Soils and subsoils from a sanitary point of view : with especial reference to London and its neighbourhood / by Horace B. Woodward.

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Soils & Sub-soils.

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

SOILS AND SUB-SOILS

FROM A SANITARY POINT OF VIEW;
WITH ESPECIAL REFERENCE TO
LONDON AND ITS NEIGHBOURHOOD.

By
HORACE B. WOODWARD, F.R.S.

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PREFACE.

At the Offices of the Geological Survey constant enquiries are made by the public for information regarding sites for houses and other questions involving the practical applications of geological science. In view of this great and ever-increasing demand for advice, it seemed desirable to put in popular and accessible form a summary of what is known as to the relations between the nature of soils and sub-soils and the sanitary requirements of the community, and to select, for the purpose of illustrating the subject, the district of London and its suburbs.

Accordingly, Mr. Horace B. Woodward has prepared the present treatise. His long connection with the Geological Survey has given him special fitness for the task. Besides a wide acquaintance with the geology of the southern half of England, he formerly took part in the detailed mapping of the London area, and in his capacity as Resident Geologist at this Office he is now thrown into daily contact with those who are practically engaged in well-sinking, draining, building, and other occupations in which geological assistance is sought for. He has thus been able to gather much general information on the subjects discussed in the following pages, his own personal observations being supplemented by those obtained from medical officers, engineers, and architects, as well as from house-hunters, who have communicated their various experiences.

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In the preparation of this hand-book to the soils and sub-soils of London and its neighbourhood the author has consulted the valuable "Transactions of the Sanitary Institute" and other works, and among those individuals to whom he is more particularly indebted for assistance he desires to express his thanks to Dr. James Murie, Mr. Harold L. Barnard, M.B., F.R.C.S., Mr. George Abbott, M.R.C.S., Mr. Frederick Meeson, Architect, and Mr. W. Whitaker, F.R.S.

The small sketch-map which accompanies this pamphlet may serve as a guide to the more detailed information contained in the larger maps of the Geological Survey. A full index has been added, in which the heights are given of all places mentioned on the map or referred to in the text.

ARCH. GEIKIE,
Director-General.

Geological Survey Office,
28, Jermyn Street,
London, S.W.
6th November, 1897

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Map of the Sub-Soils around London. *At end of vol.*

SOILS AND SUB-SOILS

FROM A SANITARY POINT OF VIEW:

WITH ESPECIAL REFERENCE TO LONDON AND ITS NEIGHBOURHOOD.

CHAPTER I.

INTRODUCTION.

The problem of choosing a place of residence exercises the minds of many whose homes are not fixed by the bonds of inheritance nor by the necessities of their mode of livelihood.

In every civilized country a constantly increasing proportion of the population has to seek abode within a certain limit in or near some large town or city. Together with this aggregation of humanity around crowded centres it has slowly been realized that especial attention requires to be paid to the sanitary conditions which depend on the nature of the sub-soil. Around London, for example, the idea has become widespread that a site on Chalk, on gravel or sand, or on some other dry and porous material is to be preferred to one on clay. Increasing attention is now given to the subject by Architects and Physicians. Nevertheless, a good deal of misapprehension exists with regard to the advantages of gravel as a sub-soil, and of the disadvantages of clay: in certain circumstances either may be good, or both may be bad as sites for houses.

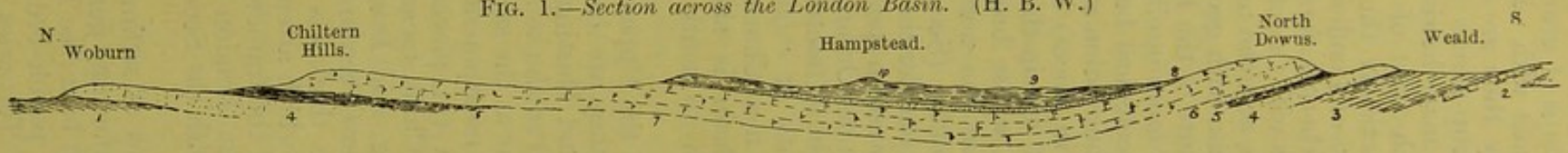
The object of the present little work is therefore to supply such information as may be needed by those who are compelled to be careful in the choice of their place of residence. All house-hunters indeed would do well to consider the general sanitary conditions connected with proposed sites; and to bear in mind that a healthy habitation depends on several considerations, apart from the nature of the sub-soil. There are the elevation of the ground and other local circumstances, and more important still the construction of the house itself, its damp-proof basement, its airy and sunny position, and the system of drainage. Lastly, the water-supply is a question of vital importance.

London and its Neighbourhood.

London being the chief centre of attraction to Britons, it is desirable to describe in some detail the nature of the various sub-soils which occur over the large area embraced by the city and its suburbs.

If we take the district known at the General Register Office

FIG. 1.—*Section across the London Basin.* (H. B. W.)

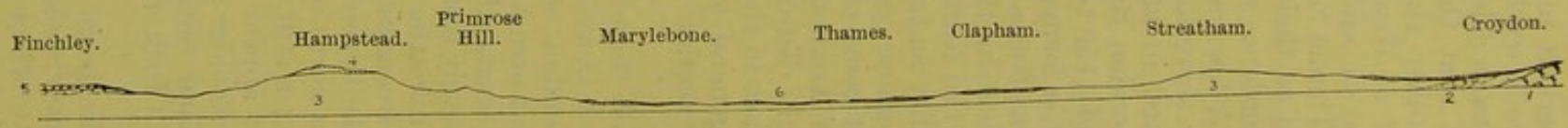


Alluvium and Valley gravel (not shown).
10. Bagshot Beds.
9. London Clay.

8. Blackheath Beds. Woolwich & Reading Beds Thanet Beds.
7. Chalk.
6. Upper Greensand.

5. Gault.
4. Lower Greensand.
3. Weald Clay.
2. Hastings Beds.
1. Oxford Clay.

FIG. 2.—*Section across London from Finchley to Croydon.* (H. B. W.)



6. Valley gravel and loam.
5. Boulder-clay with underlying sand and gravel.
4. Bagshot Sand.
3 London Clay.

2. Blackheath Beds. Woolwich and Reading Beds. Thanet Beds.
1. Chalk.

divided into the Thanet Sand, Woolwich and Reading Beds and Blackheath Beds; overlain by a great mass of clay, termed the London Clay (9); and followed by a group of sands with clayey bands, known as the Bagshot Beds (10), which in London itself cap the higher grounds of Hampstead and Highgate. Of these strata the London Clay occupies the most extensive area, the thinner group below (8) appearing at the surface over a comparatively narrow belt. All, however, occur in regular sequence.

Overlying many of these strata, and, indeed, resting indifferently on any portions of them, there are other gravels, loams, and clays, classed as Quaternary. They do not partake of the bend to which the Tertiary strata beneath have been subjected; but the curve (as shown in Fig. 1) is too slight to be observed, save in a diagram where the vertical scale is exaggerated. These newer deposits comprise local accumulations of clay-with-flints and loam on the Chalk tracts; also of chalky clay (Boulder-clay) and high-level gravel and sand, as at Muswell Hill, Finchley, and Barnet. (See Fig. 2.) They include the more extensive sheets of gravel and loam along the Thames valley: deposits which were accumulated and distributed by the river in ancient times. They comprise also the more modern strip of marshland or Alluvium, which immediately fringes the river over small areas above London, and over broader tracts in southern Essex and northern Kent.

These newer deposits are scattered somewhat promiscuously over the abraded surfaces of the Bagshot Beds and older strata. They have a sequence of their own in point of time, but this is not maintained, as in the case of the older deposits, by the regular succession at any one locality of all the deposits, although two or more of them may in places be in sequence. They lie at various levels and appear in different localities. Some have been formed only over limited tracts, like the Alluvium, certain of the gravels, and the clay-with-flints; others have formerly spread over much wider areas; and all, with the exception of the Alluvium, have since suffered more or less destruction or erosion, so that in some localities only scattered patches of gravel or Boulder-clay may now remain of former extensive sheets.

Arranged in the order of their natural sequence or period of formation, the soils and sub-soils are as follows:—

	Geological Formations and Soils.		Characters.
Quaternary.	Made Ground and Natural Soil		Superficial covering of *mould* and disturbed ground.
	Alluvium		*Silt*, *marl*, *clay*, and *peat*.
	Valley or River Gravel and Brickearth		*Gravel* and *loam*.
	Clay-with-flints (of varying age)		*Clay*, *loam*, and *flints*.
	Glacial Drift		*Boulder-clay*, *loam*, *gravel*, and *sand*.
Tertiary.	Bagshot Beds	Upper	*Sand*.
		Middle	*Sand*, *loam*, and *clay*.
		Lower	*Sand*.
	London Clay		*Clay*.
	Blackheath (or Oldhaven) Beds		*Gravel*.
	Woolwich and Reading Beds		*Clay*, *sand*, and *gravel*.
	Thanet Beds		*Sand*.

Secondary.	Chalk	Soft white *limestone*, with bands and nodules of *flint*.
	Upper Greensand	*Sandstone* and *sand*.
	Gault	*Clay*.
	Lower Greensand	*Sand* and *sandstone*, with *limestone*, *chert*, and *clay*.
	Weald Clay	*Clay*.
	Hastings Beds	*Sand*, *sandstone*, and *clay*.

The little map which accompanies this work will be useful as an index to the general distribution of the sub-soils in the area around London. Maps on the scale of six inches to a mile are, however, absolutely necessary for all practical purposes. All the recent work of the Geological Survey has been carried out on these large maps, MS. copies of which are preserved at the Office; but at present very little of the country around London has been surveyed geologically on a scale larger than that of one inch to a mile.

CHAPTER II.

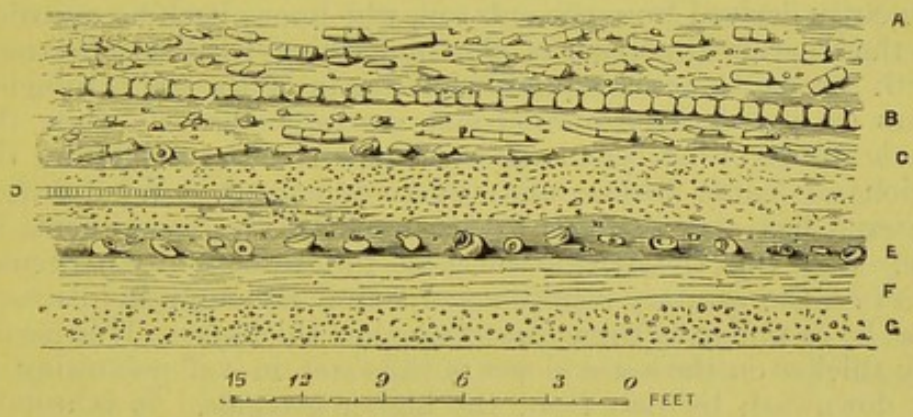
SOILS AND SUB-SOILS OF LONDON AND ITS NEIGHBOURHOOD.

Soils.

Made Ground.—The surface-soil of London, and also of many other large cities and towns, is a mixture of mould, gravel, or clay, with débris of ancient buildings and rubbish. Much of his has been upturned over and over again, so that it comprises an accumulation of brick-bats, fragments of crockery, and what not, commingled with relics of the soil and sub-soil. In a few localities in London it has accumulated steadily, or at irregular intervals, at the rate of from 6 inches to 1 foot a century. Much of the "Made Ground" is thus of ancient date, and in these undisturbed areas it has preserved trophies of the Roman occupation, of the Great Fire, and other interesting episodes. (See Fig. 3.)

FIG. 3.—*Section in Cannon Street.*

(W. Chaffers.)[1]



Made Ground.
- A. Level of the street.
- B. Roadway before the Great Fire of London, in 1666.
- C. Earth in which Norman and Early English Pottery is found.
- D. Roman tesselated pavement.
- E. Black soil in which red lustrous (Samian) and other Roman ware is found.

Valley Drift.
- F. Loam.
- G. Gravel.

Made Ground may be from a foot or two to about 25 feet in thickness, the greater thicknesses being here and there due to the in-filling of old pits. At the Bank of England there were 22 feet of Made Ground, resting on four feet of gravel. Such

[1] F. W. Rudler, "Handbook to Collection of British Pottery and Porcelain," 1893, p. 67; Whitaker, "Geology of London" (Geol. Survey), vol. ii., p. 324.

artificial "Soil" of varying character and thickness, no doubt extends over the whole of old London. Mr. Whitaker has remarked that Belgravia is probably in great part built on ground of this character, otherwise it would be lower and damper.

In itself Made Ground is not always an unsatisfactory foundation for a house. Much of it, as we have stated, is of ancient date. Moreover good material may artificially be brought to level an irregular tract. The serious matter is that in these enlightened days it is possible for houses to be erected on pits in which all kinds of rubbish, with decaying vegetable and animal matter, have recently and intentionally been shot.

Sir Douglas Galton has spoken strongly on the subject, and he asks, "What then can be more dangerous, what more wicked, than the everyday proceedings, in the metropolis and elsewhere, of those persons who purchase a building site, who extract from it the healthy clean gravel and sand which it contains, allow the hole to be filled with rubbish, and then proceed to build upon it?"[1] It is well known that injurious emanations come from an impure soil or sub-soil, and may rise into a house; so that on such an unwholesome foundation it is absolutely necessary that the basement be securely cemented. The bye-laws of the Local Government Board will, it is hoped, prevent any further building of houses on polluted sites.

Natural Soil.—The natural soil is of varied composition, being primarily derived from the sub-soil, which may itself be regarded as the weathered portion of the underlying hard or soft strata. With the decomposed mineral ingredients of the soil is mingled more or less decayed animal and vegetable matter; while the whole soil-layer has been largely re-constituted as mould by the action of earth-worms and micro-organisms. Wind-drifted material has also to some extent modified the constituents of soil. As a rule, the natural soil is too thin to have any particular effect on the sanitary conditions of a site, although in places it may be as much as three feet or more in thickness. It is naturally thicker on the lower slopes of hills and in valleys, owing to its downwash by rain from the higher grounds. It is usually thicker also on the sandy and loamy areas than on the stiff clays.

Sub-soils.

Marshland.

Alluvium.—The low-lying tracts which immediately border the Thames and its tributaries, and which fringe the lower courses of most rivers, should be regarded as essentially the property of the river. Originally marshlands, they sometimes remain so, and at any rate they are liable to be flooded when the river is so swollen as to overflow its natural banks. Artificial ramparts may preserve these tracts as meadow-lands, but they are to be avoided as sites for residences; and it is noteworthy that they were not

[1] Trans. Sanit. Inst., vol. i., 120.

chosen by the early settlers. Composed of silt and clay with peat and occasional layers of marl or gravel, and varying in thickness from 5 to 40 feet, they form a damp and unreliable foundation. Gravel usually underlies the Alluvium, and this is often waterlogged, so that if the river be in flood and the Alluvium be thin or porous, water may rise in the cellars of houses built upon such low-lying ground.

Fortunately there are but small areas of Alluvium in the heart of London; there are tracts at Walbrook and Pimlico, and also at Lambeth, Deptford, Rotherhithe, and the Isle of Dogs. After long-continued rains the Thames sometimes rises so as to flood the lowest parts of Wapping, Deptford, and Rotherhithe, of Southwark, Lambeth, and Vauxhall.

In certain localities a protective covering of Made Ground, 4 to 6 feet thick, renders the old marshland habitable, as at Pimlico. There the Alluvium itself is from 6 to 30 feet in thickness, the deeper portion being nearer the river. At the Grosvenor Hotel there were 4 feet of Made Ground, overlying 11 feet of Alluvium and 9 feet of sand and gravel. Westminster is thus situated on old marshland, part of the area being formerly the island known as Thorney.[1]

Basements of houses erected on river-flats are in any case liable to be damp, and should be well cemented. Permanent injury may be done to buildings if in more open country such sites are chosen, and the river occasionally asserts its rights by flooding the tract. In wet weather sheets of water may cover areas of Alluvium for some length of time. This is the case on Staines Moor in the Colne valley, a tract of Alluvium which extends from Watford and Rickmansworth to Staines, and where the ground contains much peat.

