the help of Sir Richard Owen (a biologist and palaeontologist), he was able to design dinosaurs to be included in the collection. Concurrently, a model of geological strata and a lead mine were built to illustrate the natural state of geological resources including coal, iron and lead. These were constructed by James Campbell, an engineer and mineralogist.

4.190 The animal models were originally set out so they followed a rudimentary timeline; Palaeozoic, Mesozoic and Cenozoic eras were each represented by a separate island within an artificial lake. The Cenozoic models were later moved to different areas within the park and subsequently became damaged. Funding for the models was cut in 1855 before all those planned had been completed.

4.191 By the end of the 19th Century, further research into the species on display had revealed that the models were highly inaccurate and they drew many critics. The popularity of the models declined and they fell into disrepair – this was compounded by the fire in 1936 which destroyed the Crystal Palace. The models and much of the park became overgrown.

4.192 In the 1950s Victor H C Martin carried out a full restoration of the models during which time they were moved to fresh sites. After this restoration, the models were once again left to decay with the exception of occasional touch ups. This was the case for the whole park until 2002 when the Institute of Historic Building Conservation completed renovation of the models. The models were mended and repainted; missing models were reconstructed using fibreglass. The vegetation around the models was also restored to reflect the plant life that would have existed when the exhibited animals were alive.

4.193 There are now 29 models in the park representing the following genera:

Anaplotherium; Dicynodon; Hylaeosaurus; Ichthyosaurus; Iguanodon; Labyrinthodon; Irish Elk; Megalosaurus; Megatherium; Mosasaurus; Palaeotherium; Plesiosaurus; Pterodactyl; and Teleosaurus.

4.194 The models are now part of a 'Prehistoric Monster Trail' which leads visitors through time with information boards explaining each model and how they would differ if constructed today.

Quaternary

4.195 A number of flint artefacts have been found in London of Early and Late Palaeolithic age (corresponding to Early to Late Devensian in geological time). These include hand axes, blades, and other small tools.

4.196 Pleistocene bone, plant and insect remains have been found at a number of localities in London. The main sites are Isleworth, Ilford, Brentford, Kew, Trafalgar Square, Ponders End, Erith, East Ham and Crayford. The Corbetts Tey – Mucking/Lynch Hill – Taplow terraces have yielded cave lion, wolf, mammoth, rhinoceros, giant ox and red deer, with

Ilford being one of the best sites. The East Tilbury Marshes/Kempton Park terrace has yielded hippopotamus, beaver, hyaena, cave lion, brown bear, elephant, boar, bison, giant ox and red deer, with Brentford and Trafalagar Square being the best examples. More recent deposits associated with the Devensian ice age have yielded lemmings, hyaena, cave lion, polar bears, woolley mammoth, rhinoceros, reindeer, bison, ox and antelope. Erith, Twickenam and the Lea Valley are the best examples. The alluvium has yielded beaver, wolf and giant ox with East Ham being the best known site.

Evidence of early Man

4.197 Palaeolithic artefacts have been found in the river terrace deposits of the Thames and its tributaries, and in associated interglacial deposits, reflecting the presence of human occupation along the water's edge.

4.198 The oldest such remains were found in interglacial deposits dating from the Hoxnian (which immediately followed the Anglian glaciation) about 400 000 years ago, in association with the post-diversionary Boyn Hill Gravel. Such deposits at Barnfield Pit, Swanscombe (in Kent, about 6 km east of the London district) have yielded some of the oldest hominid fossils so far found in Britain.

4.199 Tools are found in deposits dating from the subsequent two interglacials, at about 320 000 years ago (associated with the Lynch Hill and Hackney gravels) and 250 000 to 200 000 years ago (associated with the Taplow Gravel). The fossil record indicates that humans were then absent from Britain until about 70 000 years ago (Stringer, 2006).

4.200 From the late 19th century onwards, archaeologists realised that flint weapons and tools were contemporary with the remains of many extinct animals, representing a long period of time prior to the appearance of modern man. Gradually, distinctive assemblages of tool types were identified, coincident with the cultural evolution of man. For further details see Sumbler (1996).

5. Geological resources and built heritage

Mineral resources

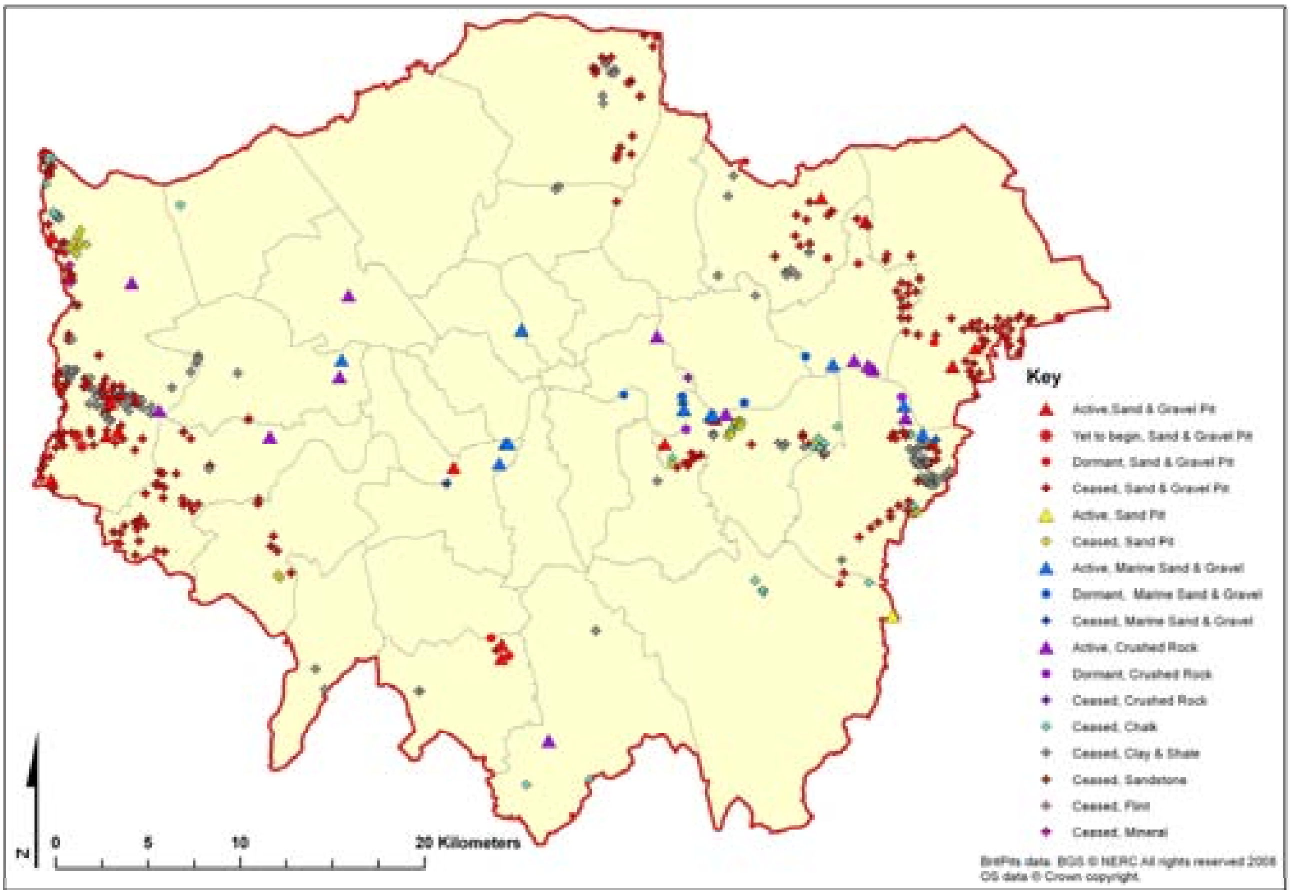
5.1 The most valuable mineral resources of Greater London are those used by the construction industry, notably sand and gravel, brick clay and cement-making materials. The rapid growth of London from the 19th century onwards created great demands for these products, much of which were met from outside London.

Sand and gravel

5.2 There are relatively small reserves of land-won sand and gravel in London. Most aggregates used in London come from elsewhere including marine sand and gravel and land-won materials from other regions. The main sources of aggregate both historically and at the present day are the Thames river terrace deposits (paragraphs 4.140-4.144). The most recent London aggregates monitoring report (GLA, 2005) identifies six active sand and gravel quarries across London (Figure 21). Fifteen active rail depots together handled some 350 000 tonnes of land-won sand and gravel. There were also 15 active wharves landing marine-dredged sand and gravel. The current regional apportionment for land-won sand and gravel, set by the GLA, indicates a commitment to a significant level of ongoing aggregates extraction across the region.

5.3 The impact of former aggregates extraction on the region is further evidenced by the fact that the BGS database of mines and quarries contains over 250 entries for sand and gravel extraction. However, modern levels of extraction are not representative of the scale of extraction which has occurred over the centuries.

Figure 21 Mines and quarries of Greater London



Brick clay

5.4 The London Clay Formation does not meet modern standards for brick-making due to its high smectite content, which causes extensive shrinkage and distortion during drying and firing. However, in the past it was used with the admixture of sand, or chalk, or in some instances blended with street sweepings of grit and cinder. The Claygate Member yielded more suitable material and was widely used, for example at Willesden Green. The London Clay was used more for tiles and pipes.

5.5 At Beddington, west of Croydon, the Thanet Sand Formation was once employed in the manufacture of ' sand-lime ' bricks. Although the Quaternary brickearths (paragraphs 4.148-4.150) are relatively thin deposits, they were once used extensively to manufacture bricks, and in some areas were completely cleared. Much development then took place in former brickfields. It has been reckoned that "an acre [of brickearth] yielded a million bricks for each foot of earth". The glacial till of Church End, Finchley, was at one time used, after washing, for making bricks, as was also the alluvial clay of Hackney Marsh.

Chalk and clay for cement

5.6 'Cementstone' beds, including septarian nodules, from the London Clay were formerly used for making cement, particularly during the 'stucco period ' of London architecture (paragraphs 5.15-5.21). The Chalk has been extensively worked for cement manufacture at several places just outwith the London area.

Chalk mining

5.7 Man-made cavities in the Chalk have been made during flint mining and chalk extraction, probably from pre- Roman times until the 19th century. The smaller mines are typically narrow vertical hand-dug shafts 10 to 20 m deep, known as dene holes. Dene holes can occur singly or in groups of up to 70, or more, and in some areas may be only 20 m apart. At the base of the shaft there may be a bell-shaped excavation or a number of short galleries.

5.8 More extensive chalk mines are known at Pinner [TQ 114 906], Chislehurst [TQ 4275 7015], at several locations near Plumstead [e.g. 472 784; 464 774], and Blackheath [383 767]. Mined cavities are usually stable, but the material with which they have been backfilled may suddenly subside and collapse due to the effects of natural drainage, leaking services or rainwater soakaways. Such instability may also occur due to slow deterioration of gallery roofs. In this case, the resultant collapse may lead to upward migration of the void and consequently sudden subsidence of the ground surface.

Flint

5.9 Flint occurs abundantly as nodules and tabular sheets in the Chalk and as clasts in terrace gravels. Historically, flint has been used for tool making by early man, for the manufacture of flint glass in the late 17th century, and for gun flint manufacture, which reached a peak during the Napoleonic Wars. It has also been used as a building material. The Romans used flint for the construction of fortification and defensive walls and the Normans continued the tradition with the erection of defensive sites and castles. In the absence of readily available alternative building stone, flint continued to be used in small vernacular buildings, as rubble flint walling and frequently in the base or plinth of timber framed structures and early brick buildings.

5.10 Flint was used extensively in the 18th and 19th centuries for road construction and maintenance where it was used to form a solid base for a gravel top surface prior to the widespread introduction of macadamized roads. In more recent times, flint was produced as a by-product of chalk working. The BGS BritPits database indicates that the Springwell Lock Chalk Pit used to supply flint for brick manufacture, but the pit has ceased operations.

Moulding sand and glass sand

5.11 The occurrence of easily accessible and large reserves of sand suitable for moulding led to the selection of Woolwich as the site of the principal arsenal in Great Britain. The sand lies towards the base of the Thanet Formation. It contains sufficient clay to give it 'binding' properties. Known as the 'Erith' or 'Blackfoot' moulding-sand, it was once sent to all parts of Great Britain and to many foreign countries, and was considered by some to be superior to the Triassic 'Bunter' sands of the English Midlands.

5.12 The uppermost metre or so of these beds was once worked for rough green bottle glass manufacture in the London district.

Building stone and built heritage

5.13 High-quality building stone is scarce in Greater London, but an interesting variety of local substitutes have been used. Rounded flint pebbles (paragraphs 5.11-5.12) and 'puddingstone' (ferricrete) from the Lambeth Group and the Thames terrace gravels have been used; the latter are best seen in the Norman churches around Heathrow, Greenford and Staines. Ferricrete from the Basghot Formation of Harrow on the Hill is well displayed in the tower and walls of the Norman church, Flints, septaria and ferricretes were usually framed and strengthened in building by quoins, string-courses and lintels of either Kentish Ragstone (Lower Greensand) from the Medway Valley, or the softer Reigate Stone (Upper Greensand) from northern Surrey. These stones were often replaced with Bath Stone (Great Oolite) by Victorian restorers.

5.14 Kentish Ragstone and Reigate Stone have been used extensively for more substantial buildings in London since Roman times, when they were used in the walls of Londinium. After the Great Fire of 1666, London, as redesigned by Wren, became a showcase for Portland Stone. The stone was transported in large quantities by sea from quarries on the Isle of Portland in Dorset. It was often used in combination with brick, or brick rendered with a white stucco finish which characterises the squares and terraces of Bloomsbury and Belgravia. The expansion of London and the building of new parish churches saw a resurgence of the use of Kentish Ragstone, mainly from the Medway Valley, and transported by barge to city wharves. Virtually all the London suburbs have a parish church of greyish buff Kentish Ragstone with yellowish brown Bath Stone dressings.

5.15 With the arrival of the railways, Victorian architects such as Sir Charles Barry and Gilbert Scott were able to utilise a wide range of new materials such as Scottish, Irish and Cornish granites. The advent of cladding techniques in the 20th century, using thin slabs of stone over a concrete interior, has greatly increased the range of rock types utilised. For more information on the building stones of London see Robinson (1984a,b) and the University College London Earth Sciences website *Building London*.

5.16 A good example of the increasing choice of building materials available in London is the construction of the Houses of Parliament between 1840 and 1860. The old parliamentary buildings were destroyed by fire in 1834 and a competition was organised to design a new set of buildings. The winner, Sir Charles Barry, originally chose Portland Stone to be used in the building due to its known durability and ease of use. However, the air in London was becoming increasingly polluted and research had suggested limestones would not be sufficiently resistant to the more sulphurous air. Therefore a Select Committee was established comprising the architect, a mason/sculptor and two geologists. They surveyed 102 stone quarries across the country, inspected reference buildings and completed laboratory tests.

5.17 The dolomitic Bolsover Moor stone was the final choice due to its dense crystalline nature (less surface area for chemical agents to react upon) and the resistance of dolomite to dilute acid. Unfortunately the quarry was unable to provide enough stone of sufficient size and so two further quarries were used.

5.18 Unfortunately it was not long until the stone began to crumble, in particular the intricately carved detail. Further investigation revealed that much of the stone contains small crystal-lined cavities and is commonly minutely cellular: on weathered surfaces, randomly oriented calcite veins stand proud. These faults had been overlooked by the original surveyors but would eventually lead to the stone crumbling when exposed to the weather. As a consequence of this, much of the original stone has been replaced by the more durable Clipsham Stone (a pale yellow Middle Jurassic limestone from Lincolnshire).

5.19 A wider consequence of the publication of the Houses of Parliament stone survey was that it inspired architects to source stone from places other than Portland. This was helped by the expansion of the railways making quarries across the country accessible and their stone financially viable.

Water resources

5.20 The Chalk is the principal aquifer of London. It is mostly confined by the overlying London Clay and Lambeth Group and is in hydraulic continuity with the sands of the Thanet Sand and Upnor formations, which together are commonly referred to as the 'Basal Sands'. The upper boundary of the aquifer is generally regarded as a clay layer with a thickness greater than about 3 m. In most places this clay lies within the Lambeth Group; it is coincident with the Lower Shelly Clay in much of central London, the Reading Formation in the west and north of the district, but probably the London Clay in the south-east of the district where the older Palaeogene strata consist mainly of sand.

5.21 The Chalk aquifer is naturally recharged by rainfall at outcrop in the Chiltern Hills to the north and the North Downs to the south. The groundwater flows towards the centre of the London Basin. Prior to abstraction in the 19th century it discharged mainly at springs, many under artesian conditions, in Chalk valleys and along the Thames particularly between Erith and Gravesend.

5.22 Relatively minor aquifers in the district include the river terrace deposits, the confined Lower Greensand in the south-east and, locally for example Harrow on the Hill, the Bagshot Formation.

5.23 The majority of the Chalk public supply sources in the Chalk aquifer are in the North Downs and the Darent and Lea valleys. Development is now taking place in the Greater London area to use the confined Chalk aquifer resource resulting from rising groundwater. Small quantities are abstracted from sources in the Lower Greensand from wells through the Chalk in the North Downs.

Development of groundwater resources in the London Basin

5.24 The growth of the City of London was constrained for many centuries by the availability of local water supplies, thus early expansion of the city was restricted to areas where river gravels are present. Until the 13th century water supplies for London were obtained from the Thames and its tributaries, and from springs and shallow wells in the river gravels. As the city expanded these resources became inadequate or polluted and further supplies were obtained via conduits, including the New River, from the Chiltern Hills. In the 18th century attempts were made to develop deeper groundwater beneath London. The first deep wells in the Chalk were constructed in the 1820s, although there was probably a reluctance to develop the confined aquifer because of difficulties in coping with the quicksands (or 'running sands') within the basal sands that were under artesian pressure. By the 1890s, many of the early large diameter wells in the Chalk also had adits, some heading several hundreds of metres from the main shaft.

5.25 The rate of abstraction from the confined part of the aquifer peaked around 1940 and subsequently decreased, whereas that from the unconfined area continued to rise until the 1970s. Public water supply has dominated water use since the 1860s.

5.26 In the confined Chalk, groundwater is considered to flow in corridors of high permeability Chalk separated by blocks of low yield. There is a general decrease in aquifer permeability from the Chalk outcrop towards the centre of the London Basin. Where Chalk is deeply confined, yield is commonly low. Yields from individual large-diameter wells at favourable valley sites at outcrop may exceed 9000 m3/day. Yields from pumping stations in the outcrop area, which may have several wells and may include adits, often exceed 14 000 m3/day. By contrast, in the confined aquifer, yields are usually considerably less, commonly of hundreds of m3/day. Some very high yielding sites (in the order of 7000 to 10 000 m3/day) in the confined aquifer are probably related to the high permeability corridors.

Groundwater management and protection issues

5.27 In central London the original natural groundwater level was 7.5 m above Ordnance Datum. By the mid-1960s this had been lowered by pumping from boreholes to around 88 m below Ordnance Datum. The fall in groundwater levels in the confined aquifer caused a reduction in spring flows and some river flows, and induced the intrusion of saline water from the Thames into the Chalk downstream of the Isle of Dogs. Reduction in groundwater abstraction since around 1965 has resulted in recovery of the groundwater level. Rates of water level rise approached 3 m/year in places in the 1990s. Left unchecked, rising groundwater beneath London would have several serious consequences including resaturation and a change in bearing strength of the London Clay and other bedrock formation, flooding of tunnels and basements, and a potential buoyancy effect on sealed structures. In addition, the groundwater rising through the Palaeogene formations can be sufficiently acidic, following oxidation of pyrite in the vadose zone, to cause corrosion of buried infrastructure.

5.28 Since 1995, rates of groundwater rise in central London have decreased to around 0.5 m/year due to a combination of natural causes and a strategy to manage the water levels.

Former spas

5.29 There were formerly many mineral springs in the London area – some were used for medicinal purposes and others for leisure. The water for many of these springs came from the London Clay. Having originally been derived from gravels overlying the clay, the water passed into the London Clay through cracks, passing along sandy layers. Whilst within the London clay the water absorbed salts, mainly magnesium sulphate or sodium sulphate. This saline water produced wells at places such as Bagnigge Wells and Sadler's Wells in the Fleet valley, Kilburn Wells in the Westbourne valley, Beulah and Streatham. Other springs contained chalybeate (containing salts of iron) water. Hampstead Wells are an example of chalybeate waters that were derived from the base of the Bagshot Sand.

5.30 Well-known examples from the Greater London area are the springs at Epsom which gave the name to Epsom Salts – the magnesium sulphate which is the principal salt in the water. The springs at Epsom were discovered in 1618 and were regularly used in the 17th and 18th centuries.

6. Evaluating London's geodiversity

Review of geodiversity guidance and assessment criteria

6.1 The next stage involved reviewing current systems of geodiversity evaluation and site assessment criteria. The mains systems in use in the UK for geodiversity auditing are:

- UKRIGS system
- BGS GeoDiversitY Database
- Geodiversity Profile Handbook (David Roche Geo Consulting)

UKRIGS

6.2 In consultation with their Member Groups, UKRIGS have developed a standardized procedure for recording, assessing, designation and notification procedures for RIGS sites. The assessment proposed includes general criteria, such as access, safety and condition of exposure, and scientific criteria, the latter showing the type of geological feature(s) exposed. Scott (2005) noted that "RIGS groups do not have a coordinated approach to site assessment. This is a strength in that local criteria are used, but also a weakness that relative values of sites across county or area boundaries cannot be established."

6.3 The assessor records the site name, location, and a description, and assesses the sites by scoring from 1 to 10 in four main categories: access and safety; education and science; culture, heritage and economic; and geodiversity value. In practice the procedure is not easy to use; the explanations in the notes do not cover all scores and the wording is subjective. It is also not appropriate to score access to the site and safety issues.

6.4 The UKRIGS site recording system is, however, the most widely adopted process for the selection of Local Geological Sites in the UK and is recommended by the Defra Local Sites guidance. Selection is based on four broad criteria or values: scientific, educational, historical and aesthetic which are central to the UKRIGS approach which assesses the quality of access (UKRIGS, 2001).

6.5 To maintain consistency with Local Site selection elsewhere the UKRIGS system has been adapted in London. Access and safety are assessed but not scored and the four main criteria are assessed and scored in two sections: 'Culture, heritage and Economic' which corresponds to the UKRIGS system and 'Geoscientific Merit' which is equivalent to the UKRIGS assessment of Education and Scientific values. In addition, The BGS GeodiversitY Database (see below) provides a further mechanism for scoring the rarity and quality of sites as well as the quantity of published literature which allows a further useful refinement of the site assessment system.

BGS GeoDiversitY Database

6.6 The BGS GeoDiversitY database was designed in MS Access for rapid and objective geodiversity data collection in the field, either on a hard copy form, or direct input via PC. The database was set up and tested during BGS projects in the North Pennines, County Durham and West Lothian (Scotland). In this system, only geological scientific merit, education value and community site value are scored on a 0 to 10 scale. Access, site fragility, potential use and other site details are entered via tick-box, drop-down menu or free text. The database is designed as a front-end to tables stored in the BGS Oracle database system.

Geodiversity Profile Handbook (David Roche Geo Consulting)

6.7 A new procedure for the recognition of high value geodiversity was developed in the MIST (Mineral Industry Sustainable Technology Programme) funded project, GeoValue by David Roche GeoConsulting, and a book entitled 'The Geodiversity Profile Handbook' was published (Scott et al., 2007) (see also www.mi-st.org.uk/section_c.htm). It provides a standardised procedure for auditing the geodiversity at a defined geological site or area, followed by a numerical procedure for valuing it, known as the Geodiversity Profile. The criteria, namely scientific, educational, historical, cultural and aesthetic are broadly similar to that adopted in assessing RIGS of County Geology Sites, and promoted by UKRIGS. Examples of the valuing of sites with differing geodiversity are provided. The purpose of the Geodiversity Profile is to provide an independent procedure for valuing a geological site and thus aid decision-making on its future management. It is developed especially for use in quarries. It is not designatory or intended to replace existing statutory or other designations. The Geodiversity Profile is not available in database format.

System used for this project – London-GDY

6.8 After comparing the above systems we decided to use the BGS GeoDiversitY database. However, in order to make it more compatible with the UKRIGS Site Assessment procedures it was adapted to use the best features the UKRIGS system. The revised system is herein termed **London-GDY**. Access, fragility, potential use, other site details and geoscientific merit, community and education site values are retained from the original BGS GeoDiversitY database as we consider the scoring system to be more robust, logical and easier to use than the UKRIGS procedure. The classes used in Geoscientific merit scoring in the London-GDY and the scoring guidance is listed in Appendix 2.

6.9 The London-GDY data entry forms were also redesigned to allow the system to run on BGS MIDAS (Mobile Integrated Data Acquisition System) ruggedised field notebook PCs (Figure 22). MIDAS allows collection of digital data/information in the field, including digitising geodiversity site boundaries. One of its main strengths is the facility to bring practically any digital dataset to the field including DiGMapGB (BGS digital geological map data), historic Ordnance Survey maps, scanned geological field maps, NEXTMap digital terrain/surface models etc. The system also has an inbuilt GPS. MIDAS uses a combination of heavily customised ArcGIS, MS Access and InfiNotes.

Figure 22 BGS MIDAS Tablet PC (GoBook) for digital field data capture

Geodiversity auditing

6.10 The UKRIGS system sets out a staged approach to Local Site assessment which is followed here. This involves desk and field based documentation of sites including a site description, boundary details, sketches and photographs. This is followed by an assessment of the 'value' of the site using various criteria, a comparative evaluation of assessed sites and the formal recommendation of the site to the local authority for designation.

6.11 The audit began with a review of the available documentation and datasets that could potentially provide information on geodiversity sites in the GLA. These sources included:

- South London RIGS Group list of potential RIGS
- SSSI and GCR documentation (Natural England)
- BGS 1:10 000 standards and field maps
- BGS BritPits database of Mines and Quarries (Map 4, Volume 2)
- BGS London Memoir (Ellison et al., 2004) and Regional Guide (Sumbler, 1996)
- Parcels of geology interest database (from GLA)
- Borough geology and landscape review documents (GLA)

6.12 Information from these sources was entered into a spreadsheet, giving a total of around 470 potential sites. The site locations were then exported to a GIS and cross-checked against recent digital aerial photography (25 cm resolution) to further ascertain geodiversity value. This was backed up by BGS staff geological expertise to narrow the potential list for field checking and auditing to 100 sites (Appendix 1).

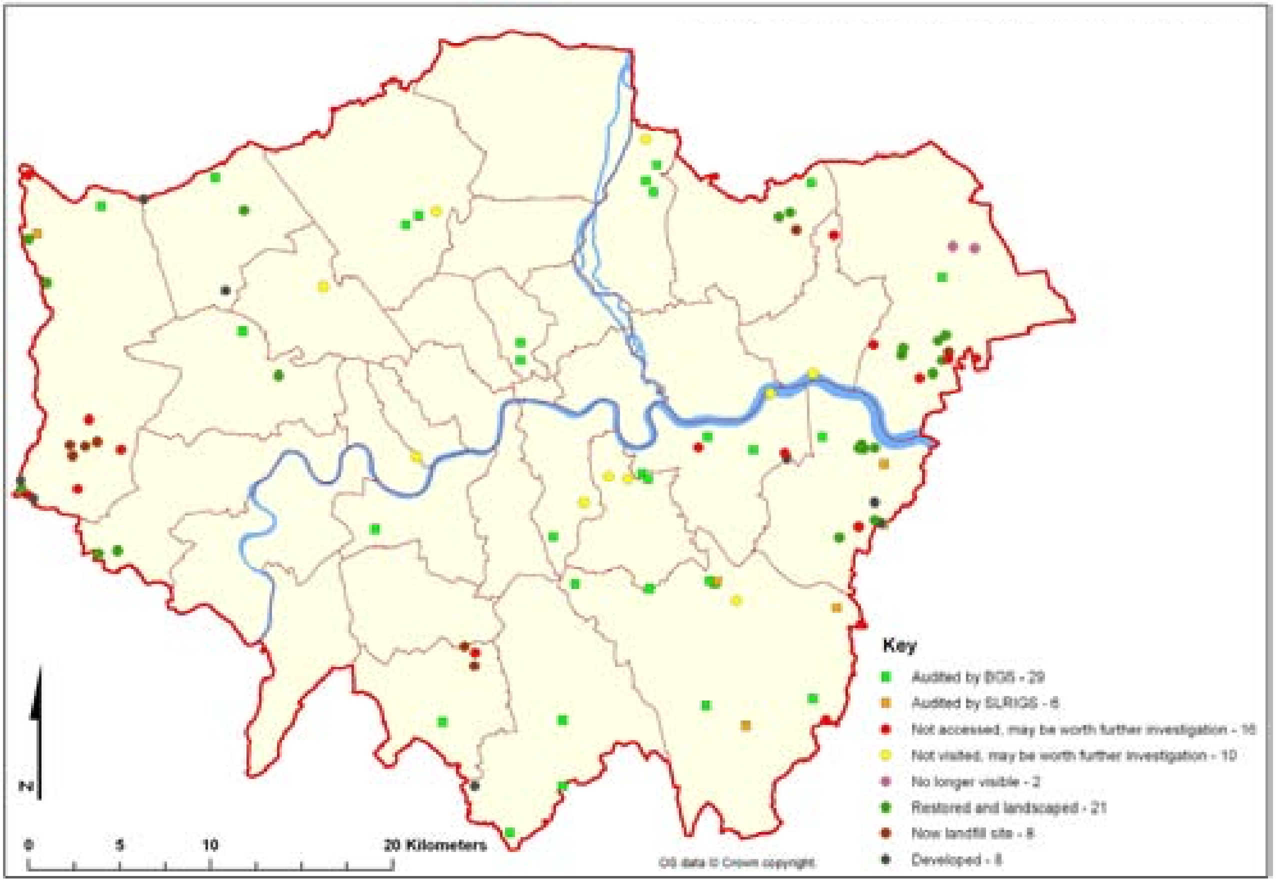
6.13 Field auditing was carried out between November 2007 and February 2008. As far as possible landowners were contacted prior to visiting or accessing sites, but ownership was not established for every site visited. From the list of 100 sites selected to be visited during field work (Appendix 1), access was not obtained for 16 of these sites and a further 11 sites were not visited for logistical reasons, with planned revisits not possible due to lack of time. A further 30 potential sites were identified during the consultation period of preparing this report. It is recommended that these 57 sites be assessed in the future.

6.14 Of the visited sites, 39 did not present any potential geodiversity value: 21 were found to have been restored and landscaped, particularly former aggregate extraction sites; 8 were developed for housing; and 8 used as landfill sites; 2 sites were not located or the features were no longer visible (Figure 23). In total, 35 were found to be suitable for auditing (Figure 24), including site information for 6 sites provided by South London RIGS Group. A further site was audited in November 2008 by the Harrow and Hillingdon Geological Society, bringing the total to 36 sites.

6.15 The auditing and updating of sites will be an ongoing process. The survey work identified in this report represents the start of the process. Auditing the further potential sites identified in Appendix 1 will be the next priority. This process may highlight additional sites that should be protected.

6.16 The experience of auditing sites in the urban landscape of Greater London was significantly different to the experiences of others auditing more rural areas. The urban nature of Greater London means that access to sites is often more difficult. This leads to a greater requirement for advance planning – researching landowners and contacting them to gain access. Ensuring that access to sites is sought at an early stage and that a detailed itinerary is completed prior to fieldwork are essential to the success of an urban audit. The quality of the sites in urban areas is often poorer than those in open countryside. Due to space being of a premium, most sites are redeveloped once they have ceased to be useful for economic purposes (e.g. quarries). Therefore, many of the sites in London are already public open spaces where the geology happens to be associated with a green space. This is a positive aspect in terms of accessibility and protection.

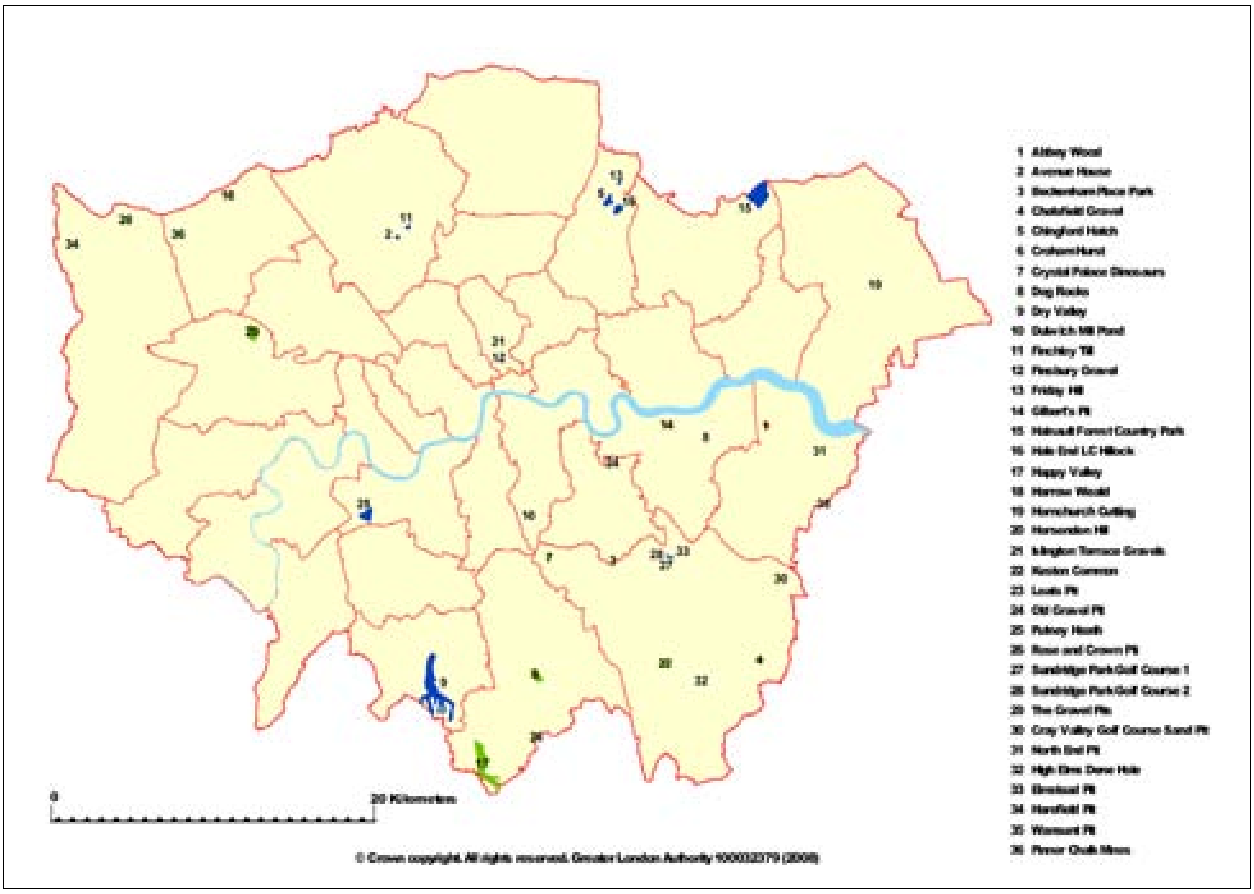
Figure 23 Selected visited and audited geodiversity sites in Greater London



Project GIS

6.17 A project GIS (in ESRI ArcGIS) was established to display the location of geodiversity information and examine spatial relationships between geodiversity and other environmental considerations. A wide range of digital data was acquired and the datasets translated to a suitable format for display in ArcGIS. The GIS was also used to produce figures and maps for this report. Datasets and their sources are listed in Appendix 4.

Figure 24 Greater London geodiversity sites



7. Geodiversity audit results and recommendations

7.1 On completion of the field audit, data was downloaded from London-GDY on the MIDAS tablet PC and exported to MS Word. Field-digitised site boundaries were placed on Ordnance Survey map extracts and digital site photographs added to illustrate the site descriptions and geodiversity scoring. The overall geodiversity value scores were then assigned to each site, using the professional judgement of the audit geologist (Appendix 5). Appendix 6 summarises the geological strata of the sites.

