NOTICES OF MEMOIRS.

Royal Commission on the Water Supply for the Metropolis. Report of the Commissioners. Presented to both Houses of Parliament by command of Her Majesty. London: Eyre and Spottiswoode. 1869. Fscap. pp. 128.

THIS important Report is now issued, and from it we extract the following:—

General Remarks on the Sources and Springs in the Thames Basin. (pp. xxxv.–xl.)

It may now be well to review all the resources of the Thames basin before we proceed to consider the important question of the future water-supply of the Metropolis.

The drainage of the Thames valley above Kingston extends over 3,676 square miles; this area receives an average annual rainfall of about 27·2 inches, and one-third of the quantity due to this rainfall flows down the Thames at Hampton.

This delivery is the result of very complex conditions. One-third of the area consists of impermeable clays, and two-thirds (or about 2,450 square miles) of permeable Oolitic limestones, sands, and Chalk. From the former, the rainfall, after allowing for evaporation and for vegetation, flows off at once, and whenever in excess gives rise to floods, whereas the rainfall on the latter is at once stored up, and its ultimate delivery through springs to the streams and rivers is spread over weeks or months. To this cause is owing the permanence of flow of a river draining a permeable rock district, compared with the irregular delivery of a river draining an impermeable district, and it is a consideration of great importance in a question of water supply.

All permeable formations tend necessarily, by the absorption of rain, to become charged with water up to the level generally of the streams and rivers of the district; and further, owing to the resistance experienced by the rain water in passing through the strata, the water, wherever the ground rises above the level of the rivers, accumulates therein in proportion to the length, breadth, and height of the range of hills, so that instead of the line of underground water level presenting a flat surface between two valleys, it presents a curved surface varying according to certain conditions. Taking the lowest point of escape as determining the permanent level above which all the water tends to run off in springs, the height of the curve above this level gives the head of water on which the springs depend for their supply. The rise of the water being from the circumference of the hills to the centre, the underground reservoirs form more or less dome-shaped masses, the surface of which is constantly fluctuating in proportion to the difference between the amount of rain percolating through the strata and the quantity of water which escapes by the springs.

In the district we have to deal with, the crown of the curve often rises 50 to 200 feet or more above the permanent spring levels, while the actual height of the curve is known to vary in accordance with the variation in the rainfall, in many cases as much as 50 to 80 feet or more. Where the conditions are favourable to a large underground reservoir, the springs hardly ever run dry. Mr. Beardmore, as the result of many years' observations in the Chalk district of the Lea, sees reason to believe that the storing power of the Chalk hills there holds out at least 16 months.

Further, some of the water below the lines of permanent level inland has a slow underground movement to still lower levels, unless intercepted or thrown out by faults in the strata or by some other cause. This underground drainage is not, however, coincident with the surface drainage; and while some of the water-bearing strata of the Thames basin are not available as underground sources of supply by means of wells at or near London, other strata, on the contrary, out of the London basin, are so available from the circumstance of the dip of the beds being towards London.

Where the permeable strata only cap the hills the springs issue of course on the sides of the valleys at the junction of the impermeable strata.

In the order of superposition the highest permeable strata near London, excluding the superficial beds of gravel, are—

The *Bagshot Sands*, which are from 100 to 350 feet thick, and extend over an area of 211 square miles. As these strata consist almost entirely of loose quartzose sands, the underground water oozes out commonly at their junction with the London clay, and is rarely conducted into any particular channel of escape so as to form springs, and the loss by evaporation is large. There are, in fact, throughout this area no springs of any importance; only a few small tributaries of the Thames and the Wey have their sources in this district, and the supply to the wells is not large. The water generally is soft and pure, but in some places it is ferruginous. We cannot look to these sands for any additional water-supply (although they attracted a good deal of attention a few years since), for the whole of the water now delivered by them passes into the Thames or the Wey. None passes elsewhere underground.