Along the Brent valley between Greenford and Hanwell, the Alluvium consists chiefly of re-deposited London clay, and the tract of flat meadow-land is subject to floods. There is a broad tract of Alluvium along the Lea valley, forming the marshes of Enfield, Tottenham, Walthamstow, Hackney, and West Ham; and a similar tract extends along the north side of the Thames in the Levels of Plaistow, East Ham, and Barking.

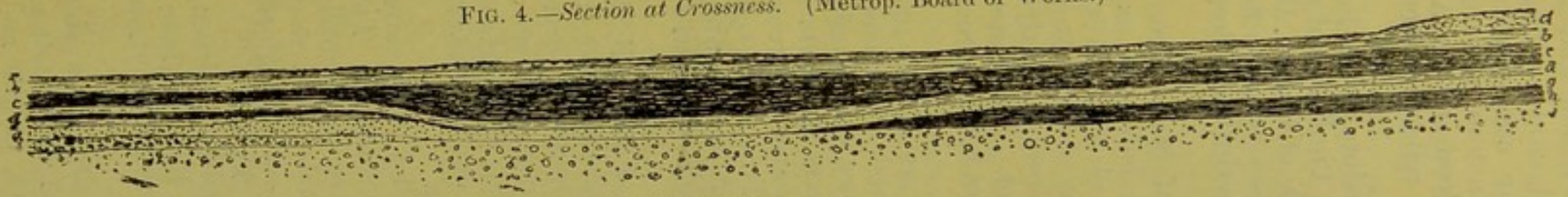
Severe floods sometimes occur in the Lea valley, and cause injury to the market-gardens in the low grounds. The Walthamstow, Hackney, and Stratford marshes are occasionally covered by two or three feet of water, and flood-waters may occupy the flats by Waltham Cross, Cheshunt, and Chingford. The valley of the Roding at Ilford is also liable to floods.

On the south side of the river there are the marshes of Greenwich and Plumstead, areas which are embanked; but the basements of houses at Lower Charlton and elsewhere along their borders have at rare intervals been flooded.

In places these low-lying tracts, some of which are below the level of high-water mark, have been utilized in the construction of Docks. Elsewhere gas-works, chemical factories, candle and

[1] See W. J. Loftie, "History of London," 1883, vol. ii., p. 34.

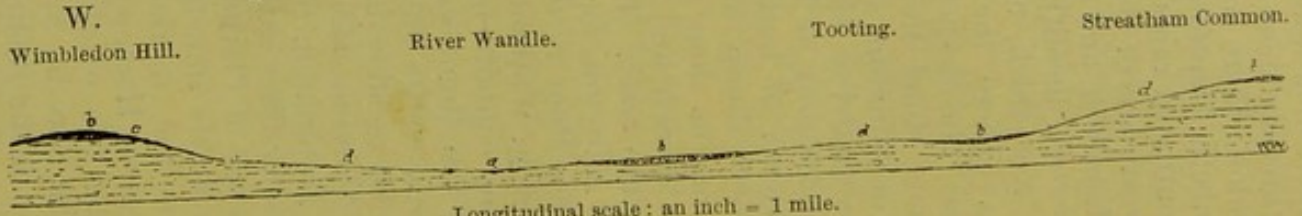
FIG. 4.—*Section at Crossness.* (Metrop. Board of Works.)[1]



Scale 88 feet to an inch.

a. Soil.
Alluvium { *b*. Silt. *c*. Peat. *d*. Clay. *e*. Peat. *f*. Clay. *g*. Sand and clay. *h*. Peat and clay.
i. Gravel.

Fig. 5.—*Section across the valley of the Wandle.* (W. Whitaker.)[2]



Longitudinal scale: an inch = 1 mile.

a. Alluvium. *b*. Gravel. *c*. Bagshot Sand. *d*. London Clay.

[1] Whitaker, "Geology of London," vol. i., fig. 98, p. 466.

[2] *Ibid.*, vol. i., fig. 86, p. 428.

soap-works have been established. There are indeed growing populations on the East Ham and Plaistow Levels, as at Beckton and Silvertown; but where the necessities of livelihood or calling do not require residence in them, such areas are in general undesirable, though I have been assured that Beckton is not unhealthy. Perhaps the disinfecting influence of the gas-works may contribute to the salubrity.

Crossness again, with its main-drainage works, is not a locality which one would naturally choose as a residence, but the best care is taken of those who are obliged to seek a habitation near the works. (See Fig. 4.)

One of the most serious objections to any large population on alluvial grounds, as pointed out to me by Mr. F. J. Bennett, is the difficulty of introducing any effective system of house-drainage, owing to the want of fall to carry away the sewage. Another difficulty may be the water-supply, as at Rainham Ferry, on the Essex marshes, where in the absence of a deep well "the inhabitants are entirely dependent for their supply on rain water and on condensed water from the manufactories."[1]

Gravel, Sand, and Sandstone.

Valley Gravel.—The Valley gravel and loam (brickearth) are ancient alluvial deposits of the Thames and its tributaries, occupying tracts above the level of the marshland, and indeed rising to elevations of 150 feet at Highbury, 160 feet at Castlebar, Ealing, and 180 feet at Wimbledon. The loam occurs irregularly in and over the gravel, and their respective areas at the surface have not as yet been ascertained in detail along the Thames valley above London.

The gravel is most largely composed of flint in the form of subangular stones and pebbles, together with quartz and quartzite pebbles. It contains much sand in places, and occasionally peaty layers occur.

The greater part of old London and the villages now incorporated in modern London, were built on tracts of the valley gravel. Naturally they include some of the better residential sites in London and the vicinity; but it must be remembered that the tracts vary a good deal in elevation, some being but a few feet above the Alluvium, and that the sanitary condition of the ground largely depends on the thickness of the gravel. In low-lying areas especially, where there are broad tracts of gravel, the sub-soil is likely to contain much water, and the basements of houses are apt to be damp. This is the case sometimes at higher elevations where the gravel is thin, and where living-rooms are constructed partially beneath the surface.

The larger portion of the broad valley of the Thames from Eton, Uxbridge, and Colnbrook, Chertsey and Staines, eastwards to Kingston, Hounslow, and Brentford, Hanwell, Ealing and Acton, is occupied by valley gravel and sand, with here and

[1] Report to Local Government Board, by E. Evans, 1894.

there small areas of loam. Moreover, a loamy covering extends over a considerable portion of the gravel tracts, and this has tended to modify the character of the soil upon which the loam has exercised an important and beneficial influence. This district has in consequence been long celebrated for fruit and vegetables, although many a famous market-garden or nursery-ground has now vanished from neighbourhoods such as Chelsea and Hammersmith, where in old times they flourished. It has been remarked by Dr. Poore that the prosperity of London market-gardens is due partly to the proximity of a market, partly to the large amount of stable-manure that can be readily obtained.[1]

On the south side of the river, Mitcham and other localities have also furnished market-gardens, and grounds celebrated in particular for the cultivation of lavender, camomile, and other medical herbs.

Walton-on-Thames, Molesey, and Thames Ditton are situated on valley gravel, so also are Kew, Mortlake, and Barnes. Near the Thames in these as in other similar localities, the gravel is especially liable to contain a good deal of sub-soil water, and basements of houses may be damp. This would be the case after long-continued rain, when, as sometimes happens, the river rises so high that the islands near Twickenham, Richmond, and Isleworth are covered with water, while the low grounds bordering the river from Kingston to Barnes and Chiswick may be flooded. Under such conditions cellars are sometimes partially filled with water, for the ground-water naturally rises to the level of the swollen river. When the Thames is in flood the low grounds extending from Eton by Datchet, Wyrardisbury (Wraysbury), and Egham to Staines and Chertsey are not unfrequently under water.

On the south side of the river the valley gravel occurs in isolated tracts, or "outliers," on the London Clay, so that Richmond, Putney, Wandsworth, Clapham, Brixton, Tooting and Mitcham, Wimbledon, Surbiton, and also Lewisham are partly on gravel and partly on London Clay, the old villages having outgrown the limits of the gravel-areas on which they were originally fixed. On the higher and more isolated tracts of gravel, the sites are drier than in the lower grounds, as the sub-soil water more readily escapes in the form of springs. The lower parts of Lewisham have been flooded after long-continued rain, and so also have similar tracts at Mitcham and Merton.

East of London the valley gravel, which occupies the area of Stepney, Bow, and Hackney, extends on the east side of the Lea valley from Stratford to Barking, Romford, and North and South Ockendon, interspersed with loam at Ilford; while north-eastwards it stretches to Leyton and Wanstead, and over parts of Walthamstow. In many portions of this region there are market-gardens. The lower grounds of Romford have at times suffered from the flooding of the stream which flows through the town.

---

[1] "Essays on Rural Hygiene," p. 317.

On the west side of the Lea valley there is a broad belt of valley gravel, which occupies the area from Cheshunt by Waltham Cross and Enfield to Tottenham.

Old Islington, with Canonbury, Barnsbury, and parts of Highbury (east of Highbury Park) lie on gravel; so also in great measure do Bloomsbury, Paddington, Kensington, and Chelsea, a loamy surface-soil occurring in places. Kensington gravel-pit was situated on the borders of Notting Hill, north-west of Kensington Gardens; similar gravel may now be seen in the railway-cutting between High Street and Gloucester Road Stations. The gravel often contains much water, and this afforded in old times a supply to the villages now incorporated in London. During drainage-operations at Highbury, east of Highbury Park and Grove, much water was encountered in the gravel. This moisture is a cause of dampness to some underground breakfast-rooms in that part of London. It has been suggested that water from this source might be pumped for use in watering roads, &c., but there would be some danger of weakening the foundations of buildings if such a proceeding were generally adopted.

The valley gravels and associated loams are from five to about forty feet in thickness. As instances of the variable character of the subsoils, the following sections may be noted [1]:—

Brentford. (W. Gravatt.)

Loam	9 feet.
Gravel	7 „
Loam	5 „
Sand and gravel	4 „
	25 „

Endsleigh Street, Euston Square. (Dr. H. Hicks.)

Made ground	8 feet.
Clay	7 „
Sand	2 „
Gravel	5 „
	22 „

Highbury New Park. (H. B. W.)

Made ground	2 feet.
Loam	18 „
Sand	9 „
Peat	4 „
Gravel and sand	8 „
	41 „

Peckham. (D. Allport.)

Gravel	3 feet.
Loam and sand	14 „
Gravel	3 „
	20 „

On the southern side of the North Downs tracts of valley gravel border the Wey between Godalming and Guildford, the Darent between Westerham and Otford, and the Medway from Maidstone to Leybourne and Snodland.

[1] *See also* Whitaker, "Geology of London," 2 vols., 1889.

Gravel of Higher Grounds.—Beds of gravel and sand occupying, as a rule, higher levels than the valley gravel, occur in many tracts of the country around London, on the clay areas of Buckinghamshire, Middlesex, Hertfordshire, and Essex. Other extensive tracts of gravel, many of them at somewhat lesser elevations, occur on the Chalk tracts between St. Albans and Beaconsfield, and they furnish sites as dry probably as any to be found in the area under consideration.

These gravels are mostly from a few feet to about 25 feet in thickness, and rarely as much as 50 feet, and they vary in character from pebble-gravel or shingle, largely made up of flint and small quartz pebbles, to coarser sub-angular gravel and sand containing, in addition to flint and quartz, many pebbles of quartzite and other stones.

On the clayey area there are patches of gravel at Shooter's Hill, over parts of Woodford, Chigwell, Buckhurst Hill, High Beech, and near Epping. Again, there are tracts of gravel and sand at Southgate, Colney Hatch, Friern Barnet, Whetstone, Totteridge, High Barnet, Monken Hadley, Ridge, Shenley, Potter's Bar, and Northaw, at Finchley, Hendon, Neasden, Stanmore Heath, and Harefield. Other patches of gravel lie to the south-west between Denham and Fulmer, and on Fulmer and Stoke Commons to the north of Stoke Poges.

It is worthy of note that these gravels have sometimes a clayey or loamy matrix, and that they may therefore locally be of a retentive nature. I was told by a gentleman who had taken a house, situated on a gravel-patch at Totteridge, that his gardener informed him the soil was a "heavy clay." Nevertheless, in excavating for a water-tank he had dug out several tons of pebbles! The gravel, in fact, consisted of a stiff sandy clay packed with pebbles.

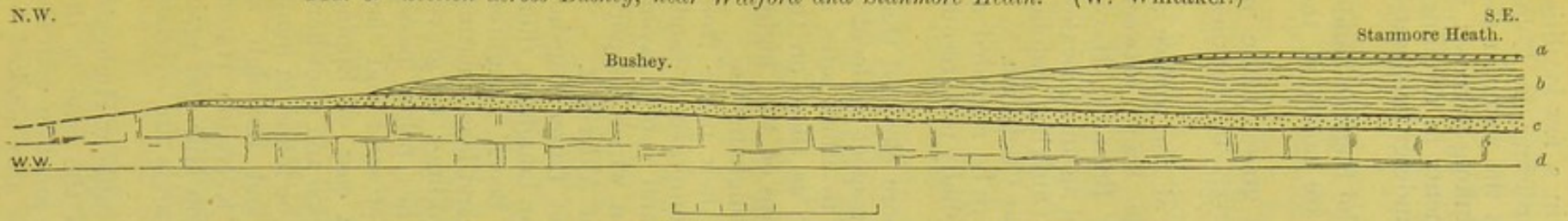
There are thin patches of gravel at Mount Pleasant, Highwood Hill, and also at Mill Hill to the south of the King's Head Inn and to the east of Frith Manor House. Sprinklings of gravel occur elsewhere on the higher clay hills, serving to lighten the soil.

At Hendon, as pointed out by Dr. Henry Hicks, there is a thick bed of brown clay intercalated in the gravels, and a similar band locally occurs at Finchley. These are re-assorted masses of brown London clay, which have become incorporated with the gravel during its accumulation.

These gravels form, as a rule, good residential sites, for occurring in limited tracts on the clay-areas, the sub-soil water is to a large extent drained off by springs on their margins. Moreover they occupy breezy positions.

More extensive tracts of gravel and sand occur, as beforementioned, on the Chalk in Hertfordshire and Buckinghamshire. These comprise certain areas at Hatfield, Sandridge, St. Albans, London Colney, Aldenham, Watford, Chipperfield, Sarratt, Chenies, and the higher grounds above Rickmansworth, Chalfont St. Peter, and Chalfont St. Giles. So far as the sub-soil is concerned these areas may be highly commended; they are

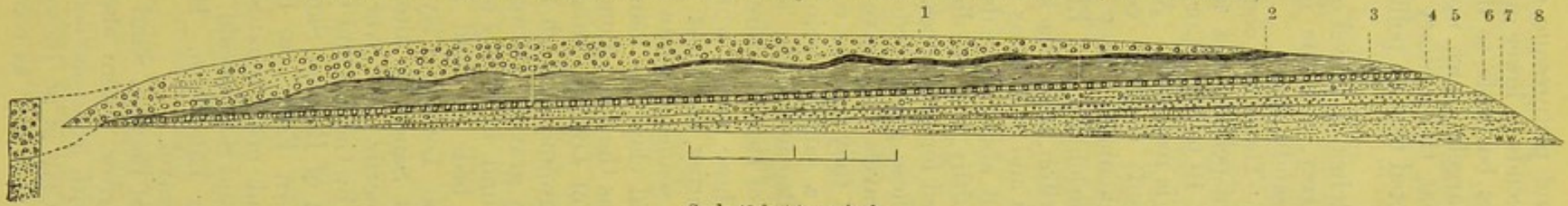
FIG. 6.—*Section across Bushey, near Watford and Stanmore Heath.* (W. Whitaker.)[1]



Longitudinal Scale, 3 inches to a mile. Vertical scale, 880 feet to an inch.

a. Pebble-gravel. *b*. London Clay. *c*. Reading Beds. *d*. Chalk.

FIG. 7.—*Cutting on the South-Eastern Railway at Chislehurst Station.* (W. Whitaker.)[2]



Scale 40 feet to an inch.

1.	Pebble-gravel.	Blackheath Beds.
2.	Clay with shells.	Woolwich Beds.
3.	Bluish and greenish-grey clay.	
4.	Sand with pebbles.	
5.	Green loam.	
6.	Green sand.	
7.	Whitish sand.	Thanet Sand.
8.	Buff sand.	

[1] "Geology of London," vol. i., fig. 105, p. 493.