Criteria for selection of RIGS and LIGS

7.2 The main selection criteria for RIGS sites are covered by the four main themes in paragraph 3.6. Detailed site selection criteria are listed in Appendix 2. The main considerations for selecting RIGS and LIGS included quality of exposure/feature, access, rarity, community use and safety. Sites recommended in this report for RIGS designation are generally easy to access safely and have good exposure/features. Where a site lacks one of the features listed, it may still be recommended as a RIGS site due to the strength of other factors. For example, GLA 26 Rose and Crown Pit does not have good access but has excellent exposure of the Chalk and is in an area used frequently by the local community. GLA 4 Chelsfield Gravel is the only exposure of this deposit and therefore is suggested as a RIGS site despite limited exposure.

7.3 Potential LIGS sites suggested in this report are generally weak in several of the factors listed above but have value as local sites. They are commonly areas that are used daily by the local community and could easily be visited by local school groups. These sites would not necessarily be of interest to regional educational groups but may be of interest to researchers.

7.4 RIGS sites may be ideal for use as regional or national sites with potential for research. Those with good access are ideal for educational use and for tourism, for example with the creation of geological trails. LIGS may also be suited to local educational use. The installation of information boards provision of fact sheets, leaflets and posters would be ideal at all sites that have good access.

Audited SSSIs

7.5 Of the 36 sites audited, seven sites are designated as SSSIs (GLA 1 Abbey Wood, GLA 14 Gilberts Pit, GLA 18 Harrow Weald, GLA 19 Hornchurch Cutting, GLA 33 Elmstead Pit, GLA 34 Harefield Pit and GLA 35 Wansunt Pit).

Recommended RIGS

7.6 Fourteen of the 36 sites were judged worthy of designation as RIGS (Figures 25 and 26), using the criteria outlined in paragraph 7.2. Of the 33 London boroughs, RIGS are proposed in seven, with five in Bromley, three in Croydon and one each in Lewisham, Ealing, Greenwich, Harrow, Hillingdon and Bexley. It is recommended that these sites be designated by the boroughs in their Development Plan Documents and be protected and promoted in line with policy 3D.16 of the London Plan.

Figure 25 Recommended RIGS for Greater London

Figure 26 Recommended RIGS for Greater London

Site Number	Site Name Borough	NGR Area (ha)	Created by Aggregate Extraction	Geo-diversity Value	Comments and stratigraphy
GLA 3	Beckenham Place Park Lewisham	TQ 385 703 0.51	No	5	London Clay Formation, Eocene
GLA 4	Chelsfield Gravel Bromley	TQ 476 642 9.55	No	5	Chelsfield Gravel Formation, Pliocene – Pleistocene
GLA 6	Croham Hurst Croydon	TQ 338 630 34.57	No	6	Harwich Formation, Eocene Lambeth Group, Paleocene – Eocene Thanet Sand Formation, Paleocene Chalk Group, Late Cretaceous
GLA 7	Crystal Palace Dinosaurs Bromley	TQ 345 705 5.37	No	8	Geological illustrations including dinosaur models
GLA 8	Dog Rocks Greenwich	TQ 443 779 0.02	No	5	Harwich Formation, Eocene
GLA 17	Happy Valley Croydon	TQ 309 568 142.21	No	6	Chalk Group, Late Cretaceous Geomorphology interest
GLA 20	Horsenden Hill Ealing	TQ 162 844 43.15	No	5	Dollis Hill Gravel Formation, Pleistocene Claygate Member, London Clay Formation and London Clay Formation, Pleistocene
GLA 22	Keston Common Bromley	TQ 417 638 11.82	No	5	Harwich Formation, Eocene
GLA 26	Rose and Crown Pit Croydon	TQ 338 594 3.66	No	7	Chalk Group, Late Cretaceous
GLA 29	The Gravel Pits Hillingdon	TQ 084 913 5.47	Yes	4	Lambeth Group, Paleocene – Eocene
GLA 30	Cray Valley Golf Course Sand Pit Bromley	TQ 489 692	Yes	7	Thanet Sand Formation, Paleocene

GLA 31	North End Pit Bexley	TQ 515 771 0.43	No	6	Crayford Silt Formation, Pleistocene
GLA 32	High Elms Dene Hole Bromley	TQ 439 627 0.02	No	7	Chalk Group, Late Cretaceous
GLA 36	Pinner Chalk Mines Harrow	TQ 116 905	Yes	9	Chalk Group/Woolwich Formation, Upper Cretaceous/Paleocene

Potential LIGS

7.7 Fifteen of the 36 sites have the potential to be designated as LIGS (Figures 27 and 28), using the criteria outlined in paragraph 7.3. These sites are located in nine boroughs, three in Waltham Forest, two in Bromley, two in Islington and one each in Barnet, Lewisham, Redbridge, Wandsworth, Southwark and Sutton. Further auditing work could uncover further potential candidates for LIGS, such as visiting the 26 sites short listed but not audited in this report (paragraph 6.10).

Figure 27 Potential LIGS for Greater London

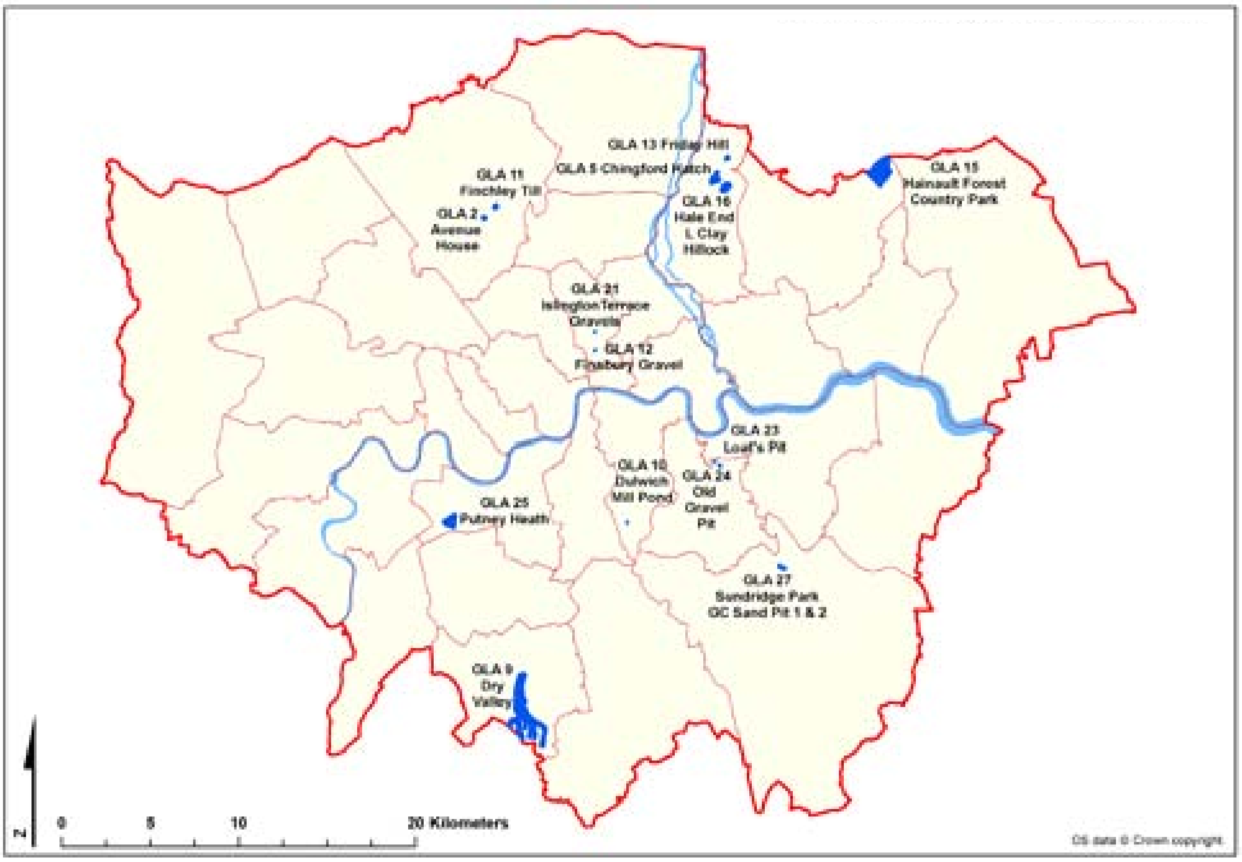


Figure 28 Potential LIGS for Greater London

Site Number	Site Name Borough	NGR Area (ha)	Created by Aggregate Extraction	Geo-diversity Value	Comments and stratigraphy
GLA 2	Avenue House Barnet	TQ 252 903 3.17	No	3	Lowestoft Formation, Pleistocene
GLA 5	Chingford Hatch Waltham Forest	TQ 384 927 17.87	No	4	Woodford Gravel Formation, Eocene

GLA 9	Dry Valley Sutton	TQ 272 629 228.20	No	4	Chalk Group, Late Cretaceous Geomorphology interest
GLA 10	Dulwich Mill Pond Southwark	TQ 333 731 0.45	No	4	London Clay Formation, Eocene Geomorphology interest
GLA 11	Finchley Till Barnet	TQ 259 908 3.86	No	3	Lowestoft Formation, Pleistocene
GLA 12	Finsbury Gravel Islington	TQ 315 828 0.23	No	3	Finsbury Gravel Member, Maidenhead Formation, Pleistocene
GLA 13	Friday Hill Waltham Forest	TQ 390 936 2.79	No	3	London Clay Formation, Eocene Geomorphology interest Important for Islington water story
GLA 15	Hainault Forest Country Park Redbridge	TQ 475 926 119.45	No	4	Head, Pleistocene Lowestoft Formation, Pleistocene Claygate Member, London Clay Formation, Eocene
GLA 16	Hale End London Clay Hillock Waltham Forest	TQ 388 921 20.45	No	3	London Clay Formation, Eocene Geomorphology interest
GLA 21	Islington Terrace Gravels Islington	TQ 315 838 0.27	No	2	Boyn Hill Gravel Formation, Pleistocene
GLA 23	Loats Pit Lewisham	TQ 382 766 0.25	Yes	3	Lambeth Group, Paleocene – Eocene Thanet Sand Formation, Paleocene Chalk Group, Late Cretaceous
GLA 24	Old Gravel Pit Lewisham	TQ 385 763 0.84	Yes	2	Harwich Formation, Eocene Lambeth Group, Paleocene – Eocene
GLA 25	Putney Heath Wandsworth	TQ 235 735 35.30	No	3	Black Park Gravel Formation, Pleistocene London Clay Formation, Eocene
GLA 27	Sundridge Park Golf Course 1 Bromley	TQ 422 705 1.89	No	4	Harwich Formation, Eocene Lambeth Group, Paleocene – Eocene Thanet Sand Formation, Paleocene
GLA 28	Sundridge Park Golf Course 2 Bromley	TQ 419 707 1.19	No	4	Harwich Formation, Eocene Lambeth Group, Paleocene – Eocene Thanet Sand Formation, Paleocene

8. Geodiversity guidance to boroughs

Policy

8.1 This chapter provides advice which is intended to guide the development and implementation of policy at the borough level. Chapter 7 of this report illustrates the relationship between geodiversity designations that are appropriate in London, and lists those areas which require special consideration in planning in London.

8.2 PPS9 paragraphs 4 and 5 deal directly with LDDs and state that policies should:

- reflect the national, regional and local priorities and objectives
- indicate sites of importance for geodiversity within the hierarchy
- identify and support areas or sites for restoration or creation.

8.3 As set out in Chapter 2 of this report, London Plan policy 3D.16 (Figure 2) states that planning policy and decisions should provide protection for important geological sites. Development and regeneration proposals should take geodiversity into account and incorporate positive elements that contribute to improving and enhancing geological conservation. Development should avoid any adverse impact on geological interest, or where this is not possible, to minimize the impact and seek mitigation measures.

8.4 PPS9 states that local authorities should ensure that policies in Local Development Documents are consistent with national and regional policy. The geodiversity policy set out in PPS9 and the London Plan should be adequate for most purposes and additional local policies should only be required where specific sites have been identified for protection.

8.5 The Defra Local Sites guidance (2006) emphasises the equivalence of Local Wildlife and Local Geological Sites. This is reflected in the recently established local authority performance indicator for biodiversity, National Indicator 197 (Defra, 2008). The measure of performance for the indicator is based on the proportion of local sites (both wildlife and geological) in positive conservation management. In London, the measurement of this indicator should be inclusive of both wildlife and geology.

8.6 Monitoring of the condition of RIGS and LIGS is also important. A standard approach to Local Geological Site monitoring has recently been established and is recommended for use in London (Geology Trusts and UKRIGS, 2008). Critically, it provides a basis for assessing the condition of a site linked to the site's management requirements and whether positive conservation management is being undertaken. This provides an important supportive mechanism for assessing the national performance indicator for biodiversity 197.

Geodiversity and the wider landscape

8.7 The geodiversity auditing described in paragraphs 6.10-6.12 concentrated on individual geodiversity sites. However, geodiversity also includes assessing, valuing and protecting the wider landscape. PPS9 states "In taking decisions, local planning authorities should ensure that appropriate weight is attached to designated sites of international, national and local importance; protected species; and to biodiversity and **geological interests within the wider environmen**t" (our emphasis).

8.8 Greater London has distinctive natural landscapes shaped by geological processes:

- undulating chalk downlands with dry valleys in south London

- gentle escarpment of older Palaeogene strata rising up to the Chalk dip slope in southern and south-west London
- Palaeogene outliers of low, well-drained hills with convex slopes, occurring in the floors of shallow valleys to the south and east
- a broad swathe of low-lying, subdued topography of the London Clay in the Thames Valley. Even where dissection has been most pronounced (as between Stanmore and Hampstead) only gently rolling ground with convex slopes of generally less than 4° is found
- the prominent Bagshot Formation hills of Hampstead Heath and Highgate in north London, Harrow On The Hill in the north-west, and Havering-atte-Bower in the north-east. It gives rise to relatively steep convex slopes up to 12°. It is characteristically free-draining and in a natural or semi-natural state supports typical heathland vegetation
- river terraces forming long flat areas e.g. underlying Heathrow airport or Hyde Park, separated by steeper areas of terrace front slopes, e.g. leading from the Strand to Temple tube.

8.9 Natural England has devised Landscape Character Areas (LCA) for Greater London (Figure 29), but these largely do not reflect the wider geodiversity of London described above. There is scope for revising these LCAs to take more account of natural physical landscapes.

Figure 29 Greater London Landscape Character Areas

8.10 The natural topographic geodiversity underlying London should be understood, respected and only altered in the knowledge of its origin and form. This would require planning policies rather different to those used to protect individual geological sites:

- **landforms** - maintain integrity of landform(s). Encourage authentic contouring in restoration work and new landscaping schemes
- **landscape** - maintain contribution of natural topography, rock outcrops and active processes to landscape. Encourage authentic design in restoration work and new landscaping schemes

- **processes** - maintain dynamics and integrity of operation. Encourage restoration of process and form using authentic design principles
- **soils** - maintain soil quality, quantity and function.

Implementation

8.11 In order to implement the policy aims set out in PPS9 and the London Plan, the following advice highlights where geodiversity considerations should be taken into account. This advice should be used by local authorities and developers when considering planning proposals and the preparation of Supplementary Planning Documents where a geodiversity issue is clearly involved.

Have regard to geodiversity in planning proposals

8.12 Perhaps the greatest threat to geodiversity is inappropriate development. New developments often destroy or conceal valuable geological exposures and disrupt the natural processes that helped form them. New development should assess the potential impacts on geodiversity, take steps to mitigate any damage that cannot be prevented, and identify opportunities that might benefit geodiversity. For example, some developments might allow the creation of more rock exposures, or offer an opportunity to re-establish natural systems; in others, planning permission may insist on mitigation, such as future monitoring and maintenance work. Traditionally, the conservation of geodiversity has focused on individual sites but, in the future, effective conservation will need to integrate the efforts of all interested parties and seek to conserve geodiversity in the wider landscape (paragraphs 8.5-8.8). However, geodiversity is not and should not be regarded merely as concerned with conservation of geological sites or features. As an essential part of natural heritage it influences fields as varied as economic development and historical and cultural heritage.

8.13 Where development proposals may have an impact on geodiversity an evaluation of the geological significance of an area should be required prior to undertaking any reclamation, groundworks, re-working or planting. Recommendations relating to the geodiversity interest should be fully taken into account in undertaking any such works.

Protect, manage and enhance geodiversity

8.14 Sites should be monitored for condition and threats to geological features. Opportunities should be sought to implement maintenance appropriate to maintaining the quality of the exposure of geological features at the site and opportunities sought to enhance the condition and interpretation of such features where appropriate. Advice for the conservation of sites is provided by Prosser et al. (2006). In addition to nationally designated sites, boroughs should seek to establish and maintain a series of regional and local sites representative of the geology in the London area. The recommended RIGS sites in this report should be identified in borough LDDs. Boroughs should consider whether the potential LIGS sites identified in this report should also be identified and protected.

8.15 Using the method and criteria set out in Chapters 6 and 7 and Appendices 2 and 3, the boroughs should also consider auditing further sites that may be of local importance. Table A1 in Appendix 1 identifies 27 sites that were not visited during the audit but may be of potential value. Table A2 identifies a further 30 sites with potential geodiversity value that were identified during the consultation on the draft version of the report. It is recommended that these 57 sites are audited in the future to determine whether they are worthy of protection as a RIG or LIG. Additional guidance is available in the Defra Local Sites Report (Defra, 2006).

8.16 In order to protect, manage and enhance geodiversity, boroughs are encouraged to:

- review any buildings or structures for which conservation measures are proposed to establish the presence of any features of geodiversity interest. Appropriate recommendations can then be made to ensure the safeguarding of significant features
- integrate geodiversity interest on all sites or features of archaeological, wildlife or other interests, where conservation management is taking place or being contemplated. Equally, the other conservation interest of what might be primarily considered 'geological sites' should also be assessed and secured in any management works
- work with quarry operators to promote active conservation and enhancement work on geological sites.

Enhance geodiversity in new developments

8.17 When geodiversity is identified as an appropriate issue, new development proposals may provide opportunities to enhance the geodiversity of a site. Road improvement works, for example, may require the construction of new cuttings. Such operations offer opportunities to reveal hitherto unexposed geological sections, either temporarily during construction, or as permanent features. The geological features exposed in cuttings or quarries should be viewed in a positive light as contributing to the natural heritage of the area. It is common practice in road construction to cover rock exposures in cuttings, thus permanently obliterating potentially important geological exposures. Whereas a normal reaction at such an important site might be to resist any planned clearance of vegetation, road widening or similar work, the exposure, and thus its scientific value, could be very greatly enhanced by such operations. Such enhancement would, of course, be dependent upon good liaison between road engineers and geologists, and would require suitable provision for retaining the exposure upon completion of any works. Similarly, quarries often provide superb opportunities to examine, record, study and perhaps to establish permanent sections of key geological features.

8.18 In order to integrate geodiversity enhancements in new development, boroughs are encouraged to:

- work with developers and quarry operators to liaise with local and national museums, the BGS, local university earth science departments, and other appropriate bodies, in the recovery and recording of important geological material and information
- ensure proposals for permanent sealing of underground workings should include provision for appropriate recording of geological features prior to sealing
- work with landowners who propose to re-establish access to underground workings to record geological features exposed in the re-opened workings, or to invite qualified geologists to visit the site to make such records. All such records should be lodged with a permanent public archive.

Promote public access, study, interpretation and appreciation of geodiversity

8.19 Positive measures to enhance geodiversity can include the promotion of the geodiversity resource. Opportunities can include:

- encouraging local community involvement in identifying and developing initiatives
- providing for controlled, safe access to sites for educational, interpretational and recreational use
- developing access arrangements to quarries for educational and interpretational use on specified occasions, or as part of geological events
- providing on and off-site interpretation.

9. Geodiversity action planning

9.1 Geodiversity Action Plans (GAPs) provide a long-term framework for the conservation of geodiversity, in the same way that Biodiversity Action Plans work for nature conservation. A GAP should take into account both local and strategic needs and involve a wide range of partners, from local community bodies and conservation organisations, to local government and industry. A GAP should establish objectives and targets for audit, conservation, management, education and communication as well as the influencing of local development documents and policies and the securing of resources to implement the plan.

9.2 This report forms a key element in preparing a GAP for Greater London. The report provides a broad depth of information on the geodiversity of London. An action plan would set out the objectives and actions for the sustainable management, planning, conservation and interpretation of all aspects of geodiversity in Greater London.

9.3 The main aims of a Greater London GAP could include:

- to establish and grow the London Geodiversity Partnership
- to promote overall awareness, understanding, enjoyment and care of Greater London's geodiversity through partnership and community involvement
- to 'embed' geodiversity into future development planning and environmental management, monitoring and interpretation policies
- to provide guidance to planners, landowners and other individuals and organisations on sustainable management of geodiversity in the area
- to identify threats to geological sites or features and recommend strategies to conserve and protect geological features
- to develop links with built geodiversity resource, including building stone, economic uses and influence on the growth of London
- to identify opportunities to enhance or restore the value of geodiversity features
- to engage industry, local communities and voluntary groups in caring for Greater London's geodiversity.

9.4 Specific, measurable, achievable, realistic and time-base (SMART) objectives could include:

- ensure protection of sites through GLA and Borough policies and strategies
- set up process for alerting specialists to enable recordng of temporary exposures
- communication and education – promoting an understanding and a wider awareness of geodiversity, encouraging participation in the action planning process and interpretation of the geological resource.
  - public awareness of geodiversity and interpretation
  - produce a map of geological trails in London
  - education and training
  - contact and organise local interest in geology
- conservation and management – establishing clear goals for the management and conservation of geological sites, natural processes and the geodiversity of Greater London's landscape.
  - designate and maintain data on RIGS and LIGS
  - provide information on protected sites via a website
  - audit the potential sites listed in Tables A1 and A2 in Appendix 1
  - establish a site monitoring system for RIGS and LIGS
  - set up practical conservation initiatives.

Appendix 1 Sites selected for geodiversity auditing

The Sites selected for field auditing are listed in the Table A1 below. Site numbers prefixed with a GLA number are either SSSIs (orange rows), recommended RIGS (green rows), or potential LIGS (blue rows) – a total of 35 sites. The remaining 66 sites that were shortlisted are shown with a PS (Potential Site) prefix. Future visits are recommended for those sites highlighted in yellow to determine whether they should be protected. Table A2 identifies additional sites with potential geodiversity value worthy of protection that were identified during the consultation on the draft version of the report.

Table A1

Site No.	Site Name	Borough	NGR (all TQ)	Aggreg Site	GD Value	Comments
GLA 1	Abbey Wood	Bexley	480 786	No	8	SSSI
GLA 2	Avenue House	Barnet	252 903	No	3	Potential LIGS
GLA 3	Beckenham Place Park	Lewisham	385 703	No	5	Recommended RIGS
GLA 4	Chelsfield Gravel	Bromley	476 642	No	5	Recommended RIGS
GLA 5	Chingford Hatch	Waltham Forest	384 927	No	4	Potential LIGS
GLA 6	Croham Hurst	Croydon	338 630	No	6	Recommended RIGS
GLA 7	Crystal Palace Dinosaurs	Bromley	345 705	No	8	Recommended RIGS
GLA 8	Dog Rocks	Greenwich	443 779	No	5	Recommended RIGS
GLA 9	Dry Valley	Sutton	272 629	No	4	Potential LIGS
GLA 10	Dulwich Mill Pond	Southwark	333 731	No	4	Potential LIGS
GLA 11	Finchley Till	Barnet	259 908	No	3	Potential LIGS
GLA 12	Finsbury Gravel	Islington	315 828	No	3	Potential LIGS
GLA 13	Friday Hill	Waltham Forest	390 936	No	3	Potential LIGS
GLA 14	Gilbert's Pit	Greenwich	418 786	Yes	8	SSSI
GLA 15	Hainault Forest Country Park	Redbridge	475 926	No	4	Potential LIGS
GLA 16	Hale End London Clay Hillock	Waltham Forest	388 921	No	3	Potential LIGS
GLA 17	Happy Valley	Croydon	309 568	No	6	Recommended RIGS
GLA 18	Harrow Weald	Harrow	147 929	No	6	SSSI
GLA 19	Hornchurch Cutting	Havering	547 874	No	6	SSSI
GLA 20	Horsenden Hill	Ealing	162 844	No	5	Recommended RIGS
GLA 21	Islington Terrace Gravels	Islington	315 838	No	2	Potential LIGS
GLA 22	Keston Common	Bromley	417 638	No	5	Recommended RIGS
GLA 23	Loats Pit	Lewisham	382 766	Yes	3	Potential LIGS
GLA 24	Old Gravel Pit	Lewisham	385 763	Yes	2	Potential LIGS
GLA 25	Putney Heath	Wandsworth	235 735	No	3	Potential LIGS
GLA 26	Rose and Crown Pit	Croydon	338 594	No	7	Recommended RIGS
GLA 27	Sundridge Park Golf Course 1	Bromley	422 705	No	4	Potential LIGS
GLA 28	Sundridge Park Golf Course 2	Bromley	419 707	No	4	Potential LIGS
GLA 29	The Gravel Pits	Hillingdon	084 913	Yes	4	Recommended RIGS
GLA 30	Cray Valley Golf Course Sand Pit	Bromley	489 692	Yes	7	Recommended RIGS
GLA 31	North End Pit	Bexley	515 771	No	6	Recommended RIGS
GLA 32	High Elms Dene Hole	Bromley	439 627	No	7	Recommended RIGS
GLA 33	Elmstead Pit	Bromley	4232 7066	No	6	SSSI
GLA 34	Harefield Pit	Hillingdon	049 898	No	8	SSSI

Site No.	Site Name	Borough	NGR (all TQ)	Aggreg Site	GD Value	Comments
GLA 35	Wansunt Pit	Bexley	515 738	Yes	9	SSSI
GLA 36	Pinner Chalk Mines	Harrow	116 905	Yes	9	Recommended RIGS
PS 1	Stanwell Upper Mill	Hillingdon	0405 7573	Yes	0	Landscaped ground
PS 2	Hainault Farm	Redbridge	4669 9001	Yes	0	Landfill Site
PS 3	Fairlop	Redbridge	4572 9072	Yes	0	Landscaped ground and Lake
PS 4	Upminster	Havering	5530 8910	No	0	No longer visible; overgrown
PS 5	Upminster	Havering	5650 8899	No	0	No longer visible; overgrown
PS 6	Beddington Farmlands	Sutton	2897 6600	Yes	0	Landfill site
PS 7	Beddington Farmlands	Sutton	2842 6707	Yes	0	Landfill site
PS 8	Erith	Bexley	510 780	No	0	Nothing seen, landscaped?
PS 9	Crayford	Bexley	510 750	No	0	Nothing seen; now school
PS 10	Knockholt	Bromley	483 630	No	?	Seen from road but could not gain access. Cutting in Chalk
PS 11	Manor Farm Gravel Pit	Bexley	5010 7363	Yes	?	Active working; access not gained
PS 12	Ingrebourne Valley	Havering	5247 8312	Yes	0	Restored and landscaped, water feature
PS 13	Albyns Farm	Havering	5257 8351	Yes	0	Restored and landscaped
PS 14	Broadwater Farm	Hillingdon	044 895	Yes	0	Water filled
PS 15	Harmondsworth Lane	Hillingdon	0685 7755	Yes	0	Landfill Site
PS 16	Holloway Lane	Hillingdon	0670 7815	Yes	0	Landfill Site
PS 17	Beddington	Sutton	2901 6672	Yes	?	Active workings, access not gained
PS 18	Feltham	Hounslow	0932 7232	Yes	0	Restored and landscaped; playing fields
PS 19	Chipstead Valley	Croydon	2898 5938	No	0	Developed – housing and gardens
PS 20	Springwell Lane Chalk Pit	Hillingdon	0441 9300	No	?	Did not obtain access, but worth investigating
PS 21	Harrow Hill	Harrow	1526 8667	No	?	Developed – housing and gardens
PS 22	Hangar Hill	Ealing	1818 8198	No	0	Old reservoir, now playing fields, nothing seen
PS 23	Hunts Hill Farm	Havering	5659 8293	Yes	?	Access not gained, but worth further investigation
PS 24	Hainault Quarry	Redbridge	4635 9096	Yes	0	Restored and landscaped
PS 25	Marks Warren Farm, Romford	Barking & Dagenham	4875 8970	Yes	?	Active workings, access not gained
PS 26	Rainham Quarry	Havering	547 828	Yes	0	Restored and landscaped
PS 27	South Hall Farm	Havering	5347 8184	Yes	?	Active workings, access not gained
PS 28	Berwick Ponds Farm	Havering	545 839	Yes	0	Restored and landscaped; water feature
PS 29	Wall Garden Farm	Hillingdon	0754 7808	Yes	0	Landfill Site
PS 30	Robb?s Nurseries	Hillingdon	0439 7540	Yes	?	Gravel Pit for T5 development
PS 31	Heathside Sand and Gravel Pi	Bexley	5134 7385	Yes	0	Housing Estate
PS 32	Parish's Pit 1	Bexley	5040 7793	Yes	0	Restored and landscaped
PS 33	Parish's Pit 2	Bexley	5028 7819	Yes	0	Restored and landscaped
PS 34	Parish's Pit 3	Bexley	5014 7797	Yes	0	Restored and landscaped
PS 35	Wickham Lane Brick Works	Greenwich	4615 7748	Yes	0	Developed – housing and gardens
PS 36	Bleak Hill Sandpit	Greenwich	4605 7771	Yes	?	Partly developed for housing; access not gained, but worth investigation
PS 37	The Warren	Greenwich	4129 7803	Yes	?	Partly developed for housing; access not gained, but worth investigation
PS 38	Upper College Farm Gravel Pit	Bexley	4905 7305	Yes	0	Restored and landscaped
PS 39	Mardyke Farm	Havering	5095 8366	Yes	?	Access not gained, disused sand and gravel pit, but worth investigation
PS 40	Berwick Pond Road	Havering	5492 8421	Yes	0	Restored and landscaped
PS 41	Gerpins Lane (W)	Havering	5506 8328	Yes	0	Landfill Site
PS 42	Ayletts Farm Camp	Havering	5507 8286	Yes	?	Active workings, access not gained
PS 43	Launder?s Lane	Havering	5421 8208	Yes	0	Restored and landscaped

Site No.	Site Name	Borough	NGR (all TQ)	Aggreg Site	GD Value	Comments
PS 44	Chislehurst Caves	Bromley	434 696	No	?	Tourist attraction, info from www.chislehurstcaves.co.uk
PS 45	St John's Station	Lewisham	374 763	No	?	Not visited; worth investigation
PS 46	Gun Club	Bexley	510 740	Yes	0	Restored and landscaped
PS 47	Cranford Lane	Hillingdon	095 779	Yes	?	Active Sand and Gravel Pit; access not gained
PS 48	Harefield Halt	Hillingdon	0543 8707	Yes	0	Restored: water features
PS 49	Sipson Lane	Hillingdon	0819 7832	Yes	0	Landfill Site
PS 50	Bourne Wood Thanet Sand Quarry	Bromley	5023 6828	Yes	?	Active Sand Pit; access not gained
PS 51	Bedfont	Hounslow	0828 7219	Yes	0	Restored and landscaped; recreation ground
PS 52	Poyle	Hillingdon	0398 7619	Yes	0	Developed – M25
PS 53	Spout Lane	Hillingdon	0468 7519	Yes	0	Developed – reservoir?
PS 54	Lake at Peckham Rye Park	Southwark	3497 7499	No	?	Not visited; worth investigation
PS 55	Pole Hill	Waltham Forest	384 950	No	?	Not visited; worth investigation
PS 56	Pinner Hill	Harrow	1075 9168	No	0	Housing and Golf course
PS 57	The Mount, Belmont	Harrow	1629 9107	No	0	Golf Course
PS 58	Broads Dock	Hillingdon	0775 7954	No	?	Water-filled Brickearth extraction site; access not gained
PS 59	Heathrow Airport	Hillingdon	0711 7574	No	?	Landscape feature – all of Heathrow Airport is built on Taplow Gravel Formation Terrace
PS 60	Tripcock Ness	Greenwich	4527 8098	No	?	Not visited; worth investigation
PS 61	New Cross Gate Cutting Nature Reser	Lewisham	3635 7641	No	?	Not visited; site of major landslip
PS 62	St Andrew's Church, Kingsbury	Brent	2064 8686	No	?	Not visited; worth investigating. Lynch Hill Gravel exposed?
PS 63	Mud flats near Gores Brook	Barking & Dagenham	4758 8209	No	?	Not visited; worth investigation. Active processes - mudflats
PS 64	Chelsea Creek	Hammersmith & Fulham	2577 7751	No	?	Railway line; no access
PS 65	Glebelands Local Nature Reserve	Barnet	2686 9102	No	?	Not visited; worth investigation

Table A2

Site No.	Site Name	Borough	NGR (all TQ)	Aggreg Site	GD Value	Comments
PS 66	Coldfall Wood	Barnet		No	?	Goring by glacial streams. Lowestoft Till. Adjacent to St Pancras cemetery
PS 67	Finchley cemeteries	Barnet		No	?	Jurassic fossils
PS 68	Erith submerged forest and saltings	Bexley	5285 7801	No	?	Thames foreshore. Holocene Alluvium eg paleobotany
PS 69	Biggin Hill Valley	Bromley		No	?	
PS 70	Charnwood Farm chalk mine	Bromley		Yes	?	
PS 71	Civic Centre	Bromley		No	?	Listed Pulhamite rockwork
PS 72	Cudham Valley	Bromley		No	?	
PS 73	Downe Valley	Bromley		No	?	
PS 74	Klinger Pit, Foots Cray	Bromley	478 703	Yes	?	Exposure of Thanet Sand. No access
PS 75	Spring Park	Bromley	381 649	No	?	Water processes
PS 76	St Martin's Hill	Bromley		No	?	
PS 77	Sundridge Park	Bromley		No	?	Listed Pulhamite rockwork
PS 78	Top of North Downs	Bromley		No	?	View across Greensand Ridge
PS 79	Sandy Heath (Hampstead Heath)	Camden	270 865	No	?	Bagshot Formation: exposures and ponds caused by iron panning. Viewpoint. Geomorphology – spring lines, vegetation, slope
PS 80	Kenwood House	Camden		Yes	?	Bagshot Formation: section at overgrown old quarry
PS 81	Riddlesdown	Croydon		No	?	Dry Valley

Site No.	Site Name	Borough	NGR (all TQ)	Aggreg Site	GD Value	Comments
PS 82	Trent Park	Enfield		No	?	Glacial Till
PS 83	Springfield Park	Hackney	346 876	No	?	Bagshot sand. Local Nature Reserve of geological interest. Hackney Terrace exposures and spring lines
PS 84	Highgate / Queens Wood gorges	Haringey		No	?	Features associated with Anglian periglacial outwash
PS 85	Pinner chalk mine	Harrow	114 906	Yes	?	Mine
PS 86	Whalebone Lane	Havering	487 893	No	?	Periglacial patterned ground
PS 87	Havering Ridge, Havering-atte-Bower	Havering	513 931	No	?	Bagshot Sand ridge and viewpoint. Includes Havering Country Park and Bedfords Park
PS 88	Rainham submerged forest	Havering	5160 7950	No	?	Exposed on Thames foreshore at Rainham Marsh. Can be seen at low tide
PS 89	Summerhouse Lane chalk pit	Hillingdon	044 918	Yes	?	Large chalk quarry. New housing but face and features still evident
PS 90	Thames foreshore, Isleworth	Hounslow		No	?	London Clay exposure
PS 91	City of London Cemetery, Wanstead	Newham	423 863	No	?	Geology of building stones
PS 92	Wanstead Flats	Redbridge	405 865	No	?	Lynch Hill / Corbets Tey terrace surface
PS 93	Knighton Wood, Woodford Wells	Redbridge	413 935	No	?	Exposures of Woodford Gravel
PS 94	Rotherhythe pingo	Southwark		No	?	Anglian ice-age pingo
PS 95	Leyton Flats (Snaresbrook Park)	Waltham Forest	393 889	No	?	Boyn Hill / Orsett Heath terrace surface

Appendix 2 Site selection criteria

Site Type: Feature

Selection criteria for features are given below:

CODE	DESCRIPTION	TRANSLATION
N_SECTION	NATURAL SECTION	Natural outcrop of one or more geological features forming a linear exposure (river section, cliff face, shoreline etc)
N_EXPOSURE	NATURAL EXPOSURE	Natural outcrop of geological feature
N_LANDFORM	NATURAL LANDFORM	Constructional or erosion geomorphological feature (valley, crevasse, dune, all Q features etc)
N_VIEW	NATURAL VIEW	Collection of geological features forming a landscape overview interpretation
A_MINWORKS	ARTIFICIAL MINE WORKINGS	Feature produced by minerals/coal workings (adit, spoil, hush etc)
A_QRYWORKS	ARTFICIAL QUARRY WORKS	feature produced by stone/aggregate workings (quarry, pit, waste dumps etc)
A_SECTION	ARTIFICIAL SECTION	section exposure created artificially by work to construct a road/track/path etc
A_EXCAV	ARTIFICIAL EXCAVATION	Artificially created exposure (excavation - not related to any of the above)
N_SAMPLE	Natural geological sample not in situ	Natural geological sample not in situ
A_SAMPLE	Manmade Artefact	Manmade Artefact

Site Type: Current use

Selection criteria for current use are given below:

CODE	DESCRIPTION	TRANSLATION
IN_USE	IN CURRENT USE	Feature still used for primary purpose (working quarry etc)as defiend by the FEATURE term
DISUSED	DISUSED	Feature no longer used for primary purpose and has no other current use
OPEN_CNTRY	OPEN COUNTRY	Feature on publicly accessible natural countryside with no unique use (mountains national park land etc)
PVTE_CNTRY	PRIVATE COUNTRY	Feature is on privately owned, natural countryside with limited/no public access (Estate land etc)
AGRIC_LAND	AGRICULTURAL LAND	Feature is used/forms part of land used for agricultural purposes (farm fields and grazing areas etc)
DOMESTIC	DOMESTIC LAND	Feature falls within the limits of private lands associated with dwellings (gardens, stately home grounds etc)
URBAN	URBAN	Feature is on publicly accessible lands (but not recreational lands) within the urban limits (allotments, road verges etc)
RECREATION	RECREATIONAL LAND	Feature is on land specifically designed or modified for recreational uses (parks, picnic areas etc)
MILITARY	MILITARY LAND	Feature is on MOD land or land used for military perposes
INDUSTRIAL	INDUSTRIAL LAND	Feature is on land used for industrial purposes (including waste land forming part of/owned by an industrial complex)
DISPOSAL	DISPOSAL USE	Feature is used or is on land used for waste disposal (quarries now used for land-fill etc)

Site Area

Entered where known. Generally large sites are usually more important than small sites as relationships between rock units are more likely to be demonstrated. They are also more able to withstand visitors, by diluting their pressure within a wider space.