The *London Clay* underlies the Bagshot Sands and forms a great impermeable bed from 400 to 450 feet thick.

Lower Tertiary Sands.—These beds, which are only from 50 to 100 feet thick, are of no importance so far as springs are concerned at their outcrop, but they have been useful sources of supply to some of the deep wells under London. Owing, however, to the great increase in the number of these wells, and the fall in the level of the water, the underlying Chalk is now generally resorted to as the better source of supply. In many places round London, where they have not been so drawn upon, they still yield a good supply of water.

The *Chalk*, from its large area (1,047 square miles above Kingston, but more than double that in the whole basin), from its great thickness—500 to 1,000 feet—and from its peculiar lithological character, forms a very important source of water-supply, both by springs and by means of wells. Almost all the rain falling on its surface is

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absorbed or percolates through the fissured surface. So close is its texture that the bulk of the rain takes weeks and months to filter down to the level of the water line in the interior of the Chalk hills—a line the depth of which below the surface of the ground may vary from 100 to 300 feet according to the height of the hills. The water thus stored escapes in several ways—some by the streams rising within the Chalk district,—some by springs feeding directly the larger rivers flowing through it,—another portion overflows at the outer escarpment of the Chalk,—and a larger portion issues near its junction with the Tertiary strata. A certain quantity also passes underground, supplies the wells, in the central Tertiary area, and escapes in part at still lower levels at more distant points.

Where the rise of the bottom of the valleys is more rapid than that of the line of water level, the valleys assume the character so common in Chalk districts, of dry valleys. Others of these valleys tap the springs in their lower part, whilst the upper part of the same valley is dry. In these cases the head of the stream will often change its position two or three miles higher or lower in the valley, accordingly as the rise and fall of the water level in the hills are influenced by the rainfall. Where the deeper and larger river valleys traverse the Chalk area and intersect the line of water level, these valleys become fringed on the river level with a series of springs, as the Thames in its course from Wallingford to Taplow, the Lea above Broxbourne, the Ravensbourne, the Cray, and the Darenth, and the Thames again from Woolwich to Gravesend.

The springs along the line of outcrop of the Chalk-marl and Gault being on a higher level than any others, the head of water supplying them is much smaller than that supplying the springs on lower levels within the Chalk area, and consequently with few exceptions these springs are small. They are, however, extremely numerous. Almost every little village under the range of the Chalk downs in Wiltshire, Oxfordshire, and further eastward, has its spring near the foot of the Chalk hills. These collectively would furnish a considerable quantity of water, but they are too scattered and wide apart to be available for any general purpose. There are, however, a few large springs amongst them. There is one, for example, at Cherhill, near Calne. This spring never fails, and is said to yield from two to three million gallons of water daily. There are also copious springs near Ellensborough, at Barton-in-the-Clay, near Prince's Risborough, near Swindon, and at many places along the foot of the North Downs of Kent and Surrey.

Another and more important class of springs are those which escape along the inner edge of the Chalk along or near the line where it passes under the Tertiary strata, and again where it approaches the sea level. These springs are all placed on relatively low levels, and derive their supplies from the large head of water which extends in the Chalk hills beyond them up to the outcrop of the beds underlying that formation. As the difference of level between these exterior and interior springs varies often from 150 to 300 feet, the latter are necessarily much more powerful and

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permanent, and will continue to run long after most of the others have become dry. Among the more copious and remarkable springs of this class are those at Chadwell near Ware, Otter's Pool near Watford, Froxfield near Hungerford, Beddington and Carshalton, Orpington, Grays Thurrock, Springhead near Gravesend, Ospringe near Faversham, besides a number of smaller ones. The origin and source of supply of some of these springs are indicated in the sections.

In the neighbourhood of London the wells in the Chalk form an important auxiliary source of water-supply, and they might, no doubt, be considerably increased in Kent without interfering with the springs in the valleys above London, as the store from which those wells draw their supplies overflows in numberless springs along the Thames below London at levels where they are not generally available.