[2] *Ibid.*, vol. i., fig. 26, p. 164.

pleasantly situated and picturesque, and only in a few localities where the gravel descends to lower grounds bordering the Colne valley would the sites be liable to damp. As the water in the underlying Chalk is largely drawn upon for drinking-purposes, it is most desirable that the sanitary arrangements in dwelling-houses be so constructed that no pollution of underground water is possible.

Here and there patches of gravel occur on the Bagshot Sands, as in Essex and Surrey, and the localities are noted in the descriptions of these sandy areas.

Blackheath Beds.—These are composed of gravel, made up almost entirely of flint-pebbles in a sandy matrix. In thickness they vary from about 10 to 50 feet or more.

Their distribution is restricted. Appearing at the surface at Croydon they extend over a considerable tract between Addington and Beckenham; they occur at Bromley, Hayes Common, Keston, Chislehurst, and Eltham, and again at Bexley, East Wickham, Charlton, and Blackheath. Outlying patches lie south of Caterham and at Worms Heath near Chelsham.

Everywhere the soil above these deposits may be regarded as naturally dry and healthy, and the district is usually picturesque, and admirably adapted for residences.

The situation of these gravel-beds being more elevated than that of the valley gravels, they have in this respect a decided advantage. In short they may be considered to afford sites as good generally, from a sanitary point of view, as those on the large areas of the Bagshot Beds, and perhaps of the higher gravels on the Chalk of Hertfordshire and Buckinghamshire.

Bagshot Beds.—These strata, which take their name from Bagshot Heath in Surrey, are most largely composed of sands, with occasional thin seams of white pipeclay and pebbly layers. They contain a central clayey or loamy division which supports pools of water, such as the Fleet Pond, north of Aldershot.

To the north-east of London, small tracts of Lower Bagshot sands form the hilly ground at High Beech, near Loughton, there covered irregularly by gravel. Between High Beech, Loughton, and Epping, the ground is mostly of a light and loamy nature, with here and there beds of sand and sprinklings of gravel. The fact is that the London Clay, which lies below, passes up into the Bagshot Sands by alternations of sand and clay. These mixed soils occur also over the area east of Epping, near Theydon Bois, by Gaynes and Ongar Parks, and elsewhere.

More definite areas of Bagshot Sand are to be found in many parts of south-eastern Essex, at Hadleigh and Rayleigh, at Billericay, Stock, and near Ingatestone, at Kelvedon Hatch, Brentwood, Warley, and Southweald, at Langdon Hill, and again at Crabtree Hill, near Lambourn. Here the sands are overlain in places by pebble-gravel.

Again, small areas of Bagshot Sand are observable at Highgate, Hampstead, and Harrow, where also towards the base of the sand, pebbly layers with ironstone occur. The junction with the underlying London Clay is at these localities also marked by alternations of sand and clay, as recently shown in excavations

on the Kidderpore estate, West Hampstead, and in foundations for the Drawing School at Harrow.

In places, as at Hampstead, small patches of gravel are found over the Bagshot Beds, while at Wimbledon and Kingston Hill two outliers of these strata are wholly covered with gravel. (See Fig. 5.) The dry soil and elevation of these tracts of Bagshot Sand make them naturally healthy sites.

The more extensive mass of Bagshot Beds, which forms an important residential district, is that which occurs over a large area westwards from Esher and Weybridge to Woking, Horsell, Ascot, Sunninghill, Wokingham, Finchampstead, Eversley, and Aldershot. There the Lower Bagshot Beds, almost wholly sands, are upwards of 100 feet thick. Nevertheless in this large tract there are considerable areas of more or less clayey and peaty ground, for the central division of the Bagshot Beds comprises greenish sandy loams and clays, as well as sands, together 20 or 30 feet, thick, the more clayey portion being usually at the base. This lower portion holds up water in the overlying sands.

The tract from Sunningdale, over part of Bagshot Heath and the village of Bagshot, also Bisley, Pirbright, and Worplesdon, is included in this mixed area. The nature of this clayey ground is, however, somewhat modified by the downwash of sand and gravel from the more elevated tracts, such as the Chobham Ridges.

The higher elevations in the region of Bagshot Heath, comprise the Upper Bagshot Sands, about 100 feet thick, and they yield hard concretionary masses of sandstone, known as Greywethers or Sarsen Stones. These beds are capped in places by gravel.

Taken as a whole the area of the Bagshot Beds forms a picturesque heathy country, for the most part dry and sandy, from 100 to over 400 feet in elevation, and eminently adapted for building-sites.

Thanet Beds.—These deposits consist mainly of fine sand or loamy sand, and they border the Chalk from Leatherhead, by Epsom, Ewell, Cheam, and Sutton to Croydon. Their outcrop is so narrow that it is not distinguished from the Woolwich and Reading, and Blackheath Beds on the map. Indeed these sands exercise little influence on the land, and they do not occur to the north-west of London. They extend by Addington, Keston, and Orpington to Crayford; and the breadth of their exposure becomes more pronounced at Erith and Woolwich than elsewhere in the neighbourhood of London. The thickness of the Thanet Beds is from about 12 feet (at Leatherhead) to 60 feet. They furnish dry and healthy sites for houses.

Upper Greensand.—Extending along the foot of the North Downs from Guildford to Dorking, there is a narrow belt of sloping ground formed of greenish sand and calcareous sandstone. Eastwards at Gatton and Merstham these sub-soils occupy a somewhat broader tract, and are more adapted for sites of houses. (See Fig. 1.) The Upper Greensand is from 40 to 60 feet in thickness, it forms a dry tract, and the stone-beds have since early times been quarried for building-stone and hearth-stone.

On the northern side of the London Basin, the Upper Greensand appears below the Chalk escarpment, north of Wendover and Prince's Risborough.

Lower Greensand.—Far more important as a residential area, is that occupied by the Lower Greensand of Surrey and Kent—a tract separated from the Upper Greensand on the north by a narrow vale of Gault clay. The Lower Greensand consists in its upper part of loose sands, the purer varieties of which have been used for glass-making; and these sands, like those of Bagshot,

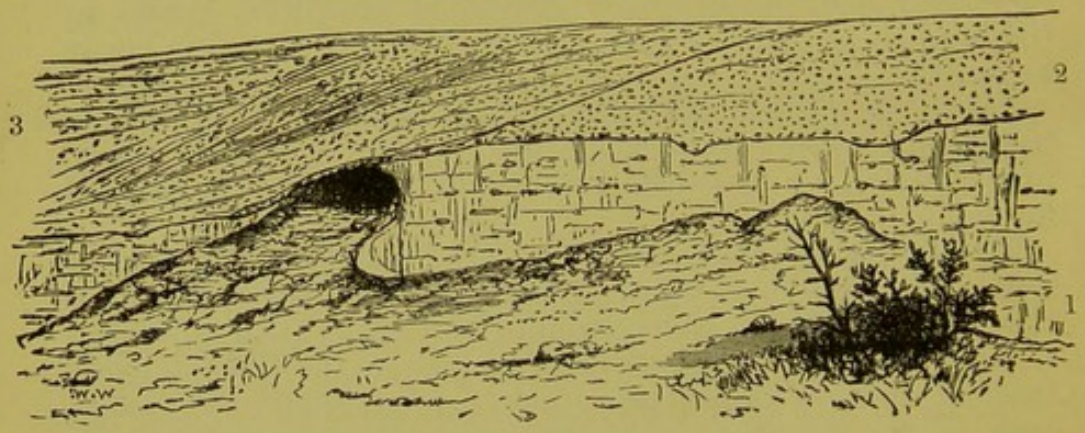
FIG. 8.—*Section across the outcrop of the London Tertiary Strata.*

(H. B. W.)

5. London Clay.
4. Blackheath Beds.
3. Woolwich and Reading Beds.
2. Thanet Beds.
1. Chalk.

FIG. 9. *Chalk-pit west of Crayford Brickyard.*

(W. Whitaker.)[1]



3. Brickearth or loam.
2. Thanet Sand.
1. Chalk.

are occasionally cemented into blocks of hard rock, as at Ightham. Lower down in the series, as at Nutfield, but occupying a small area, occur layers of Fuller's earth, a kind of clay; and below are thick beds of calcareous sandstone, occasional limestone, and sand, with ironstone and chert. The base of the series comprises a band of clay, known as the Atherfield clay, which occupies but a narrow belt of country, and merges into the thick Weald Clay which lies below it.

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[1] "Geology of London," vol. i., fig. 6, p. 112.

In the area under consideration the Lower Greensand varies in thickness from 250 to 400 feet. It occurs below the high scarp of the North Downs, at Shalford south of Guildford; and, indeed, extends from the neighbourhood of Farnham, Hind Head and Godalming, eastwards past Gomshall, Abinger, Leith Hill, Dorking, Reigate and Redhill, and onwards to Godstone, Limpsfield, Westerham, Sundridge, and Sevenoaks. Along this course it forms a belt of varying width of hilly and for the most part sandy country of exceedingly picturesque character. It is admirably adapted for healthy residences, as indeed the numerous mansions and villas make manifest. Along its southern borders it rises from about 500 to upwards of 900 feet at Leith Hill, in bold scarps which constitute the range of hills overlooking the great vale of the Weald Clay. (See Fig. 1.)

Another tract of Lower Greensand, far north of London, extends from near Leighton Buzzard to Brickhill, Woburn Sands, Aspley Guise, and Ampthill. It is famous for its generally dry and healthy soil and salubrious air. This pleasant region, from 300 to over 500 feet in elevation, overlooks the great clay-vale which extends from Fenny Stratford in a south-westerly direction to Aylesbury.

Hastings Beds.—Beyond the vale of Weald Clay, before alluded to, there is a varied tract of sandy and loamy country for the most part dry, and diversified in scenery. Tunbridge Wells stands on this tract of Hastings Sands, which extends to the south over Ashdown Forest, and westward from East Grinstead to Three Bridges, and over Tilgate and St. Leonards Forests to Horsham.

Good sites for houses occur throughout this area, the greater part of which is an elevated sandy region; while the more loamy tracts are not usually unfavourable by reason of any special dampness in the nature of the sub-soil.

Curiously enough some of the sands and sandstones belonging to the Hastings Beds are so fine in grain that in places, as Topley has remarked, "the soil holds up water almost as well as clay." Hence in examining the country "strict allowances must be made for the weather," as the percolation after heavy rain may be very slow.

The Hastings Beds include some thick beds of clay, known as the Cuckfield, Grinstead and Wadhurst Clays, which are separately coloured on the one-inch Geological Survey Map. These clays usually appear in valleys, and occupy sloping ground where there is good natural drainage; and they are often covere by a loamy soil.

In a number of places the sandstones appear at the surface as natural rocks, of which well-known examples occur near Tunbridge Wells.[1]

Mixed Sub-soils.

Woolwich and Reading Beds.—These comprise alternations of sands, shelly layers, pebble-beds or gravel, and mottled clay.

[1] See W. Topley, "Geology of the Weald," pp. 245—249.

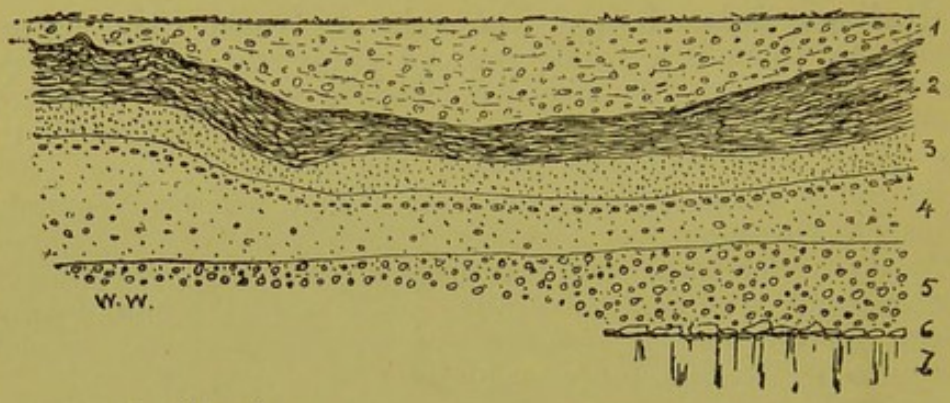
The sub-soil is essentially a mixed one, and so irregular are these alternations that only actual excavation could determine the nature of a site—whether on gravel, sand, or clay. (See Figs. 7, 10, 11.) The strata are from 25 to 50 feet thick, but they occupy very limited areas at the surface in the vicinity of London.

They appear from beneath the London Clay at Harefield, Ruislip, Eastcote and Northwood, Pinner, Bushey near Watford, Radlett, and South Mimms. At Radlett the pebble-bed is locally cemented into conglomerate, known as the Hertfordshire pudding-stone. Here the strata rest on the Chalk. They occur also westwards near Beaconsfield.

South of London the Woolwich and Reading Beds repose on the Thanet Sand, and they together form but a narrow belt of land from Leatherhead by Epsom, Ewell, and Sutton to Croydon. In this region they practically separate the London Clay area on the north from that of the Chalk on the south.

FIG. 10.—*Section south of Bushey Station, near Watford.*

(W. Whitaker.)[1]



1. Gravel.
2. Mottled clay.
3. Sand.
4. Sand with layers of flint-pebbles. } Reading Beds.
5. Pebble-gravel.
6. Layer of flints.
7. Chalk.

Eastwards, where they appear from beneath the Blackheath Beds, the outcrop is too small to exercise much influence on the ground from Addington to Farnborough. (See Fig. 7.) More marked, however, are their features along the borders of the Thames valley, from Erith to Woolwich and Greenwich. The Woolwich and Reading Beds also appear at the surface at Peckham and Dulwich.

From the limited outcrop, and from the occurrence of much sand and gravel in this group of strata, it cannot be considered as furnishing sites liable to be injurious by reason of dampness. A particular house may happen to be placed on clay, but even on

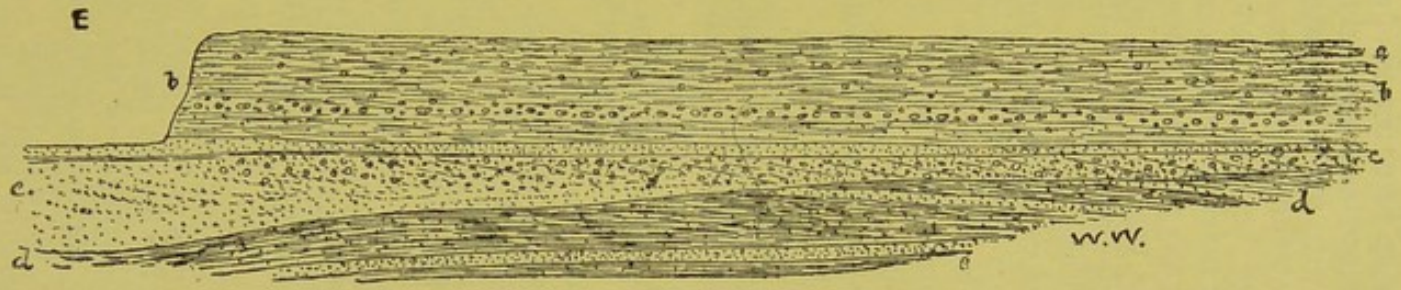
[1] "Geology of London," vol. i., fig. 32, p. 199.

W. FIG. 11.—*Cutting on the South Eastern Railway north of Mottingham.* (W. Whitaker.)[1] E.

Scale 150 feet to an inch.

		Feet.	
1. Sand with layers of clay 1'. Clay with layers of sand	about	15	Woolwich and Reading Beds.
2. Shelly clays with hard shell-rock		11	
3. Mottled plastic clay ...		7 or 8	
4. Dark sandy clay		½	
5. Sand with layers of pebbles ...		15	
6. Thanet Sand.			

FIG. 12.—*Section in Brickyard at Stoke Newington.* (W. Whitaker).[2]



	Feet.
a. Soil ... ... about	1
b. Loam	7
c. Sand and Gravel	1 to 7
d. Loam ... ... about	2 to 4
e. Sand and Loam.	

[1] "Geology of London," vol. i., fig, 27, p. 166.

[2] *Ibid.*, vol. i., fig. 73, p. 403.

that account if it be well constructed no serious objection could be taken to the site.

Valley Brickearth or Loam.—The Brickearth associated with the valley-gravel is a brown loam, or variable sandy clay, which has been extensively used in the manufacture of bricks. As it is practically impervious, it will hold up water, but being more absorbent than clay, it allows the surface-water to get away more readily on level tracts of ground.