Stratigraphy and Rock Types

The time units (chronostratigraphy), rock units (lithostratigraphy) and rock type (lithology) of the exposures present are given. Ideally, representative sections of the main formations present in the GLA area should be represented in the selected RIGS and LIGS sites.

Access and Safety

Access is an important consideration, particularly in areas of large urban populations where opportunities to experience the natural world are limited. Safety of access, Safety of exposure, Current condition, Current conflicting activities, Restricting conditions and Nature of exposure criteria are descriptive and for general guidance only. Field leaders and teachers should prepare a separate risk assessment where required.

Cultural, Heritage and Economic

These criteria are taken from the UKRIGS system and include important associations with the cultural, historical and economic aspects of geodiversity. The rating scale used is 0 to 10, with 10 reflecting important associations providing excellent opportunities for raising public awareness. The criteria used are:

1. Historic, archaeological & literary associations
2. Aesthetic landscape
3. History of Earth Sciences
4. Economic geology

It is recognised that scoring systems are difficult to apply in practice (Scottt, 2007) and the values listed should be used as a general guide only.

GeoScience Rank

Geoscientific criteria are the key intrinsic attributes of a site or feature and the main reasons to justify conserving a site, even if it has restricted or no current access. A single site is unlikely to score highly on every criterion. Rarity and quality scores are combined into a single score in Appendix 5 site assessments. Ranking criteria are given below.

RARITY	**Rating**	
The abundance or significance of the feature of the site in the global context. *Is the rarity such that the feature is one of only a few in the world, in the UK or in the regional area or is it one of many examples and only of reference or educational significance (because it is on the doorstep)?*	10	World
	8	UK
	6	Regional
	4	Local (LGAP)
	2	Educational / Reference
	0	Not Present / Relevant

QUALITY	**Rating**	
The extent to which a feature is typical or demonstrates 'text-book' features. *World class specimen or poor example?*	10	World
	8	UK
	6	Regional
	4	Local (LGAP)
	2	Educational / Reference
	0	Not Present / Relevant

LITERATURE / COLLECTIONS	**Rating**	
The detail of written literature or material collections relating to the feature.	10	Detailed Studies
	8	Interpretations
	6	Descriptions
	4	Collected Material
	2	Referenced
	0	No Data

Potential use

The following attributes are available for selection:

- Research
- Higher/further education
- school education

- on-site interpretation
- on-site geotrail
- incorporated
- multidisciplinary

Fragility

The following attributes are available for selection:

- Geohazard (e.g. landslip risk)
- weathering/erosion
- natural overgrowth
- sample/fossil collecting
- dumping
- likelihood of development.

Current Site Value

Ranking criteria for these attributes are given below:

EDUCATIONAL VALUE	Rating	
The value of the site feature for educational fieldwork (including school, degree and adult education courses). Including 'relief sites' that may relieve pressure on other popular sites. *Is it visited by UK-wide groups or local schools only?*	10	UK Educational
	8	Regional
	6	Local area schools
	4	Local (walking distance) groups
	2	Little value
	0	No value

COMMUNITY VALUE	Rating	
The value of the site to local people as a local amenity including historical or cultural associations outside the geological significance. 'Local is defined as within walking or 10 min drive distance. *Is the feature of the site used daily as common ground or rarely visited by the local community?*	10	Detailed Studies
	8	Interpretations
	6	Descriptions
	4	Collected Material
	2	Referenced
	0	No Data

Geodiversity Value

Key sites in the Geodiversity network may represent unique or outstanding features or exceptional preservation and should be designated as a RIGS and protected for their specific scientific value. Such sites may have been considered for designation as SSSIs, but not fully met the requirements. Most sites of high specific scientific value will also have high assessed ratings for education and science and for cultural, heritage and economic aspects, but there may be exceptions. High-rating examples would include sites of the only exposure of a key horizon or feature, e.g. an unconformity, a basal conglomerate, a marine band, an ash band, a dyke, a highly fossiliferous bed, waterfall or other feature listed under Geoscientific Merit. Lower ratings are given to sites with locally more common or less well preserved features.

Geodiversity Value can be considered as an assessment of the importance of the site to the local network. Geodiversity Value may appear to be a rather subjective assessment. It should take into consideration an overview of other sites in the vicinity. Suggested scoring guides are:

0 – no specific scientific interest
5 – some specific scientific interest, the average for similar sites in the vicinity
10 – key site, showing unique or outstanding features, the best site in the vicinity

Appendix 3 Field audit recording sheet

LOCAL GEODIVERSITY ACTION PLAN (LGAP)
ASSESSMENT OF GEOLOGICAL SITES

LGAP

SCORER

DATE

OBSERVED?

SITE NAME

BNG

FEATURE

CURRENT USE

CURRENT DESIGNATION

DESIGNATED FOR

ACCESS

OWNERSHIP DETAILS

GEOLOGICAL DESCRIPTION

PHOTO

REFERENCES

CURRENT SITE VALUE

EDUCATIONAL

COMMUNITY

FRAGILITY

- ☐ GEOHAZARD
- ☐ WEATHERING / EROSION
- ☐ NATURAL OVERGROWING
- ☐ COLLECTING
- ☐ DUMPING
- ☐ DEVELOPMENT

NOTES

GEOLOGICALSCIENTIFIC MERIT

	RARITY	QUALITY	LITERATURE / COLLECTIONS	1st
LITHO-STRATIGRAPHY				
SEDIMENTOLOGY				
IGNEOUS / MINERALOGY / METAMORPHIC GEOLOGY				
STRUCTURAL GEOLOGY				
PALAEONTOLOGY				
GEOMORPHOLOGY				

OTHER SCIENTIFIC FIELDS TO WHICH THIS SITE IS OF KNOWN IMPORTANCE

- ☐ BIOLOGY
- ☐ ARCHEOLOGY
- ☐ ECOLOGY
- ☐ OTHER

NOTES

POTENTIAL USE

- ☐ RESEARCH
- ☐ HE / FE
- ☐ SCHOOL EDUCATION
- ☐ ONSITE INTERPRETATION
- ☐ ONSITE GEOTRAIL
- ☐ INCORPORATED
- ☐ MULTI-DISCIPLINARY

NOTES

FURTHER INFORMATION

LOCAL GEODIVERSITY ACTION PLAN (LGAP)
ASSESSMENT OF GEOLOGICAL SITES - RANKING CRITERIA

RARITY	The abundance or significance of the feature of the site in the global context. *Is the rarity such that the feature is one of only a few in the world, in the UK or in the regional area or is it one of many examples and only of reference or educational significance (because it is on the doorstep)?*	10 8 6 4 2 0	WORLD UK REGIONAL LOCAL (LGAP) EDUCATIONAL / REFERENCE NOT PRESENT / RELEVANT
QUALITY	The extent to which a feature is typical or demonstrates 'text-book' features. *World class specimen or cruddy example?*	10 8 6 4 2 0	WORLD CLASS UK REGIONAL LOCAL (LGAP) EDUCATIONAL / REFERENCE NOT PRESENT / RELEVANT
LITERATURE & DATA	The detail of written literature or material collections relating to the feature.	10 8 6 4 2 0	DETAILED STUDIES INTERPRETATIONS DESCRIPTIONS COLLECTED MATERIAL REFERENCED NO DATA
EDUCATIONAL VALUE	The value of the site feature for educational fieldwork (including school, degree and adult education courses). Including 'relief sites' that may relieve pressure on other popular sites. *Is it visited by UK-wide groups or local schools only?*	10 8 6 4 2 0	UK EDUCATIONAL REGIONAL LGAP AREA SCHOOLS / HE LOCAL (WALKING DIST.) GROUPS LITTLE VALUE NO VALUE
COMMUNITY VALUE	The value of the site to local people as a local amenity including historical or cultural associations outside the geological significance. 'Local is defined as within walking or 10 min drive distance. *Is the feature of the site used daily as common ground or rarely visited by the local community?*	10 8 6 4 2 0	DAILY LOCAL USE WEEKLY USE MONTHLY USE YEARLY USE INFREQUENT USE NO LOCAL USE

Access and safety	***comments / details***
1 road access & parking	
2 safety of access	
3 safety of exposure	
4 permission to visit	
5 current condition	
6 current conflicting activities	
7 restricting conditions	
8 nature of exposure	
9 multiple exposure / prospect for trail	
notes	

Culture, Heritage & Economic	***comments***	***assessed rating** (circle one)*
1 historic, archaeological & literary associations		0 1 2 3 4 5 6 7 8 9 10
2 aesthetic landscape		0 1 2 3 4 5 6 7 8 9 10
3 history of Earth Sciences		0 1 2 3 4 5 6 7 8 9 10
4 economic geology		0 1 2 3 4 5 6 7 8 9 10
notes		

Geodiversity value	***brief details***	***assessed rating** (circle one)*
brief note on key specific scientific interest (fuller details recorded separately)		0 1 2 3 4 5 6 7 8 9 10

ratings: 1-2 very poor; 3-4 poor; 5-6 acceptable/useful; 7-8 quite good; 9-10 very good/excellent; NA not applicable; DK don't know

Appendix 4 GIS datasets used in the geodiversity audit

Dataset	Format	Supplier
Earth science		
1:10k, 1:50k and 1:250k Digital Geology (DiGMapGB)	ESRI shape	BGS
BritPits database of Mines and Quarries	ESRI Shape	BGS
Geological Conservation Review sites (GCR)	Web table	JNCC
Earth Science Sites of Special Scientific Interest (SSSI)	ESRI Shape	Natural England
Regionally Important Geological and Geomorphological Sites (RIGS)	MS Word	South London RIGS Group
Geology Interest Parcels	ESRI Shape	GLA
Topography and landscape		
NEXTMap Britain DSM from radar altimetry, Hill Shade	Raster images	Intermap/BGS
1:250k, 1:50k, 1:25k, 1:10k topography, National Grid, Admin Meridian	Raster and vector	Ordnance Survey
Landscape Character Assessment	ESRI Shape	Natural England
Parks and Gardens	ESRI Shape	Natural England
Habitats, ecology and biodiversity		
World Heritage Sites	ESRI Shape	Natural England
Ramsar sites	ESRI Shape	Natural England
Special Protection Areas (SPAs)	ESRI Shape	Natural England
Special Areas of Conservation (SACs)	ESRI Shape	Natural England
Biological Sites of Special Scientific Interest (SSSI)	ESRI Shape	Natural England
Areas of Outstanding Natural Beauty (AONB)	ESRI Shape	Natural England
National Nature Reserves (NNR)	ESRI Shape	Natural England
Local Nature Reserves (LNR)	ESRI Shape	Natural England
Ancient and semi-natural woodland inventory	ESRI Shape	Natural England
Community Forests	ESRI Shape	Natural England
Woodland Trust Sites	ESRI Shape	Natural England
RSPB Reserves and Ornithological areas	ESRI Shape	Natural England
Doorstep Green and Millennium Green areas	ESRI Shape	Natural England
Archaeology		
Scheduled Ancient Monuments	ESRI Shape	English Heritage

Appendix 5 Site Assessment Sheets

Sheets headed in orange are SSSIs, green denotes recommended RIGs and blue potential LIGS.

GLA 1 Abbey Wood

Grid Reference: TQ 480 786	Site Type: Natural exposure
Site Area (hectares): 6.89	Current use: Recreational land
Site ownership: London Borough of Bexley	Borough: London Borough of Bexley
Field surveyor: Joanna Brayson	Date: 21st December 2007
Current geological designations: SSSI	Other scientific:

Site Map

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Stratigraphy and Rock Types

Time Unit: Eocene	Rock Unit: Lesnes Shell Bed (Blackheath Beds), Thames Group
Rock Type: Sand and Gravel	Details: Glauconitic sandy clays and very fine grained glauconitic sands with a mainly marine fauna.
Time Unit: Paleocene	Rock Unit: Lambeth Group
Rock Type: Sand, silt and clay	Details: This clay seams overlain by grey clays and sands with Brackish fauna and interleaved red and variegated clays and sands.
Time Unit: Paleocene	Rock Unit: Thanet Sand Formation
Rock Type: Sand	Details: Glauconitic coated nodular flint at base, overlain by pale yellow-brown, fine-grained sand that can be clayey and glauconitic. Rare calcareous or siliceous sandstones.

Site Description

Abbey Wood contains some of the most fossiliferous deposits in the Greater London area providing remains of a diverse mammal assemblage of early Tertiary age. The deposits are also important for studies in the evolution of bird faunas.

The site covers deposits of early Eocene age (Lesnes Shell Bed within the Blackheath (Beds) Formation). Excavations of these Beds have yielded an important mammalian fauna of 22 species attributable to 12 orders have been listed by

Jerry Hooker (GCR), some of which have been described and the rest are under study. Additional species are still being added during most excavations. This is comparable to sites in the Paris Basin, and contains elements resembling those of the Wasatchian faunas of North America. Upnor Formation (latest Paleocene) and Thanet Sand Formation are present but the Woolwich Formation (early Eocene) is cut out by the unconformity at the base of the Blackheath beds which represents incised valley fill.

This site also yields remains of one of only two birds described from the Paleocene of Great Britain. A lower mandible has been reconstructed as the holotype of *Marinavis longirostris*, which is the only bird of this type known from this period. It appears to have been a large Procellariiform sea bird and would seem to indicate a coastal fauna. The site has great potential in that it might help solve the problem of Procellariiform - Pelecaniform ancestry.

Assessment of Site Value

Geodiversity topic: Palaeontology, sedimentology lithostratigraphy, evolution and palaeobiogeography.

Access and Safety

Aspect	Description
Safety of access	Paths run through the park and woods from the roadside. Fossil collecting site is situated a short distance from a path in the woods and surface collecintg is permitted. Fairly level and obstruction free.
Safety of exposure	Fossil collecting area consists of a flat fenced off area with an open entrance way. Safety procedures must be followed when excavating.
Permission to visit	The fossil beds can be visited at any time but excavation can only be carried out with prior permission. Important vertebrate material should be taken t a museum. Contact Bexley Parks and Open Spaces department on 020 8303 7777 or at parks&openspaces@bexley.gov.uk
Current condition	As a SSSI, the site is very well maintained by the park rangers.
Current conflicting activities	None.
Restricting conditions	Excavation and collecting of fossils only by prior permission. Feature only visible with excavation.
Nature of exposure	Flat fenced off area within woods within which Palaeontology of the Lesnes Shell Bed can be excavated from the sediment.

Culture, Heritage & Economic

Aspect	Description	Rating
Historic, archaeological & literary associations	The park in which the SSSI is situated also contains the remains of Lesnes Abbey which was established in 1178. Much research has been carried out on the site.	10
Aesthetic landscape	The park provides an important green space within the local area.	8
History of Earth Sciences	Evolution of mammal and rare bird faunas; Procellariiform – Pelecaniform ancestry.	8
Economic geology	Within the park there was an old chalk quarry which is of local economic importance	4

GeoScientific Merit

Geomorphology	None within the SSSI.	0
Sedimentology	Sedimentary processes leading to preservation of fauna.	6
Palaeontology	Diverse mammalian assemblage; rare bird fauna.	7
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Junctions between three stratigraphic units lie within the area.	6
Potential use	Research, Higher/further education, School education, On-site interpretation.	
Fragility	Finite resource; natural overgrowing.	

Current Site Value

Community	Area is used daily by the local community.	10

Education	This site is available for group use by a wide range of users.	8

Geodiversity value

SSSI: Excellently maintained site with much research potential and educational value.	8

GLA 1 Abbey Wood

Fenced off Fossil Bed area within Abbey Wood site

Fenced of Fossil Bed area used by groups for excavation

GLA 2 Avenue House

Grid Reference: TQ 252 903	Site Type: Natural Exposure
Site Area (hectares): 3.17	Current use: Recreational Land
Site ownership: Avenue House Estate Trust	Borough: London Borough of Barnet
Field surveyor: Joanna Brayson	Date: 30th January 2008
Current geological designations:	Other scientific:

Site Map

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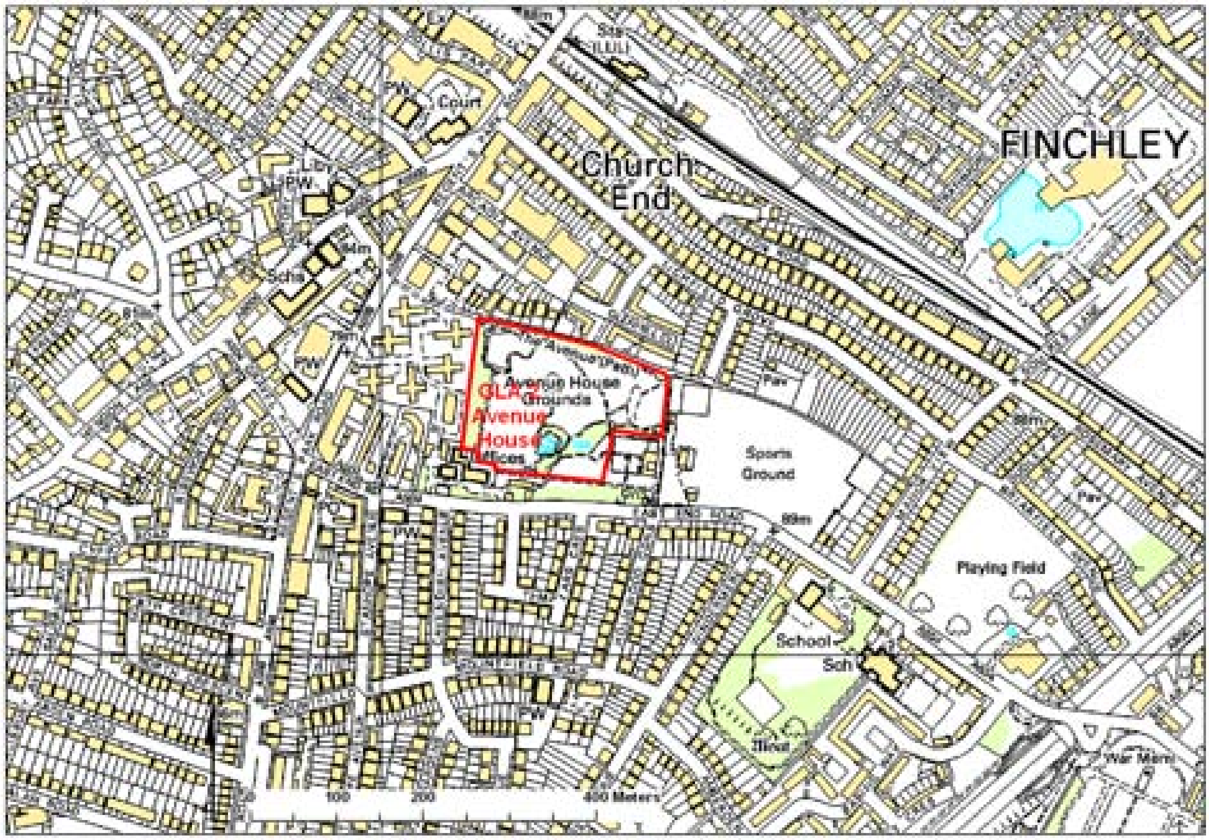

Stratigraphy and Rock Types

Time Unit: Quaternary	Rock Unit: Lowestoft Formation, Albion Glacigenic Group
Rock Type: Till	Details: Chalky till, together with outwash sands and gravels, silts and clays. The till is characterised by its chalk and flint content.

Site Description

Park area with pebbly clay exposures (Till) beneath trees.

Assessment of Site Value

Geodiversity topic: Lithostratigraphy, sedimentology.

Access and Safety

Aspect	Description
Safety of access	Public park area, footpaths and open areas.
Safety of exposure	Some exposures adjacent to steps, care should be taken.
Permission to visit	Site has open access, contact Avenue House Estate Trust for information on access for groups. www.avenuehouse.org.uk
Current condition	Landscaped ground, exposures are small and mainly in wooded areas.
Current conflicting activities	Landscaping activities.
Restricting conditions	Disturbance of grounds for further investigation would need permission.

Nature of exposure	Patches of till in open areas between trees.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	The site is the grounds of a Victorian Mansion which has a rich history.	6
Aesthetic landscape	The park is very well maintained and well used by the community with wedding and other ceremonies being held in the house and grounds.	7
History of Earth Sciences	Relationship of various till units in Essex, East Anglia and the East Midlands.	8
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	None.	0
Sedimentary	Till composition.	5
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Correlation of till with other locations.	6
Potential use	On-site interpretation; research.	
Fragility	Natural overgrowing; landscaping.	
Geodiversity value		
Potential LIGS: Small exposures in area with good potential for information for local community.		3

GLA 2 Avenue House

Till exposure in grounds of Avenue House Estate

GLA 3 Beckenham Place Park

Grid Reference: TQ 385 703	Site Type: Natural exposure
Site Area (hectares): 0.51	Current use: Recreational land
Site ownership: London Borough of Lewisham	Borough: London Borough of Lewisham
Field surveyor: Joanna Brayson	Date: 18th December 2007
Current geological designations:	Other scientific:

Site Map

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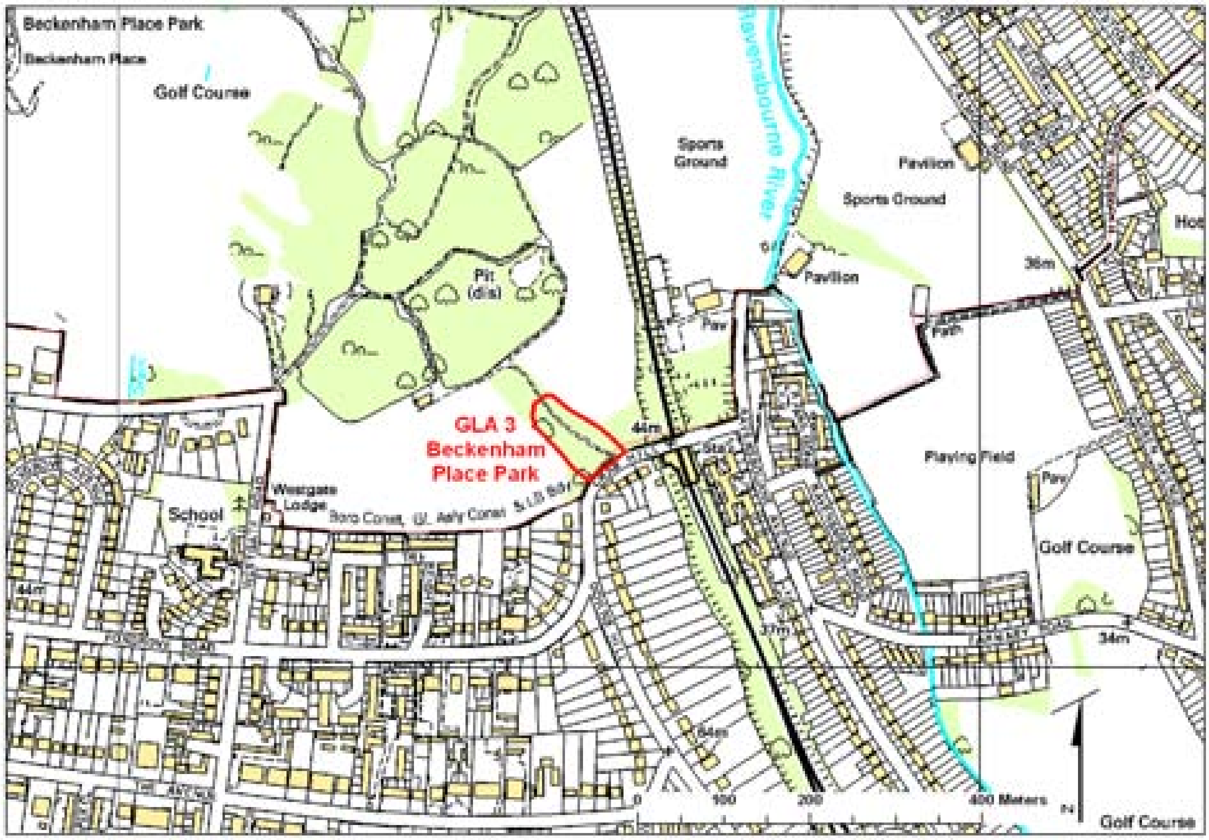

Stratigraphy and Rock Types

Time Unit: Eocene	Rock Unit: London Clay Formation, Thames Group
Rock Type: Clay and silt	Details: Fine, sandy, silty clay/ clayey silt. Glauconitic at base.
Time Unit: Paleocene - Eocene	Rock Unit: Harwich Formation, Thames Group
Rock Type: Sand and gravel	Details: Glauconitic sandy clays and very fine-grained glauconitic sands; marine fauna, locally brackish.

Site Description

Exposure of Harwich Formation (rounded flint pebbles with calcareous cement) near the entrance to the park.

Assessment of Site Value

Geodiversity topic: Sedimentology; lithostratigraphy.

Access and Safety

Aspect	Description
Safety of access	Exposures are either side of a Green Chain Walk within a public park.
Safety of exposure	Surrounding area is muddy, care should be taken near the exposures.
Permission to visit	Public space, contact Lewisham Borough for details.
Current condition	Good – leaf cover in autumn means exposures slightly covered, possibly also by vegetation in summer.
Current conflicting activities	None.

Restricting conditions	None.	
Nature of exposure	Small crags next to public path.	
Culture, Heritage & Economic		
Aspect	**Description**	Rating
Historic, archaeological & literary associations	The park contains a Grade II listed Mansion which houses a golf club house.	4
Aesthetic landscape	Provides interesting entrance to park.	4
History of Earth Sciences	Cementation of conglomerate – environmental inferences.	6
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	Crags formed by outcrop.	4
Sedimentology	Depositional environment.	6
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Correlation between outcrop and other outcrops of Harwich Formation.	6
Potential use	Research; higher further education; school education; on-site interpretation.	
Fragility	Natural overgrowing; weathering/erosion.	
Geodiversity value		
Recommended RIGS: Good exposure with easy access and good local facilities.		5

GLA 3 Beckenham Place Park

Harwich Formation boulders and outcrop

GLA 4 Chelsfield Gravel

Grid Reference: TQ 476 642	Site Type: Natural exposure
Site Area (hectares): 9.55	Current use: Recreational land/ agricultural land
Site ownership: Court Lodge Farm	Borough: London Borough of Bromley
Field surveyor: Joanna Brayson	Date: 21st February 2008
Current geological designations:	Other scientific:

Site Map

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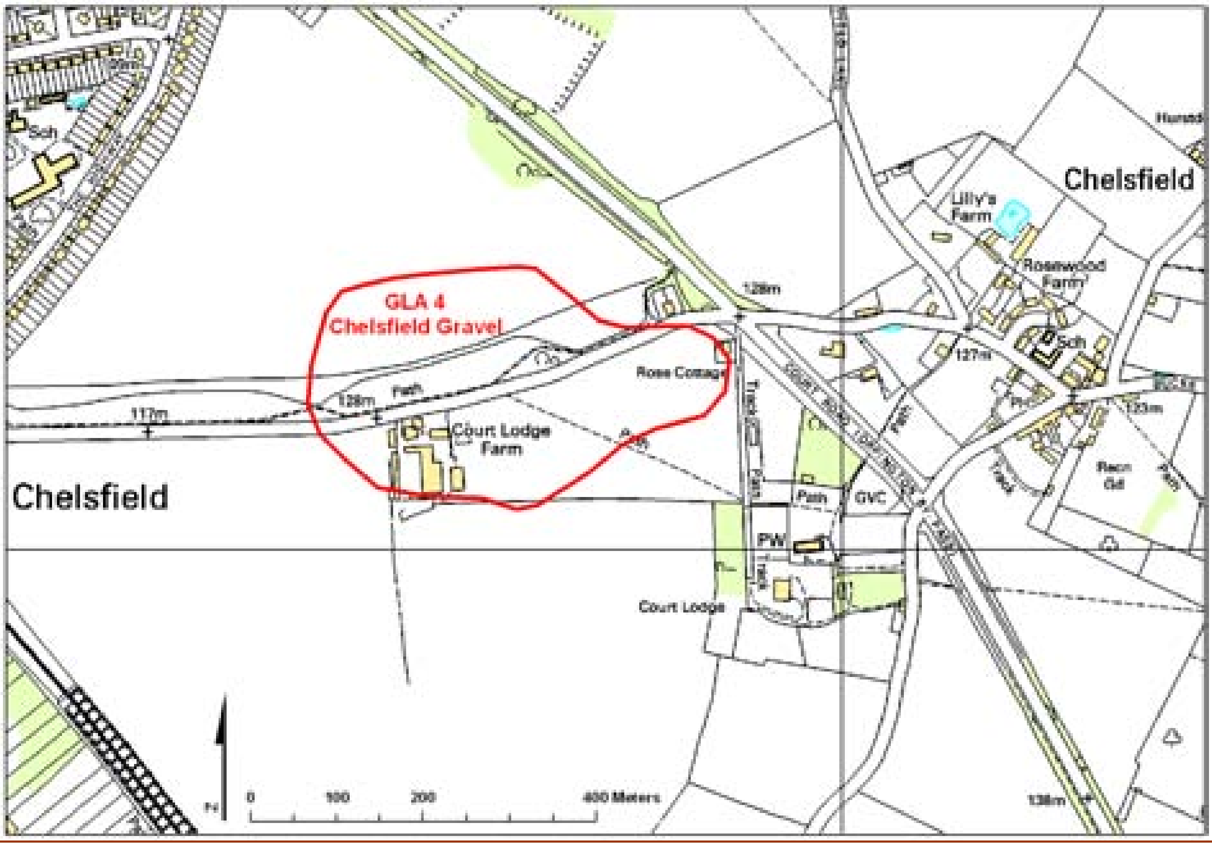

Stratigraphy and Rock Types

Time Unit: Pliocene	Rock Unit: Chelsfield Gravel Formation, Residual Deposits Group
Rock Type: Sand and gravel	Details: Well rounded flint pebble gravels, sandy gravels, pebbly sands and sands. Lithologies similar to those in Harwich Formation (formerly Blackheath Beds) from which it is thought to have been mainly derived.

Site Description

This is the type locality for the Chelsfield Gravel which has been reworked from the Harwich Formation. The deposit is interpreted as a head, partly let down with the underlying Thanet Sand into dissolution hollows in the Chalk below.

This outcrop covers an area of grassy footpaths frequented by dog walkers who use the nearby station car park. It also extends into farmland on either side which is where the gravel can be seen in ploughed fields. A viewpoint of the local area is situated at the edge of the open area. The Chelsfield Gravel can be viewed from here and geological information could be added to the existing sign.

Assessment of Site Value

Geodiversity topic: Lithostratigraphy; sedimentology.

Access and Safety

Aspect	Description
Safety of access	Footpaths leading to site from car park. Part of exposure across main road, caution should be taken crossing road.
Safety of exposure	Exposure in ploughed fields on/adjacent to public footpaths. Be aware of farm machinery.
Permission to visit	Access to some of the site is open, contact farm for access to remainder of site.

Current condition	Mostly grassed over or part of ploughed fields. Disturbed where ploughed.	
Current conflicting activities	Farming.	
Restricting conditions	Site partially on working farmland.	
Nature of exposure	Gravel seen in ploughed fields.	
Culture, Heritage & Economic		
Aspect	**Description**	Rating
Historic, archaeological & literary associations	This is a newly defined unit as described in The Geology of London (Ellison 2004)	2
Aesthetic landscape	Located within public footpath area – well used by public.	6
History of Earth Sciences	Evidence of the erosion and re-working of the Harwich Formation.	4
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	Distribution of deposit along with the Thanet Sand in hollows of the underlying Chalk.	6
Sedimentology	Reworking of Harwich Formation – surface processes.	6
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Relationship between bedrock and superficial deposits.	6
Potential use	Research; Higher Education; School Education; On-site Interpretation	
Fragility	Natural overgrowing; weathering/erosion.	
Current Site Value		
Community	Valuable open space for the local community.	10
Education		3
Geodiversity value		
Recommended RIGS: Only exposure of this local deposit with good access.		5

GLA 4 Chelsfield Gravel

View of feature forming edge of Chelsfield Gravel outcrop

GLA 5 Chingford Hatch

Grid Reference: TQ 384 927	Site Type: Natural Landform
Site Area (hectares): 17.87	Current use: Recreational Land
Site ownership: London Borough of Waltham Forest	Borough: London Borough of Waltham Forest
Field surveyor: Joanna Brayson	Date: 4th January 2008
Current geological designations:	Other scientific:

Site Map

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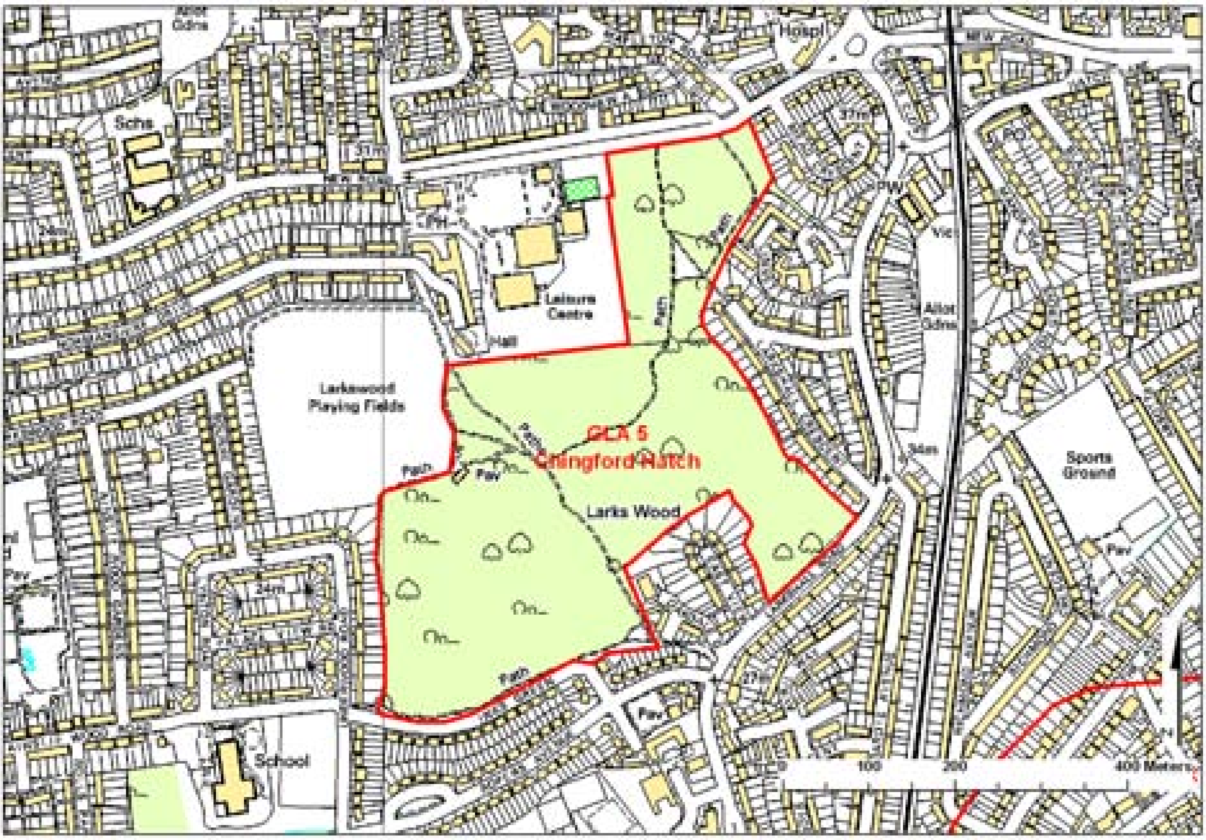

Stratigraphy and Rock Types

Time Unit: Pleistocene	Rock Unit: Woodford Gravel Formation
Rock Type: Sand and gravel	Details: Sand and gravel, locally with lenses of silt, clay or peat and organic material.
Time Unit: Eocene	Rock Unit: London Clay Formation, Thames Group
Rock Type: Clay, silt, sand	Details: Fine, sandy, silty clay/ clayey silt. Glauconitic at base.

