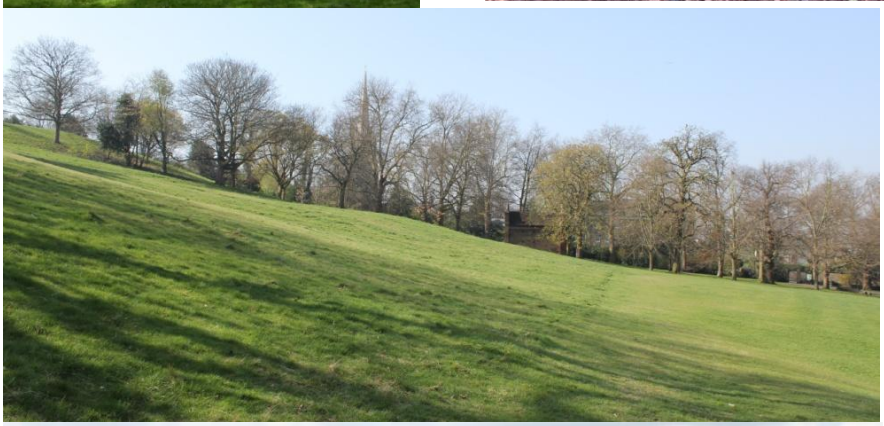
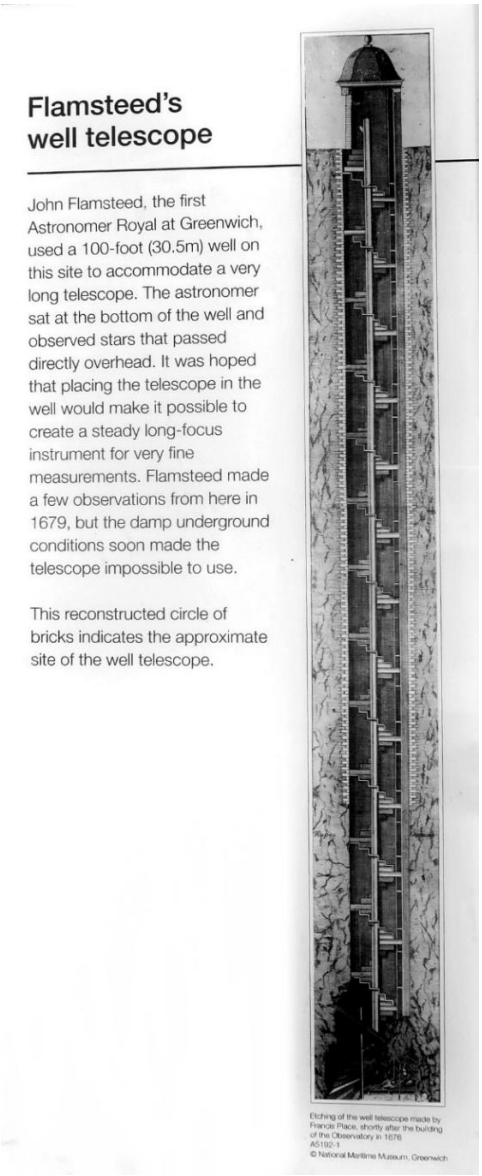
Greenwich Park Geotrail

Devised by the London Geodiversity Partnership





Flamsteed's well telescope

John Flamsteed, the first Astronomer Royal at Greenwich, used a 100-foot (30.5m) well on this site to accommodate a very long telescope. The astronomer sat at the bottom of the well and observed stars that passed directly overhead. It was hoped that placing the telescope in the well would make it possible to create a steady long-focus instrument for very fine measurements. Flamsteed made a few observations from here in 1679, but the damp underground conditions soon made the telescope impossible to use.

This reconstructed circle of bricks indicates the approximate site of the well telescope.

Etching of the well telescope made by Francis Place, shortly after the building of the Observatory in 1676
A5192-1
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Greenwich Park Geotrail

Greenwich Park is the oldest enclosed Royal Park covering 73 hectares with views across the River Thames to the Docklands and the City of London. It lies in one of the most interesting geologically areas of Greater London as nearly all the different rock types to be found are in the close vicinity, several under the Park itself. This 5km long geotrail has been designed to demonstrate the effect of the geology on the landscape. Greenwich Park is part of Maritime Greenwich World Heritage site.

The walk starts from the Thames Path at Greenwich foot tunnel and then, through the Old Royal Naval College (formerly Royal Hospital for Seamen) and past Queen's House (part of the National Maritime Museum) to enter Greenwich Park at Jubilee Gate. It finishes back on the Thames Path. The Pavilion Tea House makes a good halfway stopping off point and is conveniently placed near the famous Greenwich Meridian. The geotrail is mostly on metalled paths; there are some steep slopes.

The nearest station is Cutty Sark for Maritime Greenwich on the DLR, 20 minutes from Central London. The Cutty Sark is a short walk from Greenwich and Maze Hill railway stations. The nearest Underground station is North Greenwich on the Jubilee line, then bus 129 to Greenwich town centre. Several bus routes have stops close by: 188, 199, 129, 177, 180, 286 and 386. Access by riverboat to Greenwich Pier is from Westminster, Embankment or Tower Piers. There are nearby toilet facilities in Cutty Sark Gardens, King William Walk. Cost 50p, disabled free. Also, free toilet facilities in the Tourist Information Centre in Cutty Sark Gardens, open 10.00-19.00.

Overview of the geology

Greenwich Park is geologically interesting as more than four different geological strata underlie the Park. The differences between them are responsible for the spectacular views from the higher ground across the Thames to the hills on the far side. The high ground of the Blackheath plateau falls steeply away by about 25m to the low ground adjacent to the Thames, affording views right along the length of the escarpment. The geology is also responsible for the numerous springs that rise along the steep slope, one of which has cut back into the plateau that extends onto Blackheath at the southern end.