The loam occurs irregularly, sometimes with gravel above it, and usually with gravel beneath it. (See Figs. 12, 15.) Its actual boundaries at the surface are, therefore, vague. The soil above the loam, as before mentioned, is well adapted for nursery-grounds and market-gardens: while in general the areas occupied by the loam are suitable for residential sites.

There are tracts of this brickearth near Edmonton on the western border of the Lea valley, and again at Highbury New Park and Stoke Newington, where over large portions of the area the good earth has been removed for brick-making, while the pits have been filled with rubbish. Shepherd's Bush, Turnham Green, and Brentford are to a large extent situated on brickearth; it is dug for brick-making between Uxbridge Road and St. Quintin's Park. It occurs also over considerable areas at Southall, Hayes, West Drayton (east of the railway-station), and Langley Marsh. At Datchet and Slough, and again at Barnes, Heston, Norwood, Acton, Hammersmith, Walham Green, Parson's Green, Chiswick, and Kensington, there are in places surface-layers of loam, and this is the case also at Old Ford, Bethnal Green, Shoreditch, and Bloomsbury.

Clay-with-flints and Loam.—On the Chalk areas of the North Downs, and on the higher portions of the Chiltern Hills between Great Marlow and Prince's Risborough, between Amersham, Chesham, and Wendover, and eastwards to Bovingdon, Great Berkhampstead, Hemel Hempstead and St. Albans, there are accumulations of clay-with-flints often associated with gravel and loam, which serve to conceal the Chalk and to render the soil fertile. The clay-with-flints is partly a residue from the superficial weathering of the Chalk: portions of the limestone being carried away by water holding carbonic acid, and the flints with a small amount of red earthy residue being left on the surface. Commingled with these are relics of Tertiary clays, sands, and gravels, remnants as it were of deposits which formerly extended over a wide area of the Chalk uplands. These sub-soils occur on the plateaus, but do not themselves occupy the valleys, although a subsequent downwash of the materials may be spread over many of the slopes, and an accumulation of loose flints may occur in the bottoms of the valleys. The deposit as a whole is but partially pervious, and it may be considered useful locally in keeping surface-contamination from wells sunk into the Chalk.

The Chalk being liable to dissolution by carbonated water, its surface is frequently penetrated by irregular cavities known as "pipes." The superincumbent gravel and clay-with-flints may gradually subside into these hollows, but in some instances this

has not been the case, the superficial deposits remaining for a long period undisturbed, and then suddenly "caving in." Hence foundations need to be carefully tested. (See page 31.)

The thickness of the clay-with-flints and loam naturally varies considerably and often abruptly, according to the irregularities in the underlying Chalk. It may be from a foot or two to twenty feet and more.

Generally speaking, the areas occupied by these superficial accumulations may be regarded as dry and healthy. For the most part the situations are elevated and breezy, and the character of the surrounding ground would be dry.

Clay.

Boulder Clay.—At Finchley there is an elevated tract of stony and chalky clay and loam, 10 to 25 feet thick, known as the Boulder Clay. It is a tough, gritty clay with pebbles of chalk, flints, and a great variety of stones and fossils derived from different strata. It is for the most part impervious, though owing to the quantity of chalk and other stones in it, it is by no means so uniformly dense as the London Clay.

The Boulder Clay extends over Finchley from near Whetstone to the brow of Muswell Hill, and in this area it overlies gravel and sand. (Fig. 2.) Tracts of it occur at Bricket Wood, between Watford and St. Albans, and again at Primrose Green and Smallford, to the east of St. Albans. Small patches of the same sub-soil occur here and there between Southgate and Little Berkhampstead, on Enfield Chase and Cheshunt Common. In Essex there are tracts of it at Epping village, Theydon Bois, Chigwell Row, and Lambourn; and larger areas to the east and north-east, where it forms excellent land for wheat and beans.

The Boulder Clay as a rule would form a good firm foundation. In most of the situations above-mentioned the land is naturally drained, while in other cases where an extended area is covered with Boulder Clay, as in north Essex, the ground may require artificial draining.

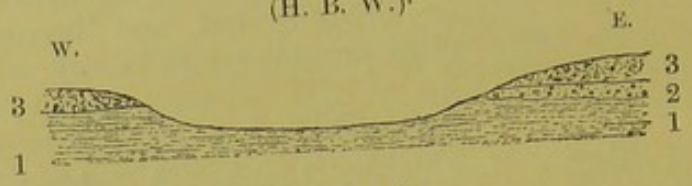
The occurrence of Boulder Clay and underlying gravels and sands is somewhat irregular. Sometimes on one side of a valley there is gravel beneath the Boulder Clay, while on the opposite side the Boulder Clay may rest directly on London Clay. (See Fig. 13.) In questions of local water-supply these irregularities are troublesome. In the area under consideration the Boulder Clay does not occupy very extensive tracts, and it may be regarded as affording fairly dry and breezy sites.

London Clay.—Of great importance as regards the London area is the clay to which it gives name. This formation comes to the surface over that large tract of gently undulating meadow and pasture land which extends from the neighbourhood of Willesden, Cricklewood, and West Hampstead to Edgware, Elstree, East Barnet, Northolt, and Ruislip. Here and there in the lower grounds there are thin gravelly accumulations, and as much as 13 feet of loam and gravel was proved at one spot at Cricklewood; this, however, is exceptional.

At the surface the London Clay is generally a stiff brown clay, though sometimes it may be a loam; deeper down it is a bluish-grey clay, and it contains nodular masses of clayey limestone with sparry divisions, known as "septaria." It underlies the valley gravels and some other deposits noted previously (p. 5) over the greater part of the area in and around London. (See Figs. 1, 2, 14.)

Fig. 13.—*Section across the valley south of Roxwell, near Chelmsford.*

(H. B. W.)[1]



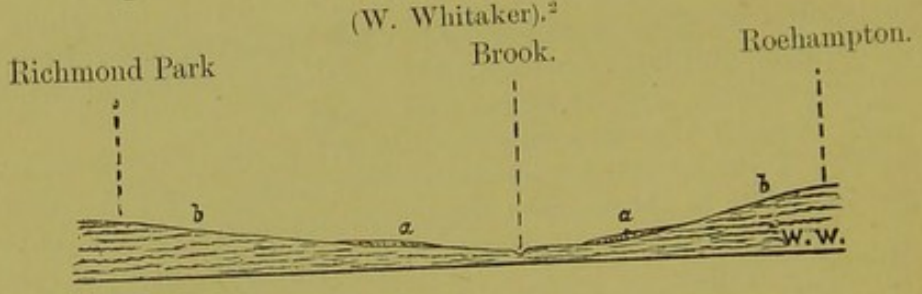
3. Boulder Clay.
2. Gravel.
1. London Clay.

It forms the surface of the ground at Kilburn, Maida Vale and Regent's Park, Haverstock Hill, Camden Town, Kentish Town, Holloway, Drayton Park, Highbury Vale, Finsbury Park, Hornsey, and Wood Green.

On the east side of the Lea Valley it extends over much of Epping and Hainault Forests, and is seen at Chingford, Chapel End, and parts of Walthamstow.

Fig. 14.—*Section from Richmond Park to Roehampton.*

(W. Whitaker).[2]



a. Gravel.
b. London Clay.

South of the Thames it comes to the surface at Kidbrooke Common, Mottingham, over the undulating tracts of Forest Hill and Sydenham, Penge, Norwood, and Streatham. Westwards it occurs over the still thinly-populated regions of Morden, Malden, and Chessington.

The thickness of the London Clay in these localities is often considerable, varying from 25 to 350 feet; but it naturally diminishes along its margin near Dulwich and Lewisham, around Shooter's Hill, near Epsom and Ewell, at Ruislip and Bushey near Watford. (See Fig. 6.)

The soil which overlies the London Clay is apt to be damp and tenacious in wet weather, as the clay absorbs a considerable

[1] Whitaker, "Geology of London," vol. i., fig. 49, p. 318.
[2] *Ibid.*, vol. i., fig. 85, p. 426.

amount of moisture, while in very dry weather the ground becomes hard and great cracks and fissures appear. On the more elevated regions, whether at Mill Hill, West Hampstead, Haverstock Hill, Crouch Hill, at Sydenham, Forest Hill or Streatham, the bulk of the water after heavy rains will rapidly disappear, although the soil in gardens may remain moist. In low grounds and hollows the rain-water will collect, if no artificial system of drainage is ready to conduct it away. On such situations, especially in a rural or semi-rural district, the London Clay is to be avoided by those who should not live on a damp clayey foundation. Thus the lower grounds of Brondesbury and Harlesden, of Wealdstone and Hatch End, those between Harrow and Edgware, and at Raynes Park and New Malden, are not to be commended in comparison with the more elevated regions of London Clay before-mentioned. Maida Vale and Holloway are so nearly built over that the drainage is practically complete, and they would suffer chiefly from their low situation in comparison with more breezy localities. Further remarks will be made in the sequel on the subject of sites on clayey areas.

Gault.—This is a stiff sandy or calcareous clay, from 150 to 300 ft. in thickness, which separates the Upper and Lower Greensand. It extends in a narrow band along the foot of the North Downs from Guildford eastwards as far as the northern part of Dorking. Further east it occupies a somewhat broader belt of ground by Buckland Green, and north of Reigate, below Merstham, and onwards north of Westerham to Dunton Green. The ground is mostly low-lying and damp; it forms a vale between the Chalk and Upper Greensand on the north, and the rising tracts of Lower Greensand on the south. The area is chiefly pasture land. (See Fig. 1.) To the north of the London Basin the Gault forms part of the Vale of Aylesbury.

Weald Clay.—This is a stiff clay which occupies a broad area of low-lying and gently undulating ground below the ranges of Lower Greensand of Leith Hill, Sevenoaks, &c., which form its northern boundary. It is 800 or 900 feet thick. (See Fig. 1.)

Like other great clay-vales this region is to be avoided by those to whom a low-lying and generally damp sub-soil is inimical. The meadows are apt to be flooded in seasons of heavy rain; while during a drought the ground is very much fissured.

Here and there the soil is ameliorated by coverings of loam and gravel, but the area in general is necessarily damp compared with the sandy hills which border it. In hot and dry weather, the district tends to be relaxing; in cold weather, from its unprotected character, it may be swept by chilling winds.

Limestone.

Chalk.—This important formation consists mainly of soft and more or less permeable white limestone, with bands of nodular flint in its upper portion; in the lower portion flints are less common, and at the base the Chalk becomes somewhat clayey, and is known as Chalk Marl. In mass it is from 620 to over 670 feet in thickness.

In London it appears at the surface, through disturbance of the strata, in small tracts north of Lewisham, at Charlton and near Plumstead, where old chalk-pits have been converted into pleasant gardens.

Elsewhere, the Chalk constitutes the broad margin of the London Basin. To the west of our area it comes to the surface at Windsor, the Castle being built upon it. On the north, it appears over much of the wide region extending north-eastwards from Taplow and Beaconsfield to Rickmansworth, Watford, North and South Mimms, Hatfield, Hertford, and Ware. The Metropolitan Railway has opened up a large area of this country at Chesham, Amersham, Great Missenden, and Wendover; while the London and North Western, Midland, and Great Northern Railways respectively, traverse the Chalk belt at Hemel Hempstead, Berkhampstead, Tring, and Dunstable, at St. Albans, Harpenden and Luton, at Welwyn, Stevenage and Hitchin. Along the north-western margin of this area the Chalk forms the elevated range of the Chiltern Hills and their continuation in the Dunstable and Luton Downs; and here the Chalk is comparatively free from superficial coverings of gravel, loam, &c. Elsewhere, it is largely covered with patches of clay-with-flints, loam, Boulder Clay, and gravel, which occupy the plateaus, while the Chalk is exposed along the borders of the valleys. These coverings are nowhere of great thickness, and they do not much interfere with the generally dry and healthy character of this great tract of country. The local water-supply requires, however, to be carefully considered, as so much of the ground is porous, and water obtained from shallow wells sunk into the Chalk in such situations is liable to contamination from cess-pits, grave-yards, cemeteries, &c. (See Fig. 1.)

On the south side of the London area the Chalk is less concealed by superficial deposits. It occupies the surface in a comparatively narrow belt at Guildford, widening, however, eastwards in the Downs of Clandon, Fetcham, Mickleham, Epsom, and Banstead. A little further south and eastwards the Chalk tracts are to some extent covered with irregular accumulations, of no great thickness, of clay-with-flints, loam, and occasional sand and gravel, as at Banstead Village, Coulsdon, Chaldon, Caterham, Farley, and Downe; and again, nearer the brow of the Chalk Downs, from Box Hill to Knockholt and Shoreham. A large part of the area is from 300 to upwards of 700 feet in elevation.

Along the Darent valley, from Shoreham by Eynesford to Dartford, the Chalk is exposed, as well as in irregular areas at Orpington, St. Mary's Cray, Crayford, and Erith. It appears also at Purfleet and Grays in Essex.

The Chalk, with the exception of its lowermost portions, forms nearly everywhere a dry healthy surface, as rain sinks readily into the ground. It constitutes admirable sites for building, although its soil, unless ameliorated by coverings of loam, &c., is comparatively poor, and generally unsuitable for plantations and floriculture. With regard to buildings on Chalk tracts, care must be taken to prove the security of the foundation, for reasons elsewhere noted (pp. 22, 30).

CHAPTER III.

GENERAL REMARKS ON THE SUB-SOIL WITH REFERENCE TO SITES AND FOUNDATIONS FOR HOUSES.

In considering the general character and thickness of the sub soil on which a house may be situated, it is needful to bear in mind not only the ordinary variations in character and thickness of some of the formations before mentioned, but also those local variations in thickness which must occur along the margin or outcrop of the strata. This will be readily understood from the accompanying diagrams.

Thus Fig. 15 shows the thinning of beds of gravel and loam along their margins; while Fig. 8, p. 18, shows the thinning of strata at particular points along their outcrop where the thickness has been reduced by the wearing away of portions of each formation.

Fig. 15.—*Section of Valley-gravel and Loam.* (H. B. W.)

3. Loam.
2. Gravel.
1. London Clay.

If all other circumstances are favourable it may be concluded from the remarks in the preceding chapter, that the formations best adapted for healthy residences in and near London, are the porous sands and gravels and the Chalk. Those gravels on the higher grounds, also the Bagshot Sands, Blackheath Beds, and Thanet Beds, together with the Chalk, are generally to be preferred to the Valley Gravels, which for the most part lie on lower ground and occupy positions which are, on the whole, somewhat sheltered and relaxing.

The Woolwich and Reading Beds, from their mixed character, the Boulder Clay, the Clay-with-flints and Loam, and the Valley Loam or Brickearth, from their partially retentive nature, belong to a group second in order of merit.

Clay and Gravel Sub-soils.

The London Clay, which has naturally a moist and heavy nature, should in certain areas be avoided by those who may suffer from the effects of damp. The least desirable sites are those situated in the midst of a large tract of bare clay, and especially in the low-lying tracts between Uxbridge, Willesden and Edgware, and again between Leatherhead,

Kingston and Merton. The same remarks apply to the broad area of Weald Clay south of Leith Hill and Reigate.

In these rural and semi-rural areas there are large tracts of land, where in wet weather the clayey soil retains its surface moisture until it is removed by evaporation or absorbed by vegetation; and the atmosphere in consequence is then much damper than that over tracts of gravel, sand, and Chalk, and much damper than that in the clay areas now built over. In hot dry weather the clay ground is parched.

The disadvantages of living on clay are lessened by elevation where there is good natural drainage. They are diminished also in certain areas south of the Thames between Richmond and Croydon, where the clay-tract is much broken up by coverings of gravel. Artificial changes indeed have exercised so much influence over the more populous parts of the London area that the naturally wet and heavy soil of the London Clay has been largely obscured by transported soil and gravel, as well as by ordinary made-soil and pavements. Hence elevation and situation have there come to be of more importance than the original soil.