Site Description

A London Clay hillock in woodland (Larks Wood) near Chingford Hatch with a capping of Woodford Gravel. The Woodford Gravel has been interpreted as the river terrace deposits of south-bank tributaries of the ancestral Thames. The gravel consists of angular flint (83%), rounded flint (14%), quartz (1%) and Lower Greensand Chert (1%) and is 3–4 m thick.

Assessment of Site Value

Geodiversity topic: Lithostratigraphy; sedimentology; geomorphology.

Access and Safety

Aspect	**Description**
Safety of access	Footpaths through woodland.
Safety of exposure	Exposure in woodland – observe general safety in woodlands.
Permission to visit	Open access.

Current condition	Ok – exposures small and scattered.	
Current conflicting activities	None.	
Restricting conditions	Trees and leaf cover in autumn.	
Nature of exposure	Small exposures in woodland.	
Culture, Heritage & Economic		
Aspect	**Description**	Rating
Historic, archaeological & literary associations	Mentioned in London Borough of Waltham Forest information.	2
Aesthetic landscape	Footpaths through woods used by local community.	4
History of Earth Sciences	Distribution of gravels used to determine location and behaviour of ancestral Thames.	6
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	Distribution of exposures of Woodford Gravel used to determine location relative to ancestral Thames.	6
Sedimentology	Research into composition of the gravels could give more information on the provenance of the gravels and therefore the river that deposited them.	6
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Relationship of river terrace deposits.	6
Potential use	Research; further education; on-site interpretation.	
Fragility	Dumping; natural overgrowing; weathering/erosion.	
Current Site Value		
Community	Valuable green space.	8
Education		2
Geodiversity value		
Potential LIGS: Small exposures with reasonable access for local community.		4

GLA 5 Chingford Hatch

Chingford Hatch

GLA 6 Croham Hurst

Grid Reference: TQ 338 630	Site Type: Natural exposure
Site Area (hectares): 34.57	Current use: Recreational land
Site ownership: London Borough of Croydon	Borough: London Borough of Croydon
Field surveyor: Joanna Brayson	Date: 21st December 2007
Current geological designations:	Other scientific: SSSI (Bio)

Site Map

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Stratigraphy and Rock Types

Time Unit: Paleocene/Eocene	Rock Unit: Harwich Formation, Thames Group
Rock Type: Sand and gravel	Details: Glauconitic sandy clays and very fine-grained glauconitic sands; marine fauna, locally brackish.
Time Unit: Paleocene	Rock Unit: Lambeth Group
Rock Type: Sand and gravel	Details: Glauconitic sands overlain by grey clays and sands with Brackish fauna and interleaved red and variegated clays and sands.
Time Unit: Paleocene	Rock Unit: Thanet Sand Formation
Rock Type: Sand	Details: Glauconite-coated, nodular flint at base, overlain by pale yellow-brown, fine-grained sand that can be clayey and glauconitic. Rare calcareous or siliceous sandstones.
Time Unit: Cretaceous	Rock Unit: Lewes Nodular Chalk Formation, Seaford Chalk Formation and Newhaven Chalk Formation Undifferentiated, Chalk Group
Rock Type: Chalk	Details: Chalk

Site Description

Small exposures of ferruginous cemented rounded flint pebbles belonging to the Harwich Formation. Also evidence of chalk in fallen tree roots.

Assessment of Site Value

Geodiversity topic: Sedimentology; lithostratigraphy.

Access and Safety

Aspect	Description
Safety of access	Footpaths through woods. Slippery in autumn with leaf cover.

Safety of exposure	As above.	
Permission to visit	Open access, check with local borough for organised visits.	
Current condition	Patchy exposures, hard to find in autumn due to leaf cover.	
Current conflicting activities	None.	
Restricting conditions	Small exposures in woods.	
Nature of exposure	Small exposures on floor of woodland.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Evidence of a Mesolithic settlement and occupation up until Bronze age burials.	6
Aesthetic landscape	Valuable green space.	6
History of Earth Sciences	Boundaries between 4 different formations are located at this site, excavation could provide information on these formations and their boundaries.	6
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	Shape of hill due to the properties of different formations.	6
Sedimentology	Depositional environment of 4 different formations.	6
Palaeontology	Possible in the chalk if excavated.	6
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Relationships between 4 formations.	8
Potential use	Research; higher education; on-site interpretation.	
Fragility	Natural overgrowing; weathering/erosion.	
Current Site Value		
Community	Valuable green space.	10
Education		4
Geodiversity value		
Recommended RIGS: Small exposures of a range of lithologies in woodland with adequate access.		6

GLA 6 Croham Hurst

Exposure within woodland

GLA 7 Crystal Palace Dinosaurs

Grid Reference: TQ 345 705	Site Type: Man-made artefact
Site Area (hectares): 5.37	Current use: Recreational land
Site ownership: London Borough of Bromley	Borough: London Borough of Bromley
Field surveyor: Joanna Brayson	Date: 4th January 2008
Current geological designations:	Other scientific: Listed building Grade I

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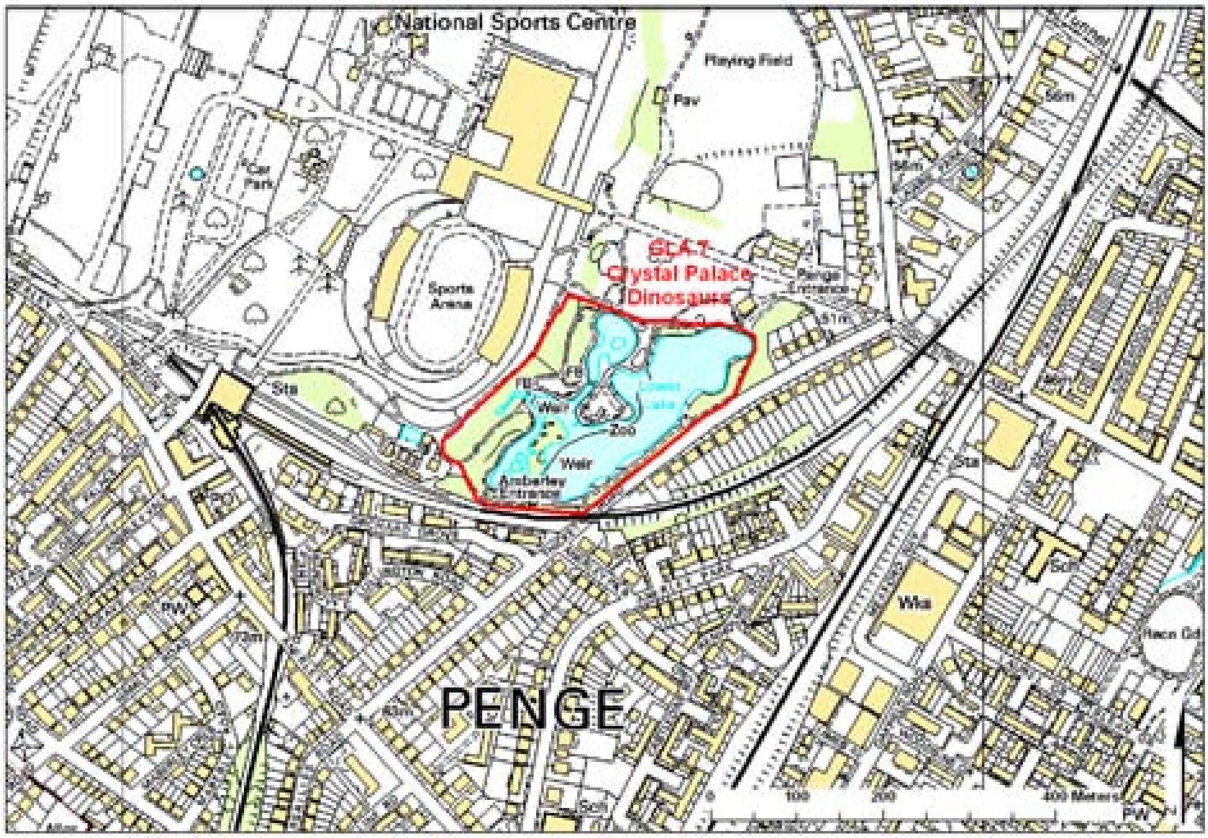

Stratigraphy and Rock Types

Time Unit: N/A	Rock Unit: N/A
Rock Type: N/A	Details: N/A

Site Description

The Crystal Park Dinosaurs are located at the southern edge of Crystal Palace park. They were designed and sculpted by Benjamin Waterhouse Hawkins between 1852 and 1854 under advice from Sir Richard Owen. The collection includes 15 complete species of dinosaurs and mammals, although more had been planned until funding was cut. The models are now known to be largely inaccurate due to a lack of information at the time of design.

Several periods of neglect and movement lead to the models becoming damaged. A full restoration project was completed in 2002 and the site now has excellent footpaths and explanatory signs. The new signs give information about the models and how modern interpretations of the creatures differ to the models. The animals are set on strata of appropriate age.

There are also two man-made exposures illustrating geological resources.

Assessment of Site Value

Geodiversity topic: Palaeontology, geology

Access and Safety

Aspect	Description
Safety of access	Very good – pathways suitable for wheelchairs. Fencing around lakes.
Safety of exposure	Models are viewed from pathways.
Permission to visit	Public park, access during park opening hours.

Current condition	Recently restored (2002) – excellent.	
Current conflicting activities	None.	
Restricting conditions	None.	
Nature of exposure	Extinct dinosaur and mammal models with descriptions and additional information within a public park.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Historic models.	8
Aesthetic landscape	Situated in a well used public park, well maintained.	8
History of Earth Sciences	History of palaeontology, highlights the increase in information since the models were made but also the interest in Geology at the time.	8
Economic geology	Man-made illustrative sections explaining economic geology.	8
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Man-made illustrative models explaining sedimentation in relation to economic geology.	8
Palaeontology	Dinosaur models.	8
Igneous/mineral/ Metamorphic Geology	Some aspects of illustrative sections illustrate metamorphism.	6
Structural Geology	Faults are illustrated in the man-made sections.	6
Lithostratigraphy	Illustrated in the man-made sections.	6
Potential use	School education; on-site interpretation (already present).	
Fragility	Needs continuous care and maintenance.	
Current Site Value		
Community	Valuable open space used everyday.	10
Education	Excellent introduction to geology and palaeontology.	8
Geodiversity value		
Recommended RIGS: Excellent educational site accessible and interesting to all age groups.		8

GLA 7 Crystal Palace Dinosaurs

Anoplotherium models

GLA 8 Dog Rocks

Grid Reference: TQ 443 779	Site Type: Natural Exposure
Site Area (hectares): 0.02	Current use: Recreational land
Site ownership: London Borough of Greenwich	Borough: London Borough of Greenwich
Field surveyor: Joanna Brayson	Date: 30th November 2007
Current geological designations:	Other scientific:

Site Map

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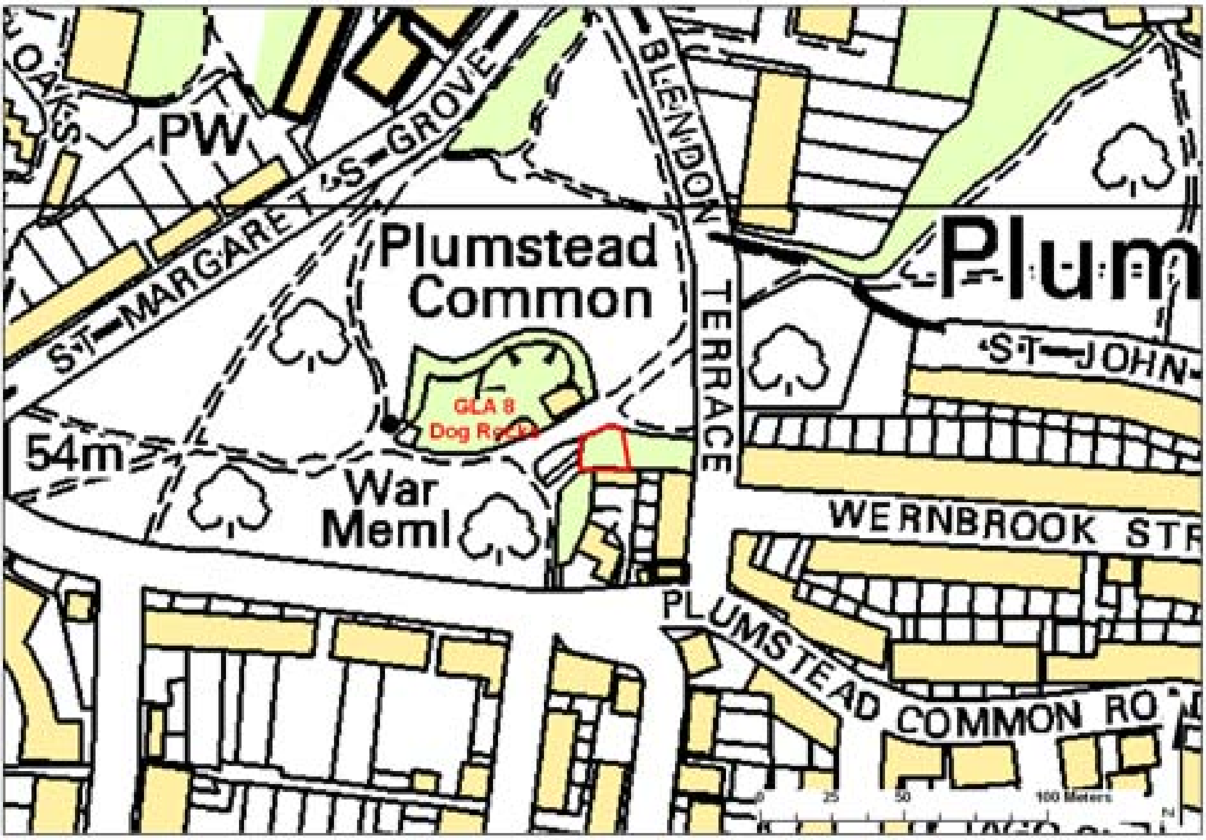

Stratigraphy and Rock Types

Time Unit: Paleocene/Eocene	Rock Unit: Harwich Formation, Thames Group
Rock Type: Sand and gravel	Details: Glauconitic sandy clays and very fine-grained glauconitic sands; marine fauna, locally brackish.

Site Description

Large boulders of Harwich Formation in a public park. The boulders consist of rounded flint pebbles with a calcareous cement.

Assessment of Site Value

Geodiversity topic: Sedimentology.

Access and Safety

Aspect	Description
Safety of access	In public park, adjacent to footpath.
Safety of exposure	Boulders stable.
Permission to visit	Open access.
Current condition	Exposure has suffered from graffiti.
Current conflicting activities	None.
Restricting conditions	None.

Nature of exposure	Boulders in public park.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	None.	0
Aesthetic landscape	Valuable open space.	6
History of Earth Sciences	Environment of deposition and history – cementation.	4
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Deposition and cementation of the Harwich Formation.	6
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Position of exposure within Harwich Formation.	6
Potential use	School education; on-site interpretation.	
Fragility	Weathering/erosion; vandalism.	
Current Site Value		
Community	Area used by local community everyday.	10
Education		4
Geodiversity value		
Recommended RIGS: Good exposure in an urban area; suffers from vandalism.		5

GLA 8 Dog Rocks

Dog Rocks (Harwich Formation)

GLA 9 Dry Valley

Grid Reference: TQ 272 629	Site Type: Natural landform
Site Area (hectares): 228.20	Current use: Urban area
Site ownership: Urban area	Borough: London Borough of Sutton
Field surveyor: Joanna Brayson	Date: 19th December 2007
Current geological designations:	Other scientific:

Site Map

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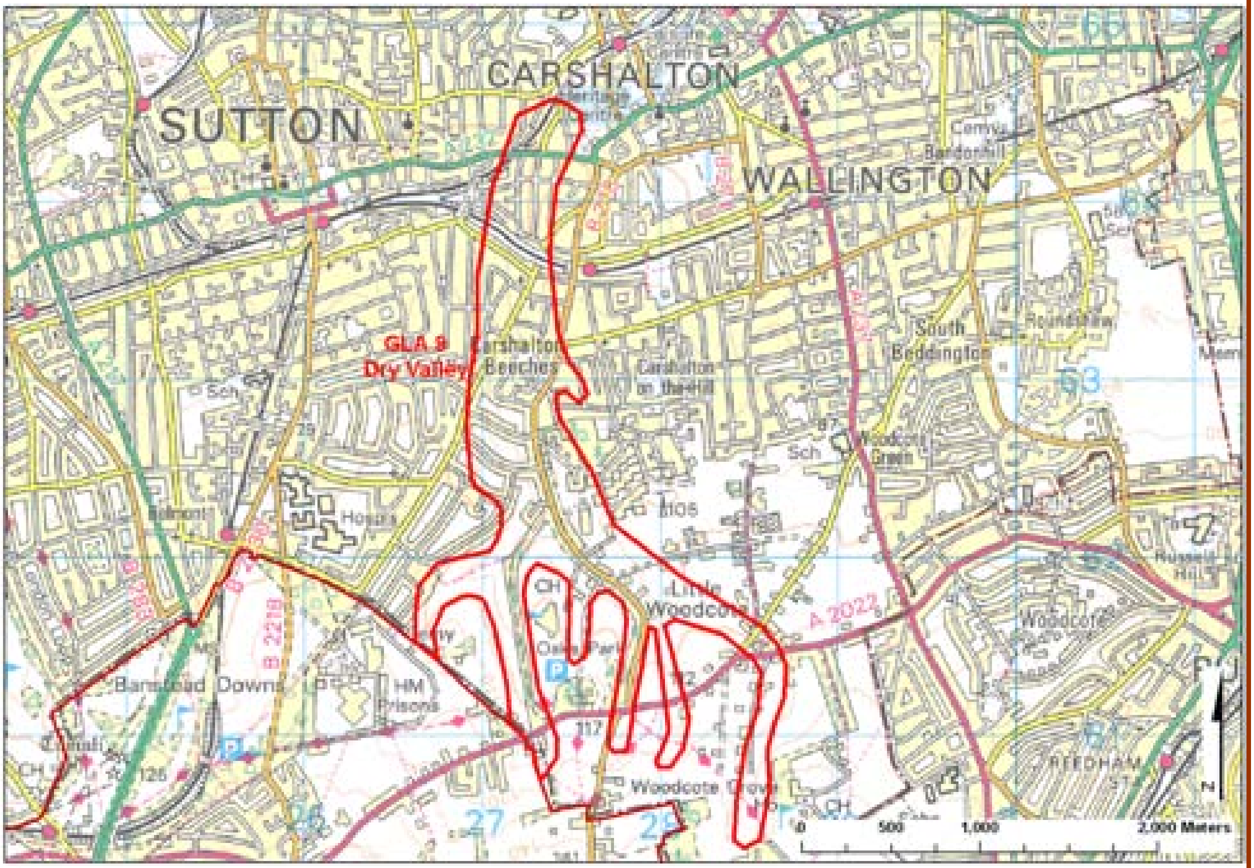

Stratigraphy and Rock Types

Time Unit: Cretaceous	Rock Unit: Lewes Nodular Chalk Formation, Seaford Chalk Formation and Newhaven Chalk Formation Undifferentiated, Chalk Group
Rock Type: Chalk	Details: Chalk

Site Description

A dry valley in the Chalk running through the area of Carshalton Beeches.

Dry valleys are formed during periods of glaciation when the normally permeable chalk becomes frozen and water is forced to run over the surface, eroding the rock and creating a valley. Now the chalk has thawed, the water is once again able to flow underground leaving the valley dry.

Assessment of Site Value

Geodiversity topic: Geomorphology

Access and Safety

Aspect	Description
Safety of access	Feature runs through urban area – visible from side of road.
Safety of exposure	Urban area – beware of traffic.
Permission to visit	Urban area – feature does not require access to private land.
Current condition	Feature is built upon but clearly visible.
Current conflicting activities	Buildings and roads cover the area but still visible.

Restricting conditions	None.	
Nature of exposure	Dry valley in urban area.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	None.	0
Aesthetic landscape	Forms the landscape.	8
History of Earth Sciences	Paths of old rivers can be determined by the dry valleys.	6
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	Shape and location of valley can be used to interpret periglacial processes.	8
Sedimentology	None.	0
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	None.	0
Potential use	School education.	
Fragility	Development (already occurred).	
Current Site Value		
Community	Urban area – forms part of living environment.	10
Education		4
Geodiversity value		
Potential LIGS: Good feature in an urban area but with little open space.		4

GLA 9 Dry Valley

Dry Valley within urban setting

GLA 10 Dulwich Mill Pond

Grid Reference: TQ 333 731	Site Type: Natural landform
Site Area (hectares): 0.45	Current use: Private land
Site ownership: Dulwich Estates	Borough: London Borough of Southwark
Field surveyor: Joanna Brayson	Date: 18th January 2008
Current geological designations:	Other scientific: Borough Grade II (Bio)

Site Map

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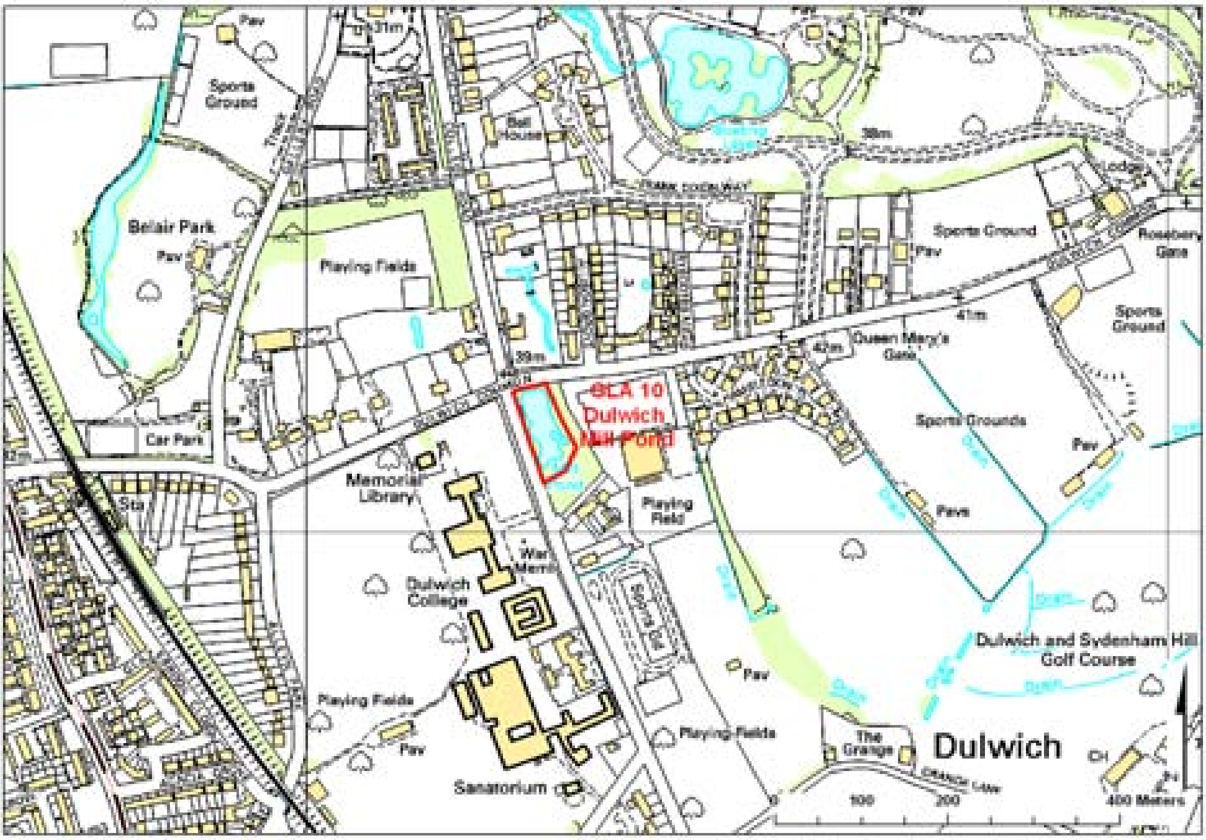


Stratigraphy and Rock Types

Time Unit: Eocene	Rock Unit: London Clay Formation, Thames Group.
Rock Type: Clay, silt, sand	Details: Fine, sandy, silty clay/clayey silt. Glauconitic at base.

Site Description

A mill pond adjacent to Dulwich College. This pond is one of the few remaining traces of the River Effra stream system in Southwark.

Assessment of Site Value

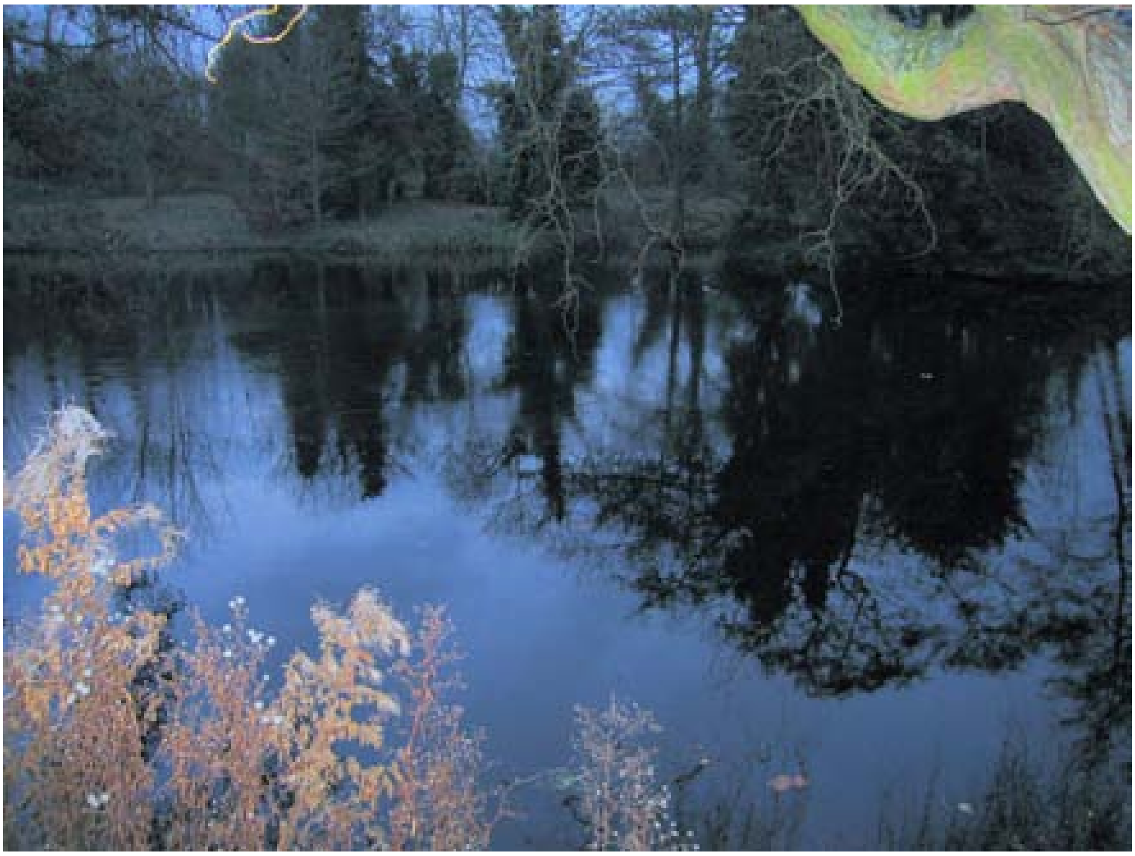
Geodiversity topic: Geomorphology

Access and Safety

Aspect	Description
Safety of access	At roadside.
Safety of exposure	Pond itself is fenced off.
Permission to visit	Unable to access pond itself but clearly visible from roadside.
Current condition	Good.
Current conflicting activities	None.
Restricting conditions	None.
Nature of exposure	Pond.

Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Oldest mill pond in area.	4
Aesthetic landscape	Pleasant water feature in relatively built up area.	6
History of Earth Sciences	Evidence of previous stream system.	6
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	Remnant of old stream system – gives information of areas drainage patterns.	8
Sedimentology	None.	0
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	None.	0
Potential use	On-site interpretation; school education.	
Fragility	Protected as Borough Grade 2 site.	
Current Site Value		
Community	Site is fenced off but can be seen from pavement.	2
Education		2
Geodiversity value		
Potential LIGS: Only remnant of stream system with poor access (seen from roadside).		4

GLA 10 Dulwich Mill Pond



Dulwich Mill Pond

GLA 11 Finchley Till

Grid Reference: TQ 259 908	Site Type: Natural exposure
Site Area (hectares): 3.86	Current use: Recreational land
Site ownership: Local Borough of Barnet	Borough: London Borough of Barnet
Field surveyor: Joanna Brayson	Date: 30th January 2008
Current geological designations:	Other scientific:

Site Map

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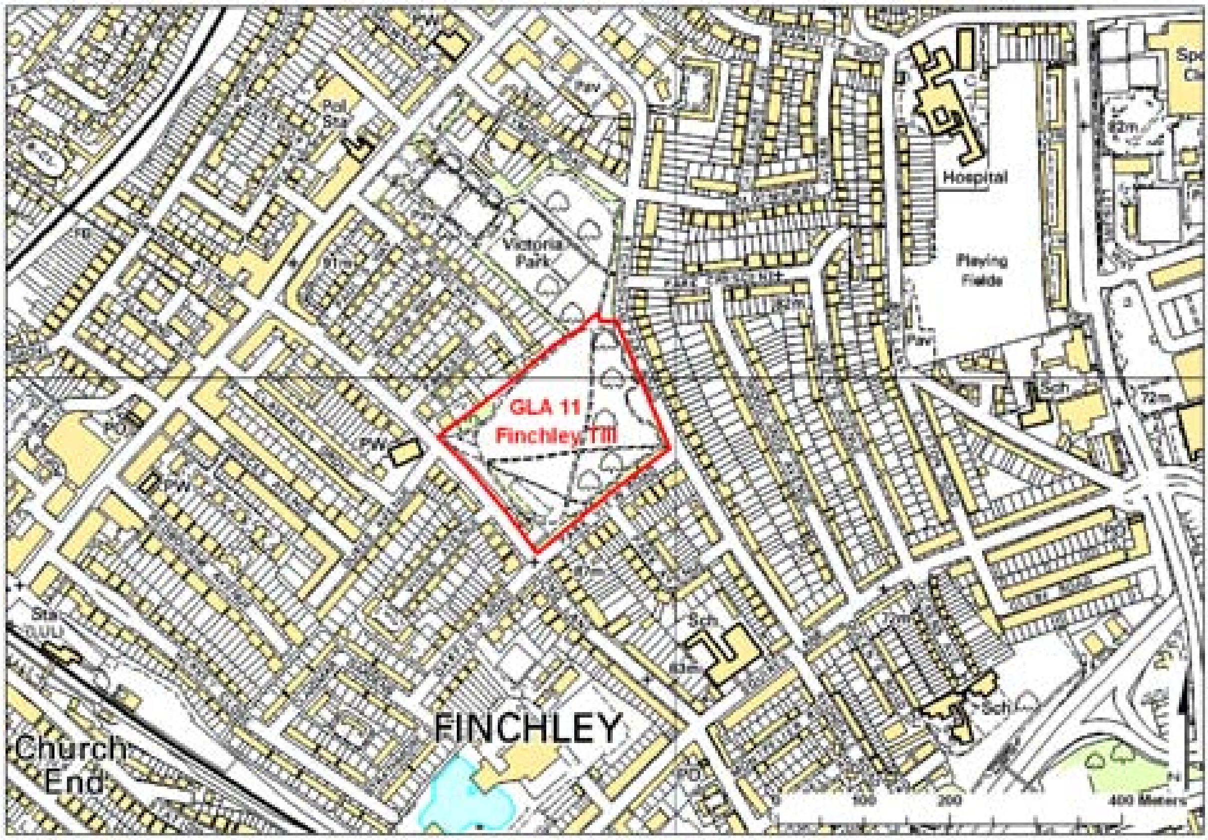

Stratigraphy and Rock Types

Time Unit: Quaternary	Rock Unit: Lowestoft Formation, Albion Glacigenic Group
Rock Type: Till	Details: Chalky till, together with outwash sands and gravels, silts and clays. The till is characterised by its chalk and flint content.

Site Description

Park area with exposures of till (pebbly clay) in the borders. Empty information board present – potential location for information.

Assessment of Site Value

Geodiversity topic: Sedimentology

Access and Safety

Aspect	**Description**
Safety of access	Public park – footpaths.
Safety of exposure	Exposures adjacent to footpaths.
Permission to visit	Open access.
Current condition	Landscaped but visible.
Current conflicting activities	Landscaping.
Restricting conditions	None.