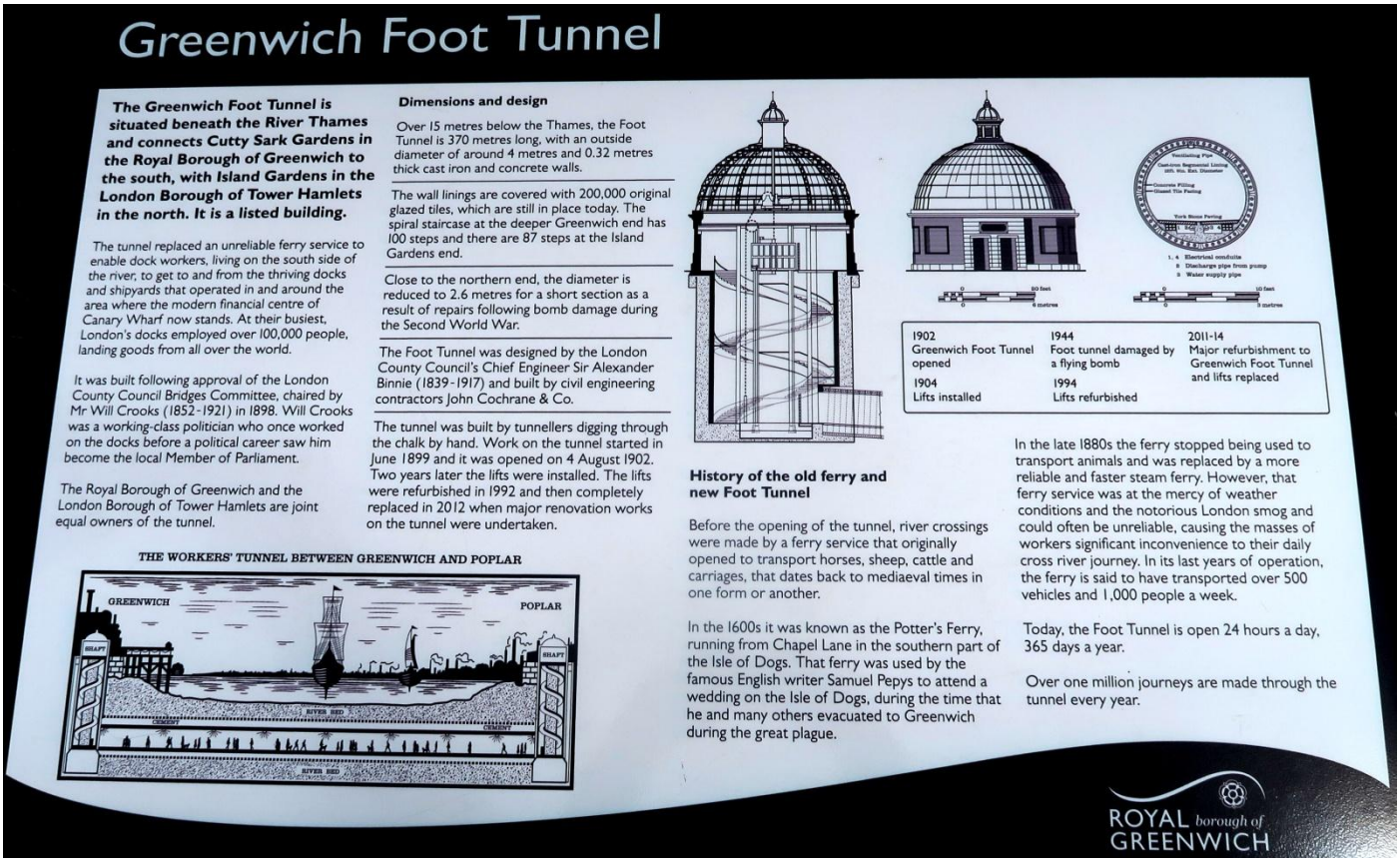
Stop 1: Thames Path at the Greenwich Foot Tunnel entrance (TQ 382 779)

This entrance is on the south side of the river, in sight of the Cutty Sark.

Greenwich Foot Tunnel, opened 1902

There is a display board outside the foot tunnel which gives the history of the tunnel and some geological information. Unfortunately, it contains a number of misleading statements relevant to the geology. Although it states that the tunnel was dug through chalk, it appears mainly to have been cut in the very variable sands and clays of the Lambeth Group and perhaps partly in Thanet Sand. It was excavated by hand but under compressed air. The top of the Chalk in the tunnel area is at about 33m below sea level (14m below the base of the tunnel).

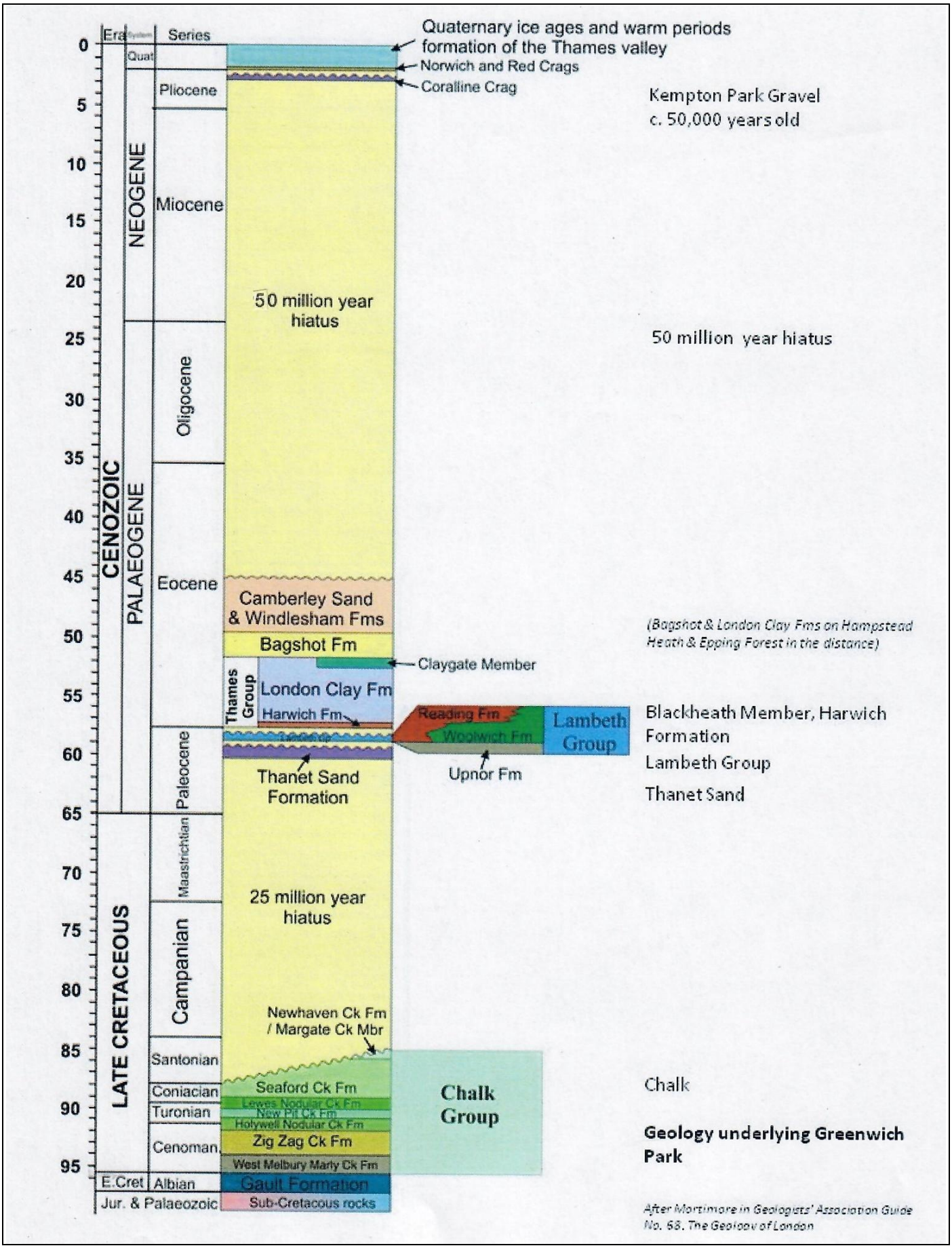
The Docklands Light Railway tunnels beneath, opened in 1999, were mainly excavated in the very variable Lambeth Group but at their deepest (about -26m below sea level) penetrate the Thanet Sand.