The lower beds of the Chalk are so argillaceous as often to hold up the water and to lose their ordinary permeable character.

The *Upper Greensand* forms so much a part of the Lower Chalk, and is so slightly developed near London, that we have grouped it with the Chalk. It is only in Wiltshire that it acquires an importance entitling it to be considered apart. Under London it becomes also so argillaceous as to lose its water-bearing character.

The Upper and Lower Greensands are separated by 100 to 200 feet of impermeable clay, known as the *Gault.* The numerous small streams rising at the foot of the Chalk hills have their source generally in springs thrown out by the Chalk-marl, or the Gault.

The *Lower Greensands* form a mass of siliceous sandy strata from 200 to 500 feet thick, and with an available area of above 500 square miles. Cropping out both to the north and south of London conformably to the Chalk, which is known to pass below the Tertiary strata under London, it was supposed that the Lower Greensands were also continuous below London, in the same way as the Lower Greensands of the plains of Champagne pass under Paris at the depth of 1,800 feet. The experience, however, obtained at Kentish Town, at the deep well sunk through the Chalk a few years since by the Hampstead Company, showed that although the Tertiary strata, the Chalk, and the Gault followed in regular order, a change took place at the base of the Gault, and instead of the Lower Greensands, a series of red and grey sandstones were met with. These were bored into for a thickness of 188 feet, without passing through them, and the work was abandoned. No organic remains were discovered to indicate the age of these sandstones, and the hand-specimens were insufficient to determine the question. They may have belonged to some member of the New Red Sandstone, or possibly to the Old Red. In any case they seem to form part of an underground ridge of old Secondary or Palæozoic rocks which, ranging from Belgium, pass under the Chalk at Calais and Harwich, at both which places they have been met with, and probably extend under London in the direction of Somersetshire. The width of this belt can only be determined by experiment.

It is known that the Lower Greensands exist at Reigate and are about 450 feet thick, and that they occur again in Bedfordshire with a thickness of about 200 feet. In both cases they dip towards London, disappearing beneath the Gault. We know that they do not exist under London (Kentish Town). It follows, therefore, that in the one case they cease at some point between Reigate or Merstham and London, and in the other between Baldock and London. As at both ends they are of considerable thickness, and the Gault is continuous, it is certain that the Greensands must range from these outcrops some way towards London, probably thinning off gradually against the flanks of the underground ridge of old rocks. So far as they continue, so far will they form a valuable and copious water-bearing bed, the water from which would overflow at the levels lower than that of their outcrop. The extent of their underground range could only be determined by boring. It might be as far as Croydon, or even still nearer to London. The same would happen to the north of London, but the distance there is greater, the beds are not so thick, and the conditions generally are less favourable. The great purity of the water from the Grenelle and other artesian wells in the Lower Greensand is well known, and there is reason to suppose that the quality of the water obtained from the same formation in the vicinity of London would prove equally good. The excessive length of filtration would at all events ensure freedom from organic impurities.

The quality of the water flowing from the Lower Greensands is excellent for all domestic purposes, being bright and limpid, of a degree of hardness varying only from about 3° to 9° of Clark's test, and generally very free from organic matter.

The springs in this formation are not very numerous, owing to the prevalence of sandy beds, but in some of the more stony beds there are some fine springs, as for example:—

1. The springs in Bradbourne Park and at Riverhead near Sevenoaks.
2. Several springs near Dorking.
3. Spring at Weston Street.
4. Spring at Moorhead Park near Farnham.

To the south of London a great thickness of *Weald Clay* separates the Lower Greensand from the *Hastings Sand* of the Weald of Kent and Sussex; but although these beds are thick they are very local, only partially permeable, and are of no avail.

The strata which next succeed are only developed in the north and north-west of the London basin.

The *Portland Stone and Sands* are from 35 to 50 feet thick, and are, in some places, of local importance, but none of the springs would be available for distant purposes.