In considering the respective merits of clay and gravel, it must be remembered that gravel may hold water, and that on a thin bed of gravel resting on clay, the amount so held may be large. Where the foundations of a house have been carried down to the clay, the excavation required for them forms a sort of tank into which water may, and often does, accumulate from the surrounding gravel. It has thus been found, in a number of cases, that the basements of houses built on gravel are damper than those constructed on clay, if the subterranean flow of water is not checked by means of artificial drainage around the house, and this precaution is not usual in London. Clay, after absorbing a certain amount of water at the surface, throws off the bulk of the rainfall, and it is only in the absence of natural or artificial drainage that the water accumulates. It is, therefore, better to reside on a bare clay-foundation in a district where the slopes provide a system of drainage, than on a flat area where thin gravel rests on clay, and water can accumulate in the sub-soil.

Mr. G. J. Symons has remarked that "a house on a clay soil is not necessarily more unhealthy than one on gravel,"[1] and my own observations quite accord with this view, so long as the site is not in a great clay vale. Clay, moreover, serves to keep impurities from water-bearing strata beneath it; a fact of importance in rural districts.

Contamination of Sub-soils.

One drawback to a residence on a porous stratum underlain by clay is the liability to contamination of this porous layer. So many villages are placed on outlying tracts of gravel and sand, or along the outcrop of sand and limestones, that the subsoil has become greatly polluted from cess-pits, sewage and other sources.

[1] "Trans. Sanit. Inst., vol. i., p. 186.

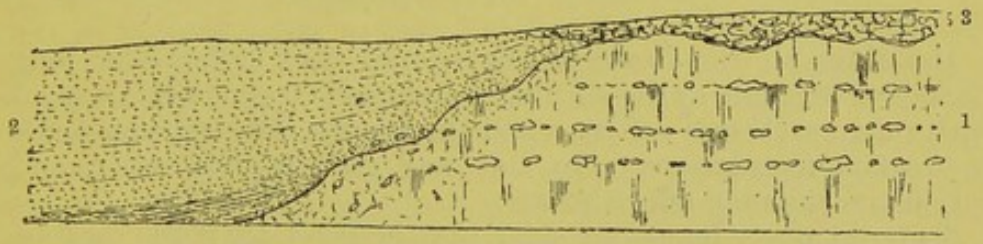
In cities, again, leakage from brick-drains or imperfectly cemented pipes tends to render porous soils and sub-soils very unwholesome. Even leakage from gas-mains is a source of poison to the air, and although Dr. Poore remarks: "It is conceivable that the impregnation of the soil by coal-gas may have helped to stop the growth of noxious microbes which make the soil their habitat,"[1] yet coal-gas will destroy useful as well as deleterious microbes. Water is usually present in the porous strata, and when the level of this sub-soil water rises, impure air is expelled into basements of houses if they are not properly cemented. Houses built on rubbish may suffer in the same way from the uprising of polluted air. In the Lea valley outbreaks of diphtheria have so originated; and in many places diarrhœa is caused. Hence it is that gravel and sand may require as solid a foundation of asphalt or other well-cemented covering over the basement floors as any habitation on clay, so as to prevent foul air as well as moisture rising from the sub-soil.[2]

Temporary fluctuations of the sub-soil water have been known to produce typhoid fever, doubtless for the reason just mentioned. The investigations of Sir George Buchanan have shown that the permanent decrease of water in the soil and sub-soil by improved drainage is most beneficial, and it has lowered the consumption death-rate.[3] Dampness of soil, especially in bleak situations, is unfavourable not only for consumptive patients, but for those suffering from lung and kidney diseases, and rheumatism.

A dry and clean sub-soil without any accumulation of water near the surface is, therefore, at all times desirable.

In rural districts the level at which water stands in wells, and the level of the outlet of springs along hill-slopes, will afford an indication of the dryness or possible dampness of particular sites.

FIG. 16—*Section at Chalk-pit between Grays and West Thurrock.*
(W. Whitaker).[4]



3. Soil and gravel.
2. Loam, 15 feet.
1. Chalk with flints.

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[1] "London from the Sanitary and Medical point of View," 1889, p. 35.

[2] See K. D. Young, "Trans. Sanit. Inst.," vol. xv., pp. 40-42; and B. Latham, *Ibid.*, vol: viii., p. 174.

[3] Report of Medical Officer of the Privy Council for 1867, 1868. See also Whitaker, Geol. Mag., vol. vi., 1869, p. 499; Topley, Address to Sanit. Inst. (Section III.), 1890; and W. H. Corfield, "Health," 1880, p. 301.

[4] "Geology of London," vol. i., fig. 83, p. 418.

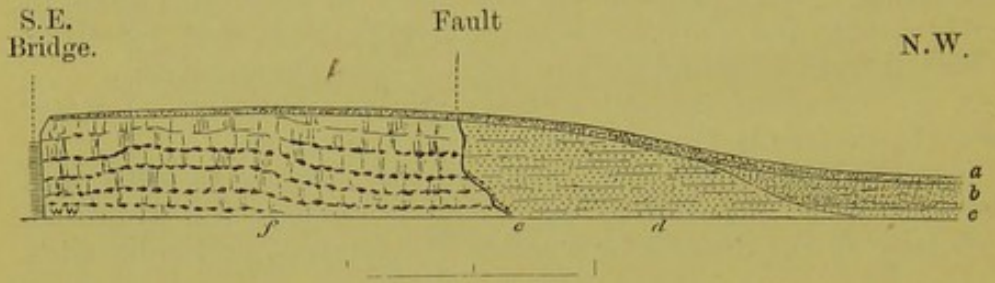
Foundations and Buildings.

For a building-site uniformity in the general character of the sub-soil is desirable. To be partly on gravel and partly on brick-earth or clay, to be on or over the margin of an old excavation since filled with rubbish, may lead to trouble on account of the different resistance to pressure made by the varying sub-strata. (See Fig. 16.) Such considerations apply more particularly to detached or semi-detached houses, for it is usually reckoned that in a row or terrace of houses one helps to support another.

On the margin of two formations, where sand or gravel rests on clay, springs may be expected; and when a house is constructed on sloping ground there should be proper provisions for drainage on the side against which the surface-water would accumulate, or from which spring-water would enter under the ground-floor. Again it is well to avoid a line of fracture where the strata are displaced, as these "faults" are planes of dislocation in the earth's crust, and they are liable to be moved during earthquake disturbances.[1] (See Fig. 17.)

Fig. 17.—*Cutting by St. John's Railway-station, near Lewisham.*

(W. Whitaker.)[2]



Scale 80 feet to an inch.

	a. Soil.	*d*. Thanet Sand.
Valley Drift	*b*. Loam.	*e*. Fault.
	c. Sand.	*f*. Chalk.

Buildings on the brows of clay-slopes may suffer after long periods of drought, as the shrunken and cracked clay, when soaked with rain, swells and softens; and this change of condition tends to weaken foundations. In this way garden-walls suffer, and serious cracks may affect houses.

To build one's house on sand may be good, for if the sand be deep and occupy a considerable area, it furnishes an excellent foundation, yielding uniformly to pressure. On the other hand, a hollow in clay occupied by sand or gravel, as No. 1 in Fig. 10, would probably be charged with a good deal of water.

To build on rock, such as Chalk, may in places be bad, for this formation is liable to undergo dissolution, and great cavities or "pipes" may be formed in it, partially, but not wholly, filled

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[1] See also Prof. J. Milne in W. K. Burton's "Water Supply of Towns," 1894, p. 273.

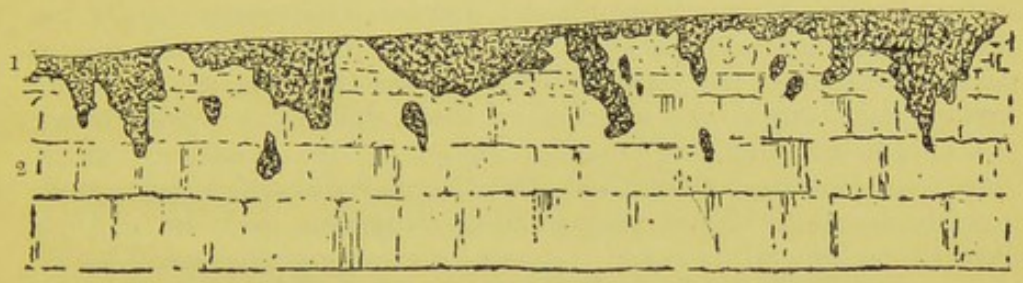
[2] "Geology of London," vol. i., fig. 7, p. 114.

with gravel and sand. (See Fig. 18.) Quite suddenly sinkings of the surface have taken place in such circumstances. Hence a chalk foundation needs to be well tested. Good examples of these "pipes" in the chalk may be seen in the railway-cuttings on the Metropolitan Railway between Rickmansworth and Great Missenden.

Referring to buildings on the alluvial grounds of Hackney Wick, where Made Ground, peat, and clay, together 12 to 14 feet thick, overlie gravel with tidal water, Mr. F. Meeson informs me that for a light building he regards the clay as a sufficient foundation, but for heavy buildings the foundations require to be carried down to the gravel. The action of the running water in the gravel would be to carry away the clay pressed down into it by the superincumbent weight, and thus cause unequal settlements.

FIG. 18.—*Chalk-pit, near Harefield.*

(W. Whitaker.)[1]



2. Gravel, with loam, sand, &c.
1. Chalk.

Settlements may be induced owing to the drainage of tracts of gravel and sand by railway-cuttings or tunnels, and they have also been produced by the bursting of pipes that convey water. Dislocation of drain-pipes may occur through ordinary settlements, irrespective of the jerry builder; it may be caused by the shrinkage of clay in dry weather.

It is, however, well to bear in mind the common-sense advice not to purchase a house about the construction of which nothing is personally known, until at least a year has elapsed after the building of it, and it has been subjected to the varying seasons of wet and drought. Only with time can the character of the structure be well established when its erection has not been watched. In many modern houses the work that is not seen has not been so carefully executed as that which is seen. It would be well, moreover, if builders made sure that an uncontaminated soil or sub-soil were the basis of all their edifices.

The "stucco-period" is happily past, but if better bricks are now used for outside work, walls too often are thinner and woodwork inferior. The fixing of a damp-course above the level of the ground, and below the ground-floor, is essential. This should consist of a layer of asphalt, glazed stoneware, slate, or Staffordshire blue-brick, placed above the basement-brickwork to

[1] "Geology of London," vol. i., fig. 47, p. 307.

prevent the uprising of moisture. Such moisture might otherwise ascend through porous bricks to a considerable height above ground, and cause much dampness to the living-rooms.[1] Dr. Poore remarks "that an evergreen creeper, such as ivy, does more to keep the foundations and walls of a house dry and pure than do any of the patent impermeable applications."[2]

Not only are bad bricks sometimes used, but worse mortar, which readily crumbles and is washed away. For outside work it is desirable that blue lias lime (or other strong lime) be used for the mortar. Good work is cheaper in the long run, when houses are not merely built for immediate sale.

Gardens.

Those who desire especially to devote attention to the cultivation of a flower-garden will unfortunately find many drawbacks in London. They must remember that the smoky atmosphere has a poisonous effect on vegetation, and hence even if the soil be fertile their horticulture may be hindered or even ruined by the dust, smoke, and noxious gases of the great city. In many parts of London the stiff brown London Clay is so near the surface that lumps of it are dug up when the soil is turned over, and this heavy clay-soil becomes caked in dry weather and is very tenacious in wet weather. Much good soil—light loam and mould—needs tc be provided in such situations, and the garden requires to be well drained. Generally speaking the gravel areas are more suitable for floriculture in London itself, and still more favourable are the loams, and the mixed soils of the Woolwich and Reading Beds, where two or three feet of good top-soil may be expected.

.Reference has been made (pp. 12, 22) to the Market Gardens in the Thames Valley to the west and south of London, situated on a loamy sub-soil or on a loamy soil overlying sand and gravel. Reference has also been made to the thin Chalk soils (p. 26). With regard to Nursery Grounds a large area which will provide a diversity of sub-soil is of course desirable, and it is needful also in selecting suitable sites both for Nursery Grounds and Orchards, to consider the aspect, and the shelter that may be afforded from northerly and easterly winds by higher grounds or belts of trees. The loamy areas in the Bagshot Beds to the south-west of Chertsey may be mentioned as affording good soils.

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[1] See K. D. Young, "Trans. Sanit. Inst.," vol. xv., pp. 40-42.
[2] "Essays on Rural Hygiene," p. 36.

CHAPTER IV.

WATER-SUPPLY AND DRAINAGE.

The question of water-supply is one that has to be considered especially in reference to each district, and again in reference to the quantity required. Thus shallow wells, and wells of moderate depth, may yield enough for a cottage or even a mansion, but they may not yield a sufficient quantity for a village. Shallow wells in porous strata, such as sand or gravel, overlying clay, as in Fig. 15, must be regarded with great suspicion in a tract where there are many habitations.[1] A deeper well carried through a bed of clay, as in Figs. 10 or 13, into underlying sand and gravel is far preferable. Here the water must be pumped from the base of the well. In other cases when deep wells are sunk into inclined strata, and the underground water is pent up between beds of clay, the water will rise to nearly the level of saturation in the porous strata. (See Fig. 8.) Again in deep wells carried into the central portion of a "basin," like that represented in Fig. 1, the water tapped beneath a mass of clay will rise to the general level of the plane of saturation in the underlying porous stratum. This is the case with the Chalk, to which further reference will be made.

In the eastern and south-eastern parts of England water can usually be obtained from wells and borings at varying depths dependent on the geological structure.

Where, however, there is a great thickness of clay—say from 300 to 500 feet, it may be more advantageous to seek a supply from adjacent hills where water-bearing strata may occur, and to convey the water in pipes. In some cases it may answer better to form a reservoir by damming up a portion of a valley into which permanent springs flow. Water, again, may be taken directly from the heads of streams or from rivers, but in the latter case a system of filtering is necessary. In the hard, rocky areas of the west of England and Wales it is often only possible to obtain a large supply of water by impounding the streams in some valley adapted for the construction of a reservoir. Rain-water collected from roofs, contains many impurities washed out of the atmosphere.

London Water Supply.

Ancient London and the many villages now engulfed in it, arose on sites where a supply of drinking-water could readily be obtained from natural springs, or by means of wells. On the tracts of gravel and sand, as pointed out by Sir Joseph Prestwich, the earlier settlements were made, and the growth of London was for long regulated by the distribution of these superficial water-

[1] See "Essays on Rural Hygiene," by Dr. G. V. Poore, 1893, p. 157.

bearing strata.[1] Thus the City expanded westwards to Chelsea, Kensington and Hammersmith; southwards to Clapham and Camberwell; eastwards to Bow and Hackney, and northwards to Islington. The clay area of Camden Town, Kentish Town, Maida Vale, Kilburn, and other tracts north of King's Cross and Marylebone were not populated until a supply of drinking-water from a distance was brought in conduits.

Some of the wells and springs in old times attained fame as holy wells and spas, such as Holywell, Bagnigge Wells, Clerkenwell, Sadler's Wells, Islington Spa, and St. Clement's. Hampstead still retains its chalybeate spring at Well Walk; it issues from a ferruginous sandy layer in the upper part of the London Clay near the junction with the Bagshot Beds, and has this year (1897) been certified as free from contamination.

The first conduit for the supply of water to London was that of Tyburn, which was completed in 1239, when water was conveyed in leaden pipes to the City. Much water, too, was obtained in buckets from the river, and in 1582 the supply was facilitated by means of water-wheels attached to the arches of old London Bridge. Wooden conduits were then used, and a more extended system of supply to houses was introduced.

As London increased, the supplies of water obtained from the gravels became contaminated, and the water of the Thames near London Bridge was doubtless as bad. From the close of the 17th century and subsequently, companies were formed for taking water from the Thames near Charing Cross, and higher up; but since 1855 no water has been drawn by any Company from the Thames below Teddington Lock.

The cutting of the New River was commenced in 1608 by Sir Hugh Myddelton, and five years later the artificial channel was completed. It was not till 1619 that the New River Company was formed.[2] Fed by springs from the Chalk near Ware, the New River furnished an abundant quantity of excellent water, and has for upwards of two and a-half centuries yielded the greater part of the supply needed for the growing population of northern London. This supply has latterly been augmented by deep wells sunk into the Chalk through the London Clay at Cheshunt, Hornsey, and elsewhere.