Nature of exposure	Exposures in borders of park.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	None.	0
Aesthetic landscape	Part of public open space.	6
History of Earth Sciences	Distribution of glacial deposits therefore extent of glaciation.	6
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Composition of till (allowing reconstruction of ice pathway).	8
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Correlation with till deposits elsewhere.	4
Potential use	On-site interpretation; school education.	
Fragility	Natural overgrowing.	
Current Site Value		
Community	Park used daily by local community.	10
Education		4
Geodiversity value		
Potential LIGS: Small Till exposure in park area well used by local community.		3

GLA 11 Finchley Till

Exposure of Finchley Till

GLA 12 Finsbury Gravel

Grid Reference: TQ 315 828	Site Type: Natural exposure
Site Area (hectares): 0.23	Current use: Recreational land
Site ownership: London Borough of Islington	Borough: London Borough of Islington
Field surveyor: Joanna Brayson	Date: 30th January 2008
Current geological designations:	Other scientific:

Site Map

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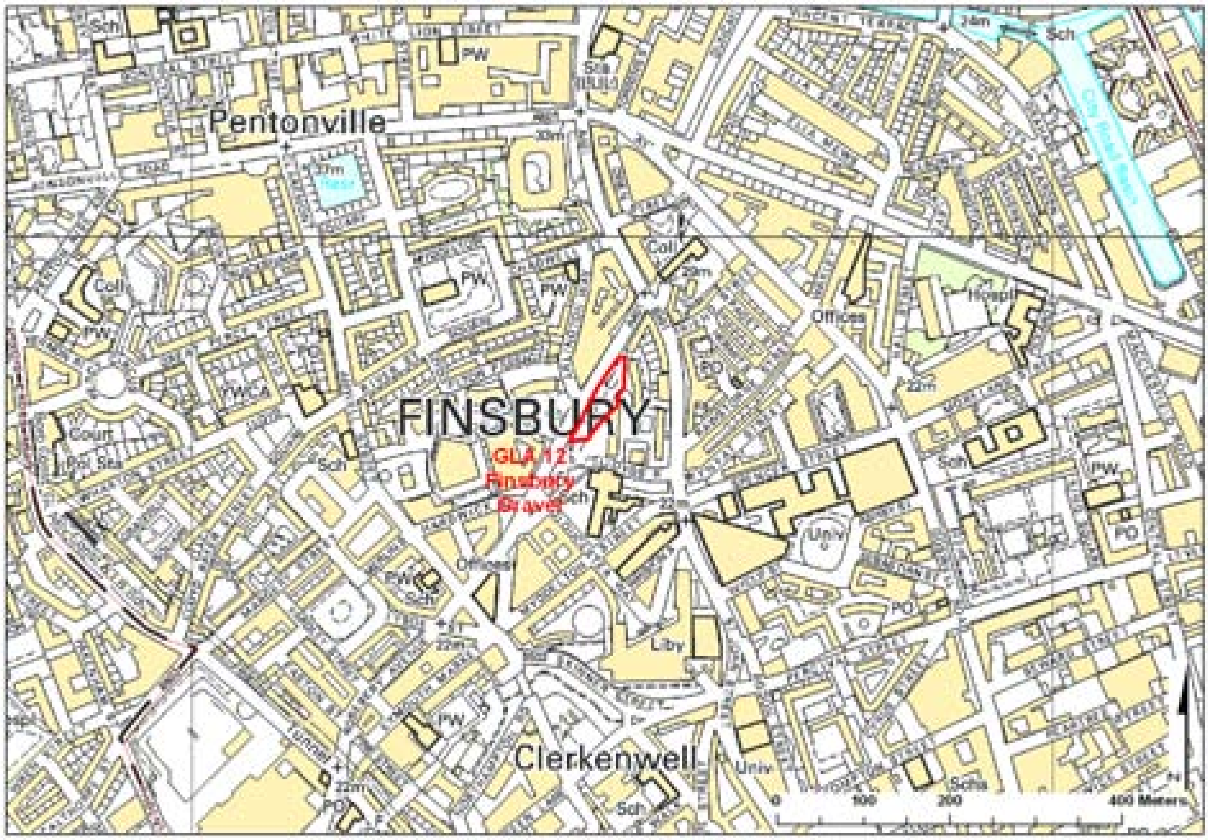

Stratigraphy and Rock Types

Time Unit: Pleistocene	Rock Unit: Finsbury Gravel Member, Maidenhead Formation, Thames Catchments Subgroup
Rock Type: Sand and gravel	Details: Sand and gravel, locally with lenses of silt, clay or peat.

Site Description

Small park area with gravel in borders. The Finsbury Gravel may be related to a phase of deposition of the Lynch Hill Gravel close to the confluence of the rivers Lea and Thames. Site of Islington Spa, famous for chalybeate water form the gravels.

Assessment of Site Value

Geodiversity topic: Sedimentology; Lithostratigraphy, water source.

Access and Safety

Aspect	Description
Safety of access	In public park – footpaths.
Safety of exposure	Exposure adjacent to and level with paths.
Permission to visit	Open space – contact Islington Borough Greenspace division on 020 75274953.
Current condition	Landscaped, possibly disturbed.
Current conflicting activities	Landscaping.

Restricting conditions	None.	
Nature of exposure	Exposures in borders of park.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Site of Islington Spa. Highlights importance of the gravels a s a source of water for early development.	0
Aesthetic landscape	Park of valuable open space.	6
History of Earth Sciences	Evolution of local river systems. Influenced of geology on development.	6
Economic geology	Water and associated tea gardens and spa	0
GeoScientific Merit		
Geomorphology	Position of gravels – reconstruct river systems. Thames terrace (100′)	6
Sedimentology	Environment of deposition, provenance.	6
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Relationship between different terrace gravels.	6
Potential use	Research; school education; on-site interpretation.	
Fragility	Natural over-growing.	
Current Site Value		
Community	Local community pass through site everyday.	10
Education		4
Geodiversity value		
Potential LIGS: Very small exposures in small park in urban area. Important Islington water story		3

GLA 12 Finsbury Gravel

Exposure of gravel in borders

GLA 13 Friday Hill

Grid Reference: TQ 390 936	Site Type: Natural landform
Site Area (hectares): 2.79	Current use: Recreational land
Site ownership: London Borough of Waltham Forest	Borough: London Borough of Waltham Forest
Field surveyor: Joanna Brayson	Date: 12th February 2008
Current geological designations:	Other scientific:

Site Map

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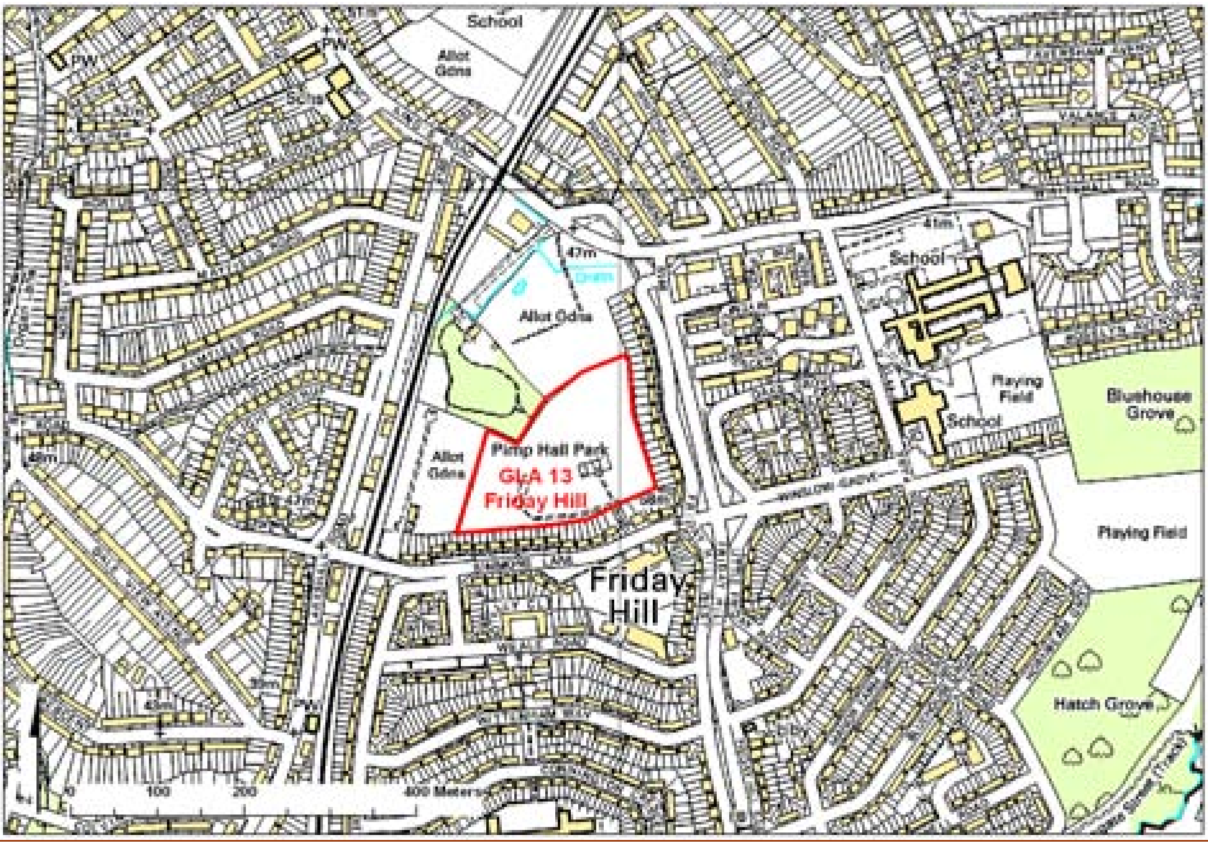


Stratigraphy and Rock Types

Time Unit: Eocene	Rock Unit: London Clay Formation, Thames Group.
Rock Type: Clay, silt, sand	Details: Fine, sandy, silty clay/clayey silt. Glauconitic at base.

Site Description

Hillock in the London Clay – fully grassed over but providing an excellent view of the surrounding area.

Assessment of Site Value

Geodiversity topic: Geomorphology.

Access and Safety

Aspect	**Description**
Safety of access	Footpaths into area, sloping grassy area – care should be taken when wet.
Safety of exposure	N/a
Permission to visit	Open access.
Current condition	Well maintained as park.
Current conflicting activities	None.
Restricting conditions	None.
Nature of exposure	No exposure, landform plus view.

Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	None.	0
Aesthetic landscape	Excellent view of surrounding area and valuable open space for local community.	8
History of Earth Sciences	Surface processes that have produced the landscape.	6
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	Hillock in London Clay.	8
Sedimentology	None.	0
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	None.	0
Potential use	On-site interpretation (including view).	
Fragility	Well maintained.	
Current Site Value		
Community	Space used by local community every day.	10
Education		4
Geodiversity value		
Potential LIGS: Good feature in park area well used by local community.		3

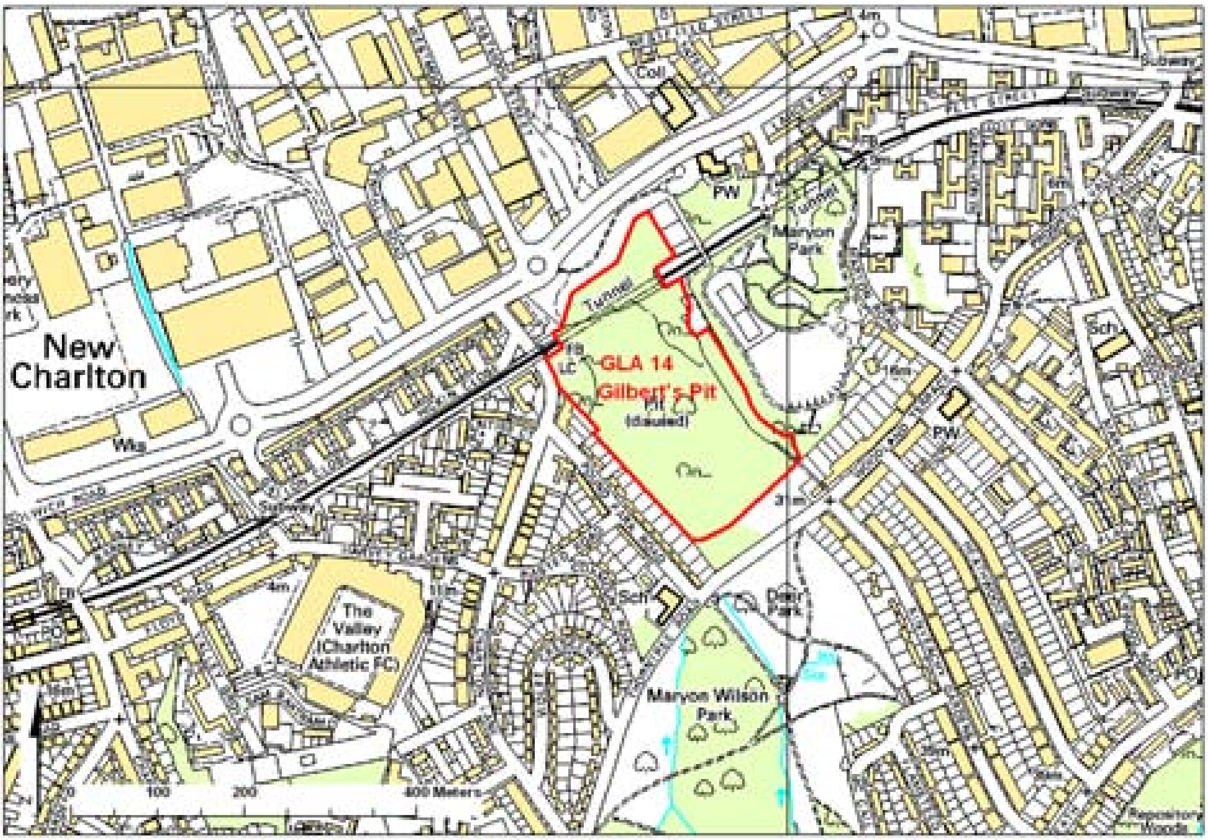
GLA 13 Friday Hill

View from hilltop of surrounding area

GLA 14 Gilbert's Pit

Grid Reference: TQ 418 786	Site Type: Former quarry works
Site Area (hectares): 5.35	Current use: Private (within recreational land)
Site ownership: London Borough of Greenwich	Borough: London Borough of Greenwich
Field surveyor: Joanna Brayson	Date: 3rd January 2008
Current geological designations: SSSI	Other scientific:

GLA 14



Stratigraphy and Rock Types

Time Unit: Paleocene/Eocene	Rock Unit: Harwich Formation, Thames Group
Rock Type: Sand and gravel	Details: Glauconitic sandy clays and very fine-grained glauconitic sands; marine fauna, locally brackish.
Time Unit: Paleocene	Rock Unit: Woolwich and Reading Formations, Lambeth Group
Rock Type: Sand and gravel	Details: Glauconitic sands overlain by grey clays and sands with Brackish fauna and interleaved red and variegated clays and sands.
Time Unit: Paleocene	Rock Unit: Thanet Sand Formation
Rock Type: Sand	Details: Glauconite-coated, nodular flint at base, overlain by pale yellow-brown, fine-grained sand that can be clayey and glauconitic. Rare calcareous or siliceous sandstones. Not now visible without digging.

Site Description

Gilbert's Pit provides one of the most complete sections through Palaeogene beds in the Greater London area. It forms a key Tertiary site for stratigraphic studies and is particularly important for a palaeographic reconstruction of the Woolwich and Reading Formations.

The site covers a disused pit cut into a sequence of Palaeogene sediments dating from approximately 55 millions years ago. Faces are present on the eastern and southern sides and rise to over 20 metres above the pit floor. A narrow causeway separates the eastern and southern exposures from an abutting face of a second pit at Maryon Park. The faces formerly provided a sequence from the Chalk, through the overlying Thanet Sand Formation and Woolwich Formation. Now only the Lambeth Group and capping of Blackheath Beds are visible. Some of the beds are highly fossiliferous, yielding mollusc, rare fish, plant and reptile remains. The Woolwich Formation in particular is noted for an abundant but very low-diversity brackish water molluscan fauna. These beds also contain a number of named subdivisions which include the Woolwich Shell Bed and Striped Loams (Leaf-bed of Lewisham).

The site has attracted scientific study for over 120 years and a substantial amount of literature has been published on the various geological features present. The fossil fauna has been described in particular detail.		
Assessment of Site Value		
Geodiversity topic: Palaeontology; sedimentology; lithostratigraphy.		
Access and Safety		
Aspect	**Description**	
Safety of access	Access to actual site is restricted but site can be viewed from footpaths adjacent to fenced off area.	
Safety of exposure	Exposure unstable and steep.	
Permission to visit	Entry to fenced off area via Greenwich Greenspace Ranger. Gate at North end of site.	
Current condition	Vegetation and slumping obscure the faces of the pit.	
Current conflicting activities	Lack of maintenance.	
Restricting conditions	Controlled access.	
Nature of exposure	Old pit faces, fenced off, with information board.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Many	8
Aesthetic landscape	Highest point of site provides excellent view over much of Greater London. Also part of the Green-chain network of footpaths.	7
History of Earth Sciences	Environment of deposition.	6
Economic geology	Sand from the pit was used for glass making and for the Woolwich Arsenal.	5
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Various formations – sedimentary environments.	8
Palaeontology	Highly fossiliferous beds.	8
Igneous/mineral/ Metamorphic Geology		0
Structural Geology		0
Lithostratigraphy	Succession of formations at one site.	8
Potential use	Research; higher further education; school education; on-site interpretation; on-site geotrail.	
Fragility	Natural overgrowing; geohazard; weathering/erosion.	
Current Site Value		
Community	Site passed by on a daily basis.	10
Education	Particularly important for engineers to learn about the nature of the Lambeth Group.	8
Geodiversity value		
SSSI: Excellent exposure of several lithologies with economic history. Information signs already present. Great potential for research and site improvement allowing further uses.		8

GLA 14 Gilbert's Pit

Slumped material viewed from top of site

Information sign in front of slumped material

GLA 15 Hainault Forest Country Park

Grid Reference: TQ 475 926	Site Type: Natural exposure
Site Area (hectares): 119.45	Current use: Recreational land
Site ownership: London Borough of Redbridge	Borough: London Borough of Redbridge
Field surveyor: Joanna Brayson	Date: 29th January 2008
Current geological designations:	Other scientific:

Site Map

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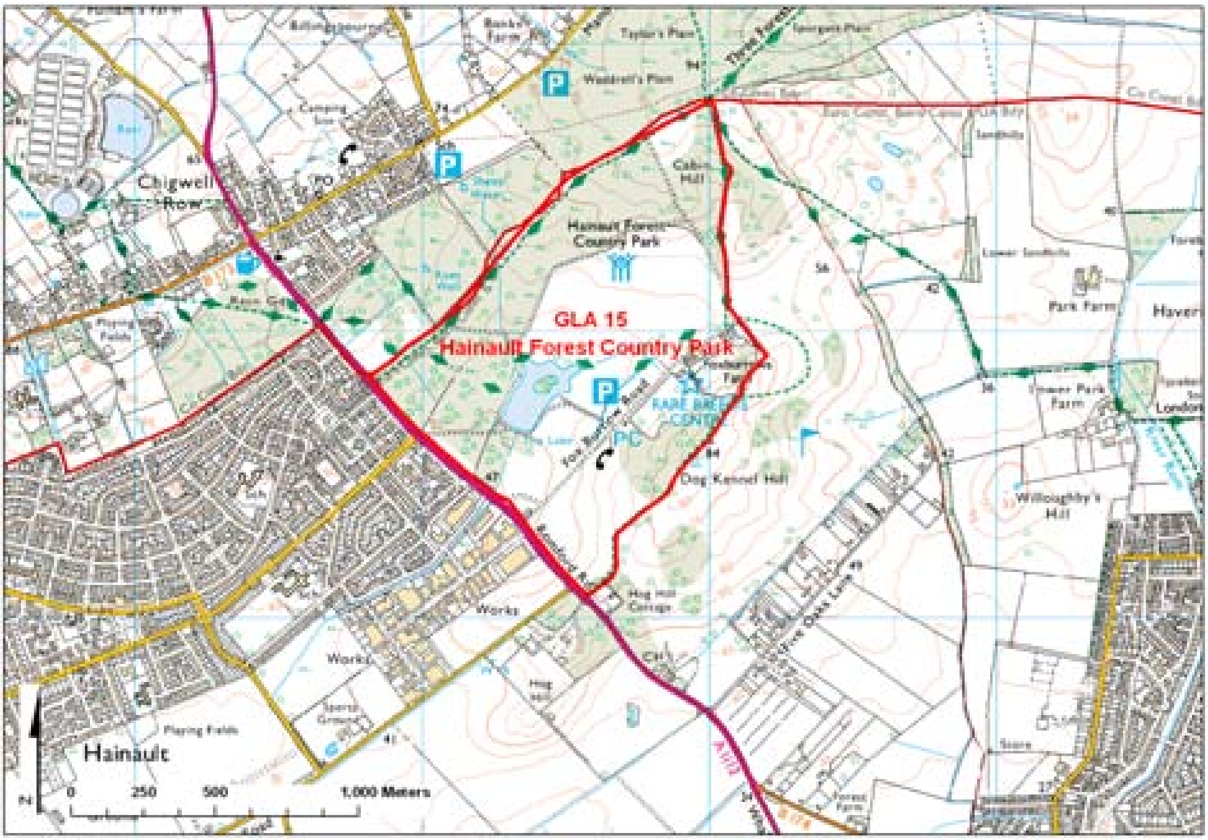

Stratigraphy and Rock Types

Time Unit: Quaternary	Rock Unit: Head
Rock Type: Clay, silt, sand and gravel	Details: Polymict deposit comprising poorly sorted and poorly stratified deposits formed mostly by solifluction and/or hillwash and soil creep.
Time Unit: Quaternary	Rock Unit: Lowestoft Formation, Albion Glacigenic Group
Rock Type: Till	Details: Chalky till, together with outwash sands and gravels, silts and clays. The till is characterised by its chalk and flint content.
Time Unit: Eocene	Rock Unit: Claygate Member, London Clay Formation, Bagshot sand
Rock Type: Sand, silt and clay	Details: Interbedded fine-grained sand, silt and clay.
Time Unit: Eocene	Rock Unit: London Clay Formation
Rock Type: Clay, silt, sand	Details: Fine, sandy, silty clay/clayey silt. Glauconitic at base.

Site Description

Large public park showing the geomorphology of Claygate Member capped London Clay.

Assessment of Site Value

Geodiversity topic: Geomorphology; Lithostratigraphy.

Access and Safety

Aspect	**Description**
Safety of access	Large open space with footpaths, some suitable for wheelchairs.

Safety of exposure	No specific exposure.	
Permission to visit	Open access, check with park rangers before group visits.	
Current condition	Well maintained as open space.	
Current conflicting activities	None.	
Restricting conditions	None.	
Nature of exposure	No specific exposure – geomorphology.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	None.	0
Aesthetic landscape	Valuable open space.	8
History of Earth Sciences	Weathering and erosion of London Clay Formation/Claygate member to current landscape.	4
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	Landscape in relation to underlying geology.	6
Sedimentology	Underlying geology.	4
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Relationship between the London Clay and the Claygate Member.	6
Potential use	Higher further education; school education; on-site interpretation; on-site geotrail.	
Fragility	Weathering/erosion; natural overgrowing.	
Current Site Value		
Community	Site well used by local people for dog walking, jogging, family outings etc.	10
Education		4
Geodiversity value		
Potential LIGS: Good feature in country park very well used by local community.		4

GLA 15 Hainault Forest Country Park

View of hills topped with Claygate Member, London Clay Formation

GLA 16 Hale End London Clay Hillock

Grid Reference: TQ 388 921	Site Type: Natural landform
Site Area (hectares): 20.45	Current use: Urban area
Site ownership: Urban area	Borough: London Borough of Waltham Forest
Field surveyor: Joanna Brayson	Date: 3rd January 2008
Current geological designations:	Other scientific:

Site Map

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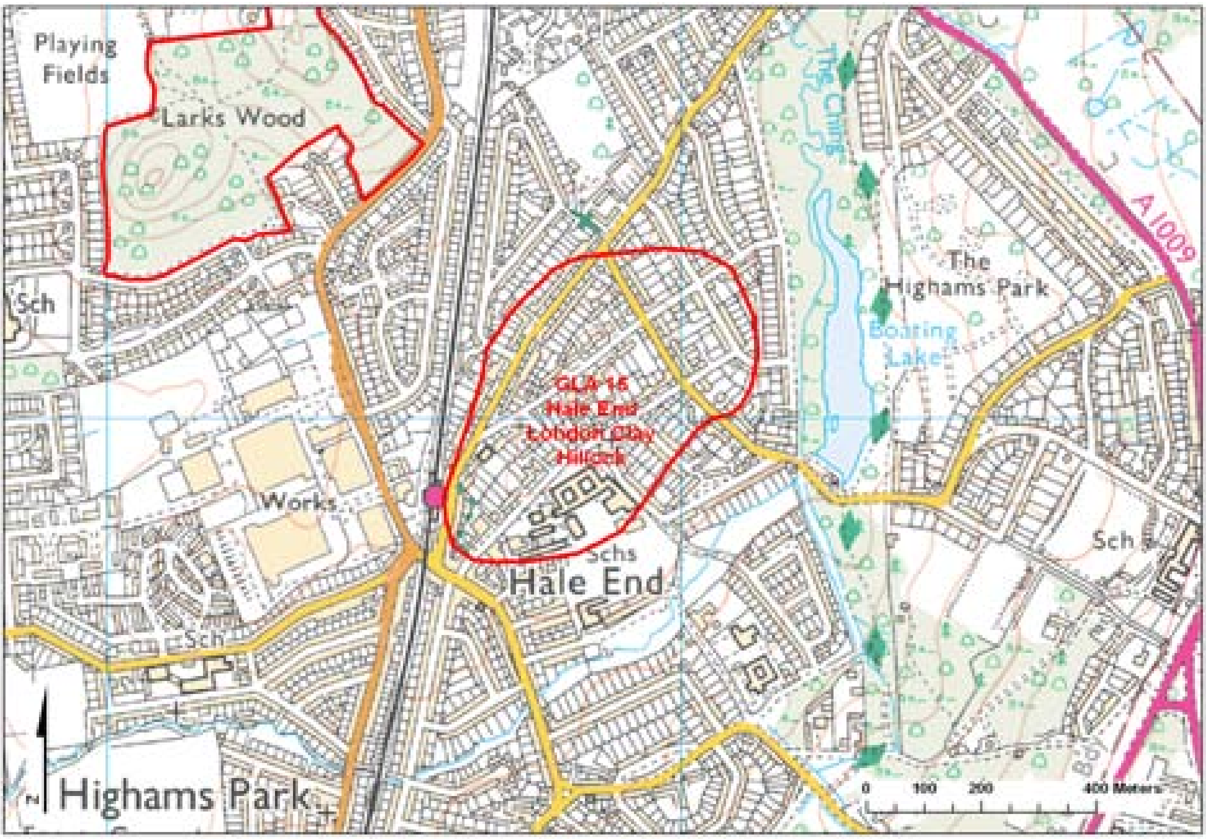

Stratigraphy and Rock Types

Time Unit: Eocene	Rock Unit: London Clay Formation
Rock Type: Clay, silt, sand	Details: Fine, sandy, silty clay/clayey silt. Glauconitic at base.

Site Description

London clay hillock in urban area.

Assessment of Site Value

Geodiversity topic: Geomorphology.

Access and Safety

Aspect	Description
Safety of access	Viewed from side of road.
Safety of exposure	N/a.
Permission to visit	Urban area – open access to roads.
Current condition	Developed but feature visible.
Current conflicting activities	Housing.
Restricting conditions	None.
Nature of exposure	Landform.

Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	None.	0
Aesthetic landscape	Provides feature within urban area.	6
History of Earth Sciences	None.	0
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	London Clay hillock.	4
Sedimentology	None.	0
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	None.	0
Potential use	School education.	
Fragility	Development.	
Current Site Value		
Community	In urban area so used every day.	10
Education		4
Geodiversity value		
Potential LIGS: Good feature in urban area.		3

GLA 16 Hale End London Clay Hillock

London Clay Hillock in residential area

GLA 17 Happy Valley

Grid Reference: TQ 309 568	Site Type: Natural Landform
Site Area (hectares): 142.21	Current use: Recreational land
Site ownership: London Borough of Croydon	Borough: London Borough of Croydon
Field surveyor: Joanna Brayson	Date: 18th January 2008
Current geological designations:	Other scientific: SSSI (Bio)

Site Map

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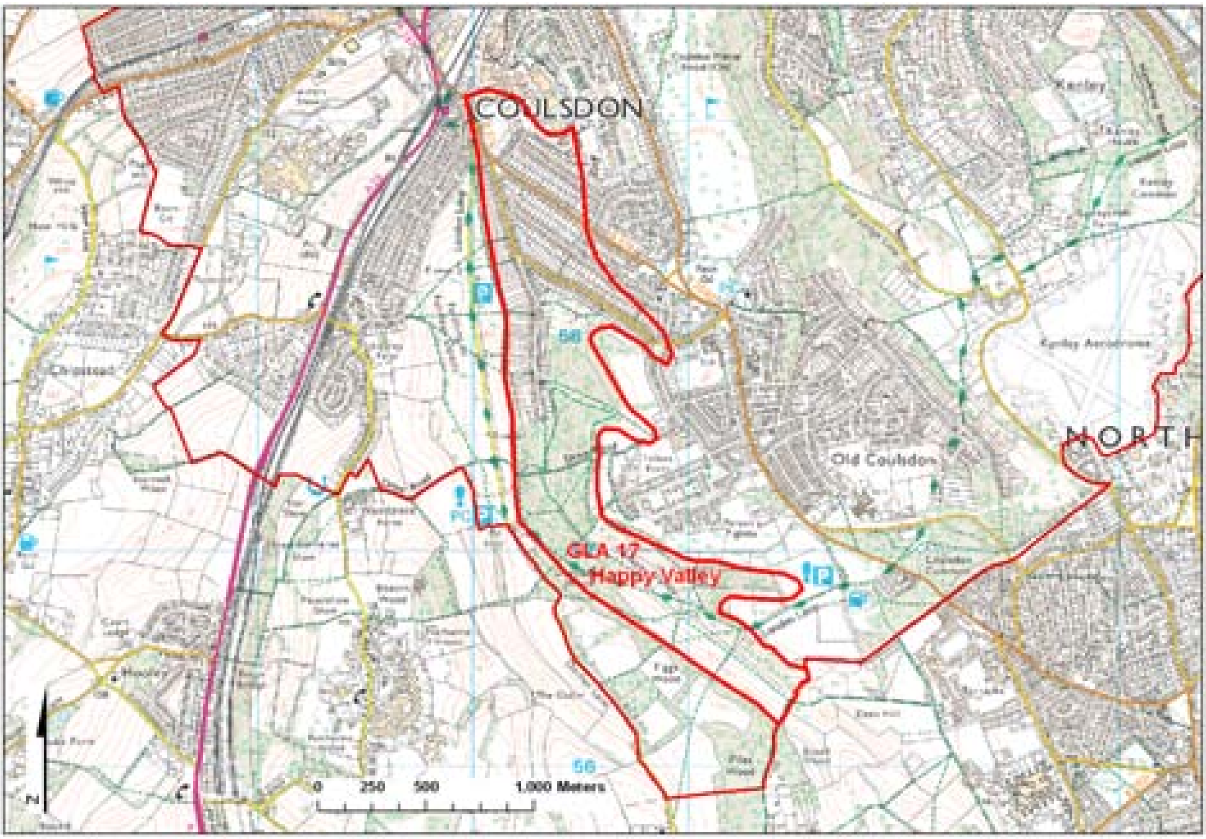

Stratigraphy and Rock Types

Time Unit: Cretaceous	Rock Unit: Lewes Nodular Chalk Formation, Seaford Chalk Formation and Newhaven Chalk Formation Undifferentiated, Chalk Group
Rock Type: Chalk	Details: Chalk

Site Description

Dry valley in the Chalk. Much of the valley is open access land with footpaths and woodland. Excellent views from the higher parts.

Assessment of Site Value

Geodiversity topic: Geomorphology.

Access and Safety

Aspect	**Description**
Safety of access	Footpaths cover area, some steep and slippy.
Safety of exposure	N/a.
Permission to visit	Open access.
Current condition	Well maintained as Happy Valley Park.
Current conflicting activities	None.
Restricting conditions	None.

Nature of exposure	Landform.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Nearby Saxon settlement.	4
Aesthetic landscape	Valuable open space with great views and topography.	8
History of Earth Sciences	Position of water courses.	6
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	Excellent example of a dry valley.	6
Sedimentology	None.	0
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	None.	0
Potential use	Research; school education; on-site interpretation.	
Fragility	Well maintained.	
Current Site Value		
Community	Well used by the local community for exercise/dog-walking etc.	10
Education		6
Geodiversity value		
Recommended RIGS: Excellent feature with good access and well used by local community.		6

GLA 17 Happy Valley

View of trees in bottom valley from valley side

GLA 18 Harrow Weald

Grid Reference: TQ 147 929	Site Type: Natural exposure
Site Area (hectares): 3.52	Current use: Private country
Site ownership: Shoots Garden Centre	Borough: London Borough of Harrow
Field surveyor: Joanna Brayson	Date: 22nd February 2008
Current geological designations: SSSI	Other scientific:

Site Map

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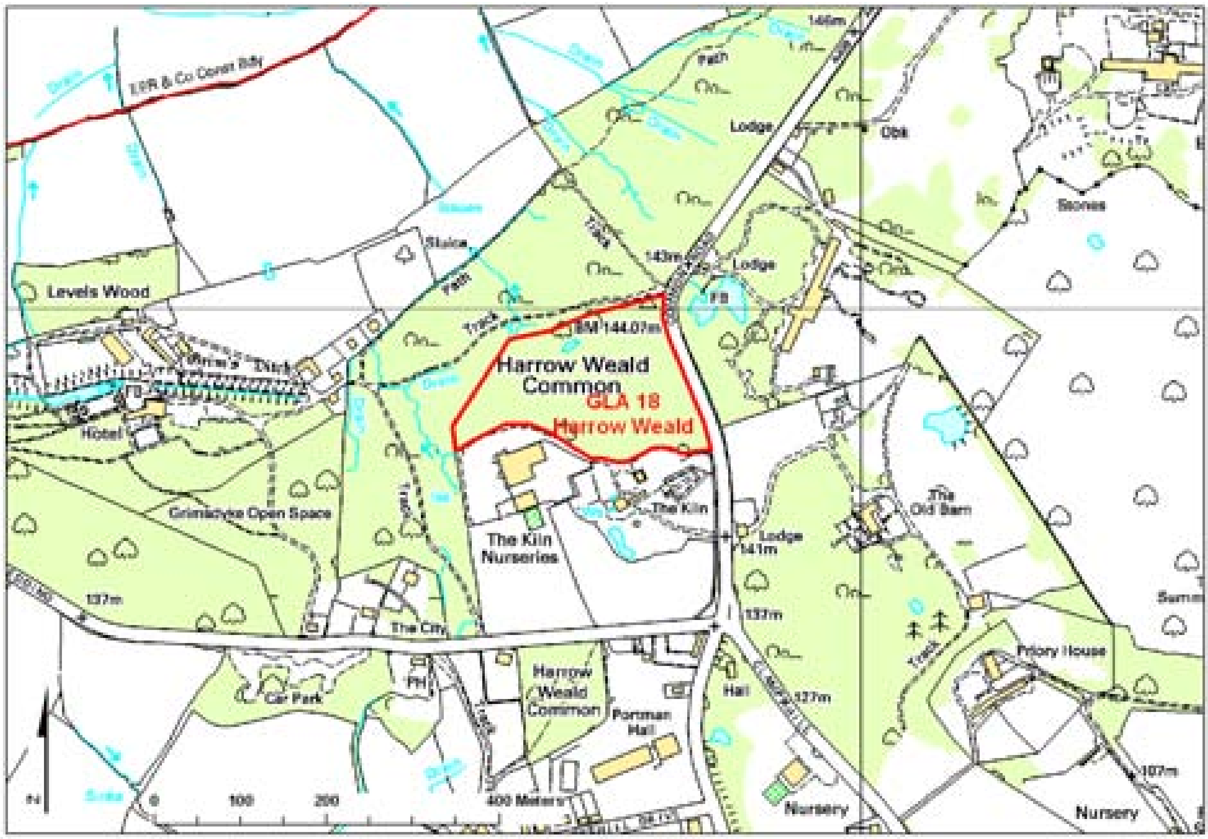

Stratigraphy and Rock Types

Time Unit: Pleistocene	Rock Unit: Stanmore Gravel Formation, Dunwich Group
Rock Type: Sand and gravel	Details: Gravel and sand, clayey near base. Gravel mostly composed of flints, up to 150mm in diameter, with a little quartz, quartzite and Lower Greensand chert in the fine fractions. Matrix of orange-brown, pale grey, red mottled clay and sandy clay, with pockets of coarse sand. Locally with layers of silt, clay or peat. Interpreted as offshore or beach gravels (Ellison et al 2004), or possibly fluvial (Bridgland 1994).
Time Unit: Eocene	Rock Unit: Claygate Member, London Clay Formation
Rock Type: Sand, silt and clay	Details: Interbedded fine-grained sand, silt and clay.