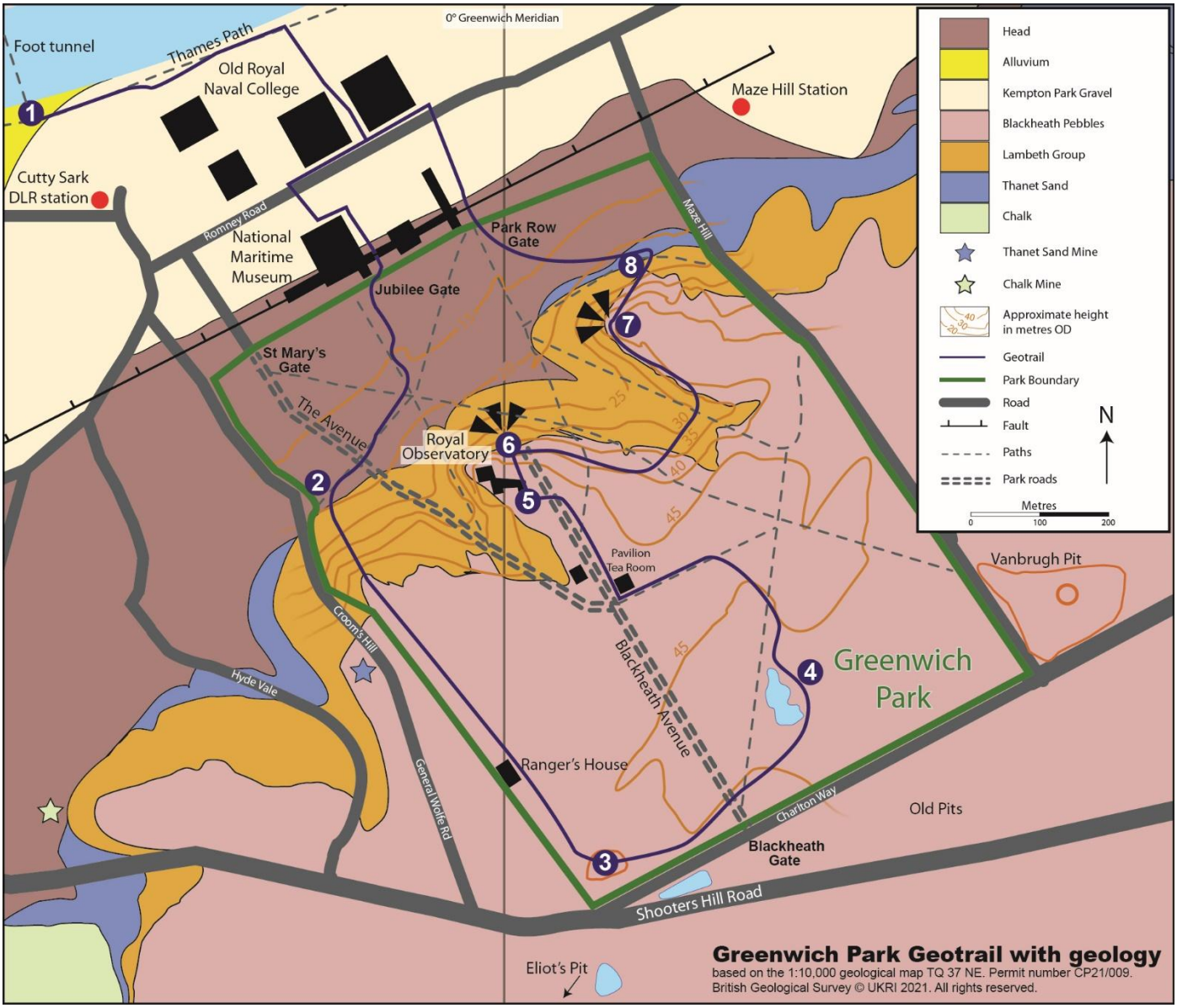
It is worth pointing out that the Meridian Estate blocks of flats immediately to the west are clearly built on a ground level perhaps 2 m lower than those of the Footway Tunnel cupola, Greenwich Pier and the Royal Naval College. The higher level is that of the lowest river terrace and the lower level that of the Thames flood plain. Building on the floodplain requires the construction of river embankments to keep out the highest river and tidal floods.

The younger sediments

The Thames floodplain is underlain by Alluvium – a mix of clays, sands and pebbles eroded from older rocks and deposited over the last 10,000 years once the most recent of the ice ages had fully melted. A few steps south from the tunnel, the underlying stratum is the Kempton Park Gravel, the youngest exposed of the Thames Terraces laid down between 100,000 and 50,000 years ago. Both these young sediments are just a few metres deep and either at or near the surface, overlying the deeper rocks that are encountered in the tunnel and to be found underfoot within Greenwich Park. There is a time gap of about 50 million years between the younger rocks and the older rocks of the Eocene (see stratigraphic column on next page).



***Stratigraphic column of the strata beneath London**. Those in Greenwich Park are indicated and others outside the park are labelled appropriately (after Mortimore in GA Guide 68, 2010)*



Geology map of the area with the route of the Geotrail shown in blue.

Head east along the Thames Path and then turn right through the Water Gate and walk between the two symmetrical domes of Royal Naval College. Turn right at the fence to cross Romney Road at the pedestrian crossing. Enter the Maritime Museum grounds and walk around the left side of the museum building, past Queen's House to enter Greenwich Park at the Jubilee Gate, walk along Jubilee Footpath, branching right to cross The Avenue and grass towards Stop 2.

Stop 2: Conduit House (TQ 386 772)

Springs in the Park

The Conduit House, otherwise known as the Standard Reservoir, is an obvious landmark to help explain how the many springs in the Park have been put to good use over the centuries, providing water to the neighbourhood. Water was an important factor in the siting of the former Military Hospital for Seamen. Water collected via lead pipes from springs in the slope behind the Conduit House was then channelled in brick-built conduits, tall enough to walk through, both to the Hospital and to the Hyde Vale Conduit, outside the Park to the west.

South  **North**

The slope towards Conduit House
Photo: Laurie Baker, March 2017

Conduit House in 2017
Photo: Theresa Ball, April 2017

The Standard Reservoir Conduit House forms part of the water supply system, which was built in the late 17th century or early 18th century. It covers a reservoir and is attributed to the architect Nicholas Hawksmoor, Clerk of Works at Greenwich between 1698 and 1735. The geology is key to the listed building's functional role in delivering water from springs to the former Royal Hospital for Seamen (now Old Royal Naval College) at the bottom of the hill.

The geology and topography of the park dictates the position of the springs. Water falling on the plateau of Blackheath pebbles percolates through gravel and sand and is forced to the surface when

it meets a layer of clay, about 15m below the top of the slope. Some water penetrates the denser sand of the Woolwich beds (part of the Lambeth Group) below to emerge as a second spring line lower down the hill. There is a spring just behind the Conduit House which can be examined by clambering up the slope.