Since the year 1790 the sinking of Artesian wells through the impervious mass of London Clay into the Lower London Tertiaries and Chalk, has been a fruitful source of water for breweries and other large establishments. The water from the Lower London Tertiaries, which was at first drawn upon, proved in time to be wanting both in quantity and quality, and borings were then carried deeper into the Chalk. Hence the chief supply now tapped by the deep borings under London may be said to have originated in the rainfall on the Chiltern Hills and North Downs, and to have percolated through the Chalk to the central portions of its mass. When some of the earlier deep wells had been sunk the

[1] Address to Geol. Soc., 1872, "Quart Journ. Geol. Soc.," vol. xxviii., p. liii.

[2] See J. Hopkinson, "Trans. Hertford Nat. Hist. Soc.," vol. vi., p. 150; and vol. iii., p. lxix.

water rose to within 40 or 50 feet of the surface, and, in a number of instances, in the lower grounds of East Essex, the Lea Valley, and at Tooting, it actually overflowed.[1] Now the water-level under London is about 120 feet below Ordnance Datum, as the general plane of saturation in the Chalk areas has been, and is still being, lowered. It is needful to bore into the Chalk until some fissure is met with, whence the water can be freely pumped; this may be at varying depths from 10 feet down to 250 or more feet in the Chalk. Thus a boring at Chelsea was carried through gravel, London Clay, &c., and Chalk, to a total depth of 528 feet.

Some of the districts to which attention has been drawn extend beyond the limits of the areas supplied by the eight Metropolitan Water Companies, but many other parts are now supplied by local companies. It is to be hoped that in time the entire country will be divided into districts to be supplied with good drinking water. At present the inhabitants of many a small country village, ill supplied with water, are not in a position to pay for the needful deep boring or reservoir. Especial attention was drawn to this subject nearly twenty years ago by H.R.H. the Prince of Wales, in a letter addressed to the Chairman of the Council of the Society of Arts. A Public Congress was summoned by the Council, and the subject was very fully discussed, and reported on in 1878. A practical scheme, however, has still to be formulated and carried out.

The area supplied by the Metropolitan Water Companies extends around London to Ware in Hertfordshire, to Romford in Essex, to Sundridge and Chevening in Kent, and to Esher in Surrey.[2] All these Metropolitan Companies, except the Kent Company, derive great part of their supply from the Thames and the Lea, supplemented in some cases by water obtained from wells. The Kent Company is supplied wholly by deep wells in the Chalk.

It is satisfactory to learn from the Report of the Royal Commission on Metropolitan Water Supply (issued in 1893) "that the water, as supplied to the consumer in London, is of a very high standard of excellence and of purity, and that it is suitable in quality for all household purposes." The Thames and its tributaries above the intakes of the companies contain, of course, much impurity, and in seasons of heavy rain and flood the amount of impurity is much greater. The system of filtration introduced in 1829, and since improved in various ways, has, however, been very efficient in providing good water. It is now known that the slime formed on the surfaces of filter-beds contains micro-organisms which are the most effective agents in the purification of the water.

It is significant that the typhoid bacillus has never yet been found in the water supplied by the companies who draw from

[1] See Prestwich, "Water-Bearing Strata of the country around London," pp. 3, 45, 69.

[2] See "London Water Supply," by Col. Sir Francis Bolton. Ed. 2, by P. A. Scratchley, 1888.

the Thames, though, of course, considering the immense quantity of water used and the tiny amounts that can be periodically examined, the fact must be taken *cum grano*.[1] Nevertheless, the character of the Thames water above Teddington is steadily improving owing to the care taken by the Thames Conservators in keeping the main river and its tributaries as free as possible from pollution. Although the water supplied is moderately hard, yet it is well known that many of the healthiest districts are those with hard water. Lead-poisoning may for a time be produced by soft water when conveyed in new leaden pipes, and, curiously enough, bacteria are said to increase more rapidly in water that is comparatively pure than in that containing mineral ingredients.[2] Nevertheless, hard and soft water appear to be equally good for drinking-purposes, when they attain a proper standard of purity.

Chalk areas are now and again looked upon with disfavour by individuals who have a tendency to gout, because it is thought that the chalky water would aggravate the complaint. This, however, is a fallacy. Moreover, it is not easy in the area adjacent to London to obtain other than hard water, much of it derived directly from wells in the chalk. The hardness is of the kind known as "temporary," being due to carbonate of lime which is held in solution by carbonic acid. This it is which furs our tea-kettles and boilers, and which wastes our soap. The hardness may be removed by the addition of quicklime to the water, a process introduced by the late Dr. Clark of Aberdeen.

Rural Water Supply and Sanitation.

In selecting a site outside the range of any great Water Company's district, and where there is no local general supply from a deep-seated or other source, the nature of the water-bearing strata must, in the first place, be carefully considered. Most villages like those in the London area have been built on porous sub-soils from which the water-supply was readily obtained, and in most cases such shallow sources have become more or less contaminated. No serious outbreak of illness may hitherto have occurred, but there is always a risk of its appearance. Cess-pits and burying-grounds may lead to disastrous contamination in such situations, and, indeed, the attention of the Local Government Board is constantly being drawn to fresh cases of typhoid fever that arise from the contamination of wells. That such illnesses are not more frequent is due no doubt to the otherwise healthy surroundings of those who live a country life.

A bed of clay intervening between the surface-deposits and the

[1] L. C. Parkes, "Trans. Sanit. Inst.," vol. xv., p. 245. See also researches of Prof. H. Marshall Ward, on the Bacterial Flora of the Thames, "Proc. Roy. Soc.," vol. lxi., 1897, p. 415; and S. Rideal, "Water and its Purification," 1897, p. 160.

[2] "Trans. Sanit. Inst.," vol. xi., p. 234; and Prof. H. Robinson, *Idem*, vol xv., p. 577.

water-bearing strata may prevent contamination from the soil, if the well be properly bricked and cemented to a little below the level of the porous surface-deposits. In the absence of such geological conditions within, say a hundred feet, of the surface, a general supply of water must be sought by deep boring, or obtained from a distance. In all cases an analysis is desirable, as an otherwise good, but highly ferruginous, water may be detrimental to health.

The great trouble in rural districts is with the sewage. Many difficulties would be overcome by the general adoption of the pail- or earth-system instead of cess-pits. Dr. G. V. Poore has strongly advocated the plan, and experiments which he has made show that two or three feet of soil filter out bacteria, the sub-soil at a greater depth being generally free from these micro-organisms. He remarks that "The living mould is our only efficient scavenger, which thrives and grows fat upon every kind of organic refuse; our only efficient filter, a filter which swells and offers an impassable barrier to infective particles, a filter which affords a sure protection to our surface wells. When we perforate the living humus with a pipe, and take our dirty water to the sub-soil, we, as it were, prick a hole in our filter, and every chemist knows what that means." [1] Hence, shallow wells should always be cemented some 6 or 8 feet down, and there should be no cess-pits or other subterranean receptacles for refuse in their vicinity. Recent researches tend to show that sewage may by means of bacterial filter-beds be so purified that the effluent water can without danger be discharged into streams and rivers.[2]

In regions where there is no main drainage and no system of water-supply, it is by no means unusual to sink "blind" or "dumb wells" into porous strata to carry off the sewage. Sometimes, branching pipes are laid down to convey the house-drainage away, and thus to distribute it into the very strata from which, at no great distance, the supply of drinking-water is obtained!

Attention has been frequently directed to the evils that, sooner or later, may arise from such systems of "dead wells" and underground drainage, whether carried into the Chalk, the Thanet Sands, the Reading Beds, or the Bagshot Sands.[3] It should be remembered that all porous strata are water-bearing, that the supply of water, especially in the case of the Chalk, may be drawn upon for drinking-purposes, and that contamination introduced into such strata may be conveyed underground to some distance from the sources of pollution. It is also well to bear in mind the important legal decision of 1885, to which Mr. Whitaker has drawn particular attention, that while every owner has the right to draw underground water to an unlimited extent, no owner has the right to pollute a source of

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[1] "Trans. Sanit. Inst.," vol. xi., pp. 33, 36, 41, 47, &c.; the *Lancet*, Dec. 14, 1895, p. 1483; "Essays on Rural Hygiene," p. 192.

[2] S. Rideal, "Water and its Purification," 1897, p. 159.

[3] See Prestwich, Address to Geol. Soc., 1872, "Quart. Journ. Geol. Soc.," vol. xxviii., p. lxix.; Whitaker, Address to Sanitary Inst. (Section III.), "Trans. Sanit. Inst.," vol. viii.; and E. Evans, Report on Uxbridge Rural Sanitary District to the Local Government Board.

water-supply common to his own and other wells.[1] In a recent Address to Section III. of the Sanitary Institute (1897), Mr. Whitaker urges that where a public supply of water is obtained from porous strata, such as the Chalk, occupying large areas at the surface, then a certain tract of ground around the water-works should be preserved from surface-contamination, whether by sewage-farm, cemetery, or other source. Since these remarks were written a serious outbreak of typhoid fever at Maidstone has proved the great need of this precaution. On the gathering grounds of certain springs which have been utilized for the water-supply of the town, there had been not long ago an encampment of hop-pickers! Other sources of contamination are likewise suspected, and these are now being investigated.

On some of the great clay-vales where local sources of water, obtained from small tracts of gravel, have been condemned, there is great difficulty as well as expense in procuring supplies. Before improving the drainage-system it is desirable to obtain a deep-seated or distant supply of drinking-water. In one instance where a village had been notorious for its unpleasant odours and its ditches with black liquid filth, I was informed that no serious illness had been known until a new drainage-scheme had been instituted. Then diphtheria and scarlatina made their appearance. No doubt the drainage-operations, in disturbing the infected soil, poisoned the area more seriously than before, and may also have opened up connection between the surface-drains and the water-supply. Typhoid (enteric) fever and cholera are essentially associated with bad sanitary arrangements, foul emanations, impure water and milk. Diphtheria may be caused by polluted air, such as that arising from neglected dust-bins, sewers, or impure sub-soils; and it is favoured by cold and damp. Nevertheless, according to the researches of Sir R. Thorne Thorne no direct relation has been established between polluted water and diphtheria.[2]

Dr. Poore urges that if the solid refuse-matter from houses be buried in the "living earth" (that is in the top layer of cultivated ground or natural soil), no evil should result. Putrescible matter when buried in earth undergoes decomposition without putrefaction; while the waste-water of the house may be allowed to run away in open gutters, or be placed on different tracts of the ground every day, whereby hedgerows and shrubberies, fruit and forest trees would be greatly benefited.[3] These plans can more readily be carried out on a large estate, or by the help of municipal authorities where cottages and houses with small gardens are concerned. The pail or dry-earth system does not appear so well suited for large towns; but I am informed by Mr. F. J. Bennett that it has been adopted with advantage in Brunswick, Essen, Bremen, and Zurich. In these towns peat-dust is supplied by the authorities for use in the earth-closets,

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[1] "Trans. Sanit. Inst.," vol. vii.

[2] "Trans. Sanit. Inst.," vol. xv., p. 7.

[3] See Poore, "Dry Methods of Sanitation," 1894, and "Essays on Rural Hygiene," p. 101.

and its employment has been found most successful on account of its deodorizing and manure-making properties.

Mr. Bennett has called attention to the bad sanitation of many village-schools. Where cess-pits are used these schools "become centres of air, soil, and water-pollution." He refers to one village "where closets can be seen emptying into the brook close to, *i.e.*, within four yards in one case, of the very spot where the villagers get their water from the spring;" and he adds "What a comment on all our technical instruction and sanitation!"[1]

Recent Reports of Medical Officers to the Local Government Board show the need of efficient sanitary administration in many parts of the area described, even in semi-rural residential districts in the Thames valley between Windsor and London.

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[1] Article printed in the *Marlborough Times* for June 12, 1893.

CHAPTER V.

GENERAL SANITARY CONSIDERATIONS IN REGARD TO SITUATION AND SURROUNDINGS OF HOUSES.

In most cases a dry and a fairly open, sunny and even breezy site is to be preferred to one that is much enclosed, whether by other buildings or in a sheltered valley or surrounded by trees. Sunshine in rooms is most desirable, and trees not only produce shade but they check evaporation from the ground and thus tend also to promote dampness. In a town the value of a garden increases in proportion to the density of the population.

Dr. Louis Parkes has observed that "it is now generally conceded that back-to-back houses without thorough ventilation, and rooms facing narrow enclosed courts in which the atmosphere is always sunless and stagnant, exercise an unfavourable influence on health, and tend to produce an excessive mortality from phthisis, respiratory diseases, diarrhœa, and zymotic diseases generally."[1] Overcrowding of houses is regarded by Dr. Poore "as infinitely the greatest of all sanitary evils."

On the other hand it is believed that flats, with good spaces between the blocks of buildings, may be healthy enough, better indeed than small houses or cottages that are crowded together. In flats the sanitary arrangements are good, and the chief drawbacks may be from the impure air and dust (from shaken carpets) that arise from the lower doors and windows, and from the occurrence of infectious or contagious diseases in the buildings.

While the growth of Inner London has led almost wholly to the effacement of nature within its bounds, yet considerable attention is paid to the preservation of open spaces, so essential to the health of the community. This is a subject that should be constantly in view, especially in the quickly growing suburbs. Indeed the rapid increase in the number and size of buildings constructed for flats, renders it more than ever desirable that additional parks and open spaces be provided.

The system of surface-draining is more complete in London than in most rural districts; and the fact that less of the rain-fall gets into the soil and sub-soil is in itself an advantage. Only here and there in very low-lying situations near the river, in a badly drained garden, or in times of sudden and heavy rain when the gratings leading to the sewers become choked, when water-mains burst, or when a canal overflows, are there serious if temporary accumulations of water. Thus a severe thunderstorm on July 21st of this year, caused disastrous floods in Stoke Newington, Hackney, and South Hornsey; roads and railways

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[1] "Trans. Sanit. Inst.," vol. xii., p. 26; see also Sir D. Galton, *Ibid.* vol. i., p 121.

were temporarily converted into canals, a sewer burst, and the basements of many houses were flooded, not merely with rain-water, but with the overflow from drain-traps of the surcharged sewers. Moreover, during severe winters when the water in mains and soil-pipes is frozen, not only great inconvenience but some danger to health may arise.

The system of house-drainage (though by no means perfect), the clearance of dust-bins, and finally the supply of good drinking-water, all tend to make London, including much of the central portion, one of the healthiest cities in the world.

Moreover, London is not so liable to those epidemics which arise in many country villages from the drinking of contaminated water. The average mortality per thousand of its inhabitants during the past ten years is not quite 20, while its population per acre is about 64. The average mortality in the outlying districts is 18, as compared with 23 in the central districts.[1]

Fogs and Sunshine, Rain and Winds.

It is true that the dusty atmosphere of London is often trying and more or less injurious, especially in dry windy weather. On such occasions the emptying of dust-bins contributes not a little to the danger and discomfort. Moreover, the city is notorious in the late autumn and winter, from October to February, for its fogs; but it is not alone in this respect among the larger manufacturing towns which lie in river-valleys, nor is it much worse than these.

Ordinary mists indeed occur all over the British Isles, irrespective of soils and sub-soils, but they are more prevalent in the clay-vales. Mr. John Aitken has shown that aqueous vapour requires free surfaces for its condensation, and that these are provided by dust, or even by very fine particles of ordinary salt derived from sea-spray; and that when air is filtered so that all floating particles of matter are removed then no cloud of condensed vapour is formed.[2]

"Wet fogs," as they are called, are produced when the particles of dust are comparatively few and the condensed moisture is excessive.

"Dry fogs," on the other hand, occur when the smoke and dust are very abundant, and while the vapour condenses on the grains of dust, the watery particles are darkened also by a coating of tarry matter arising from the combustion of coal. This delays evaporation. Added to the discomfort produced by fog, is the comparatively large amount of carbonic acid and sulphurous gases present in town-atmospheres. Mr. Aitken has shown that the quantity of burned sulphur derived from coal, which escapes from our chimneys, is most active as a fog producer, but, he remarks, "burnt sulphur is not an unmitigated evil. During fogs the air

[1] See Poore, "Essays on Rural Hygiene," p. 17.

[2] "Trans. Roy. Soc. Edin.," vol. xxx., 1883, p. 337. See also W. J. Russell, 'Nature,' Nov. 5, 1891, p. 11; and C. T. R. Wilson, "Phil. Trans.," vol. clxxxix. (A), p. 265.

is still and stagnant; there is no current to clear away the foul smells and deadly germs that float in the air, and which might possibly be more deadly than they are if it were not for the powerful antiseptic properties of the sulphurous acid formed by the burning sulphur."[1]

Although unpleasant in itself we thus have some compensation for the unwholesome character of our foggy atmosphere, and those who travel much on the underground railway between Baker Street and King's Cross may question whether any microbes are there likely to exist. They do indeed occur, but more particularly in the air of the railway-carriages.