Site Description

Harrow Weald is a small but important geological site which exhibits the most complete exposure of the Stanmore Gravel Formation overlying the Claygate Member of the London Clay. The Stanmore Gravel Formation is of uncertain origin and this has been the subject of much controversy over the past century. Recent research has cast doubt on their marine origin which was inferred by most early workers. The Harrow Weald section is important as a key site on which to base further studies of these deposits.

Assessment of Site Value

Geodiversity topic: Lithostratigraphy; sedimentology.

Access and Safety

Aspect	Description
Safety of access	Site accessed from garden centre access road, be aware of vehicles.

Safety of exposure	Wooded area, take care – rough under foot.	
Permission to visit	Contact Shoots Garden Centre on 020 8954 4628. www.shootsuk.com	
Current condition	Neglected.	
Current conflicting activities	None.	
Restricting conditions	Access.	
Nature of exposure	Exposure in wooded area.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Much research has been done here over the last century.	6
Aesthetic landscape	Not accessible to public but is adjacent to open access area.	4
History of Earth Sciences	Marine origin versus fluvial.	6
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Depositional environment (marine/fluvial).	7
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology		0
Lithostratigraphy	Relationship between superficial deposits and bedrock.	6
Potential use	Research; higher further education.	
Fragility		
Current Site Value		
Community	Not accessible.	0
Education		0
Geodiversity value		
SSSI: Exposures of units valuable for research but with poor access.		6

GLA 18 Harrow Weald

Woodland setting

GLA 19 Hornchurch Cutting

Grid Reference: TQ 547 874	Site Type: Artificial section
Site Area (hectares): 1.57	Current use: On railway line
Site ownership: Network Rail	Borough: London Borough of Havering
Field surveyor: Joanna Brayson	Date: 3rd January 2008
Current geological designations: SSSI; GCR	Other scientific:

Site Map

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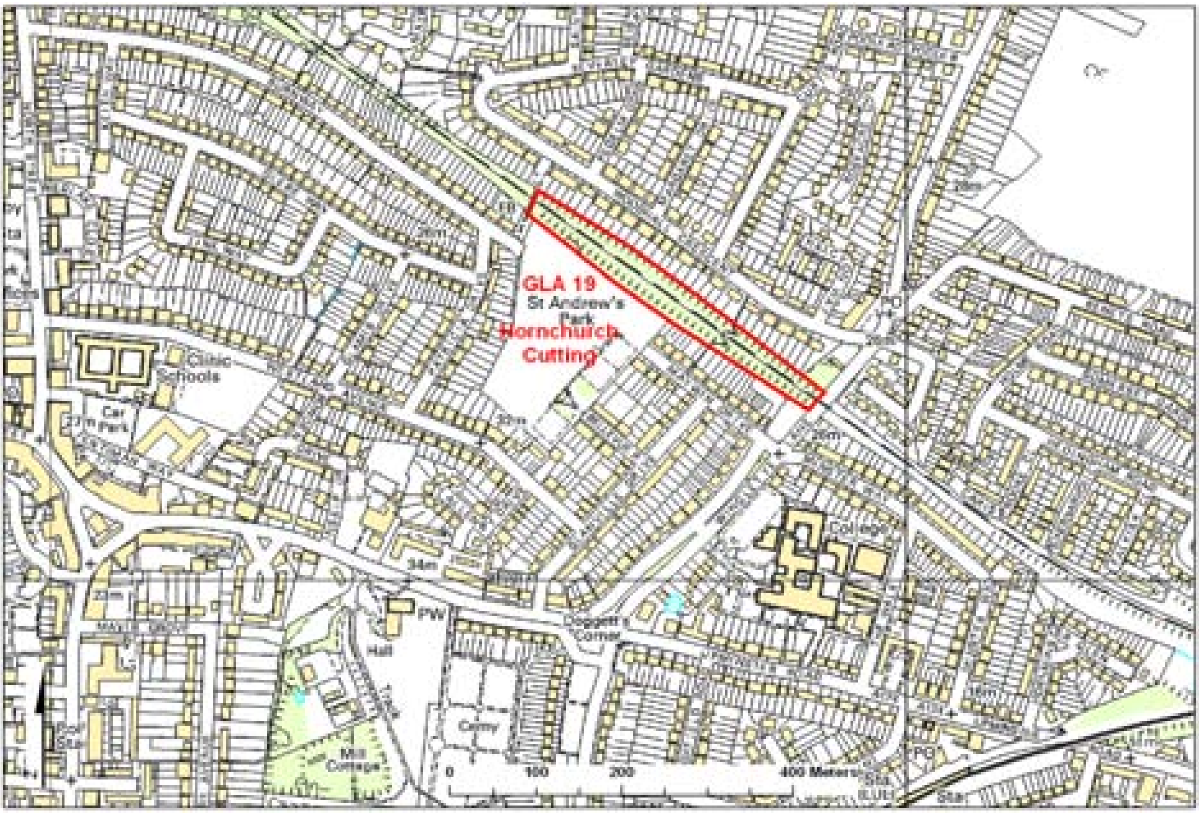

Stratigraphy and Rock Types

Time Unit: Pleistocene	Rock Unit: Black Park Gravel Formation
Rock Type: Sand and Gravel	Details: Sand and gravel, with possible lenses of silt, clay or peat. Matrix supported gravel with thin tabular cross-bedded sand channels. Gravel assemblage is characterised by abundant flint (75-89%), sparse rounded flint (3-9%), sparse vein quartz (4-10%) and sparse quartzite (1-6%).
Time Unit: Eocene	Rock Unit: London Clay Formation
Rock Type: Clay, silt, sand	Details: Fine, sandy, silty clay/clayey silt. Glauconitic at base.

Site Description

Hornchurch Cutting provides unique sections through a series of deposits which are of great stratigraphical importance for studies of the Pleistocene. In particular the site is of considerable significance for correlating the formation of the Thames terrace sequence with the glacial stratigraphy of Southern Britain.

The sections revealed by the cutting show a channel cut into the London Clay and infilled with a glacial till – the Hornchurch Till – laid down at the southern extremity of the Anglian ice sheet. This till is overlain by the Black Park Gravel (the first post-diversionary terrace of the Thames). Hornchurch is the only area where glacial deposits are known to come into contact with the Lower Thames Terrace gravels. This relationship, first demonstrated when the railway cutting was excavated in the last century, indicates that the highest terrace in the Hornchurch area is more recent than the most extensive glaciation of Eastern England. However, further research is urgently required to clarify this picture. The Hornchurch Cutting is thus clearly a site of prime stratigraphic and also historical importance.

Assessment of Site Value

Geodiversity topic: Lithostratigraphy; sedimentology; geomorphology.

Access and Safety

Aspect	Description	
Safety of access	Access to site itself would require full railway safety procedures.	
Safety of exposure	Access to site itself would require full railway safety procedures.	
Permission to visit	Contact railway owner.	
Current condition	Overgrown but maintained as part of railway network.	
Current conflicting activities	Railway.	
Restricting conditions	On railway.	
Nature of exposure	Railway cutting.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Cutting excavated last century – gave insights into processes.	8
Aesthetic landscape	None.	0
History of Earth Sciences	Cutting allowed timings of glaciations/river evolution to be suggested at an early time in investigations.	5
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	Relationship between tills and terrace gravels.	8
Sedimentology	Depositional environment and provenance of sediments.	7
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Allows correlation of terrace gravels and till.	8
Potential use	Research.	
Fragility	Overgrowing.	
Current Site Value		
Community	None.	0
Education	Not suitable for educational visits.	0
Geodiversity value		
SSSI: Exposure of rarely seen boundary between tills and terrace gravels. Excellent site for research but very difficult access.		6

GLA 19 Hornchurch Cutting

View from footbridge

GLA 20 Horsenden Hill

Grid Reference: TQ 162 844	Site Type: Natural exposure
Site Area (hectares): 43.15	Current use: Recreational land
Site ownership: London Borough of Ealing	Borough: London Borough of Ealing
Field surveyor: Joanna Brayson	Date: 5th December 2007
Current geological designations:	Other scientific:

Site Map

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Stratigraphy and Rock Types

Time Unit: Pleistocene	Rock Unit: Dollis Hill Gravel Formation
Rock Type: Sand and gravel	Details: Gravel, sandy and clayey in part, with some laminated silty beds. Sand and gravel, locally with lenses of silt, clay or peat and organic material.
Time Unit: Eocene	Rock Unit: Claygate Member, London Clay Formation
Rock Type: Sand, silt and clay	Details: Interbedded fine-grained sand, silt and clay.
Time Unit: Eocene	Rock Unit: London Clay Formation
Rock Type: Clay, silt, sand	Details: Fine, sandy, silty clay/clayey silt. Glauconitic at base.

Site Description

This site is a hill in the London Clay capped by the Claygate Member and Dollis Hill Gravel Formation. The Dollis Hill Gravel is a river terrace deposit from the pre-diversionary Thames. It forms hill-caps that decline in elevation northwards, indicating deposition in south-bank tributaries of the ancestral Thames. The gravel is composed of angular flint (58%), rounded flint (32%), quartz/quartzite (1.8%) and Lower Greensand chert (7%).

Horsenden Hill is the highest point in North West London with excellent views of the surrounding area. There are information boards explaining the view, this would be an ideal position to explain the geological landscape.

Assessment of Site Value

Geodiversity topic: Geomorphology; lithostratigraphy; sedimentology.

Access and Safety

Aspect	**Description**

Safety of access	Footpaths from car park up hill, through woods and some fields with livestock – care should be taken.	
Safety of exposure	Mostly adjacent to footpaths, some slippery due to clay nature of London Clay.	
Permission to visit	Open access, contact the ranger's office for group visits.	
Current condition	Outcrops are small, mostly grassland or woods.	
Current conflicting activities	None.	
Restricting conditions	None.	
Nature of exposure	Small exposures in fields and in woodland.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Site of an ancient hillfort.	8
Aesthetic landscape	Excellent views of surrounding area from this highest point in north-west London (site of a trig point).	8
History of Earth Sciences	Composition of gravel – provenance of material.	4
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	Formation of hill.	4
Sedimentology	Sedimentary environments and provenance.	4
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Relationship between bedrock and terrace gravels.	4
Potential use	Research; on-site interpretation; on-site geotrail.	
Fragility	Natural overgrowing.	
Current Site Value		
Community	Used daily by local community.	10
Education		6
Geodiversity value		
Recommended RIGS: Small exposures of units accompanied by good geomorphological features and good access.		5

GLA 20 Horsenden Hill

View of local area with information board

GLA 21 Islington Terrace Gravels

Grid Reference: TQ 315 838	Site Type: Natural exposure
Site Area (hectares): 0.27	Current use: Urban
Site ownership: London Borough of Islington	Borough: London Borough of Islington
Field surveyor: Joanna Brayson	Date: 30th January 2008
Current geological designations:	Other scientific:

Site Map

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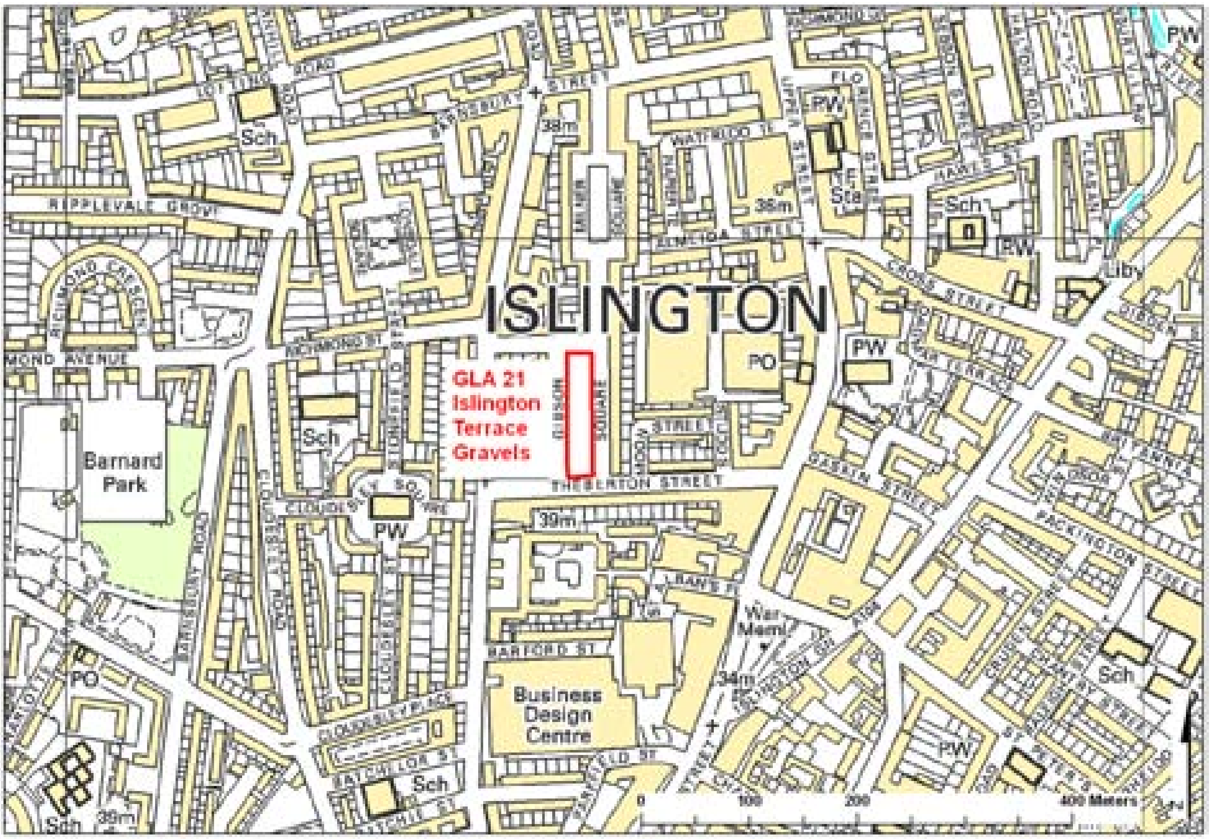

Stratigraphy and Rock Types

Time Unit: Pleistocene	Rock Unit: Boyn Hill Gravel Formation
Rock Type: Sand and gravel	Details: Sand and gravel, with possible lenses of silt, clay or peat. Poorly sorted, straffed angular flint (77-81%), sparse rounded flint (5-10%), sparse vein quartz (4-7%), sparse quartzite (1.5-5%), sparse Greensand chert (2.5-4%) and less than 1% of other types.

Site Description

Small open space in urban area with some evidence of Boyn Hill terrace gravels in flower beds – possible location for information board or research.

Assessment of Site Value

Geodiversity topic: Sedimentology.

Access and Safety

Aspect	**Description**
Safety of access	Flat area with footpath.
Safety of exposure	Adjacent to footpath.
Permission to visit	Open access.
Current condition	Landscaped.
Current conflicting activities	None.

Restricting conditions	None.	
Nature of exposure	Exposure in flower beds of small park area.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	None.	0
Aesthetic landscape	Valuable green space in urban area.	6
History of Earth Sciences	None.	0
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Depositional environment of terrace gravels.	4
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Distribution of terrace gravels.	4
Potential use	Research; on-site interpretation.	
Fragility		
Current Site Value		
Community	Valuable green space.	8
Education		2
Geodiversity value		
Potential LIGS: Poor site but potential site of information for local community.		2
GLA 21 Islington Terrace Gravels		
No photographs taken.		

GLA 22 Keston Common

Grid Reference: TQ 417 638	Site Type: Natural exposure
Site Area (hectares): 11.82	Current use: Recreational land
Site ownership: London Borough of Bromley	Borough: London Borough of Bromley
Field surveyor: Joanna Brayson	Date: 30th November 2007
Current geological designations:	Other scientific: SSSI (Bio)

Site Map

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Stratigraphy and Rock Types

Time Unit: Paleocene/Eocene	Rock Unit: Harwich Formation, Thames Group
Rock Type: Sand and gravel	Details: Glauconitic sandy clays and very fine-grained glauconitic sands; marine fauna, locally brackish.

Site Description

Small exposures of Harwich Formation within woodland.

Assessment of Site Value

Geodiversity topic: Sedimentology; lithostratigraphy

Access and Safety

Aspect	Description
Road access & parking	Car park off main road.
Safety of access	Footpaths, some uneven, take care.
Safety of exposure	Autumn leaf cover leaves ground slippery in parts.
Permission to visit	Open access.
Current condition	Small exposures, leaf cover makes them hard to find.
Current conflicting activities	None.
Restricting conditions	None.

Nature of exposure	Small exposures in woodland.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	None.	0
Aesthetic landscape	Valuable green space used by local community.	6
History of Earth Sciences	None.	0
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Environment of deposition.	6
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Correlation of Harwich Formation.	5
Potential use	Research; on-site interpretation; higher further education.	
Fragility	Natural overgrowing; dumping.	
Current Site Value		
Community	Used daily by dog walkers etc	10
Education		6
Geodiversity value		
Recommended RIGS: Small exposures with adequate access. Good research potential.		5

GLA 22 Keston Common

Harwich Formation exposure

GLA 23 Loats Pit

Grid Reference: TQ 382 766	Site Type: Former quarry works
Site Area (hectares): 0.25	Current use: Urban area
Site ownership: London Borough of Lewisham	Borough: London Borough of Lewisham
Field surveyor: Joanna Brayson	Date: 5th February 2008
Current geological designations:	Other scientific: Borough grade 2

Site Map

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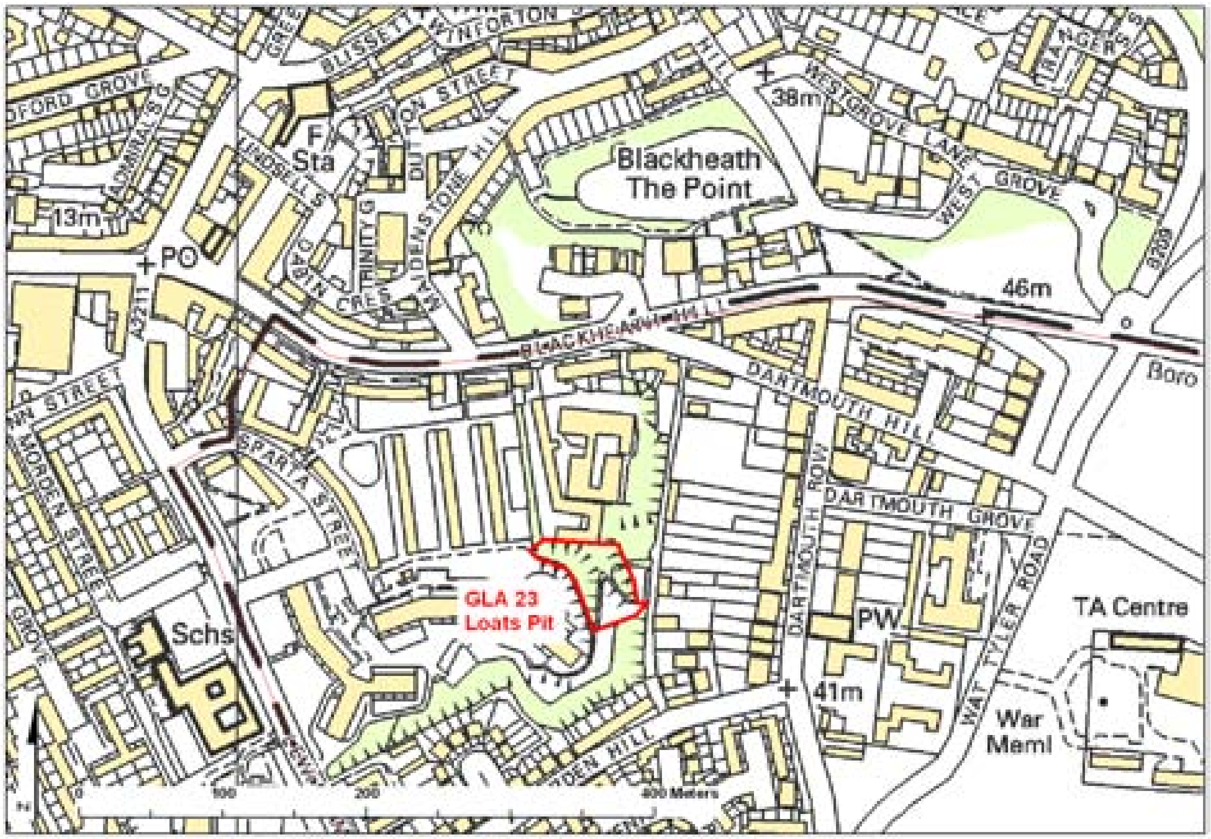

Stratigraphy and Rock Types

Time Unit: Paleocene	Rock Unit: Lambeth Group
Rock Type: Sand and gravel	Details: Glauconitic sands overlain by grey clays and sands with Brackish fauna and interleaved red and variegated clays and sands.
Time Unit: Paleocene	Rock Unit: Thanet Sand Formation
Rock Type: Sand	Details: Glauconite-coated, nodular flint at base, overlain by pale yellow-brown, fine-grained sand that can be clayey and glauconitic. Rare calcareous or siliceous sandstones.
Time Unit: Cretaceous	Rock Unit: Lewes Nodular Chalk Formation, Seaford Chalk Formation and Newhaven Chalk Formation Undifferentiated, Chalk Group
Rock Type: Chalk	Details: Chalk

Site Description

Cutting behind Lethbridge Estate.

Assessment of Site Value

Geodiversity topic: Lithostratigraphy; sedimentology.

Access and Safety

Aspect	Description
Safety of access	Steep hill with footpaths.
Safety of exposure	Felt unsafe alone but fine in groups.

Permission to visit	Open access.	
Current condition	Quite overgrown.	
Current conflicting activities	None.	
Restricting conditions	None.	
Nature of exposure	Cutting – old pit.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Old pit.	4
Aesthetic landscape	Provides a green backdrop to the estate.	6
History of Earth Sciences	Environments of deposition.	4
Economic geology	Old pit – chalk extracted.	4
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Depositional environments.	6
Palaeontology	Possibly in chalk.	4
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None	0
Lithostratigraphy	Relationship between different units.	6
Potential use	On-site interpretation.	
Fragility	Natural overgrowing.	
Current Site Value		
Community	Adjacent to housing estate, valuable green space.	**b**
Education		**4**
Geodiversity value		
Potential LIGS: Forms part of everyday landscape for community, good site for information board.		3

GLA 23 Loat's Pit

Loat's Pit located at edge of estate

GLA 24 Old Gravel Pit

Grid Reference: TQ 385 763	Site Type: Former quarry works
Site Area (hectares): 0.84	Current use: Recreational land
Site ownership: London Borough of Lewisham	Borough: London Borough of Lewisham
Field surveyor: Joanna Brayson	Date: 5th February 2008
Current geological designations:	Other scientific:

Site Map

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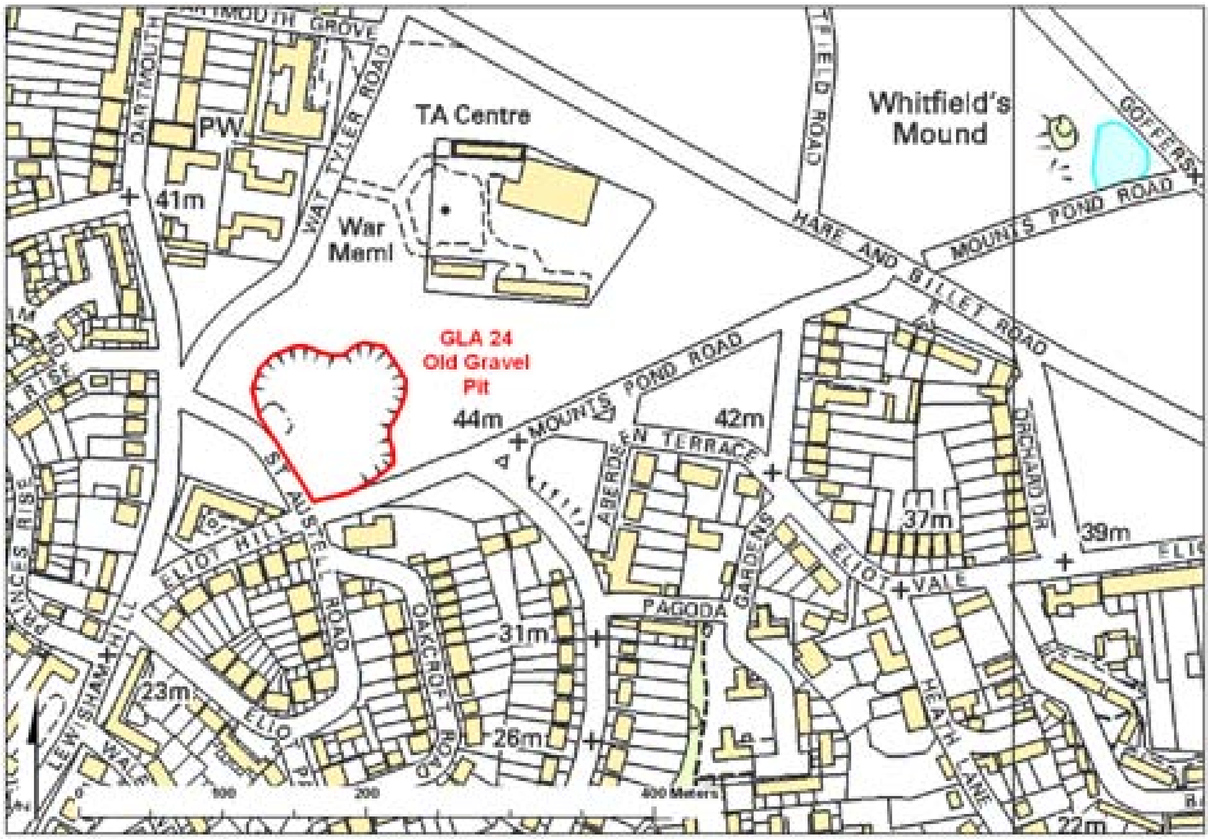

Stratigraphy and Rock Types

Time Unit: Paleocene/Eocene	Rock Unit: Harwich Formation, Thames Group
Rock Type: Sand and gravel	Details: Glauconitic sandy clays and very fine-grained glauconitic sands; marine fauna, locally brackish.
Time Unit: Paleocene	Rock Unit: Lambeth Group
Rock Type: Sand and gravel	Details: Glauconitic sands overlain by grey clays and sands with Brackish fauna and interleaved red and variegated clays and sands.

Site Description

Old gravel pit at the edge of open space in Blackheath.

Assessment of Site Value

Geodiversity topic: Lithostratigraphy; economic geology.

Access and Safety

Aspect	Description
Safety of access	Adjacent to small road, grassy area with no significant dangers.
Safety of exposure	Pit sides are short and grassed over, little risk of falling.
Permission to visit	Open access.
Current condition	Grassed over but shape visible.
Current conflicting activities	None.

Restricting conditions	None.	
Nature of exposure	Old grassed over pit.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Shown on 1896 OS Historic map as Old Gravel Pit.	8
Aesthetic landscape	Part of large open space.	6
History of Earth Sciences		0
Economic geology	Gravel extraction.	6
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	If excavation could be carried out, environment of deposition.	4
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Correlation with other units.	4
Potential use	On-site interpretation; research.	
Fragility	Natural overgrowing.	
Current Site Value		
Community	Valuable open space	8
Education		4
Geodiversity value		
Potential LIGS: Good example for economic history in local area.		2

GLA 24 Old Gravel Pit

Old Gravel Pit behind trees

GLA 25 Putney Heath

Grid Reference: TQ 235 735	Site Type: Natural exposure
Site Area (hectares): 35.30	Current use: Recreational land
Site ownership: London Borough of Wandsworth	Borough: London Borough of Wandsworth
Field surveyor: Joanna Brayson	Date: 31st January 2008
Current geological designations:	Other scientific:

Site Map

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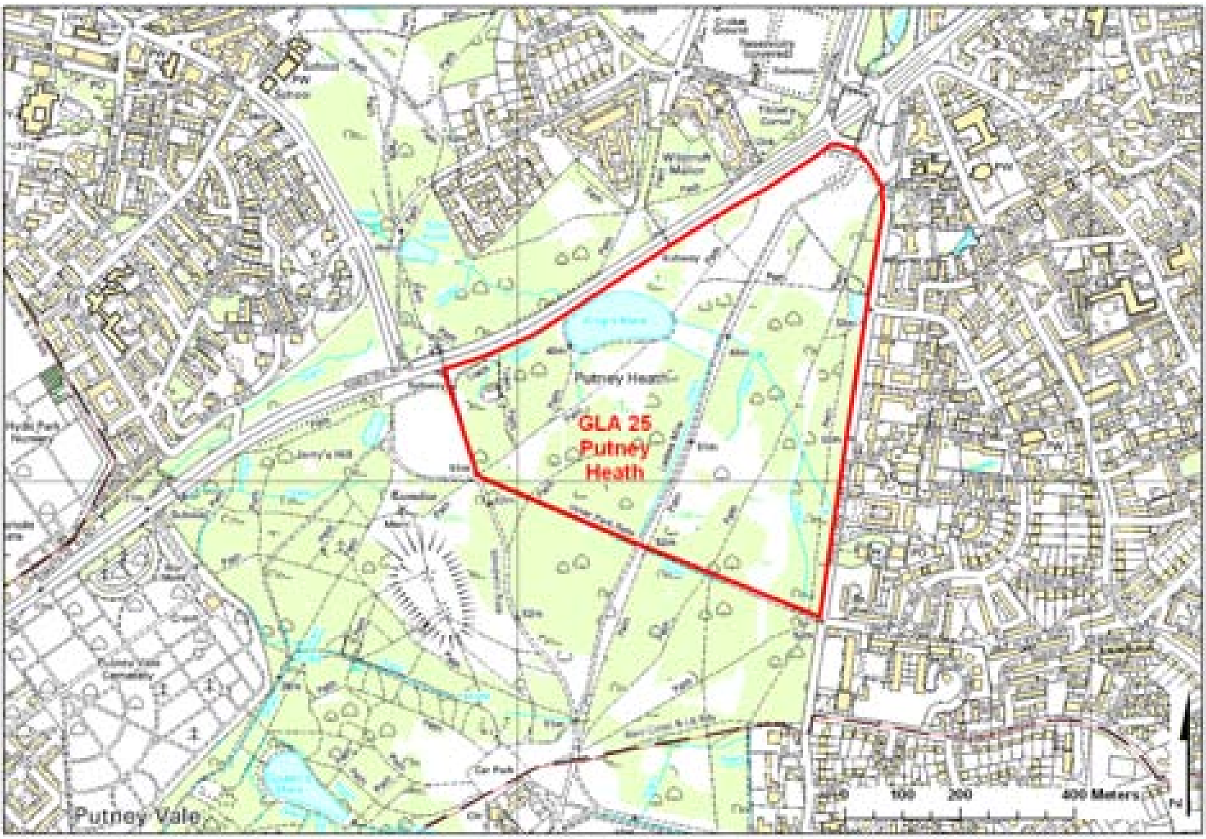


Stratigraphy and Rock Types

Time Unit: Pleistocene	Rock Unit: Black Park Gravel Formation
Rock Type: Sand and Gravel	Details: Sand and gravel, with possible lenses of silt, clay or peat. [Generic description]. Horizontally straffed, matrix supported gravel with thin tabular cross-bedded sand channels. Gravel assemblage is characterised by abundant flint (75-89%), sparse rounded flint (3-9%), sparse vein quartz (4-10%) and sparse quartzite (1-6%).
Time Unit: Eocene	Rock Unit: London Clay Formation
Rock Type: Clay, silt, sand	Details: Fine, sandy, silty clay/clayey silt. Glauconitic at base.

Site Description

Small exposures of Black Park Gravel (Thames river terrace) on the heath.

Assessment of Site Value

Geodiversity topic: Lithostratigraphy′ sedimentology.

Access and Safety

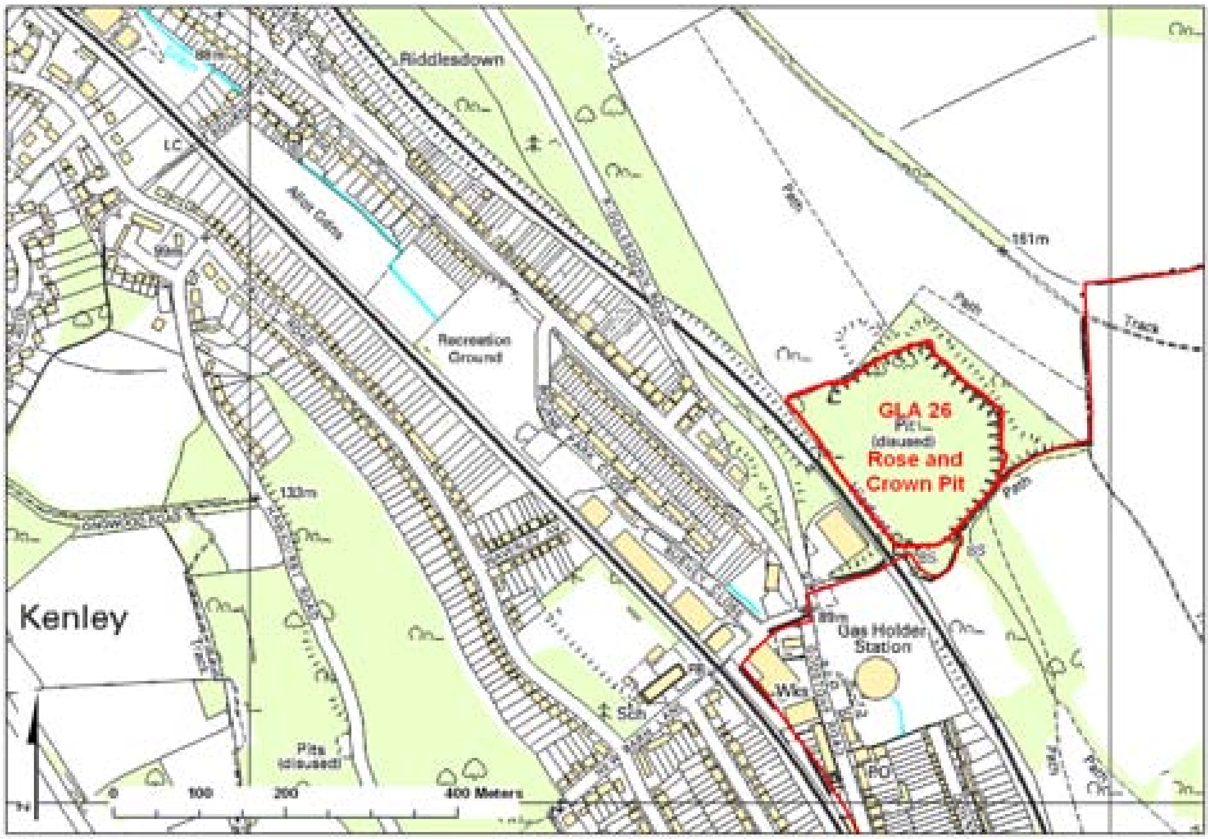
Aspect	Description
Safety of access	Footpaths, some rough.
Safety of exposure	Felt unsafe alone, fine in groups.
Permission to visit	Open access.

Current condition	Overgrown, some landscaping (paths etc).	
Current conflicting activities	None.	
Restricting conditions	None.	
Nature of exposure	Patchy exposures under bushes, in tracks.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations		
Aesthetic landscape	Part of large open space in urban area.	8
History of Earth Sciences		
Economic geology	None.	0
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Composition and depositional environment of gravels.	6
Palaeontology	None	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Relationship of terrace gravels and bedrock.	6
Potential use	On-site interpretation; research.	
Fragility	Natural overgrowing.	
Current Site Value		
Community	Valuable open space used daily.	10
Education		4
Geodiversity value		
Potential LIGS: Small exposures in large open area with good access.		3
GLA 25 Putney Heath		
No photographs taken		

GLA 26 Rose and Crown Pit

Grid Reference: TQ 338 594	Site Type: Former quarry works
Site Area (hectares): 3.66	Current use: Disused
Site ownership: City of London Corporation	Borough: London Borough of Croydon
Field surveyor: Joanna Brayson	Date: 11th February 2008
Current geological designations:	Other scientific:

Site Map



Stratigraphy and Rock Types

Time Unit: Cretaceous	Rock Unit: Lewes Nodular Chalk Formation, Seaford Chalk Formation and Newhaven Chalk Formation Undifferentiated, Chalk Group
Rock Type: Chalk	Details: Chalk

Site Description

Large abandoned chalk quarry (also called Riddlesdown Quarry) in area called Riddlesdown. Excellent exposures of chalk, marl and dissolution pipes.