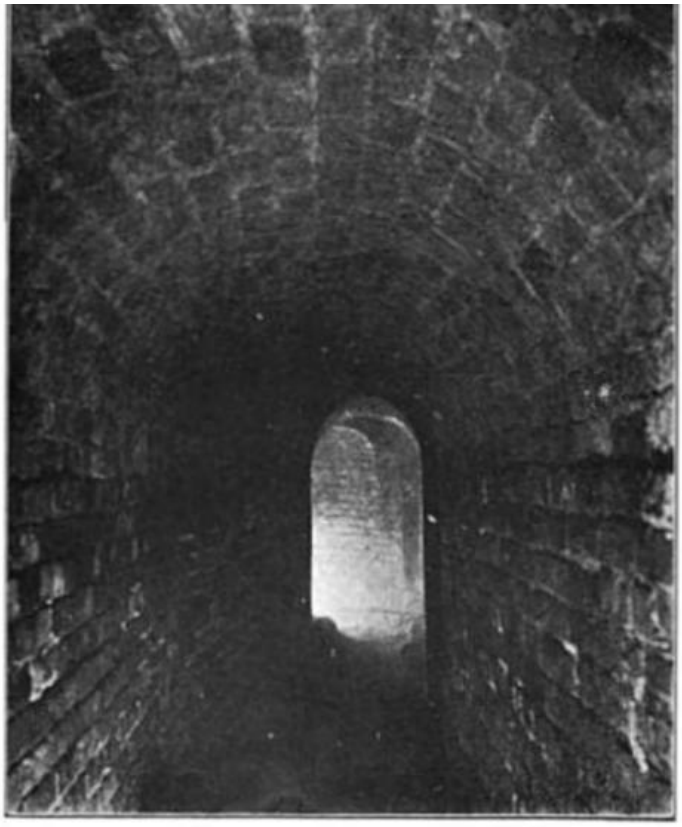
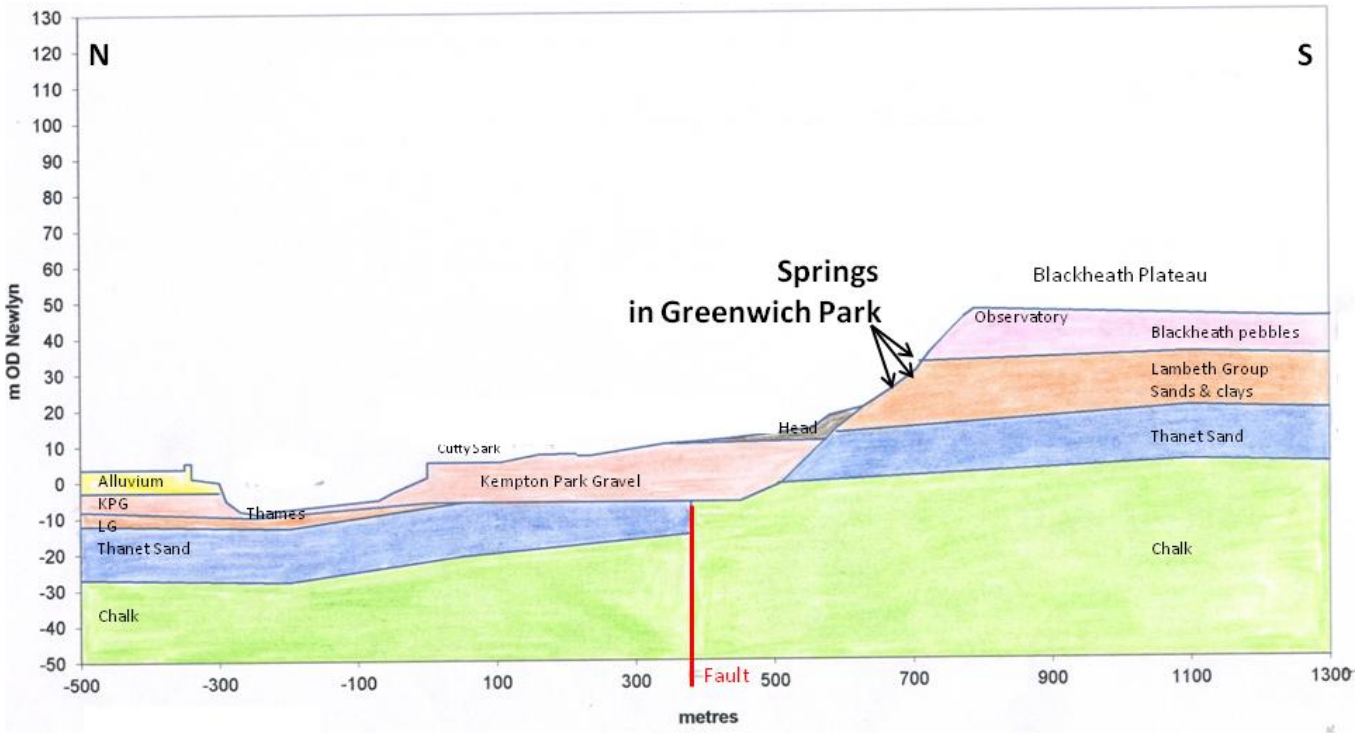


Photo by Mr. Strutt.

UNDERGROUND PASSAGE IN GREENWICH PARK.

Mr Strutt's photograph of the brick-lined conduit in about 1900.

From the former Subterranean Greenwich website.



Cross section of Greenwich Park extended north under the Thames showing location of springs on the steep slope. They occur when pebbles or sand meets less permeable rock types (mostly clays).

Drawn by Paul Rainey 2017

Head uphill bearing right past Queen Caroline's Bath. Approaching the Dell, bear left and enter the Dell opposite a tall tree stump. On the route up the steep slope from the National Maritime Museum you will have climbed up the succession from the Thanet Sand to the Lambeth Group (junction at the Conduit House), then up the successive sands and clays that make up the Lambeth Group (Upnor Formation Sand at the base, with probably some Reading Formation sands and mottled clays and the Woolwich Formation with its shell beds between various sand and clay layers). Finally, you will arrive at the plateau which is underlain by gravel of the Blackheath beds. Apart from tell-tale spring lines you are unlikely to be able to see the junctions and certainly not the rock strata unless there are temporary excavations. However, these can be seen close by at Gilbert's Pit, Charlton – see details on the London Geodiversity Partnership website.