The *Kimmeridge Clay* is impermeable and from 250 to 300 feet thick.

The *Coral Rag* and *Calcareous Grit* are from 20 to 50 feet thick and give rise but to a few small springs. These beds thin off as they range to the east and south-east, so that in Buckinghamshire, and probably underground in Berkshire, the Kimmeridge and Oxford clays come into contact, and the Coral Rag ceases to exist.

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The *Oxford Clay* is impermeable, and attains in Oxfordshire a thickness of 400 to 500 feet.

The *Great Oolite* and subordinate beds may for our purposes be taken together. They form in Oxfordshire an important group of permeable strata 250 to 300 feet thick. They have a collecting area of about 300 square miles, and give rise to a number of fine springs amongst which those of Ampney, Bibury, Boxwell, and Thames Head have been described by Mr. Bravender and Mr. Brown, and are stated by Mr. Pole to have been yielding at the time of his visit probably not less than 10 million gallons of water daily.

Most of the springs of this series are thrown out by the *Fullers Earth*, an impermeable bed of no great thickness in this district—40 to 60 feet—and persistent only over a limited part of the area.

The *Inferior Oolite* and underlying sands reposing on the Lias form another important water-bearing formation. They are from 300 to 320 feet thick, and extend in the Thames basin over about 180 square miles. As the hills of this formation rise 230 to 300 feet above the valleys, and have a considerable range, the head of underground water is large, and furnishes several important and perennial springs, such as those of Syreford and the Seven Springs, of which the yield is stated by Mr. Pole to have been at the time of his visit from three to four million gallons of water daily.

These various Oolitic strata consist of beds of rubbly limestones, soft freestones, sands and fissile sandstones, through which the water passes chiefly by fissures; and although often traversing a great thickness of strata, it is not filtered to the same extent as it is in the Chalk and Lower Greensands.

Mr. Hull has shown[1] that the Inferior Oolite and underlying sands which in the neighbourhood of Cheltenham are about 320 feet thick, thin off as they range eastward, and probably die out about the centre of Oxfordshire. In the same way he shows that the Great Oolite and accompanying beds, there about 300 feet thick, also thin to the eastward, and they apparently do not extend more than a few miles further east than the Inferior Oolite.

It follows that the underground passage of water through these Oolites, which might, had these formations ranged in full force eastward, have been carried as far as London, the dip being in that direction, is stopped by the thinning out of those beds, and by the closing in, as it were, of the Lias, Oxford Clay, and Kimmeridge Clay. Although, therefore, the surface drainage of the Cirencester and Bampton districts runs into the Thames valley, the subterranean water channels are intercepted and do not reach London, and the Oolitic series must be excluded as a possible source of supply by deep wells in the London district.

The exact proportion of the rainfall absorbed by the different permeable and porous strata, and which is given out again in the form of springs, has yet to be determined. It varies according to the lithological character of the water-bearing strata. The general results are, however, known in many cases. Thus the annual flow

[1] Quart. Journ. Geol. Soc. Vol. xvi. p. 63.

of the Thames at Hampton and of the Seine at Paris, both draining areas composed partly of permeable and partly of impermeable strata, is equal to about one-third of the rainfall. In a district where the impermeable strata predominate, the total deliveries will be larger, but they will follow close upon the rainfall; whereas, as the permeable strata predominate, so will the rainfall be stored in the hills, and its delivery be spread over a greater length of time. The summer flow in a dry season consists almost entirely of the supplies derived from deep-seated springs. Mr. J. T. Harrison, to whose evidence we would refer for many interesting details on these points, estimates this generally in the Thames district to be equal to one-sixth of the rainfall.