That in foggy weather, the number of micro-organisms becomes greatly reduced, and many forms appear to be destroyed, has been ascertained;[2] nevertheless, the death-rate is found to increase through fogs, and the reason for this is not very clearly established. Thus the returns of the Registrar-General, as pointed out by Dr. W. J. Russell, indicate that the main cause of the increase of death when fogs occur, is the sudden fall of temperature, not the fog itself. When, as occasionally happens, dense fogs occur, and the temperature is an average one, there is no increase in the death-rate.[3] On the other hand, Dr. Poore considers "that it is not merely the coldness of the fog which raises the death-rates, but rather the impurities, mechanical, chemical and infective, which it contains."[4]

Concerning the general discomfort of fog, there can be no difference of opinion; moreover, the loss of sunlight is injurious. Plants in London and at Kew suffer especially during such dark times, not only from the loss of light, but also from the sooty and tarry deposits which accumulate on the leaves.

With regard to sunshine, records for the year 1890 show that at the undermentioned localities the number of hours of sunshine were as follows:—

Bunhill Row	1157	
Greenwich	1255	
Kew	1404	(1436½ in the year 1896).
Aspley Guise	1419	
Eastbourne	1723	

It may be said, therefore, that in London we have about a quarter of the possible number of hours of sunshine during the year.

Fogs can nowhere be avoided in the London area, though they are less dense at Hampstead and Highgate, or at Streatham, than at King's Cross, Homerton, Whitechapel or Rotherhithe. Somewhat dense fogs may extend as far south as Sutton and Croydon, or even as far up the river valley as Walton-on-Thames, after an

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[1] *Op. cit.* p. 354. See also W. Mattieu Williams, "Trans. Middlesex Nat. Hist. Soc. for 1887," p. 112; and Sir D. Galton, "Trans. Sanit. Inst.," vol. iv., p. 35.

[2] Dr. A. A. Kanthack, "Nature' Dec. 31, 1896, p. 209.

[3] "Nature," Nov. 5, 1891, pp 13, 14.

[4] "Essays on Rural Hygiene,' pp. 19, 150. See also, Dr. J. B. Cohen, "The Air of Towns," Smithsonian Miscell. Coll., No. 1073, 1896, pp. 23, 29, &c.

easterly wind has drifted the smoke-laden atmosphere in that direction.

Rain clears the atmosphere of the coarser dust particles which favour the formation of fog, and in rainy seasons fogs are comparatively rare; but Mr. Aitken has shown that rain has little effect in diminishing the amount of the finer dust in the air.[1]

It may be of interest here to note the following observations made at the Kew Observatory, as they serve to indicate the general character of the climate, as it is affected by rain and wind:—

	Years		
	1894	1895	1896
Rainfall: Total inches ...	28	22	20
Number of days on which 0·01 inch of rain or melted snow was recorded	183	142	155
Wind: Number of days on which it was from—			
North	42	47	68
North-east	52	45	40
East	40	42	33
South-east...	13	19	15
South	37	30	38
South-west	99	88	80
West	50	59	55
North-west	32	35	37

The three years of rainfall above noted give an average of 23 inches, which is also the average of a number of years' rainfall recorded at Chiswick. In Hertfordshire the mean annual rainfall is 24·89 inches.

The influence of winds is, of course, all important. It may be observed that the prevalent south-west winds come across a large area of gravel-country before reaching west London, and the air on the clay tracts of West Hampstead is certainly more salubrious than that on gravel-tracts to the south-east, where the air is more contaminated by London smoke. Referring to the presence of bacteria in the atmosphere, Dr. Kanthack has remarked that "there is an extraordinary difference between the air in Oxford Street and on Wandsworth Common"[2]—to the manifest advantage of the air on Wandsworth Common. Winds may at times convey disease. Thus when a serious outbreak of small-pox

[1] "Nature," Dec. 30, 1890, p. 185. See also W. J. Russell, "Nature," Nov. 5, 1891, pp. 11-15; F. J. Brodie, *Ibid.*, Mar. 5, 1891, p. 424. See also Reports of the Kew Observatory Committee, in "Proc. Roy. Soc."; and R. C. Mossman, "Meteorology of London, 1713-1896," paper read before Royal Meteorol. Soc., June 16, 1897.

[2] "Nature" Dec. 31 1896, p. 209.

occurs, the germs of the disease may be wafted for some distance by the prevalent wind.[1]

Breezy situations are naturally healthy, as compared not only with densely-populated districts in low grounds but with pent-up and wooded valleys. Dr. A. Haviland has pointed out that certain river-valleys exercise an important and beneficial influence on health. In those valleys which lie in the direction of the prevalent winds the air is more completely and frequently changed than in valleys which lie north and south. Where the air is constantly changed and freshened, whether inland or on the seabord, there is a low mortality from heart-disease. In pent-up valleys and in unventilated streets there is a high mortality.[2]

On the other hand Dr. Haviland considers that shelter against strong winds is necessary for consumptive patients, and that they would derive benefit from a residence in a warm and fertile sandstone vale, or on sheltered and dry uplands. His observations and statistics tend to show that the highest mortality among women from malignant disease (registered under the name of cancer), occurs in valleys where the rivers periodically flood the adjacent low grounds. The lowest mortality from the same disease is found in high and dry regions, such as the Chalk Downs, or in steep valleys where the rivers are rapid and torrential and only temporarily flood the bordering land.[3]

Residential districts which, like Chelsea, Putney, and Fulham, are situated on gravel near the Thames, and are comparatively low-lying, are freshened to some extent by the currents of air that follow the course of the river.

Flowing water, so long as it does not actually contribute towards the dampness of the sub-soil, is not in itself unhealthy. Malaria is caused where land is periodically flooded, whether by overflow of rivers or by tidal action in estuaries: then the sodden ground is liable to send off noxious exhalations. Sub-soil drainage has tended largely to decrease the number of cases of ague in the marshlands of Essex; but malaria is not unknown in the low grounds of Wapping, where, floods sometimes occur. (*See* p. 9.) Salt-marshes, however, are not regarded as injurious to the same extent as the river-flats.

For those suffering from rheumatism, throat or lung diseases, and for delicate constitutions generally, proximity to rivers or marshes is objectionable, and a higher situation with less tendency to mist should be sought.[4]

Breezy situations may be found, as at Harrow, Hampstead, or Mill Hill, or in the higher sandy regions of Bagshot Heath; the more sheltered places must be looked for in the picturesque regions of Surrey and Kent, on the south side of the North Downs.

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[1] See B. A. Whitelegge, "Hygiene and Public Health," Ed. 2, 1893, p. 263.

[2] "Geographical Distribution of Disease in Great Britain," Ed. 2, 1892, pp. 28, 33.

[3] *Op. cit.*, pp. 28, 29, 234.

[4] See Hon. F. A. R. Russell, "Trans. Sanit. Inst.," vol. iv., pp. 220-222; also "The Atmosphere in relation to Human Life and Health," Smithsonian Misc. Coll., No. 1072, 1896.

Conclusions.

The conclusions to which the foregoing remarks lead, may not be deemed very definite as regards the influence of soils and sub-soils on sites for houses, or the relative importance of gravel, sand, clay, or chalk. So much, indeed, depends on the combination of all the various conditions that affect the salubrity of a district or site. One would, in fact, be disposed to conclude that it is well-nigh impossible anywhere to find all conditions in their most favourable aspect, whether in town or country, in cottage, mansion, or flat. Moreover, the constitutions of the several members of one family may so differ that all cannot with equal advantage reside in the same locality. Dry and bracing air may be required by some individuals; shelter from north and east winds by others. Some needful conditions with regard to situation or climate may have to be sought outside the regions described in this little work.

The London area presents many kinds of sub-soils, and the character of sites is modified not only in accordance with their varying nature, but also with elevation and other circumstances. In connection with the character of the great city as a healthy place of residence, the variety of thought and scene which tend to occupy and divert the mind cannot be overlooked.

In rural districts, where every natural element should favour health, the fresh air and charms of scenery may often be the chief redeeming features.

Hygienic improvements are gradually taking place, and it has been calculated that those made during the past thirty years in England and Wales have now resulted in the saving of 120,000 lives a year. Very much, however, yet remains to be done.

CHAPTER VI.

CEMETERIES.

The selection of sites suitable for cemeteries is a task requiring the most careful consideration. It is very desirable that burial-grounds be removed as far as possible from densely populated regions, and be placed in positions where the population is not likely to increase to any great extent for a long time. It is necessary that the sub-soil be of such a character as to cause no pollution of the air, and that there be no pollution of under-ground or other sources of water-supply.

So long as earth-burial continues to be the chief system adopted in this country, the subject must constantly engage the serious attention of local authorities. It may be true, as Dr. Poore maintains, that "Rational earth-burial has never been shown to be productive of any evil;" but rational interment has not always been practised. It is admitted that a rapid decay after burial is desirable, and this can only be brought about by the use of perishable coffins and by interment in porous earth. This earth should have a depth of not less than ten feet, and graves should not be more than 8 feet deep—preferably less, or from 5 to 8 feet, when (according to the "rational" system) only one body is buried in the same grave; while the level of the sub-soil water should be at least two feet below the bottom of the deepest grave.[1] In large cemeteries a greater depth of porous strata is desirable. To secure the necessary conditions attention must be paid to the physical features and geological structure of the district.

An isolated tract of elevated ground, where sands and sandy loams, or sandy and loamy gravel, of considerable thickness rest on clay also of considerable thickness, offers the most desirable site.

Probably a sandy and calcareous loam is the best material for a graveyard, for a slight amount of moisture in the earth is helpful to the process of decay, though it must not be excessive. That interment should be at no great depth is owing to the fact that the micro-organisms which produce decomposition are most active near the surface. Stiff clay, like the London clay, is in most respects bad, as dissolution is checked, and may be retarded for many years. In wet weather open graves are apt to contain much water at the time of burial. Moreover, in periods of drought, cracks appear to a depth of 7 or 8 feet or more in such clayey ground, and unpleasant and injurious emanations may

[1] See Memorandum on the Sanitary Requirements of Cemeteries, Local Government Board, 1893; also C. H. Cooper, "Trans. Sanit. Inst.," vol. xv., p. 567; Rev. F. Lawrence, *Ibid.*, vol. vii., p. 283; and Poore, "Essays on Rural Hygiene," pp. 38, 285.

arise from these fissures. Such results cannot take place in sands and sandy or loamy gravels, nor in very sandy loams, which are in themselves regarded as good deodorizers.[1] Coarse gravel comparatively free from any matrix is bad, and so also is broken rock, or any very loose and open material.

Chalk, though considered excellent as a medium for ready dissolution, is strongly to be condemned on account of its general utility as an underground reservoir for water-supply.

In porous soils the effluent water that escapes from hill-sides into brooks may be a source of danger if due attention be not paid to the matter. It need hardly be urged that no fresh sites for cemeteries should be selected within the county of London. It would be well if all those still used in thickly populated districts were closed, and especially those in the London Clay, whose fissured surfaces in dry weather may lead to pollution of the air.

There are places in the Thames valley both above and below London, and at a distance from the metropolis, where valley gravel and loam rest on the London Clay, and where appropriate sites for cemeteries may be found.

Sites may also be obtained in the areas occupied by the Bagshot Sands in Essex, and especially where the loamy passage-beds into the London Clay are well developed. In this respect *geologically* the upper part of Highgate Cemetery was suitable ground *before the district was densely populated*, and the same geological conditions occur at Harrow Churchyard.

Nowadays the cemetery at Brookwood near Woking may be regarded as one of the best examples, at a sufficient distance from London, and one which fulfils as nearly as can be the requisite sanitary conditions. Those at Finchley, in the chalky clay overlying sand and gravel, are good sites geologically, and they occupy breezy situations. It is true that they are placed in a district where the population is rapidly increasing, but at present to the south of the Marylebone Cemetery there is a large area of sparsely populated ground, for the most part meadow-land. Other cemeteries on the Woolwich and Reading Beds, and Blackheath Beds, occupy suitable ground, so far as the sub-soil is concerned.

If additional burying-grounds be required they should be formed at a further distance from the Metropolis, where the geological conditions and physical features are suitable, and where railway communication could replace transit by road.

It may, however, be mentioned that the London County Council are considering the advisability of promoting a Bill in Parliament for facilitating the provision of crematoriums in connection with London parish-cemeteries; and it need hardly be stated that the general adoption of cremation would be a great advantage from a sanitary point of view. Moreover, there would then be no occasion to close any cemeteries so long as they possessed the requisite space for monumental purposes.

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[1] See Cooper, *op. cit.*, and Sir D. Galton, "Trans. Sanit. Inst.," vol. vii., p. 285.

The sites of various cemeteries in and around London may be noted as follows:—

Valley Gravel:—Barnes, Brompton (West London), Ealing, Fulham, Hammersmith, Hanwell (Kensington), Leytonstone (St. Patrick's), Manor Park, Essex (City of London), Mortlake, Plaistow (East London), Tower Hamlets, Wandsworth, and West Ham.

Valley Gravel and London Clay:—Abney Park, Lambeth.

Bagshot Sand and Loam:—Brookwood, near Woking (London Necropolis).

Bagshot Sand (passage beds) and London Clay:—Highgate, Harrow.

Boulder Clay and Gravel:—Finchley (Islington, St. Pancras, and Marylebone).

Thanet, Woolwich, and Blackheath Beds:—Plumstead, Woolwich.

Woolwich Beds and London Clay:—Deptford.

London Clay:—Camberwell, Chingford, Greenwich, Hampstead, Kensal Green, Lee, Lewisham, Norwood, Nunhead, Paddington, Willesden, and Wimbledon.

INDEX.

Names of authors and other individuals are printed in small capitals.

The figures in *italics* refer to the principal heights (in feet) above Ordnance Datum of the localities. Names are spelt according to the New Series of Ordnance Survey Maps.

The letters which follow the names of places refer to the geological formations there represented, as follows :—

A. Alluvium (Marshland).
Bcl. Boulder Clay.
Bg. Bagshot Beds (chiefly sand).
Bl. Blackheath Beds (gravel).
C. Chalk.
Clf. Clay-with-flints and Loam.
G. Gravel and Sand of Higher Grounds.
Glt. Gault (clay).
H. Hastings Beds.
L. London Clay.
Lg. Lower Greensand.
Lm. Loam (Brickearth).
T. Thanet Sand.
Ug. Upper Greensand.
Vg. Valley Gravel.
W. Woolwich and Reading Beds (mixed gravel, sand and clay).
Wd. Weald Clay.

Places to which no reference-pages are given are not mentioned in the text, but most of them are included in the Map accompanying this work.

Abbey Wood, Plumstead, *100*, Bl. T. W.
Abbots Langley, *417*, Clf. G. W.
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Abney Park, *85*, L. Lm., 48.
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Aldborough, Essex, *90*, Vg.
Aldenham, *254*, C. G., 14.
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Amersham, *291*, C. Vg., 22, 26.
Ampthill, *320*, Lg., 19.
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Balls Pond, *70*, Lm.
Bank of England, 7.
Banstead, *507*, C. Clf., 26.
Barking, *20*, Vg., 2, 9, 12.
—— Side, *97*, Lm. Vg.
Barnehurst, Bexley Heath, *100*, Bl. W.
Barnes, *15-30*, Lm. Vg., 12, 22, 48.
Barnet, *429*, G. L., 2, 5, 14.
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——, New, *200*, L.
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Battersea, *15*, Lm. Vg.
Bayswater, *80*, L. Lm. Vg.
Beaconsfield, *374*, G. W., 14, 20 26
Beckenham, *130*, Bl. 16.
Beckton, *7*, A., 11.
Beddington, *120*, C. T.
Bedfont, East, *60*, Vg.
——, West, *70*, Vg.
Bedford Park, *30*, Lm.
Bedmond, Abbots Langley, *448*, W.
Belgravia, *24-34*, Vg. 8.
Bellingham, Catford Bridge, *60*, Vg.
Belsize Park, *200*, L.