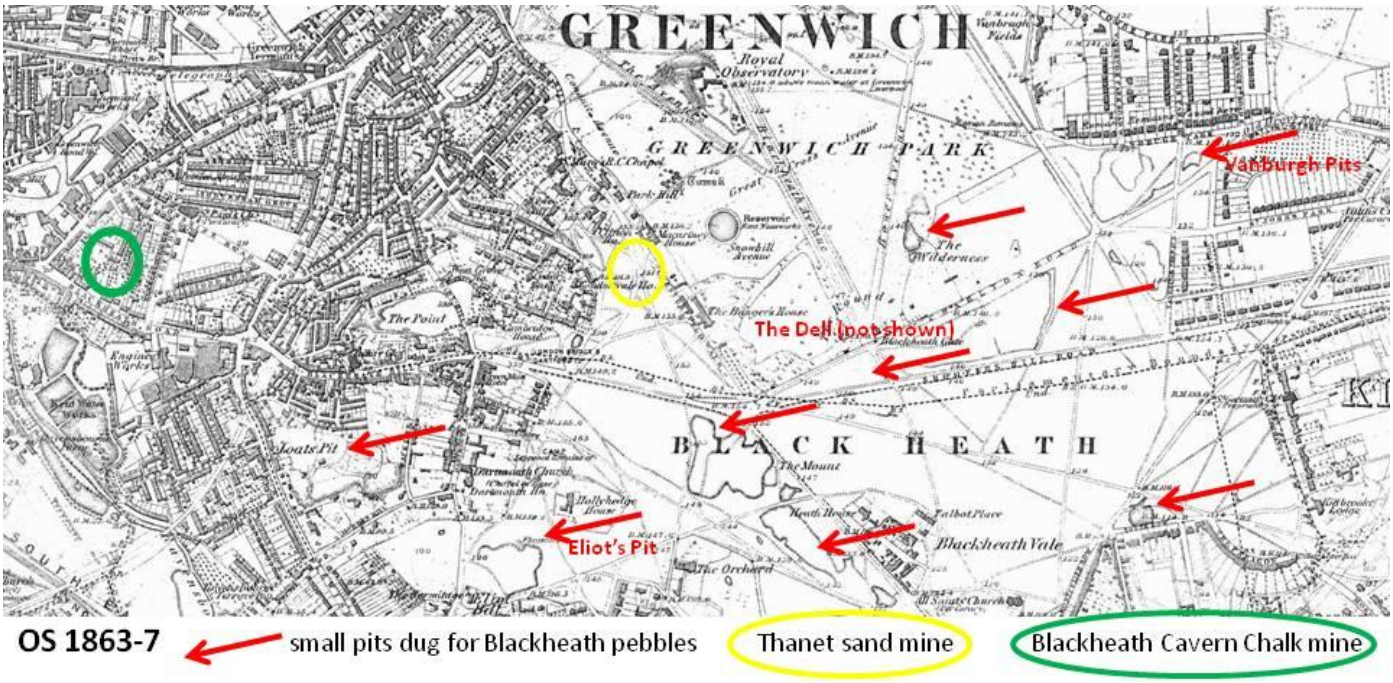
Stop 3: Old gravel pit, known as The Dell (TQ 390 767)

Black rounded Blackheath pebbles can usually be found on the bare slopes of the Dell
Photo Ann Davidson, 2017

Blackheath pebble beds (Blackheath Member of the Harwich Formation)

The Dell was once a small gravel pit quarrying the rounded black pebbles known informally as Blackheath pebble beds. There were many such quarries, both within Greenwich Park and beyond on Blackheath. Most were back-filled with war-time rubble but some became ponds (as in Greenwich Park) and three have remained as pits: The Dell here and Vanbrugh Pit just to the east of the perimeter wall, and Eliot's Pit on Blackheath in the southwest corner. It is the nature of the pebbles that gave rise first to the name of the plateau and then to the name of the village. Usually it is the other way round with the place where the stratum was first described that gives it the name used by geologists (as in Woolwich Formation). Contrary to local myth, the name 'Blackheath' has nothing to do with the Black Death. The pits were probably primarily dug for road-mending. Search around on bare slopes for the pebbles. They are all made of flint that had its origin as layers within the White Chalk. After weathering out of cliffs they must have been transported for a long time to become so evenly rounded, probably by the sea, but with no input from new material. Sometimes little white pits can be detected where the pebbles were touching when deposited.

Pebbles of the Blackheath beds



Portion of 1863-7 OS map showing position of pits within Greenwich Park and on Blackheath

The size of the pebbles implies they were deposited by high-energy currents and it is thought that in places this has channelled through the underlying strata to form thick sequences. Fossils found within the sequence inform us that the Blackheath pebble beds were laid down under the sea. The average thickness on Blackheath and at the top of Greenwich Park is up to 10m but at Abbey Wood further east it reaches nearly 30m in places. The top surface is always at much the same height, 40-45m and forms a plateau that extends from Blackheath to Erith, some 13km away. On old maps the

Blackheath beds are shown as the London Clay bottom bed and they are still associated with the London Clay at the base of the Thames Group. This 'bottom bed' equates from strata of a similar age stretching from Harwich to Reading and has been termed the Harwich Formation – an extremely variable suite of rocks which includes ash bands in the Harwich area, dating from a time, 55 million years ago when America was beginning to split away from Europe. Volcanoes on the west coast of Scotland deposited their ash in Essex and Suffolk where about 30 separate ash layers have been identified. Elsewhere the Harwich Formation consists of sands and clays, mostly including fossils as well as the rounded black pebbles we find here.

Reconstruction of an Early Eocene Forest.
From 'The Book of Life' Ed. S.J. Gould 1993. Random House

From the shelly sands of the Lessness Shell Bed at the base of the Blackheath beds at Abbey Wood further east we learn much about life on land 55 million years ago. Most of the sea shells within the sands are marine but some our estuarine, similar to the slightly older Woolwich beds in this area. Sharks teeth are common and much collected but what makes the site important is the small number of mammal fragments (Hooker, 2010). These are occasionally found when the site is opened up each year, indicating a close proximity to land and several bear no resemblance to mammals living today. Others, like the 'Dawn horse' are ancestors of groups with which we are more familiar. There are ape-like animals and early deer, and they lived in a land that was hotter than today with

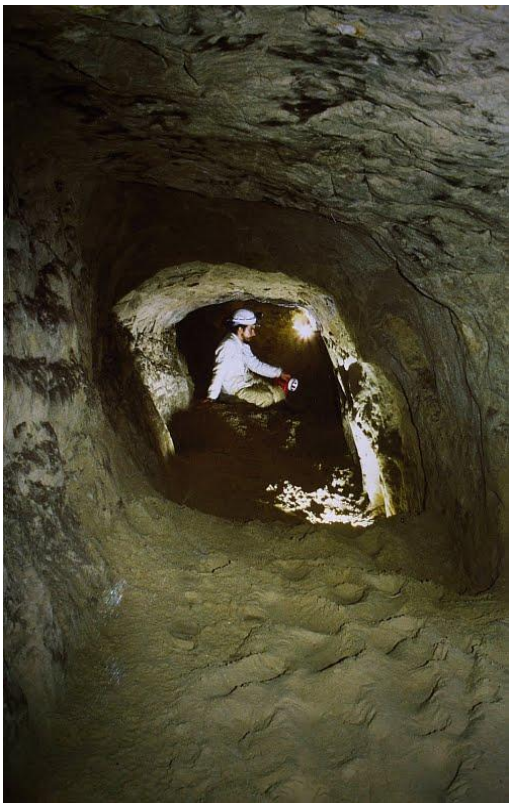
temperatures similar to Malaysia but fossil seeds indicate there was some seasonality. At that time Britain lay at the same latitude as Barcelona is today.

Head across Blackheath Avenue past Blackheath Gate to the Lake in the Flower Garden

Stop 4: Lake in former gravel pit (TQ 392 770)

The depression made by a former gravel pit has been put to good use by creating a lake. The Blackheath pebbles quarried from the pit are discussed at Stop 3 but it is worth mentioning that other strata in the neighbourhood were considered sufficiently valuable to warrant mining in times gone past. These are shown on the map accompanying Stop 3.

The nearest is the Thanet Sand, which was mined adjacent to the west perimeter wall of Greenwich Park more or less in line with the Reservoir shown on the map. A description can be found on the Subterranean Greenwich website when cavers entered the mine. Access is in Hyde Vale, with stairs descending about 20 feet to a passageway varying between 4 and 8 feet high and extending about 280 feet (85m). Old descriptions mention a maze of tunnels but none were found when visited by Subterranean Greenwich. The existing mine was rediscovered in 1986. Nearby at Gilbert's Pit, Charlton, Thanet Sand was used for foundry sand in the Woolwich Arsenal and for glass making but there is no evidence of how the sand from this mine was used.