Assessment of Site Value

Geodiversity topic: Lithostratigraphy; sedimentology.

Access and Safety

Aspect	Description
Safety of access	Access is restricted – fence surrounds site. Close to railway line, care should be taken. Quarry visible from footpaths surrounding site – these are steep and slippery in places.
Safety of exposure	Quarry contains steep faces and slumped material.
Permission to visit	Access via ranger/council (Tandridge district council 01883 722000).
Current condition	Partially overgrown but faces clear.
Current conflicting activities	None.

Restricting conditions	Fenced off, safety concerns.	
Nature of exposure	Disused quarry.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Roman road built across downs. Saxon burial sites close by.	8
Aesthetic landscape	Extremely well used surrounding area – chalk downlands.	8
History of Earth Sciences		
Economic geology	Chalk quarry.	8
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Chalk succession – environment of deposition.	8
Palaeontology	Chalk Stratigraphy determined in part by macro and micro palaeontology.	8
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Chalk succession.	8
Potential use	Research; higher further education; school education; on-site interpretation; on-site geotrail.	
Fragility	Natural overgrowing; geohazard.	
Current Site Value		
Community	Valuable open space, used daily	10
Education	Good site for fieldwork, with appropriate safety.	8
Geodiversity value		
Recommended RIGS: Excellent outcrop with great potential for research and education. Difficult access.		7

GLA 26 Rose and Crown Pit

View of north east quarry face

GLA 27 Sundridge Park Golf Course 1

Grid Reference: TQ 422 705	Site Type: Former quarry works
Site Area (hectares): 1.89	Current use: Recreational land
Site ownership: Sundridge Park Golf Club	Borough: London Borough of Bromley
Field surveyor: Joanna Brayson	Date: 3rd January 2008
Current geological designations:	Other scientific:

Site Map

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Stratigraphy and Rock Types

Time Unit: Paleocene/Eocene	Rock Unit: Harwich Formation, Thames Group
Rock Type: Sand and gravel	Details: Glauconitic sandy clays and very fine-grained glauconitic sands; marine fauna, locally brackish.
Time Unit: Paleocene	Rock Unit: Lambeth Group
Rock Type: Sand and gravel	Details: Glauconitic sands overlain by grey clays and sands with Brackish fauna and interleaved red and variegated clays and sands.
Time Unit: Paleocene	Rock Unit: Thanet Sand Formation
Rock Type: Sand	Details: Glauconite-coated, nodular flint at base, overlain by pale yellow-brown, fine-grained sand that can be clayey and glauconitic. Rare calcareous or siliceous sandstones.

Site Description

Old pit on golf course which used to have outcrops of the Lambeth Group containing *Ostrea* and *Ophimorpha*. Site now over grown and recently planted with trees.

Assessment of Site Value

Geodiversity topic: Palaeontology; sedimentology; lithostratigraphy.

Access and Safety

Aspect	**Description**
Safety of access	Danger from flying golf balls and golf buggies.
Safety of exposure	In wooded area, vegetation makes access difficult.
Permission to visit	From golf club house – helpful but not enthusiastic.

Current condition	Overgrown.	
Current conflicting activities	Tree planting.	
Restricting conditions	Access.	
Nature of exposure	Overgrown old pit.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations		
Aesthetic landscape	Part of woodland shielding golf course from railway line (in cutting).	6
History of Earth Sciences		
Economic geology	Old pit.	6
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Depositional environments.	6
Palaeontology	*Ostrea, Ophimorpha* found.	6
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Relationship of units in pit.	6
Potential use	Research	
Fragility	Natural overgrowing; tree planting.	
Current Site Value		
Community	Only as paying customers.	0
Education	None.	0
Geodiversity value		
Potential LIGS: Little exposure with poor access, possible research use.		4

GLA 27 Sundridge Park Golf Course 1

Overgrown pit, trees recently planted

GLA 28 Sundridge Park Golf Course 2

Grid Reference: TQ 419 707	Site Type: Natural exposure
Site Area (hectares): 1.19	Current use: Recreational land
Site ownership: Sundridge Park Golf Club	Borough: London Borough of Bromley
Field surveyor: Joanna Brayson	Date: 17 January 2008
Current geological designations:	Other scientific:

Site Map

Stratigraphy and Rock Types

Time Unit: Paleocene/Eocene	Rock Unit: Harwich Formation, Thames Group
Rock Type: Sand and gravel	Details: Glauconitic sandy clays and very fine-grained glauconitic sands; marine fauna, locally brackish.
Time Unit: Paleocene	Rock Unit: Lambeth Group
Rock Type: Sand and gravel	Details: Glauconitic sands overlain by grey clays and sands with Brackish fauna and interleaved red and variegated clays and sands.
Time Unit: Paleocene	Rock Unit: Thanet Sand Formation
Rock Type: Sand	Details: Glauconite-coated, nodular flint at base, overlain by pale yellow-brown, fine-grained sand that can be clayey and glauconitic. Rare calcareous or siliceous sandstones.

Site Description

Conglomerate blocks of the Harwich Formation in old quarry, situated in woodland on golf course.

Assessment of Site Value

Geodiversity topic: Lithostratigraphy; sedimentology.

Access and Safety

Aspect	Description
Safety of access	Danger from flying golf balls and golf buggies.
Safety of exposure	In wooded area, vegetation makes access difficult.
Permission to visit	From golf club house – helpful but not enthusiastic.
Current condition	Overgrown.

Current conflicting activities		
Restricting conditions	Access.	
Nature of exposure	Small exposures in woodland on golf course.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations		
Aesthetic landscape	Woodland on golf course.	6
History of Earth Sciences		
Economic geology	Old quarry.	6
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Composition of conglomerate – provenance.	7
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Correlation of Harwich Formation.	6
Potential use	Research.	
Fragility	Natural overgrowing.	
Current Site Value		
Community	Only for paying customers.	0
Education	None.	0
Geodiversity value		
Potential LIGS: Small exposures with poor access.		4

GLA 28 Sundridge Park Golf Course 2

Overgrown small quarry

GLA 29 The Gravel Pits

Grid Reference: TQ 084 913	Site Type: Former quarry works
Site Area (hectares): 5.47	Current use: Recreational land
Site ownership: London Borough of Hillingdon	Borough: London Borough of Hillingdon
Field surveyor: Joanna Brayson	Date: 4th January 2008
Current geological designations:	Other scientific:

Site Map

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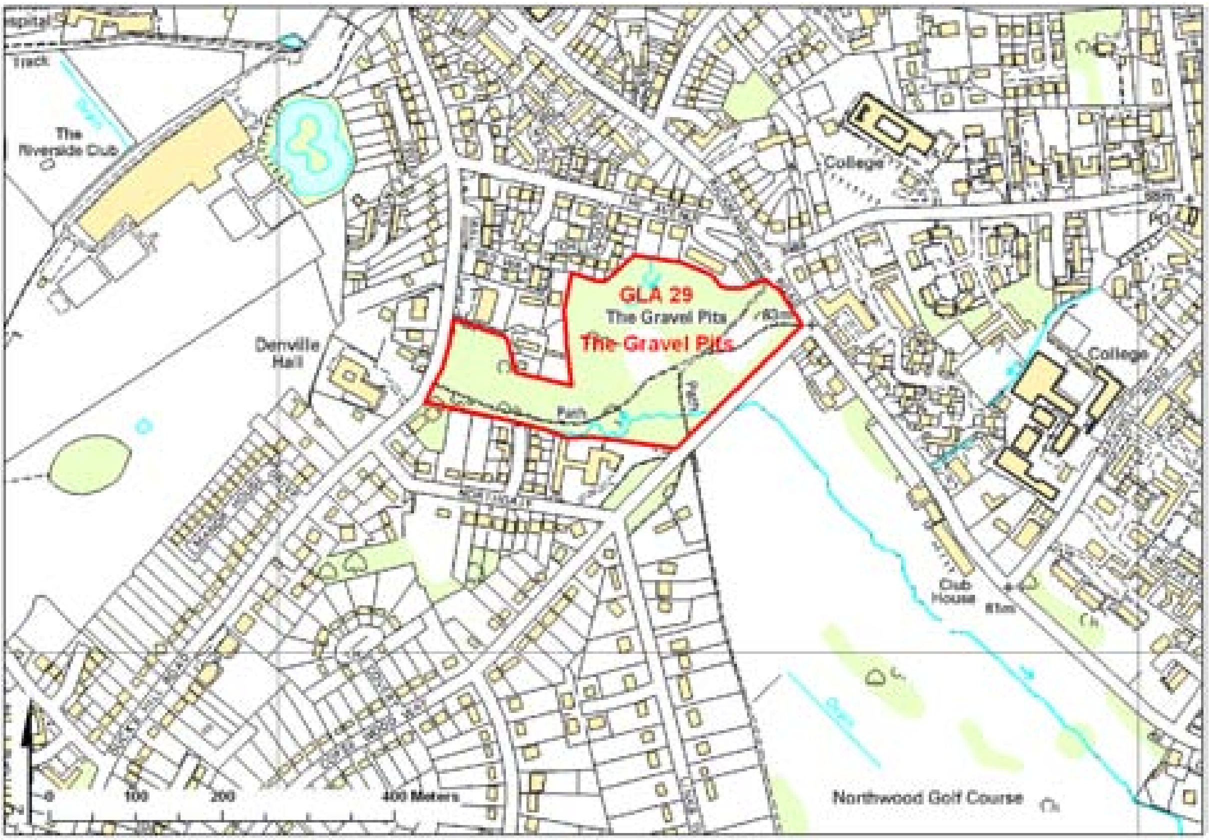

Stratigraphy and Rock Types

Time Unit: Paleocene	Rock Unit: Lambeth Group
Rock Type: Sand and gravel	Details: Glauconitic sands overlain by grey clays and sands with Brackish fauna and interleaved red and variegated clays and sands.

Site Description

An area of woodland covering old gravel pits in the Lambeth Group. The gravel from these pits was used for several hundred years for road mending in the area. The gravel was described as 'worked out' in 1898 and the area was saved as a public amenity in commemoration of Queen Victoria's diamond jubilee the previous year.

Assessment of Site Value

Geodiversity topic: Lithostratigraphy; sedimentology; economic geology.

Access and Safety

Aspect	Description
Safety of access	Footpaths.
Safety of exposure	In woodland, felt uneasy alone.
Permission to visit	Open access.
Current condition	Overgrown.
Current conflicting activities	None.
Restricting conditions	None.

Nature of exposure	Old gravel pits in woods.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Historic pits (information from Ruislip, Northwood and Eastcote Local History Society).	8
Aesthetic landscape	Valuable green space for the local community.	8
History of Earth Sciences		
Economic geology	Gravel pits used for road mending.	8
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Composition of gravels.	6
Palaeontology	None.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Correlation with other units.	6
Potential use	Research; school education; on-site interpretation.	
Fragility	Natural overgrowing.	
Current Site Value		
Community	Used daily by local community.	10
Education	Good site for local schools – history and geology.	4
Geodiversity value		
Recommended RIGS: Well used local site with information.		4

GLA 29 The Gravel Pits

Information board at The Gravel Pits

GLA 30 Cray Valley Golf Course Sand Pit

Grid Reference: TQ 489 692	Site Type: Former quarry works
Site Area (hectares): 0.57	Current use: Golf Course
Site ownership: Cray Valley Golf Club	Borough: London Borough of Bromley
Field surveyor: South London RIGS Group	Date: March 2004
Current geological designations:	Other scientific:

Site Map

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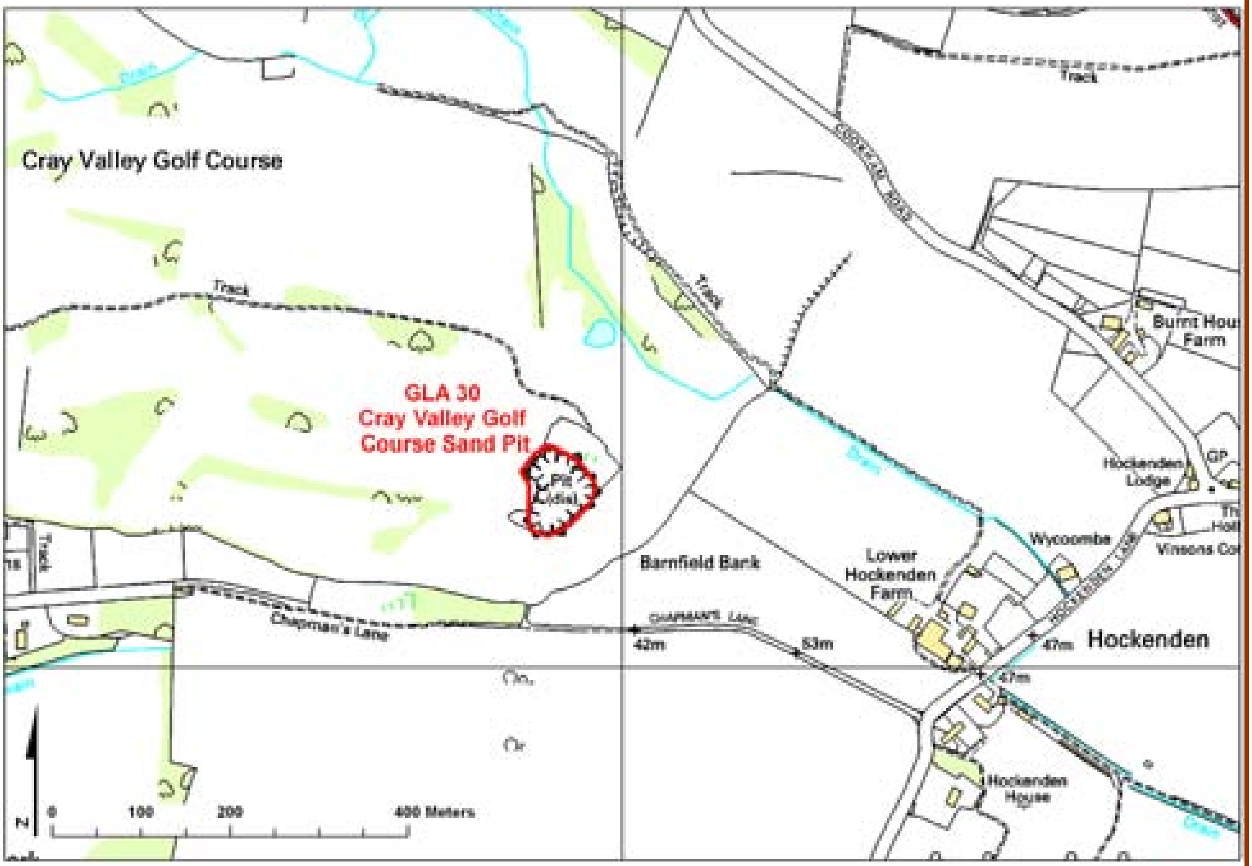

Stratigraphy and Rock Types

Time Unit: Paleocene	Rock Unit: Thanet Sand Formation
Rock Type: Sand	Details: Not known

Site Description

Clean large vertical exposures of Thanet Sand Formation in disused sand pit. They have been left after previous mineral extraction stopped. The exposures are situated towards the eastern end of Cray Valley Golf Course. Approximately 64 sand martin holes are present in the north-west facing cliff – the only known breeding colony of sand martins within the Borough of Bromley, and one of the largest in London.

Assessment of Site Value

Geodiversity topic: Lithostratigraphy and sedimentology.

Access and Safety

Aspect	Description
Safety of access	Site is on the edge of a golf course. Access normally by golf buggy hired from the club.
Safety of exposure	The quarry is not on the course and is not exposed to golf ball hazard.
Permission to visit	Access is by permission of the owners. Cray valley golf course Secretary. Telephone 016898 39677. Management at the course are helpful and permit controlled access.
Current condition	The exposed face is clear with little evidence of overgrowth

Current conflicting activities	Possibility of reuse as a sand quarry or change in golf course layout	
Restricting conditions	Private Golf Course	
Nature of exposure	Semi vertical face of disused sand pit Cliffs in disused sand pit	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	None known but site is near a Victorian rubbish dump with period relics such as glass bottles.	1
Aesthetic landscape	Sand martin nesting colony.	5
History of Earth Sciences	No associations known, but site is a very rare clear exposure of Thanet Sand. No other site of this importance is known to exist in the South London area.	5
Economic geology	Sand from this pit was used in the construction of the A20 motorway.	3
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	The sand was deposited in a coastal environment. The yellowish sand shows some evidence of weathering. No clay or silt deposits exist in the exposure. Evidence of podsoil formation is confined to the top 100mm of the formation. No detailed analysis of the sand is currently available. Sand is well sorted.	4
Palaeontology	No macrofossils are evident in the formation.	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Thanet Sand Formation.	5
Potential use	Research, school and higher education as well as its interest as a sand martin colony.	
Fragility	Natural overgrowth, potential as sand source and exposed to changes in the course layout	
Current Site Value		
Community	Available to the community under careful control.	4
Education		5
Geodiversity value		
Recommended RIGS: The best Thanet sand exposure in the area.		**7**
GLA 30 Cray Valley Golf Course Sand Pit		

Quarry Face with Sand Martin burrows, Cray Valley Golf Course Sand Pit

GLA 31 North End Pit

Grid Reference: TQ 515 771	Site Type: Not known
Site Area (hectares): 0.43	Current use:
Site ownership: Not known	Borough: London Borough of Bexley
Field surveyor: South London RIGS Group	Date: March 2004
Current geological designations:	Other scientific:

Site Map

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Stratigraphy and Rock Types

Time Unit: Pleistocene	Rock Unit: Crayford Silt Formation
Rock Type: Brickearth (silt)	Details: Not known

Site Description

A rare site of brickearth. The present housing estate was built on the site of brickworks. Vertical exposures of brickearth. Site has east access but is fenced off, overgrown and has some dumped rubbish. It needs clearing and an information board

Assessment of Site Value

Geodiversity topic: Palaeontology, sedimentology and lithostratigraphy.

Access and Safety

Aspect	Description
Safety of access	Site is fenced in currently without any access gate. Site can be viewed from outside fence.
Safety of exposure	Exposure is steep and slightly unstable.
Permission to visit	Site is in a new housing estate and is owned by the London Borough of Bexley.
Current condition	Considerable overgrowth has occurred with some obscuring by dumped rubbish. It needs clearing and an information panel.

Current conflicting activities	Rubbish dumping.	
Restricting conditions	Difficult access.	
Nature of exposure	Site is the last relic of a large brickworks that covered the area now devoted to housing. It is located on a steeply sloping bank and is fenced off.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Brickearth has been used for brick making since Roman times. Few exposures now exist. The site was part of a large brickworks, now demolished.	8
Aesthetic landscape	A potential interesting feature of a drab estate.	4
History of Earth Sciences	The last major exposure of Crayford Silt Formation.	5
Economic geology	Former brickworks and pit.	4
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	The deposit is banked up against a steep bedrock slope and consistsof fine sand and silt. Probably of windblown origin.	4
Palaeontology	Crayford brickearth has long been famous for mammalian and molluscan remains as well as Palaeolithic implements.	4
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Rare site for brickearth.	6
Potential use	Education and research.	
Fragility	Natural overgrowth, rubbish dumping and no recognition of its value e.g. a climate change indicator.	
Current Site Value		
Community	Site passed by on a daily basis.	7
Education	High value.	5
Geodiversity value		
Recommended RIGS: An interesting and rare exposure.		**6**

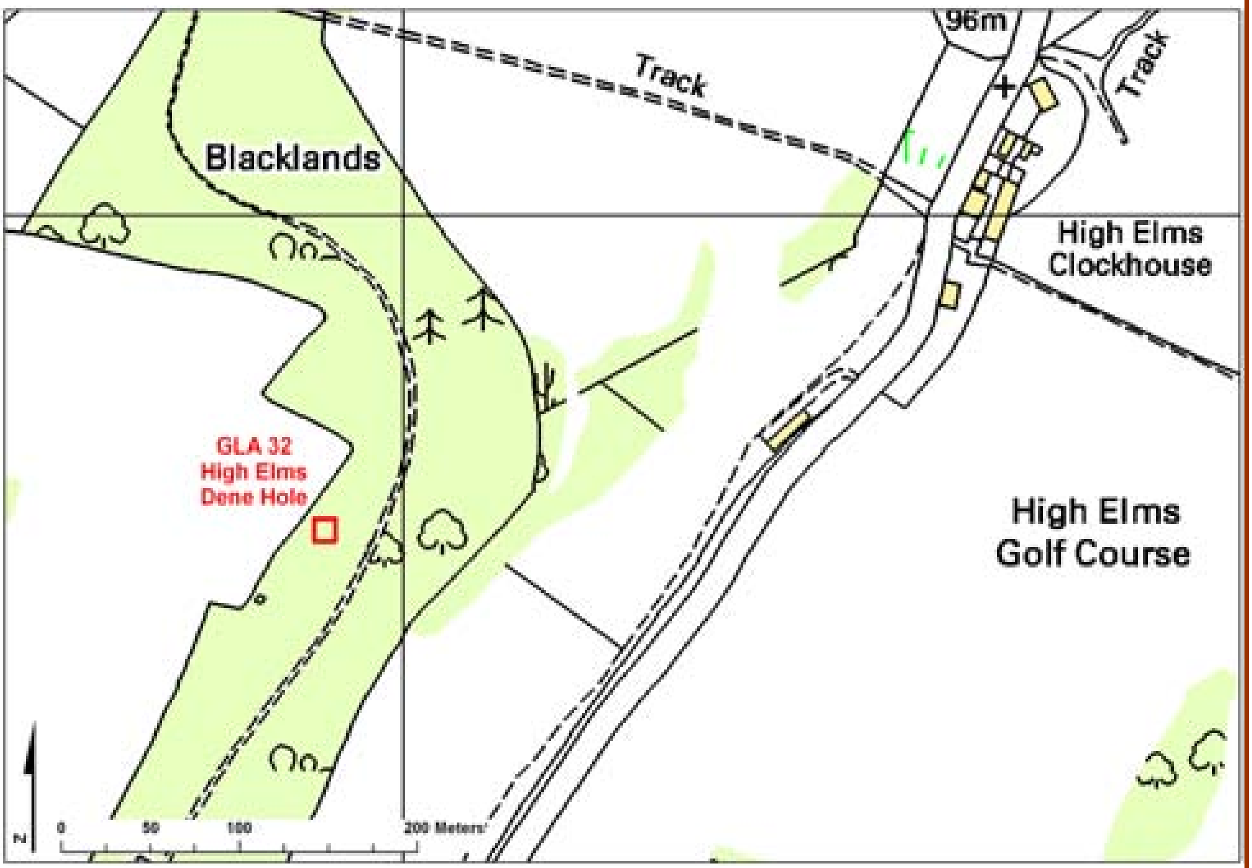
GLA 31 North End Pit

North End Pit

GLA 32 High Elms Dene Hole

Grid Reference: TQ 439 627	Site Type: Not known
Site Area (hectares): 0.02	Current use:
Site ownership: Not known	Borough: London Borough of Bexley
Field surveyor: South London RIGS Group	Date: March 2004
Current geological designations:	Other scientific:

Site Map



Stratigraphy and Rock Types

Time Unit: Cretaceous	Rock Unit: Seaford Chalk Formation and Newhaven Chalk Formation Undifferentiated, Chalk Group
Rock Type: Chalk	Details: Chalk extends to surface

Site Description

This is a well preserved and protected Chalk pit. It is located in the High Elms Country Park. Very few, if any, of the over 200 chalk pits in the area are preserved. The pit is a bat roost

Assessment of Site Value

Geodiversity topic: Palaeontology, sedimentology and lithostratigraphy.

Access and Safety

Aspect	**Description**
Safety of access	Level ground from nearby footpath.
Safety of exposure	The mine is securely protected by a steel grille.
Permission to visit	The site has open access. Permission to enter the mine must be obtained from the Head Ranger who would consult with other interested parties.
Current condition	Well preserved.
Current conflicting activities	The mine is an important bat roost.

Restricting conditions	Access to the mine workings is controlled by LBB.	
Nature of exposure	Disused trefoil type of shallow chalk mine.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Rare survivor of over 200 chalk mines in the area. Mining by this method to get chalk for marling land began in Roman times	6
Aesthetic landscape	Point of interest on popular walk route	5
History of Earth Sciences	Historic mining system	5
Economic geology	Former chalk mine	4
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Environment of deposition.	2
Palaeontology	None	0
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Seaford Chalk Formation and Newhaven Chalk Formation Undifferentiated, Chalk Group.	2
Potential use	Onsite interpretation.	
Fragility	Natural overgrowth.	
Current Site Value		
Community	Site passed by on daily basis.	8
Education	High value.	8
Geodiversity value		
Recommended RIGS: Rare survivor of an agricultural system in use for centuries.		7

GLA 32 High Elms Dene Hole

High Elms Dene Hole

GLA 33 Elmstead Pit

Grid Reference: TQ 42327066	Site Type: Former quarry works
Site Area (hectares): 0.05	Current use: Private garden
Site ownership: Private resident	Borough: London Borough of Bromley
Field surveyor: None, from Natural England website	Date: 4 November 2002
Current geological designations: SSSI	Other scientific:

Site Map

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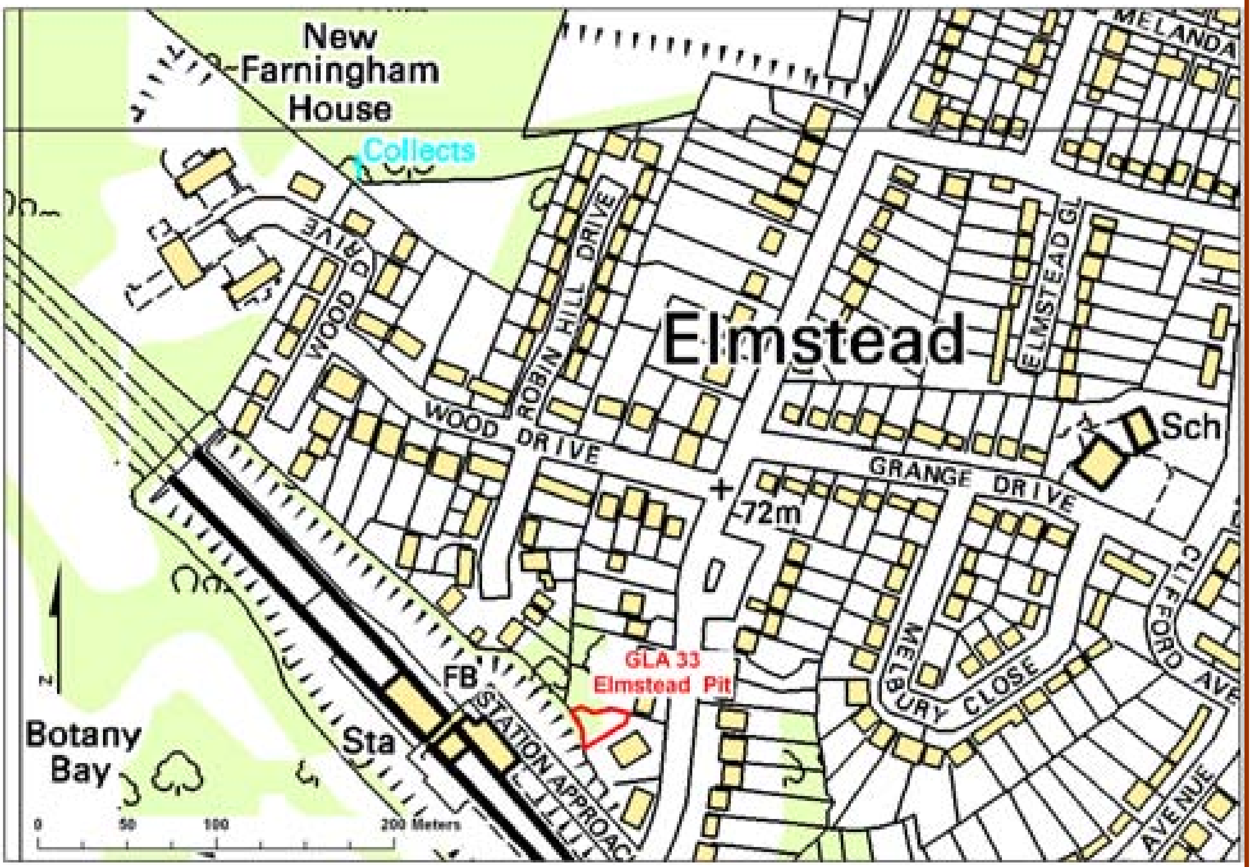


Stratigraphy and Rock Types

Time Unit: Eocene	Rock Unit: Blackheath Formation
Rock Type: Sand and gravel	Details: as specified below

Site Description

Elmstead Pit provides a nationally important exposure of the Oldhaven (Blackheath) Beds through a section containing an unusually rich fossil fauna. A wide range of geological features are present providing information on the changing disposition of land and sea in the Greater London area during Eocene times.

The site covers a 6 m high pit face cut into a series of Blackheath Beds consisting of fine quartz sands and an abundance of flint pebbles. These beds accumulated as sub-tidal bars in an estuarine environment during Eocene times approximately 50 million years ago. They are particularly noted for very large-scale 'cross-bedding' with angles of dip of up to 25 degrees.

The sediments are bound by a heavy calcite cement which has preserved an unusually abundant and diverse fossil fauna. Pits at Elmstead have yielded a substantial part of the known molluscan fauna from the Blackheath Beds and a number of sharks teeth and fish scales have also been recovered. The site is now the only exposure in this locality of these highly fossiliferous beds.

Assessment of Site Value

Geodiversity topic: Palaeontology, sedimentology and lithostratigraphy.

Access and Safety

Aspect	Description
Safety of access	Access to site over level ground.

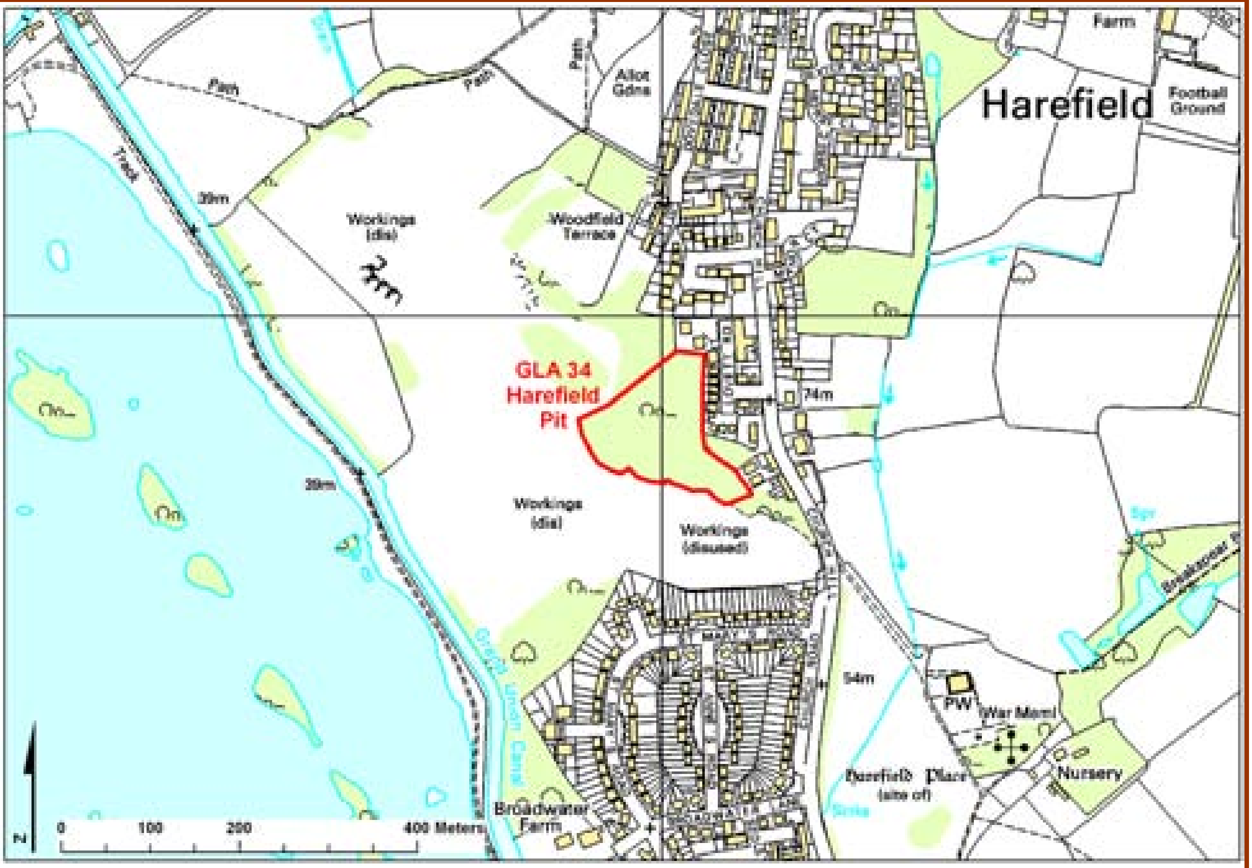
Safety of exposure	Site has consolidated vertical face and level area at bottom of face.	
Permission to visit	Permission needed from house owner, normally requested through Natural England.	
Current condition	Some encroaching ivy and shrubs that may in the long-term cause obstruction. In the long-term there may also be issues of instability of the rock face.	
Current conflicting activities	Site in a private garden.	
Restricting conditions	None.	
Nature of exposure	Vertical pit face.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	The area had a number of chalk and sand pits, all of which are now filled in for housing. This and Chislehurst caves are the only examples left	8
Aesthetic landscape	Private garden	2
History of Earth Sciences	The area has strong association with Whitaker. Described and sketched in his 1889 edition of The Geology of London	8
Economic geology	Former building stone pit, probably worked in Victorian times	5
GeoScientific Merit		
Geomorphology	None.	0
Sedimentology	Large scale cross bedding. Imbricated flint pebbles occur in bands.	6
Palaeontology	Abundant fossil molluscs, plus shark's teeth.	6
Igneous/mineral/ Metamorphic Geology	None.	0
Structural Geology	None.	0
Lithostratigraphy	Blackheath Formation.	8
Potential use	Research and education.	
Fragility	Natural overgrowth and weathering of face.	
Current Site Value		
Community	None, Access is difficult.	2
Education	High value.	5
Geodiversity value		
SSSI: Importance for its history and potential for research.		6
GLA 33 Elmstead Pit		

Elmstead Pit face detail – sand with flint pebbles

GLA 34 Harefield Pit

Grid Reference: TQ 049 898	Site Type: Land filled former quarry works
Site Area (hectares): 1.61	Current use: Fallow field, formerly dairy herd grazed
Site ownership: Ms Moyra East	Borough: London Borough of Hillingdon
Field surveyor: Information from Natural England	Date: 15 October 2002
Current geological designations: SSSI	Other scientific:

Site Map



Stratigraphy and Rock Types

Time Unit: Eocene	Rock Unit: London Clay Formation
Rock Type: Clay	Details:
Time Unit: Paleocene-Eocene	Rock Unit: Lambeth Group (Upnor, Reading and Harwich formations)
Rock Type:	Details:
Time Unit: Cretaceous	Rock Unit: Chalk Group
Rock Type: Chalk	Details:

Site Description

A key section in the London Basin for a sequence through the Upper Chalk, Reading Formation and London Clay Formation. It is also the only known site for calcareous floral remains in the Reading Formation. The site covers part of a disused chalk quarry which has been infilled leaving only the upper faces exposed. These display a superb Palaeogene section including the contact between the Upper Chalk and the Reading Formation, which has here been intensively bored by crustaceans. The faces also show a full section through the Reading Formation, up into mottled fluviatile clays of the Upper Reading Formation. These are overlain by sandy clays with a diverse marine fauna, comprising the Harefield Member of the London Clay, for which this is the stratotype locality. Harefield Pit is additionally of particular interest as the only known source of Charophytes in the Reading Formation. These are important palaeo-environmental indicators, and have potential for correlation with other coeval localities in Europe. The overlying London Clay Formation Basement Bed has also yielded plant material.
Managed by Harrow & Hillingdon Geological Society by agreement with former long-standing owners, as resources permit.