Belvidere, Erith, *75*, A. Bl. T. W.
Bennett, F. J., 11, 38, 39.
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——, Little, *347*, G. L., 23.
Bermondsey, *10*, A.
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Bickley, 237, Bl.
Billericay, *319*, Bg., 16.
Birling, Kent, *119*, Lg.
Bishopsgate, *50*, Vg.
Bisley, *148*, Bg. Vg., 17.
Blackfriars, *25*, Vg. L.
Blackheath, *100–150*, Bl., 16.
—— Beds, 5, 16.
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Bloomsbury, *83*, Lm. Vg., 13, 22.
Bobbingworth, *220*, Bcl. L.
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Bookham, Great, *250*, C. L. W.
——, Little, *250*, C. L. W.
Boreham Wood, 300, L.
Bostall Heath, Plumstead, *216*, Bl. T. W.
Botleys, Chertsey, *100*, Bg.
Bounds Green, Colney Hatch, *142*, L.
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Molesey, *33*, Vg., 12.
Monken Hadley, *420*, G., 14.
Moorfields, *60*, Vg.
Morden, *85*, L., 24.
Mortar, 32.
Mortlake, *25*, Vg., 12, 48.
Mossman, R. C., 43.
Mottingham, *90–140*, Bl. L., 21, 24.
Mould, 8.
Mountnessing, *200*, G. L.
Muswell Hill, *341*, Bcl. G., 5, 23.
Myddelton, Sir H., 34.

Navestock, *238*, Bcl. G. L.
Nazeing, *259*, Bcl. L.
Neasden, *160*, L., 14.
New Cross, *46*, L. W. Vg.
—— Malden, *45*, L.
—— River, 34.
Newington Butts, *11*, Vg.
—— Green, *90*, Lm. Vg.
Nine Elms, *15*, A. Vg.
Noak Hill, Romford, *250*, Bcl. L.
Noel Park, Wood Green, L.
Norbiton, *50*, L.
Norbury, Streatham, *130*, L. Vg.
Normandy, Guildford, *153*, Bg.
North Downs, 3, 4, 22, 25, 34.
Northaw, *377*, G. L., 14.
Northfleet, C. T.
Northolt, *129*, L., 23.
North Weald Bassett, *260*, Bcl. L.
Northwood, Pinner, *250*, W., 20.
Norton Mandeville, *220*, Bcl.
Norwood, *150–370*, L., 24, 48.
——, Southall, *100*, Lm. Vg., 22.
Notting Hill, *97*, L. Vg., 13.
Nunhead, *100*, L. 48.
Nursery-grounds, 12, 22, 32.
Nursted, Kent, *287*, C. T.
Nutfield, *420*, Lg., 18.

Oakleigh Park, East Barnet, *200*, G. L.
Oatlands Park, Weybridge, *50–100*, Bg. Vg.
Ockendon, North, *100*, Vg., 12.
——, South, *79*, Vg., 12.
Ockham, *115*, Bg. L.
Offham, Kent, *276*, Lg.
Old Ford, *42*, Lm. Vg., 22.
—— Windsor, *65*.
Oldhaven Beds, 5.
Orang Park, *340*, Bcl. G. Lm. L., 16.
Open Spaces, 40.
Orchards, 32.
Orpington *200*, C. Vg., 17, 26.
Orsett, *56*, W.
Osterley Park, *86*, Lm. Vg.
Otford, Kent, *200*, C. Glt. Ug., 13.
Ottershaw, Chertsey, *125*, Bg.
Oxford Clay, 3.
Oxshott, Esher, *246*, Bg. L.
Oxted, *300*, Lg.

Paddington, *100*, Vg., 13, 48.
Page Green, Tottenham, *36*, L.
Palmers Green, *133*, L. Vg.
Parks, 40.
Parkes, Dr. L. C., 36, 40.
Parliament Hill, *319*, L.
Parsons Green, *14*, Lm. Vg., 22.
Pasture-land, 23, 25.
Peat, 9.
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Peckham, *15–50*, Lm. Vg. W., 13, 20.
—— Rye, *50–100*, W.
——, East, Kent, *200*, Lg. Wd.
——, West, *262*, Lg. Wd.
Penge, *150–200*, L., 24.
Pentonville, *127*, L. Vg.
Perivale, *70*, Vg.
Petersham, *23*, Vg.
Phthisis, 29, 40, 44.
Pimlico, *20*, A. Vg. 9.
Pinner, *160–200*, L. Vg. W., 20.
"Pipes" in Chalk, 22, 30.
Pirbright, *140*, Bg., 17.
Plaistow, *30*, Vg., 9, 11, 48.
Plants, 42.
Plantations, 26.
Plashet, Plaistow, *33*, Vg.
Plaxtol, Kent, *400*, Lg.
Plumstead, *50–100*, T., 9, 26, 48.
Pollution. *See* Contamination.
Ponders End, *60*, Vg.
Poore, Dr. G. V., 12, 29, 32, 33, 37, 38, 40, 41, 42, 46.
Poplar, *22*, Vg.
Portland Town, St. John's Wood, *130*, L.
Potters Bar, *400*, G. L., 14.
Prestwich, Sir J., 33, 35, 37.
Primrose Green, Bcl., 23.
—— Hill, *216*, L. 4.
Prince's Risborough, 18, 22.
Pudding-stone, 20.
Purfleet, *21*, C., 26.
Putney, *30–170*, Vg. L., 12.
Pyrford, *100*, Bg., Vg.

Quaternary, 5.
Queen's Park, Kilburn, *150*, L.

Radlett, *300*, C. G. W., 20.
Rainfall, 43.
Rain-water, 33.
Rainham, *16*, Vg.
—— Ferry, A., 11.
Ratcliff, *32*, Vg.

Ravensbourne Park, Catford Bridge, *100*, L. Vg.
Ravenscourt Park , *17*, Lm.
Rayleigh, *230*, Bg. G., 16.
Raynes Park, *45*, L., 25.
Reading Beds, 5, 19.
Redbourn, *320*, C. Vg.
Redhill, *250–475*, Lg., 19.
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Reigate, *220–400*, Lg., 19, 25.
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Richmond, *25–100*, L. Vg., 12, 24.
Rickmansworth, *150*, A. C. Vg., 9, 14, 26, 31.
Rideal, Dr. S., 36, 37.
Ridge, *400*, G. L., 14.
Ridley, Kent, *500*, C. Clf.
Ripley, Woking, *86*, L. Vg.
River Gravel, 5, 11.
Robinson, Prof. H., 36.
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Roehampton, *150*, L. Vg., 24.
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Rosslyn Park, Hampstead, Bg. L., *330*.
Rotherhithe, *10*, A., 9, 42.
Roupell Park, Tulse Hill, *218*, L.
Roxeth, Harrow, *240*, L.
Roxwell, *150*, Bcl. G. L., 24.
Rudler, F. W., 7.
Ruislip, *150*, L. W., 20, 23, 24.
Rushy Green, Catford Bridge, *58*, Vg.
Russell, Hon. F. A. R., 44.
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Ryarsh, Kent, *100*, Glt. Lg.

Sadlers Wells, *97*, L. Vg., 34.
St. Albans, *325*, C. Clf. G. W., 14, 22, 23, 26.
— Clement's, 34.
— James' Park, *15*, A. Vg.
— John's, Lewisham, *70*, Vg. W., 30.
— —— Wood, *160*, L.
— Leonard's Forest, *300–462*, H., 19.
— Margaret's, Twickenham, *20*, Vg.
— Mary Cray, *180*, C. T. Vg., 26.
— Pancras, *80*, L. ; Cemetery, 48.
— Patrick's Cemetery, 48.
— Paul's Cathedral, *61*, Vg.
— Paul's Cray, *200*, C. T. Vg.
— Quintin's Park, *50*, L., 22.
— Stephen's, St. Albans, *338*, Clf.
Salt-marshes, 44.
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Sanderstead, Croydon, *532*, Clf.
Sandridge, Hatfield, *274*, Bcl. C. G., 14.
Sands End, *16*, Vg.
Sandstone, 11, 17, 19.
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Sarratt, *408*, C. G., 14.
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Scratchley, P. A., 35.
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Selhurst, Croydon, *170*, Bl. L. Vg.
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Septaria, 24.
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Sevenoaks, *510*, Lg., 19, 25.
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Shacklewell, *82*, L. Vg.
Shadwell, *20*, Vg.
Shalford, *141*, Lg. Vg., 19.
Sheen, East, *59*, Vg.
Shelley, *207*, Bcl. G.
Shenfield, *272*, Bg. L.
Shenley, *426*, G., 14.
Shepherd's Bush, *24*, Lm. Vg., 22.
Shepperton, *40*, Vg.
Shere, *270*, Lg. Lm.
Shipborne, Kent, *200*, Wd.
Shirley, Croydon, *230*, Bl. C. L. T. W.
Shoreditch, *55*, Lm. Vg., 22.
Shooter's Hill, *418*, G. L., 14, 24.
Shoreham, Kent, *186*, A. C., 26.
Shorne, Gravesend, *250*, Bl. W. T.
Shortlands, Bromley, *150–200*, Bl. T. Vg. W.
Sidcup, Chislehurst, *150*, Bl.
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Sipson, Harlington, *90*, Vg.
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Somers Town, *70*, L.
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Southall, *100*, Lm. Vg., 22.
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Southend, *50–100*, L. Lm. Vg.
——, Beckenham, *100*, L. Vg.
Southfields, Wimbledon, *100*, L. Vg.
Southfleet, *100*, C. T.
Southgate, *220*, G., 14, 23.
Southwark, *20*, A., 9.
Southweald, Brentwood, *300*, Bg., 16.
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Spitalfields, *50*, Vg.
Spring Grove, Isleworth, *60*, Lm. Vg.
Springfield Park, Acton, *100*, Vg.
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Staines, *50*, Vg. 2, 9, 11, 12.
Stamford Hill, *100*, L. Vg.
Stanford Rivers, *180*, Bcl. L.

Stanmore, *300*, G. L., 14, 15.
Stansted, Kent, *500*, C. Clf.
Stanwell, *70*, Vg.
Stapleford Abbots, *253*, Bcl. L.
—— Tawney, *200*, Bcl. L.
Starch Green, *25*, Lm.
Stepney, *32*, Lm. Vg., 12.
Stevenage, *300*, Bcl. G. C., 26.
Stifford, *50*, T. W. Vg.
Stock, *300*, Bg., 16.
Stockwell, *50*, Vg.
Stoke, Guildford, *120*, L. W. Vg.
—— D'Abernon, *113*, L. Vg.
—— Newington, *100*, L. Lm., 21, 22, 40.
—— Poges, *140*, Vg., 14.
Stondon Massey, *279*, Bcl. G. L.
Stone, Dartford, *50*, C. Vg.
Stonebridge Park, *90*, L.
Strand-on-the-Green, Chiswick, *23*, Lm. Vg.
Stratford, *25*, Vg., 9, 12.
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Streatham, *100–184*, L. Vg., 4, 10, 24, 25, 42.
Stroud Green, *150*, L.
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Sunbury, *37*, Vg.
Sundridge, Sevenoaks, *280*, Lg. Vg., 19, 35.
—— Park, Bromley, *200*, Bl. C. T. W.
Sunningdale, *200*, Bg. Vg., 17
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Surbiton, *100*, L. Vg., 12.
Sutton, *115–220*, C. T. Vg. W., 17, 20, 42.
—— at-Hone, Kent, *90*, C. Vg.
Swanley, *160*, C. T.
Swanscombe, *120*, C. T. Vg.
Sydenham, *300*, L., 24, 25.
Symons, G. J., 28.
Syon Park, Isleworth, *22*, Vg.

Talworth, Surbiton, *83*, L.
Tandridge, *327*, Lg.
Taplow, *100*, C. W. Vg., 26.
Tatsfield, *743*, C. Clf.
Teddington, *30*, Vg., 34, 36.
Temple Fortune, Finchley, *220*, G. L.
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Thorne, Sir R. T., 38.
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Thorpe, Chertsey, *50*, Vg.
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Titsey, *500*, C. Ug.
Tollington Park, *120*, L.
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Topley, W., 19, 29.
Tottenham, *20–50*, L. Vg., 9, 13.
Totteridge, *410*, G., 14.
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Tower Hamlets, 48.
Tring, *460*, C. Vg., 3, 26.
Trotterscliffe, *300*, Glt.
Tufnell Park, *120*, L.
Tulse Hill, *182*, L.
Tunbridge Wells, *300–458*, H., 19
Turnham Green, *25*, Lm., 22.
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Two Waters, Boxmoor, *259*, A. Vg
Twyford, Ealing, *100*, L.
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Uphall, Ilford, *35*, Lm. Vg.
Upminster, *80*, Lm.
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Upton, *33*, Vg.
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Waddon, Croydon, *150*, C. T.
Wadhurst Clay, 19.
Walbrook, London, A. Vg., 9.
Wales, Prince of, 35.
Walham Green, *16*, Lm. Vg., 22.
Wallington, Carshalton, *120*, C. T.
Waltham Abbey, *70*, Vg.
—— Cross, *70*, Vg., 9, 13.
Walthamstow, *80*, L. Vg., 9, 12, 24.
Walton-on-Thames, *50*, Vg., 12, 42.
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Walworth, *14*, Vg.
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Wandsworth, *20–70*, L. Lm. Vg., 12, 43, 48.
Wanstead, *70*, L. Vg., 12.
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Warley Street, Great, *325*, Bg G. L., 16.
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Wateringbury, Kent, *100*, Lg.
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Welham Green, North Mimms, *290*, C. G. W.
Welling, Bexley, *150*, Bl.
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Welwyn, *250*, C. Vg., 26.
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Wennington, *20*, T. Vg. W.
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—— End, Hampstead, *180–300*, L., 17, 23, 25, 43.
—— Green, Tottenham, *73*, L.
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Westcombe Park, *50–140*, Bl. C.T.W.
Westcott, Dorking, *248*, Lg.
Westerham, *367*, Lg. Vg., 13, 19, 25.
Westminster, *16*, A. Vg., 9.
Westow Hill, Norwood, *368*, L.
Wexham, Slough, *130*, Vg.
Wey, River, 13.
Weybridge, *75*, Bg. Vg., 17.
Wheathampstead, *300*, C. G.
Whetstone, *312*, G., 14, 23.
Whips Cross, Walthamstow, *100*, L. Vg.
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Whitchurch St. Lawrence's, Stanmore, *200*, L.
Whitechapel, *47*, Vg., 42.
Whitehall Park, Highgate, *280*, Bg. L.
Whitelegge, Dr. B.A., 44.
Whitton Dean, Hounslow, *50*, Lm. Vg.
Wickham Court, *300*, C. T.
——, East, *150*, Bl. W., 16.
Wickham, West, *261*, Bl.
Widford, Essex, *166*, Bcl. G. L.
Widmore, Bromley, *223*, Bl.
Willesden, *100–170*, L., 23, 27, 48.
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Wilmington, Kent, *120*, C. Lm. T. Vg.
Wilson, C. T. R., 41.
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Winchmore Hill, *150*, G.
Windlesham, *159–310*, Bg.
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Windsor, *60–100*, C. L. Vg. W., 26.
Wisley, Byfleet, *55*, A. Vg.
Woburn, Bedfordshire, *400*, Bcl. Lg., 4, 19.
Woking, *80–120*, Bg. Vg., 17, 47, 48.
Wokingham, *200*, Bg. G., 17.
Woldingham, *770*, C. Clf.
Woodberry Down, Finsbury Park, *108*, L.
Wood Green, *112*, L., 24.
Woodford, *169*, G. L., 14.
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Woodham, Woking, *110*, Bg. Vg.
Woodmansterne, *480*, C. Clf.
Woodside, Croydon, *150*, L.
—— Park, Finchley, *250–300*, Bcl. G. L.
Woolwich, *20–150*, Bl. C. T. W., 17, 20, 48.
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Worcester Park, Malden, *100*, L.
Wormley, *100*, Lm. Vg.
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Worms Heath, *752*, Bl., 16.
Worplesdon, Guildford, *200*, Bg., 17
Worton, Isleworth, *50*, Vg.
Wotton, Dorking, *457*, Lg.
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Writtle, *150*, Bcl. G. L.
Wrotham, Kent, *400*, C. Glt
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GEOLOGICAL SURVEY OF ENGLAND

MAP OF THE SUB-SOILS OF THE COUNTRY AROUND LONDON 1897.

Scale—1 Inch to 4 Miles.