Investigating the sand mines

Image of the Blackheath Chalk Caverns

Source: Subterranean Greenwich (see: https://subgreenwich.weebly.com/)

A natural exposure of Chalk occurs in the Valley of the Ravensbourne slightly further west. Again, Subterranean Greenwich can supply some details of chalk mining in the area. Mines were cut back into Maidenhead Hill and Trinity Grove, known as Blackheath Cavern Chalk mines. Subsidence seems to have been an on-going problem in the area since their closure. Chalk was used as a lime fertiliser

on sandy soils and many ancient mines and Dene Holes in the area were used for this purpose. A map dated 1770 with the purpose of selling land for building states in two places: *Digging Chalk x Burning lime* so presumably that was the use to that point. During the 17th and 18th centuries chalk was needed to mix with London Clay to stop shrinkage in brick-making. It would be nice to think that the chalk was used for this purpose as it is difficult to track where the chalk that was imported to north London to mix with London Clay there came from. This is undoubtedly the nearest exposure and its proximity to the Thames will have eased the cost of transport but there is so far no evidence to support its export and it seems that this site at least was scheduled for building from an early age. There is evidence that in the mid-19th century the caverns were no longer operating and had been turned into pleasure pursuits with a Ballroom and bar. They were forced to close for building purposes in 1841 and never re-opened.

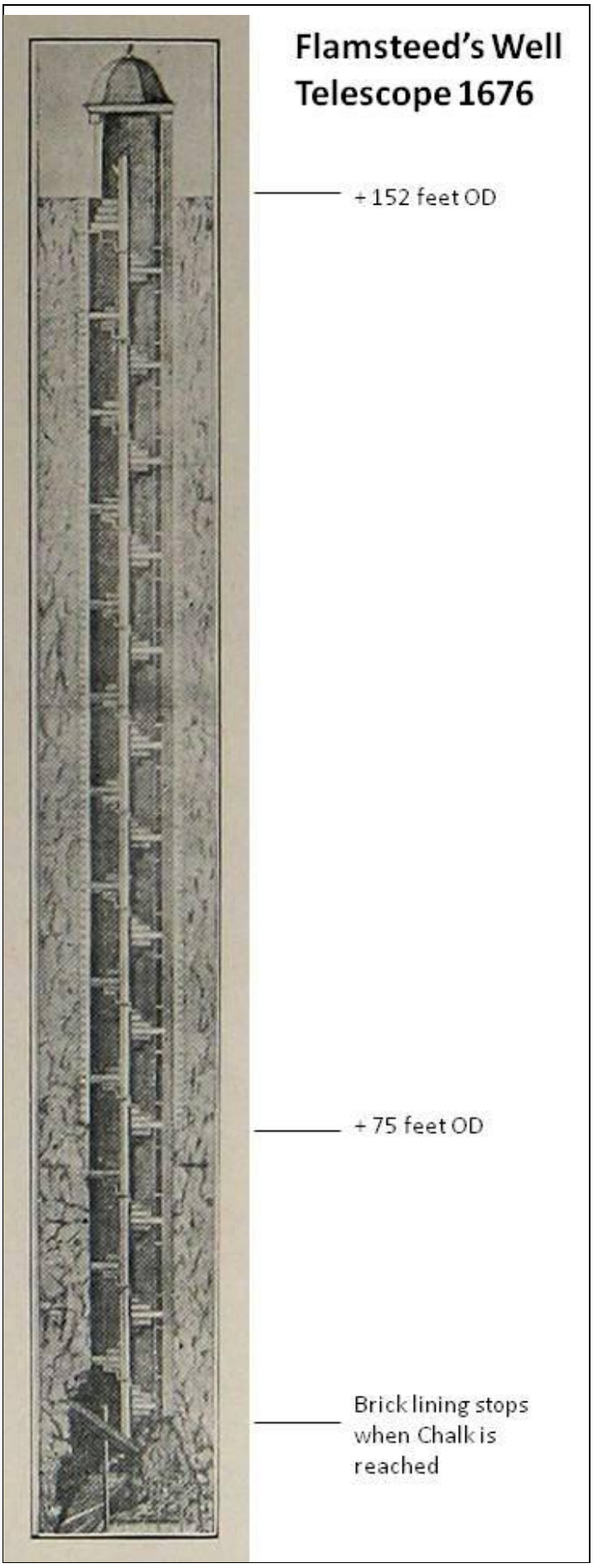
Head across Bower Avenue with the Bandstand on your right to the Pavilion Tea House

Pavilion Tea House (TQ 390 772)
This is a good stopping off point with large seating area inside and out. Refreshments include hot food, sandwiches and salads.

The Pavilion Tea House

Continue across Blackheath Avenue towards Observatory entrance and look for the plaque to Flamsteed's Well.

Stop 5: Flamsteed's Well telescope '1676' (TQ 388 773)



A plaque at the well site, next to the Observatory, shows an engraving of the well telescope by Francis Place dated 1676.

It is not known exactly when Flamsteed's well was dug but descriptions variously put the well at 100, 124 or 130 feet deep (40m). The engraving shows a brick lining about 80 ft deep which seems likely to be penetrating the Blackheath pebbles and the variable sands and clays of the Lambeth Group through to reach the Chalk, which did not need lining. It is interesting that the image of Flamsteed lying on his back at the bottom of the shaft implies that the bottom is dry.

On returning to Blackheath Avenue, turn left towards the viewpoint with Wolfe's statue and the Greenwich Meridian (Stop 6).

Stop 6: Greenwich Meridian (TQ 388 773)

Greenwich is known all over the world as home of the Prime Meridian. But why was Greenwich chosen for this distinction? The Observatory here was built in 1675 but it took almost a century of observations and calculations until Neville Maskelyne, the fifth Astronomer Royal, was able to publish first the Nautical Almanac, from which navigators anywhere in the world could use observations of the Moon to work out what time it was at Greenwich. This enabled them to get their Longitude, and it was in use by over 70% of the world's shipping by 1884 when this Meridian and Greenwich Mean Time were adopted as international standards. As measurement accuracy improved with atomic clocks and Earth satellites, it was discovered that the Earth is not a stable unchanging body. The rotation rate fluctuates, the poles wander and the continental plates drift, all by measurable amounts. So, a new measurement system had to be devised in the 1960s, the International Terrestrial Reference Frame, which is defined by the centre of the Earth and the average positions of all the continental plates. The result is that the ITRF Meridian no longer coincides precisely with that marked in the Observatory, but is currently 102 metres to the east. Similarly, Universal Time is allowed to vary by up to 1 second from GMT. These are small differences, however, and Greenwich is still the home of time and location for reasons of historical continuity.