Assessment of Site Value

Geodiversity topic: Palaeontology, sedimentology and lithostratigraphy.

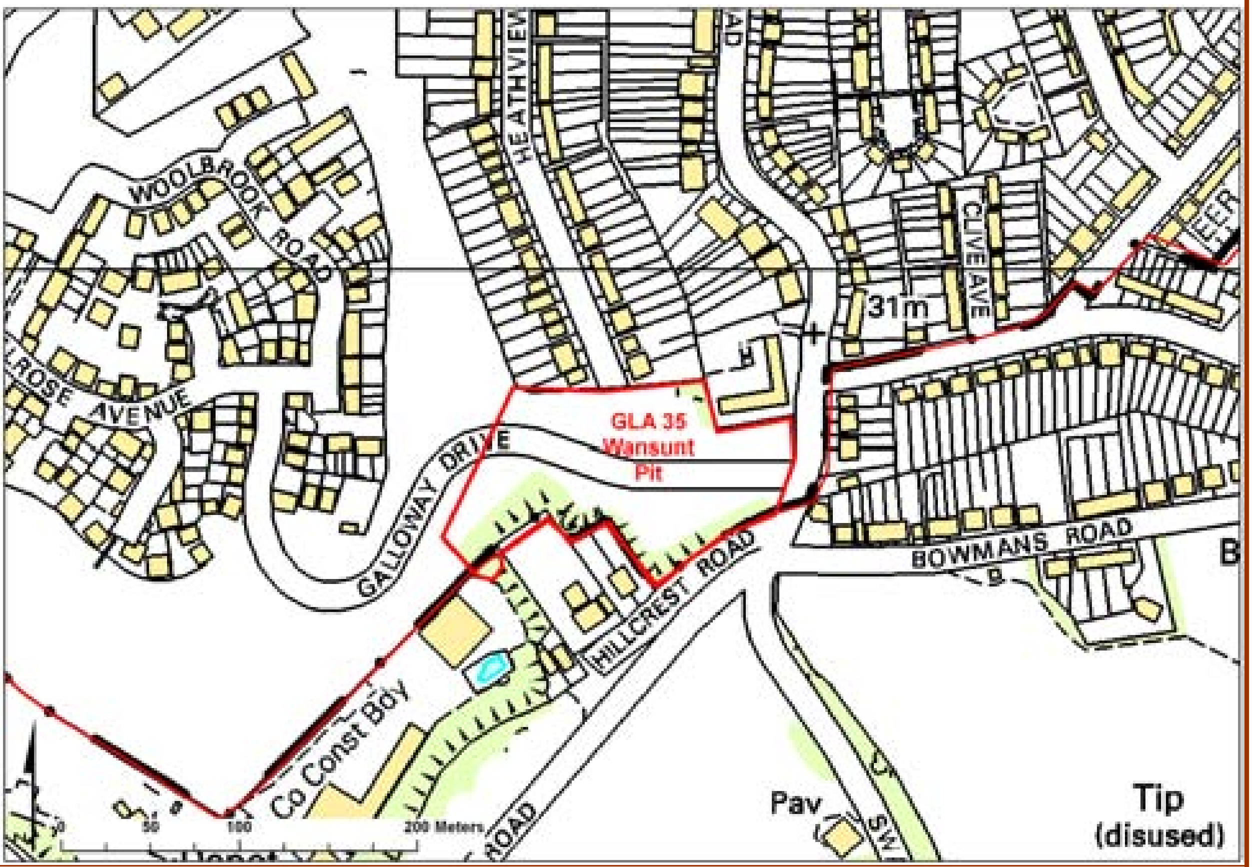
Access and Safety		
Aspect	**Description**	
Safety of access	Difficult access from road and to the top section of the exposure.	
Safety of exposure	Collapse has occurred in one section.	
Permission to visit	Permission to visit required	
Current condition	Scrub grown up on part of site and brambles making access to geological sections difficult. Clearance works necessary, in particular, clearance and on-going management of vegetation	
Current conflicting activities	Not known.	
Restricting conditions	Site is overgrown and difficult to use	
Nature of exposure	Infilled chalk quarry. Top of chalk quarry protected during landfill.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	One of the major Colne valley chalk quarries developed beside the Grand Union Canal to serve the 19th century building expansion of London.	
Aesthetic landscape	Good view across the Colne valley to proto-Thames terraces.	
History of Earth Sciences	Site is well documented, earliest reference 1864, throughout working life as a quarry and subsequently. A critical source of both palaeontological and stratigraphical information	7
Economic geology	Former chalk quarry local interest	4
GeoScientific Merit		
Geomorphology	None.	
Sedimentology	Important locality for understanding the sedimentology of the Reading Formation and its relationship with the overlying Oldhaven and London Clay Formations. Also exposed is the unconformable relationship with the underlying Cretaceous Chalk	8
Palaeontology	Only known locality to have yielded fossil charophytes (stoneworts) from the Reading Formation. – important environmental indicator and for comparison with similar aged sites across Europe. Interesting burrows of Upnor Formation into the top of the Chalk, originally described as *Terebella harefieldensis*.	9
Igneous/mineral/ Metamorphic Geology	None.	
Structural Geology	None.	
Lithostratigraphy	Has been and remains a critical site in understanding Reading and Woolwich Formation lithostratigraphy. Former (?) type section of the Tilehurst Member of the Oldhaven Formation	8
Potential use	Research, higher education and potential for wider interpretation (subject to access arrangements)	
Fragility	Threatened by vegetation and build up of scree	
Current Site Value		
Community	Access by permission only	2
Education	Restricted access but potentially an important field locality for university students. Keen local group interest	6
Geodiversity value		
SSSI: Of high scientific value for Tertiary palaeobotany and Tertiary stratigraphy		8

GLA 34 Harefield Pit

GLA 35 Wansunt Pit

Grid Reference: TQ 515738	Site Type: Not known
Site Area (hectares): 1.44	Current use: Not known
Site ownership: Not known	Borough: London Borough of Bexley
Field surveyor: Information from Natural England	Date: 16 October 2001
Current geological designations: SSSI	Other scientific:

Site Map



Stratigraphy and Rock Types

Time Unit:	Rock Unit: Dartford Heath Gravel
Rock Type:	Details:

Site Description

This site provides exposures in the Dartford Heath Gravel, a deposit which has been the subject of considerable controversy since the turn of the century. It has been variously attributed to the Boyn Hill Terrace, part of the Swanscombe sequence or to an older, higher terrace. The presence or absence of archaeological material in the gravel itself is questionable, but a working floor of Acheulian age has been discovered in loam overlying the gravel in Wansunt Pit. The question of whether or not the Dartford Heath gravel is equivalent to any part of the Swanscombe sequence, and what its relationship is to the Thames Terraces, is one of the more burning issues in the Thames Pleistocene studies, and therefore the exposures here are of considerable importance.

London Wildlife trust responsible for site management.

Assessment of Site Value

Geodiversity topic: Sedimentology and lithostratigraphy.

Access and Safety

Aspect	Description
Safety of access	Not known
Safety of exposure	Not known
Permission to visit	Permission to visit required

Current condition	Part filled former gravel pit. Part developed for local industrial units with access roads. Enclosed by housing and mainly over grown. Recent development of land within the pit has resulted in land raising up to the base of the SSSI and construction of a new access road into the development site. Several exposures have been created on the northern face of the SSSI as part of the planning conditions.	
Current conflicting activities	Not known	
Restricting conditions	Vegetation and flytipping	
Nature of exposure	Overgrown in southern part of the site. Managed exposures in northern part of the site	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Source of palaeolithic artefacts	7
Aesthetic landscape	Not known.	
History of Earth Sciences	Significant history of research and a critical (and controversial) site in the interpretation of the Thames Gravel sequence	7
Economic geology	Former gravel pit – local interest	4
GeoScientific Merit		
Geomorphology	Not rated.	
Sedimentology	Not rated.	
Palaeontology	Mammalian remains	7
Igneous/mineral/ Metamorphic Geology	None.	
Structural Geology	None.	
Lithostratigraphy	Critical site for the interpretation of the Thames Gravel sequence and for correlation across Europe (esp. development of the Rhine River system). Presence of Palaeolithic artefacts adds significant value.	8
Potential use	High research interest, potential local and regional educational value	
Fragility	Vegetation management necessary, critical sections in northern part of site	
Current Site Value		
Community	Access permission required for much of the site	2
Education	Important educational locality especially university level and research, possible regional and local interest particularly in northern managed part of site	10
Geodiversity value		
SSSI: High scientific value for its Thames Terrace sequence, critical site for interpreting Thames Terraces and for comparison across Europe		9
GLA 35 Wansunt Pit		
Site not visited		

GLA 36 Pinner Chalk Mines

Grid Reference: TQ 116 905	Site Type: Former mine workings
Site Area (Hectares): 90	Current use: Under recreational land
Site ownership: London Borough of Harrow	Borough: London Borough of Harrow
Field surveyor: Harrow & Hillingdon Geol. Soc.	Date: 24 November 2008
Current geological designations: RIGS	Other scientific:

Site Map

OS Topography © Crown Copyright

Stratigraphy and Rock Types

Time Units: Upper Cretaceous/ Paleocene	Rock Units: Chalk Group/ Woolwich Formation (Lambeth Group)
Rock Types: Chalk with flints/ puddingstone	Details:

Site Description

Pinner Chalk Mines extend over a large area, with mixed extraction methods recorded from the 14th century. Access to most is no longer possible, and this survey is of the 1830-70 mine.

Assessment of Site Value

Geodiversity topic: Sedimentology; Palaeotology; Lithostratigraphy;.

Access and Safety

Aspect	Description
Safety of access	Public footpath steep/slippery in places. Mine shaft enclosed in security fence with locked cover.
Safety of exposure	Accessible galleries with pillar and stall in good condition (only 2 roof falls in last 160 years, one caused by contractors during construction of latest shaft access cover).
Permission to visit	By request to Council Licensee (ken.kirkman@btinternet.com, or via Harrow & Hillingdon Geological Society).
Current condition	Good
Current conflicting activities	None

Restricting conditions	Availability of Caving Group that provides means of access by 35m caving ladder with safety harness, and HHGS geological support.	
Nature of exposure	Old mine workings.	
Culture, Heritage & Economic		
Aspect	**Description**	**Rating**
Historic, archaeological & literary associations	Well documented with summary and references in Pinner Local History Society's publication Pinner Chalk Mines' ISBN 0 9507955 6 9 and Harrow & Hillingdon Geological Society's 'A guide to Pinner Chalk Mine' ISBN 0 9520325 0 3.	10
Aesthetic landscape	Potential for Interpretation Board, subject to survey of surface safety and vandalism history.	3
History of Earth Sciences		
Economic geology	Local economic importance	8
GeoScientific Merit		
Geomorphology		
Sedimentology	Chalk with flint and overlying puddingstone	8
Palaeontology	Chalk with flint	7
Igneous/mineral/ Metamorphic Geology		
Structural Geology		
Lithostratigraphy	Chalk and puddingstone succession	8
Potential use	Continued research; Higher and further education; School education.	
Fragility	Roof potentially, as in most mines, due to external influences. Surface overgrown and subject to vandalism.	
Current Site Value		
Community	Under recreational space access.	6
Education	Long-standing and continuing research, education and public interest. Training 'ground' for Fire Service and Met. Police.	9

Geodiversity value

Recommended RIGS: Rare regional example of 'deep' chalk mining with well-documented history and wide educational value.	9

GLA 36 Pinner Chalk Mines

Appendix 6 Summary of geological strata of sites

	GLA Site No. and Name		Rock Units: Quaternary			Bedrock						
			Post-Anglian	Till	Pre-Anglian	Bagshot Formation	Claygate Member	London Clay	Harwich Formation	Lambeth Group	Thanet Sand	Chalk Group
SSSI	GLA 1	Abbey Wood							■	*	▨	▨
	GLA 14	Gilbert's Pit							■	■	▨	▨
	GLA 18	Harrow Weald			■		■					
	GLA 19	Hornchurch Cutting	■	■				■				
	GLA 33	Elmstead Pit							■			
	GLA 34	Harefield Pit						■	■	■		■
	GLA 35	Wansunt Pit	■									
RIGS	GLA 3	Beckenham Place Park						■	■			
	GLA 4	Chelsfield Gravel	**									
	GLA 6	Croham Hurst							■	■	■	■
	GLA 8	Dog Rocks							■			
	GLA 17	Happy Valley										■
	GLA 20	Horsenden Hill			■		■	■				
	GLA 22	Keston Common							■			
	GLA 26	Rose and Crown Pit										■
	GLA 29	The Gravel Pits								■		
	GLA 30	Cray Valley Golf Course Sand Pit									■	
	GLA 31	North End Pit	***									
	GLA 32	High Elms Dene Hole										■
	GLA 36	Pinner Chalk Mines								■		■
LIGS	GLA 2	Avenue House		■								
	GLA 5	Chingford Hatch			■			■				
	GLA 9	Dry Valley										■
	GLA 10	Dulwich Mill Pond						▨				
	GLA 11	Finchley Till		■								
	GLA 12	Finsbury Gravel	■									
	GLA 13	Friday Hill						■				
	GLA 15	Hainault Forest Country Park	■	■			■	■				
	GLA 16	Hale End London Clay Hillock						■				
	GLA 21	Islington Terrace Gardens	■									
	GLA 23	Loats Pit								■	■	▨
	GLA 24	Old Gravel Pit							■	■		
	GLA 25	Putney Heath	■					■				
	GLA 27	Sundridge Park Golf Course 1							■	■	▨	
	GLA 28	Sundridge Park Golf Course 2							■	■	▨	

▨ Not visible without excavation (may apply to other sites)

* No known Lambeth Group, but contains Chalk pit

** Uncertain Position

*** Brick Earth

Glossary

Ammonite	Extinct group of marine animals of the subclass Ammonoidea in the class Cephalopoda, phylum Mollusca. They are excellent index fossils, and it is often possible to link the rock layer in which they are found to specific geological time periods. They originated in the late **Silurian**, were extremely abundant during the **Mesozoic** and became extinct at the end of the **Cretaceous**.
Anglo-Brabant Massif	Part of the **Caledonian** fold belt which extends from East Anglia to central Belgium.
Allochthonous	Pertaining to materials, particularly rock masses, that formed somewhere other than their present location, and were transported by fault movements, large-scale gravity sliding, or similar processes. Autochthonous material, in contrast, formed in its present location. Landslides can result in large masses of allochthonous rock, which typically can be distinguished from autochthonous rocks on the basis of their difference in composition. Faults and folds can also separate allochthons from autochthons.
Alluvial	Environments, actions and products of rivers or streams.
Anticline	An arch-shaped fold in rock in which the rock layers are upwardly convex. The oldest rock layers form the core of the fold, and outward from the core progressively younger rocks occur.
Avalonia	Avalonia was an ancient microcontinent or **terrane** whose history formed much of the older rocks of Western Europe, Atlantic Canada, and parts of the coastal United States. The name is derived from the Avalon Peninsula in Newfoundland.
Axial zone	The area on either side of a fold axis
Basin inversion	Is the process whereby a sedimentary basin is uplifted and partially extruded. This uplifting is a result of crustal shortening and fault reactivation.
Bedding	A feature of sedimentary rocks, in which planar or near-planar surfaces known as bedding planes indicate successive depositional surfaces formed as the sediments were laid down.
Bedrock	A term used to describe unweathered rock below soil or superficial deposits. Can also be exposed at the surface.
Belemnite	Belemnites (or belemnoids) are an extinct group of marine cephalopod, very similar in many ways to the modern squid and closely related to the modern cuttlefish. Belemnites were numerous during the **Jurassic** and **Cretaceous** periods, and their fossils are abundant in **Mesozoic** marine rocks, often accompanying their cousins the **ammonites**. The belemnites became extinct at the end of the **Cretaceous** period.
Bioturbation	The disruption of depositional sedimentary structures by organisms e.g. activities such as burrowing.
Bivalve	Class of molluscs with paired oval or elongated shell valves joined by a hinge.
Bouguer Gravity Anomaly	The remaining value of gravitational attraction after accounting for the theoretical gravitational attraction at the point of measurement, latitude, elevation, the Bouguer correction and the free-air correction. The difference between the actual value and the predicted value is the gravity anomaly, which results from differences in density between the actual Earth and reference model anywhere below the measurement station.
Brachiopods	A phylum of solitary marine shelled invertebrates.
Bryozoa	Tiny colonial animals superficially similar to coral. They date back to the Ordovician, 480 million years ago, to present day. Mainly living in a marine environment, they cover rocky surfaces like moss.
Calcite	Calcium Carbonate [$CaCO_3$] a widely distributed mineral and a common constituent of sedimentary rocks, limestone in particular. Also occurs as stalactites and stalagmites and is often the primary constituent of marine shells.
Calcrete	**Conglomerate** consisting of surficial sand and gravel cemented into a hard mass by calcium carbonate precipitated from solution and redeposited through the agency of infiltrating waters, or deposited by the escape of carbon dioxide from vadose water.
Caledonides	The mountain belt formed during the **Caledonian Orogeny**
Caledonian	Refers to a major mountain-building (**orogeny**) event related to the closure of the Iapetus Ocean and the convergence of the Laurentia, Baltica and Avalonia crustal

	blocks during the **Ordovician**, **Silurian** and early **Devonian**. It affected eastern North America, Scotland, Ireland, Scotland, Scandinavia and Greenland.
Carboniferous	A geological period [359–299 Ma] of the Palaeozoic Era preceded by the **Devonian** and followed by the **Permian**.
Chronostratigraphy	The branch of **stratigraphy** linked to the concept of time. Chronostratigraphical units are defined as bodies of rock that formed during a specific interval of geologic time. Chronostratigraphical units are thus special rock bodies that are conceptual, as well as being material.
Conglomerate	A sedimentary rock, a significant proportion of which is composed of rounded pebbles and boulders, greater than 2 mm in diameter, set in a finer-grained groundmass.
Cenozoic	[Cainozoic] A geological era covering 65.5 Ma [65.5 – present day]. It is preceded by the **Mesozoic**, the **Cretaceous** – Tertiary (K-T) extinction event marks this boundary.
Clast	Particle of broken down rock, eroded and deposited in a new setting.
Craton	An old and stable part of the continental crust that has survived the merging and splitting of continents and supercontinents for at least 500 million years. Some are over 2 billion years old. Cratons are generally found in the interiors of continents and are characteristically composed of ancient crystalline basement crust of lightweight felsic igneous rock such as granite. From the Greek kratos; "strength"
Cretaceous	A geological period [145–65.5 Ma] of the **Mesozoic** Era preceded by the **Jurassic** and followed by the **Neogene**.
Crinoid	A sea dwelling creature (class Crinodea) which has survived since **Ordovician** times. They are known as sea-lilies and have three sections, the stem, the calyx and feather-like arms by which they collect food. There abundance in the **Palaeozoic** era has meant that their remains have formed large thicknesses of limestone due to their calcareous skeletons.
Cross-bedding	Cross-stratification formed by the migration of dunes and sand waves on a sediment surface.
Cryoturbation	A collective term to describe the churning, modification and all other disturbances of soil resulting from frost action. The repeated freezing and thawing of the soil eventual leads to patterned ground.
Devensian	The last glacial stage in Britain, lasting from around 70 000 BP (Before Present) to about 10,000 BP.
Devonian	A geological period [416–359 Ma] of the Palaeozoic Era preceded by the **Silurian** and followed by the **Carboniferous**.
Dinoflagellate	The dinoflagella are a large group of flagellate organisms. Most are marine plankton, but they are also common in fresh water habitats. Their populations are distributed depending on temperature, salinity, or depth. Dinoflagellate cysts are commonly preserved in the fossil record and are useful for stratigraphic correlation and palaeoenvironmental analysis.
Earth heritage	The geological and landscape heritage of an area. Used mostly in the context of geoconservation
Earth science	Science related to planet Earth. Also known as geoscience. Includes disciplines such as economic geology, geochemistry, geomagnetism, geomorphology, geophysics, glaciology, hydrogeology, mineralogy, palaeontology, petroleum geology, petrology, stratigraphy, structural geology, engineering geology, sedimentology, seismology.
Echinoid	Sea urchins (class Echinoidea) found in oceans all over the world. Their shell or "test", is globular in shape and covered with spines. The size of an adult test is typically from 3 to 10 cm. The earliest known echinoids are found in the rock of the Late part of the Ordovician period, and they have survived to the present day.
Eocene	A geological epoch [55.8 – 33.9 Ma] belonging to the **Palaeogene** period. It is preceded by the **Paleocene** and succeeded by the Oligocene.
Eustatic	World-wide changes in sea-level caused either by tectonic movement or growth or melting of glacial ice-sheets (glacioeustatic).
Fault	A fracture in the Earth's crust across which the rocks have been displaced relative to each other.
Ferricrete	A conglomerate consisting of surficial sand and gravel which has been cemented into a hard mass by iron oxide.
Fluvial	Referring to a river environment.

Fold	A bend in planar structures such as rock strata or bedding planes.
Fold axis	A line which lies parallel to the hinge line and marks the intersection of the axial plane with the hinge zone
Foraminifera	The Foraminifera, or forams for short, are a large group of amoeboid organisms. They typically produce a shell, or test, which can have either one or multiple chambers. About 275 000 species are recognized, both living and fossil. They are usually less than 1 mm in size and are commonly preserved in the fossil record. Useful for stratigraphic correlation and palaeoenvironmental analysis.
Formation	The fundamental unit used in lithostratigraphy. Specific features distinguish one formation from another. Formations may be subdivided into members and several formation may constitute a group.
Glaciofluvial	Refers to sediments deposited by flowing glacial **meltwater.**
Glaciolacustrine	Refers to deposits and landforms derived from materials brought by glacial meltwaters into lake environments.
Glauconite	A greenish mineral belonging to the mica group.
Hercynian	A period of mountain building in Europe throughout the late **Palaeozoic**, synonymous with the **Variscan Orogeny.** The northern Alps are said to be Hercynian.
Holocene	The youngest epoch of the **Quaternary** Sub-Era. Covers the last 11 800 years. Part of the **Cenozoic** Era.. The concept of the Holocene ending at the end of the 18th Century is gaining ground, with the following Epoch termed the Anthropocene.
Inlier	Area where older rocks are surrounded completely by younger rocks, produced by, faulting or folding followed by erosion.
Involution	Irregular folds in sedimentary strata caused by **cryoturbation.**
Jurassic	A geological period [200–145 Ma] of the **Mesozoic** Era preceded by the **Triassic** and followed by the **Cretaceous**.
Lacustrine	Refers to a lake environment.
Laurentia	An ancient supercontinent comprising the Canadian shield, North America, Greenland and parts of North-West Europe.
Lithology	The character of a rock expressed in terms of its mineral composition, structure, grain size and arrangement of its constituents.
Lithostratigraphy	The branch of **stratigraphy** concerned with the description of rock units in terms of their lithological features and spatial relationships
London Platform	A block of **Palaeozoic** rock, part of the **Anglo-Brabant Massif**, which underlies most of the south-east of England.
Ma	Abbreviation for mega-annum (million years)
Marl	Calcareous (lime-rich) mudstone, or clay-rich chalk.
Mass-movement	The down slope movement of earth material due to the force of gravity.
Meltwater	Water produced by melting of snow or ice.
Mesozoic	The geological era between the **Palaeozoic** and the **Cenozoic**. It covers the time span between 251–65 Ma.
Milankovitch Cycles	The collective effect of changes in the Earth's circumnavigation of the Sun upon its climate. The cycles are eccentricity (100,000 years), axial tilt (41,000 years), and precession (23,000 years). Together, variations in these three cycles create alterations in the seasonality of solar radiation reaching the Earth's surface. These times of increased or decreased solar radiation directly influence the Earth's climate system.
Miocene	A geological epoch [23 – 5.3Ma] preceded by the Oligocene and followed by the **Pliocene**. Part of the **Neogene** Period
Nannoplankton	Plankton of minute size, especially plankton composed of organisms measuring from 2 to 20 micrometers.
Neogene	A geological period [23 Ma–present day] of the **Cenozoic** Era, preceded by the **Palaeogene**.
Ordovician	A geological period [488–444Ma] of the **Palaeozoic** Era preceded by the **Cambrian** and followed by the **Silurian**.
Orogeny	A period of mountain building by tectonic activity.
Ostracod	Small aquatic crustacean dating back to **Cambrian** times, [class : Ostracoda]. They vary in size from 0.2mm to 30mm and have a bivalve-like protective shell. They are very important in correlating palaeoenvironments due to their worldwide

	occurrence.
Outlier	Area where younger rocks are surrounded completely by older rocks, produced by erosion, faulting, folding or any combination of these.
Palaeogene	The lowest period belonging to the **Cenozoic** Era [65.5–23Ma].
Paleocene	The lowest epoch of the **Palaeogene** period, [65.5–55.8Ma]
Palaeozoic	The lowest era of the Phanerozoic Eon. It is preceded by the **Proterozoic** and is followed by the **Mesozoic**, [542–251Ma].
Palynomorph	Microscopic organic particles found in sedimentary rocks. They include pollen and spores and are important for indicating past climatic conditions.
Pelecyod	Benthic dwelling mollusc belonging to the class Bivalvia.
Pericline	A fold where the strata dips away from the centre to form a dome or where the strata dips towards the centre to create a basin.
Periglacial	Conditions, processes and landforms associated with cold, nonglacial environments.
Permian	A geological period [299–251 Ma] of the **Palaeozoic** Era preceded by the **Carboniferous** and followed by the **Triassic**.
Pingo	A **periglacial** landform, a conical hill of earth covering ice found in the Arctic, subarctic and Antarctica. The name is derived from the Inuit word meaning small hill.
Pleistocene	A geological epoch [1.8Ma–11.5 Ka] preceded by the **Pliocene** and followed by the **Holocene**. Part of the **Cenozoic** Era and **Quaternary** Sub-Era.
Pliocene	A geological epoch [5.3 – 1.8Ma] preceded by the **Miocene** and followed by the **Pleistocene**. Part of the **Cenozoic** Era.
Proterozoic	The Late eon [2500–542Ma] of the Precambrian followed by the Achaean.
Quaternary	A geological sub-era [1.8Ma to present day] of the **Cenozoic** Era, following the **Neogene**
Radiolarian	Planktonic organisms that occur throughout the water column. They have been in existence since **Cambrian** times. Due to the preservation of their silicon skeletons they are important as palaeoenvironment indicators.
Sedimentary rock	A rock formed in one of three main ways: by the deposition of the weathered remains of other rocks (clastic sedimentary rock); by the deposition of the results of biogenic activity; and by precipitation from solution. Four basic processes are involved in the formation of a clastic sedimentary rock: weathering (erosion), transportation, deposition and compaction.
Silcrete	A conglomerate consisting of surficial sand and gravel which has been cemented into a hard mass by silica.
Silurian	A geological period [444–416 Ma] of the **Palaeozoic** Era preceded by the **Ordovician** system and followed by the **Devonian**.
Smectite	A family of clay minerals that includes montmorillonite and bentonite
Solifluction	Solifluction is a slow downslope flow of water-saturated fragmental material or soil. It is promoted by the existence of permafrost which traps snow and ice melt within the surface layer making it more fluid.
Strata	Rocks that form layers or beds.
Stratigraphy	The definition and description of the stratified rocks of the Earth's crust.
Syncline	A basin- or trough-shaped fold in rock in which rock layers are downwardly concave. The youngest rock layers form the core of the fold and outward from the core progressively older rocks occur.
Terrane	A fault-bounded body of rock of regional extent, characterized by a geological history different from that of contiguous terranes. A terrane is generally considered to be a discrete **allochthonous** fragment of oceanic or continental material added to a **craton** at an active margin by accretion.
Terrigenous	Derived from the erosion of rocks on land.
Thrust	The movement of one crustal surface over another.
Triassic	A geological period [251–200 Ma] preceded by the **Permian** and followed by the **Jurassic**.
Unconformable	A term generally applied to younger strata that do not conform in position or that do not have the same dip and strike as those of the immediately underlying rocks. Also applies to the contact between unconformable rocks.
Unconformity	A surface of contact between two groups of **unconformable** strata. Represents a break in the geological record where a combination of erosion and lack of

	deposition was taking place.
Variscan	A period of continental collision and mountain building in Europe throughout the late **Palaeozoic**. The Variscan **Orogeny** occurred when the continent of Gondwana collided with Laurasian continent creating the supercontinent of Pangaea. The Appalachian mountain range is an outcome of the Variscan **Orogeny**.

References and resources

Most of the references listed here can be consulted at the BGS Library, Keyworth. The BGS Library may be able to provide copies of other material, subject to copyright legislation. Links to the BGS Library catalogue and other details are provided on the BGS website: www.geolib.bgs.ac.uk.

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Archive and Materials collections

Documentary Sources

Many years of geological observation, recording and research in Britain have created an enormous archive of information, published and unpublished, and collections of geological materials. Although some of these collections and archives may now reside at locations remote from the source area, they are, nonetheless, vital parts of that area's geodiversity. In particular, such collections may include information on, or specimens from, locations or features which are no longer accessible and for which they now offer the only means of study and research.

The most significant geological archives relevant to Greater London are considered below.

The British Geological Survey

As the national geological survey, BGS has an incomparable archive of information and materials collections relating to the district, dating back to the earliest years of geological mapping and research in the 19th century and continuing to the present day. Information sources held by BGS include original field maps (field slips), published maps, memoirs, reports, open-file maps and reports, borehole records, mine plans, fossils, rock samples, thin sections, hydrogeological, geochemical, geophysical and geotechnical data and photographs.

Further information on BGS publications, data sources and information available from the British Geological Survey can be accessed at www.bgs.ac.uk.

Soil Survey
Specialised information on soil character, properties and classification may be obtained from the publications of the Soil Survey of England and Wales, now the Soil Survey and Land Research Centre. www.silsoe.cranfield.ac.uk/nsri.

Other Documentary Sources
Information on geological Sites of Special Scientific Interest (SSSIs) within Greater London is held by Natural England www.naturalengland.org.uk. Information on other geologically significant sites is held by South London and North West London RIGS Groups www.ukrigs.org.uk.

Materials Collections

Many specimens of rocks and fossils collected within Greater London are held in the collections of Britain's national museums and university departments; important material is also held by BGS. These specimens, and their accompanying locality and other data, comprise an extremely important aspect of the Greater London's geodiversity.

Natural History Museum
The Museum's palaeontology collection of around 9 million specimens from all over the globe is one of the world's great palaeontological collections. Specimens have come from scientists who were at the fore of the developing science of geology, including Charles Darwin, William Smith, the Sowerbys, Buckman, Murchison, Samuel Beckles, James Bowerbank, Thomas Davidson, and Gideon Mantell. The mineralogy collection at the museum includes the Building and Decorative Stones Collection, set up by a nationwide survey of all building stones after the fire at the Palace of Westminster in 1834. Special collections within the main collection include the Nicholson Collection of marble and decorative stones and the London Natural History Society Collection of marbles. There is also a unique collection of roadstones and macadams, which contains samples of rock from quarries used to dress road surfaces.

British Geological Survey
The BGS Collections hold rock and fossil specimens taken from surface exposures and boreholes within Greater London. Thin sections of rocks from the district are registered in the BGS sliced rock collection.

Croydon Natural History and Scientific Society Museum
This museum houses a large collection of rocks, fossils and minerals, made by Society members. It includes the W H Bennett Collection, bequeathed in 1975, and a collection of industrial objects linked to mining and quarrying in Reigate and Godstone areas.

Essex Field Club
Collection of rocks and fossils, including a large number from the east London boroughs. The collection is currently in temporary storage in central Essex.

National and Local Societies

National Geological Societies:

Geological Society of London

The Geological Society, Burlington House, Piccadilly, London. W1J 0BG
Web: www.geolsoc.org.uk

Geologists' Association
The Geologists' Association, Burlington House, Piccadilly, London. W1J 0DU
Web: www.geologists.org.uk/ Email: geol.assoc@btinternet.com

Local Societies:

Amateur Geological Society
Julia Daniels, 25 Village Road, Finchley, London N3 1TL

Brent Geological Society
John Stevens, 8 Winchester Road, Kenton, Middlesex. HA3 9PE
Web: www.brentgeology.co.uk Email: ruthweinberg@ntl.world.com

Croydon Natural History and Scientific Society
96a Brighton Road, South Croydon, Croydon. CR2 6AD
Web: www.greig51.freeserve.co.uk/cnhss/index.htm

East Herts Geology Club
Web: www.ehgc.org.uk

Essex Rock and Mineral Society
Web: www.erms.org

Farnham Geological Society
Shirley Stephens, 27 Dinorben Close, Fleet, Hampshire. GU52 7SL
Web: www.farnhamgeosoc.org.uk Email: secretary@farnhamgeosoc.org.uk

Harrow & Hillingdon Geological Society
Web: www.hhgs.org.uk

Ravensbourne Geological Society
Mr Maurice Green, 49 Station Road, West Wickham, Kent. BR4 0PY

Staines Geological Society
Mrs Sally Hurst, 4 Prince William Court, Clarendon Road, Ashford, Middlesex. TW15 2PU

Other formats and languages

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Chinese

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Hindi

यदि आप इस दस्तावेज की प्रति अपनी
भाषा में चाहते हैं, तो कृपया निम्नलिखित
नंबर पर फोन करें अथवा नीचे दिये गये
पते पर संपर्क करें

Vietnamese

Nếu bạn muốn có văn bản tài liệu
này bằng ngôn ngữ của mình, hãy
liên hệ theo số điện thoại hoặc địa
chỉ dưới đây.

Bengali

আপনি যদি আপনার ভাষায় এই দলিলের প্রতিলিপি
(কপি) চান, তা হলে নীচের ফোন্ নম্বরে
বা ঠিকানায় অনুগ্রহ করে যোগাযোগ করুন।

Greek

Αν θέλετε να αποκτήσετε αντίγραφο του παρόντος
εγγράφου στη δική σας γλώσσα, παρακαλείστε να
επικοινωνήσετε τηλεφωνικά στον αριθμό αυτό ή ταχυ-
δρομικά στην παρακάτω διεύθυνση.

Urdu

اگر آپ اِس دستاویز کی نقل اپنی زبان میں
چاهتے هیں، تو براہ کرم نیچے دئے گئے نمبر
پر فون کریں یا دیئے گئے پتے پر رابطہ کریں

Turkish

Bu belgenin kendi dilinizde
hazırlanmış bir nüshasını
edinmek için, lütfen aşağıdaki
telefon numarasını arayınız
veya adrese başvurunuz.

Arabic

إذا أردت نسخة من هذه الوثيقة بلغتك، يرجى
الاتصال برقم الهاتف أو مراسلة العنوان
أدناه

Punjabi

ਜੇ ਤੁਹਾਨੂੰ ਇਸ ਦਸਤਾਵੇਜ਼ ਦੀ ਕਾਪੀ ਤੁਹਾਡੀ ਆਪਣੀ ਭਾਸ਼ਾ
ਵਿਚ ਚਾਹੀਦੀ ਹੈ, ਤਾਂ ਹੇਠ ਲਿਖੇ ਨੰਬਰ 'ਤੇ ਫ਼ੋਨ ਕਰੋ ਜਾਂ ਹੇਠ
ਲਿਖੇ ਪਤੇ 'ਤੇ ਰਾਬਤਾ ਕਰੋ:

Gujarati

જો તમને આ દસ્તાવેજની નકલ તમારી ભાષામાં
જોઇતી હોય તો, કૃપા કરી આપેલ નંબર ઉપર
ફોન કરો અથવા નીચેના સરનામે સંપર્ક સાધો.

MoL/Mar09/MR D&P/GLA1238

GREATER LONDON AUTHORITY