The importance of such a condition of things for the supply of this large Metropolis cannot be over-estimated. It ensures that permanence and regularity which are necessarily among the most important elements in a Metropolitan water supply. With natural subterranean reservoirs extending over above 2,000 square miles, a storage reserve is provided comparatively independent of the seasons, and maintained by the ordinary operations of nature, while no filtration can equal that effected through masses of sand, sandstone, earthy limestones, or chalk, from 50 to 300 feet thick. The quantity of mineral matter taken up is in most cases moderate, while the really objectionable ingredient—the organic matter—is reduced to a minimum. However different the results obtained in other cases, the two under-mentioned eminent chemists agree in their conclusions on this point, as will be seen by the following table, the quantities having reference in the first case to 100,000 parts, and in the second to a gallon of water:—

Sources of Waters Analysed.	Dr. Frankland.			Prof. Wanklyn
	Organic Carbon.	Organic Nitrogen.	Nitrogen as Nitrates and Nitrites.	Albuminoid Ammonia (representing the Organic matter containing Nitrogen).
Caterham Well (Chalk)............	·020	·006	·027	0·000
Spring near Moor Park (Lower Greensand)	·030	·010	·045	—
Cold Harbour (Lower Greensand)	—	—	—	0·000
Otter Spring (Chalk)...............	·026	·012	·422	—
Loch Katrine	·256	·008	·031	0·130
Welsh Waters.........................	·289	·004	·022	—
Cumberland Lakes.........	·211	·006	·009	—
Thames Water at Hampton	·260	·024	·192	0·134

At the same time the water is kept at a uniform low temperature, and protected from light and air, conditions unfavorable to the existence of living organisms. Springs from such sources probably represent potable waters in their best state; and amongst the favourable specimens of such waters may be instanced many Chalk springs, the water from the Lower Chalk at Caterham, and some of the springs of the Lower Greensands of Surrey.

It is satisfactory to know that there exists within easy reach of London a supply of the best and purest spring water which, in case of need, could readily be rendered available as an auxiliary source of water-supply for the Metropolis, in quantity sufficient at all events for drinking, if not for other purposes.

REVIEWS.

I.—The Mississippi Valley: its Physical Geography, including Sketches of the Topography, Botany, Climate, Geology, and Mineral Resources; and of the progress of development in population and material wealth. By J. W. Foster, LL.D. Illustrated by maps and sections. Chicago: S. C. Griggs & Co. London: Trübner & Co. 1869. 8vo. pp. 444.

THE author, having devoted many years to the exploration of the Mississippi valley, describes in the volume before us the physical geography of that portion of this wonderful region which lies west of the great dividing line—the Mississippi River.

It was with a view of illustrating the gradations between the forest, prairie, and desert; the varying conditions of temperature and moisture, and their effects in determining the range of those plants cultivated for food; and, at the same time, to trace the character of the fundamental rocks over the whole of this region, pointing out the mode of occurrence of those ores and minerals useful in the arts, and, finally, to trace the colonization of this region from its feeble beginnings to its present magnificent proportions, that this work was undertaken by Dr. Foster.

It is not intended to be a strictly scientific work, but rather to present a series of sketches of the great phenomena of the region under consideration in a form which should at once interest and instruct the general reader.

Among the many chapters calculated to interest the general reader there are some which may be considered as more especially attractive to the physicist and geologist. Of these we might mention, firstly, the chapters in which the author discusses the origin of prairies, including not only those of the great Mississippi basin but also those of South America and other countries.

Dr. Foster discusses the various views put forth by other authors as to their origin, whether as due to peat-growth, texture of soil, or annual burnings; and concludes, after a careful consideration of all the conditions, that "a study of the physical features of the country in connection with the prevailing winds, the consequent distribution of moisture, and also the lines of equal temperature, will show—firstly, that these great changes in the geographical distribution of plants, under nearly equal lines of temperature, are not due to the mechanical texture or chemical composition of the soil, but to the variable supplies of moisture; secondly, that in the winds, as the agents in the distribution of that moisture, we have an adequate cause to explain all the phenomena of forest, prairie, and desert."