Head east past the Queen Elizabeth Oak, the fountain at the end of the conduits and another quarry pit, and up towards One Tree Hill avoiding steps

Stop 7: One Tree Hill (TQ 390 775)

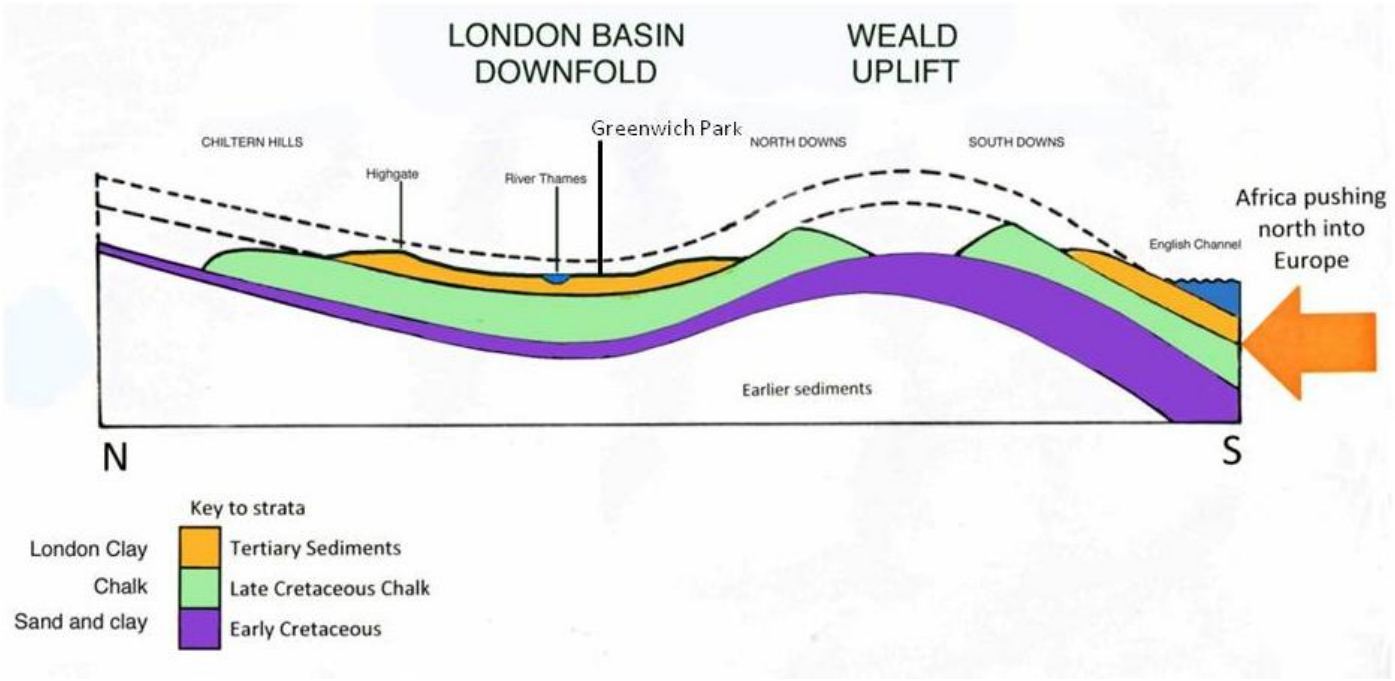
Overview of the geology from this view point

This is a good view point to recap on the local geology and also to look beyond the Park to younger, higher, strata. The view point is on the edge of the Blackheath Plateau which is here about 2 m thick. Below, the ground falls steeply away through the variable soft sands and clays of the Lambeth Group with a break of slope where the junction with the Thanet Sand is met. With such a steep slope it is not surprising that it has failed from time to time leaving a tumble of mixed material, termed Head covering much of the Thanet Sand. This has been accumulating for about 20,000 years as the land warmed up after the most recent ice age. As discussed at Stop 1, close to the Thames the solid strata are overlain by the Kempton Park Gravel. What is surprising is that the Kempton Park Gravel is directly overlying Chalk in places (see geology map, Stop 1). In north London Chalk is only encountered at depth, beneath the deepest of the infra-structure. Here it is brought to the surface by a fault, or more likely a series of faults to create the Greenwich Anticline whereby rocks have been pushed up, then eroded, leaving the oldest rocks exposed in the centre of the upfold. The fault-line runs along the edge of the Park in front but luckily for the iconic buildings behind it there seems to have been no recent movement. This is why it was possible to mine Chalk close to the surface in the Greenwich area (see Stop 4).

View from One Tree Hill towards central London and Hampstead Ridge
Photo: Laurie Baker, September 2020

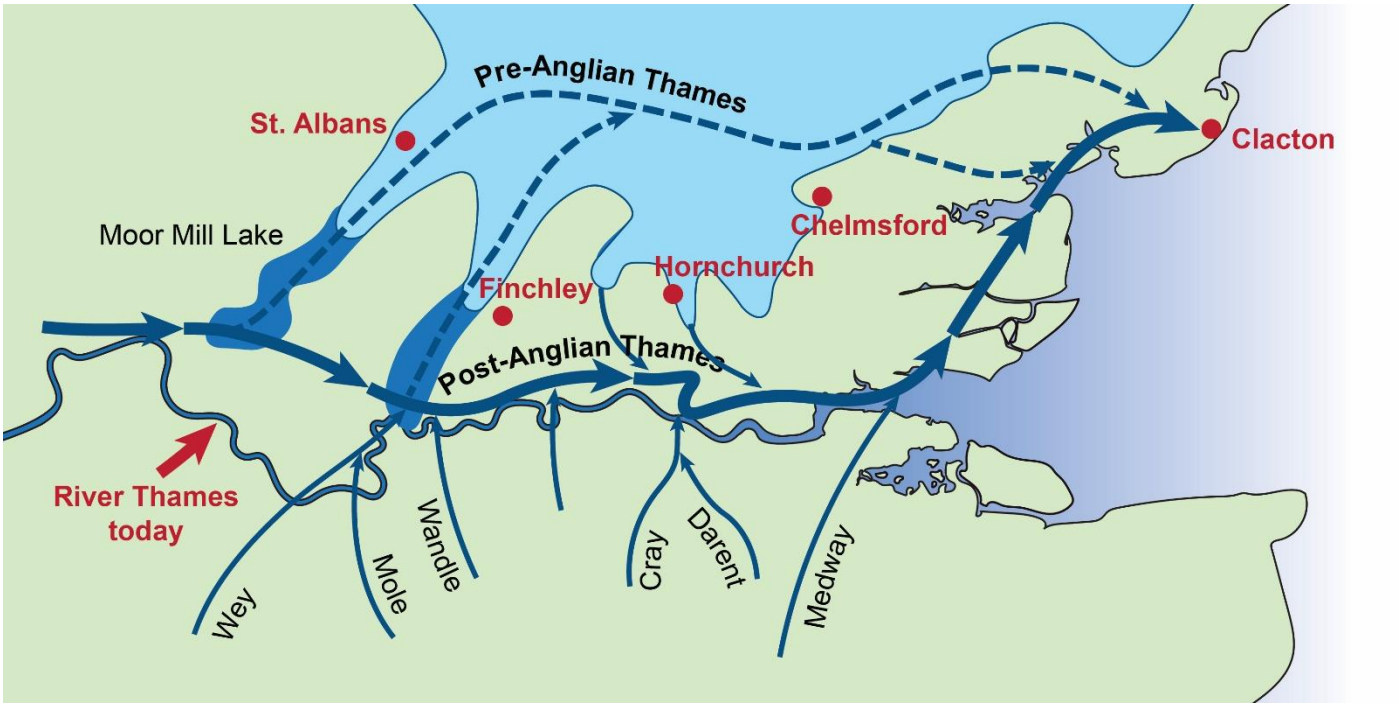
Current transport projects under London have revealed many more faults than were previously realised and the ground investigation boreholes have added greatly to what is known about the structure beneath London. Movement on the faults is the result of Africa colliding with Europe. Gradually the Mediterranean Sea is closing as the Alps are pushed upwards but the push extends to Britain and is responsible for the uplift of the Weald to the south of London and the downfold of the London Basin. Small anticlines such as the ones at Greenwich, Purfleet and Streatham are all perturbations within this overall downfold.

The far distant hills on the other side of the Thames on a good day, are higher than Greenwich Park and display younger solid geology. The Blackheath pebble bed beneath your feet at this point underlies the London Clay which is the surface rock under much of London. On the highest of the hills the full depth of the London Clay is present, including the sandy layer at the top known as the Claygate Beds, a maximum of 110m. All of this has been eroded from Greenwich but can be found not far away on Shooters Hill. The youngest rocks of the solid geology, the Bagshot sands (about 40 million years old) cap the highest of the hills, Hampstead Heath and Harrow-on-the-Hill in the west and Epping Forest in the east. It is not found on Shooters Hill or Sydenham Hill in south London. It probably once covered the whole area but over millions of years has been mostly eroded.



Formation of the Weald Anticline and the London Basin Syncline
After Friend 2008, Fig. 10

It was during the 50-million-year time gap between the deposition of the Bagshot Sands and the laying down of a series of gravel terraces on either side of the Thames that the earth movements that caused the present structures happened. During this time Britain ceased to be under the sea and became land, initially joined to Europe but probably severed by the English Channel at the end of the most extensive ice age by a vast lake of water that built up from the Thames and the Rhine with nowhere to go. Eventually the remaining neck of land was broken through and water cascaded down the English Channel to the Atlantic. The ice sheet reached as far as North London and lakes built up at the margins. As the ice melted about 400,000 years ago these too burst their banks and forced the Thames into more or less its current position.



Diversion of the River Thames by the Anglian ice sheet
After Bridgland and Gibbons, 1997

Head down the steps past a Conduit Head below One Tree Hill and Stop 8

Conduit Head at One Tree Hill, which formed part of Greenwich Park's water supply network
Photo: Laurie Baker, September 2020

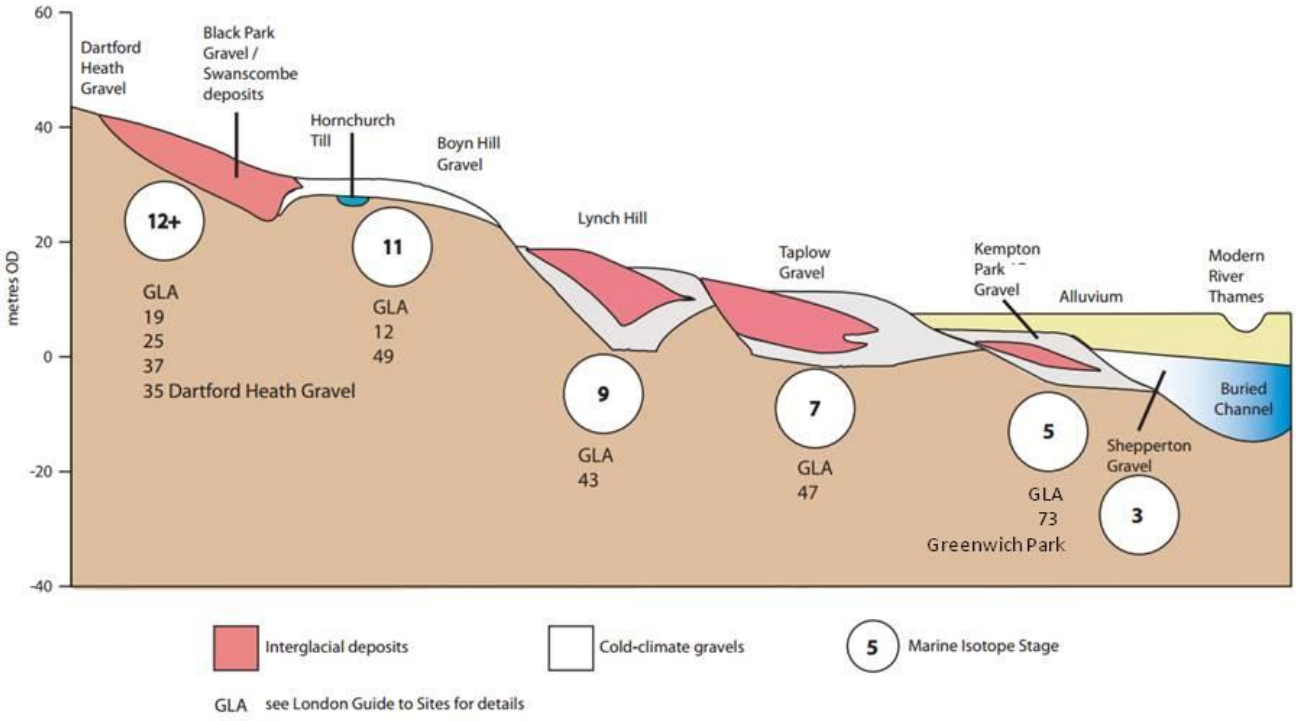
The conduit head is another part of the water supply system which channelled natural groundwater from the high ground of the Greenwich escarpment, northwards to the buildings of the Royal Hospital for Seamen (the Old Royal Naval College).

It again dates from the late-17th or early-18th century, and is tentatively attributed to the renowned architect Nicholas Hawksmoor, Clerk of the Works at Greenwich between 1698 and 1735.

Stop 8: East Coombe (TQ 391 776)

Even though the great Anglian ice sheet did not reach south London, its effects were felt. All the land in front of the ice sheet would have been frozen permafrost and as it melted a vast amount of water would have been released. East Coombe in front of you would have been formed in this way. Since the Anglian ice advance, at its height 450,000 years ago there have been five subsequent glaciations, but none of the ice sheets reached as far as London. Nevertheless, the same process of permafrost and melt water would have chiselled away areas where water was flowing, creating the coombs, or 'bites in the landscape' that we see today. With each glaciation the Thames deposited floodplain sands and gravels which became terraces as the river then down cut further. The one adjacent to the Thames in Greenwich is the Kempton Park Gravel laid down between 100,000 and 50,000 years ago.

View from top of east combe towards the Thames showing the effect of past water flows
Photo by Laurie Baker, June 2019



Idealised section through the Thames terrace staircase, with the oldest deposited gravels at the top. The Kempton Park (Floodplain) Gravel (MIS 5) underlies the National Maritime Museum and Queen's House. During each cold period the ground was completely frozen.

To return to the Thames Path, exit the park by the Park Row Gate and follow the route down Park Row. Or, for transport connections listed at the beginning, exit via the St. Mary's Gate at the north-west corner of the park.

This Geotrail was compiled by Diana Clements, Ann Davidson, Theresa Ball, Paul Rainey, Laurie Baker and Alister Hayes, June 2019.
Minor revisions: October 2025

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