

These doubts I expressed in my Monograph,¹ and acting on the evidence of the age (Devonian), and the published figure of Schlotheim's specimen, I restored Phillips' specific name of *gemmulifera* for this Carboniferous Limestone form, and discarded that of Schlotheim (*T. pustulatus*) as untenable. Having lately seen and consulted my friend Prof. Dr. Ferdinand Roemer, of the Mineralogisches Museum, Breslau, our highest authority on the fossils of the Eifel, he very kindly promised me, on his return journey, in passing through Berlin to Breslau, to compare my figures of *Phillipsia gemmulifera* with Schlotheim's specimen of *Trilob. pustulatus* in the Berlin Museum. I now have the pleasure to append his letter, which entirely sets the matter at rest.

“Mineralogical Museum of the Royal University of Breslau. Dear Dr. Woodward,—Schlotheim's *Trilobites pustulatus* is nothing else than a pygidium of *Phacops latifrons* from the Eifel. This is proved beyond any doubt by Schlotheim's original specimen in the Berlin Museum.—Yours very truly,

“ (17th October, 1883.)

FERD. ROEMER.”

NOTICES OF MEMOIRS.

SOME GEOLOGICAL CONDITIONS AFFECTING THE QUESTION OF WATER SUPPLY FROM THE CHALK.

[Part of the Presidential Address to the Norwich Geological Society, 6 Nov. 1883.]

By W. WHITAKER, B.A., F.G.S., of the Geological Survey.

IT has occurred to me that I might profitably take as the chief subject of my address one of practical importance, and one showing that the detailed mapping of our county by the Geological Survey, which is now all but finished, is not a matter of mere theoretical interest.

As our Survey will be finished this year, except for some questions of revision in the western part of the county, and as some time next year the officers of that Survey will be denuded from Norfolk, the present seems a fit time for bringing forward such a subject. Were the question put off for the publication of the whole of the Survey Maps, it would be at least two years before it could be brought before you, and though I suffer therefore from the want of great part of the material needful for a full consideration of the question as regards Norfolk, yet I think that we have enough to warrant its discussion, especially as it can be illustrated by reference to other districts of a like character. Indeed the amount of material in my hands is so large that I have been unable to work it all up in time, and therefore have had to neglect some parts of the bordering counties of Cambridge and Suffolk which I had hoped to have illustrated amongst the maps before you.

During the course of my work on the Geological Survey I have paid some attention to the question of water-supply, and a few years ago I had to make a set of maps for the purpose of showing the

¹ See Mon. Carb. Limestone Trilobites, 1883, part i. pp. 17–19, plate iii, figs. 1–8. See also GEOL. MAG. 1883, Decade II. Vol. X. Fig. 3, p. 450.

areas of Chalk, in part of the London Basin, that were open to receive and absorb water. It was only those parts over which the Geological Survey had mapped the various subdivisions of the Drift that were available for this purpose, for fairly clear reasons, which will be referred to at some length further on; where the Drift has not been mapped, the Survey Maps are comparatively useless.

It is to the particular subject of this set of maps, namely, the accessibility of the chalk to surface-water, that I wish to draw your attention, illustrating it by copies of some of the original maps, by what I may call an improved or second edition of some of them, and by an extension of the work into Norfolk and Suffolk.

Before doing this, however, it may be well to allude to the present state of Chalk water-supply in the county, as far as my knowledge goes. There are three ways of getting public supplies of water from the Chalk, and it is to public supplies only that I shall refer:—namely, the underground way, by wells and borings; the guarded surface way, by closed pipes from a spring-head; and the over-ground way, by an open channel, natural or artificial.

I believe that Cromer, Dereham, Swaffham and Thetford are the only Norfolk towns that get their supply by the first way. I know of no Norfolk town that gets water from the Chalk by the second way, though the seaside resort of Hunstanton is thus supplied; but the Cambridgeshire town of Wisbech does so, leading the water from the springs near the base of our Norfolk Chalk at Marham through some sixteen miles of pipes, and thus giving the great boon of good water to a district in which none occurs. The enterprise of Wisbech is thus in strong contrast to the apathy, and one may say the stupidity, of the larger town in which I have the misfortune to live, its Norfolk rival, Lynn, the corporation of which treat the inhabitants to one of the worst supplies that I know of. These guardians of the public health allow a set of Chalk springs, some pure, but others contaminated, to mix together and to flow along an open channel of six miles or so, as the crow flies, receiving on the way the drainage of a fair tract of country, and, at the last, close by the borough-boundary, some part of the sewage of the village of Gaywood. Notwithstanding that the evil of this course has been pointed out for years, and constant complaints occur, yet our town-councillors, in the multitude of whom there is not wisdom, have not yet made up their minds to any decided action, and a question that really admits of no debate is the subject of apparently endless discussion: "Words not deeds" should be the town-motto, at least as far as regards water-supply.

Since the above paragraph was written, the Town Council of Lynn adopted a scheme for the supply of good water; but I fear in a half-hearted way: at all events their scheme has been rejected at a meeting of the ratepayers, and I am therefore compelled to transfer the charges above made from the members of the council to the body of the townsmen, who seem not to be educated up to pure water pitch! When they have had a serious epidemic, perhaps they may acquire more sensible views on this matter.

The supply of Norwich, taken from the Wensum, is I believe free from serious contamination.

In the western part of Norfolk there are large quantities of chalk-water, which may be said to run to waste, and the abstraction of which it seems to me would result in the improvement of certain tracts that are now water-logged. This water flows into streams that are really little else than drains, and not always sufficient ones, for large tracts of lowland, which tracts would also be improved by being rid of some of the water. The parts where the springs rise are often of a peculiar nature, the dissolving away of the chalk having caused the formation of a great number of small hollows, more or less round in shape, from the sinking in of that rock and overlying sand and gravel. The bottoms of these hollows are filled with water, probably because they reach the saturation-level of the Chalk, the same cause that gives us the much larger sheets of water in the District of the Meres at a higher geological level in the Chalk, the tracts now alluded to being near the base of the formation.

At our last Yearly Meeting I remarked that the completion of the Geological Survey of a district did not result in the exhaustion of that district, as regards geological investigation, but rather that our work aided future workers. The set of maps to which I have now to call your attention is an illustration of this; for, whilst they can only be made after a detailed survey, yet they need for their construction something more than is shown on any Geological Survey Map, or that can be easily worked out from a Memoir. They need a consideration of various local circumstances, which it is open to any careful geological observer to make: there is indeed only one thing in which they absolutely follow the geological maps, that is, as regards the area of bare Chalk.

I would remark at once that these maps are not geological maps, and it is important that you should remember this, or you will misunderstand them, though they are founded on geological maps: their object is to show what comes between the Chalk and the rain.

For this purpose it was found that all our geological divisions, from the Chalk upwards, could be grouped under 4 heads, as follows:—

1. Areas where the Chalk is bare (except of course for soil), and in which therefore water has free access to it.
2. Areas where the Chalk is covered by permeable beds only, or by beds almost wholly permeable, and in which therefore water has nearly free access to it.
3. Areas where the Chalk is covered by beds of varying character or mixed structure, partly permeable, partly impermeable, and in which therefore water has but a limited power of access to it.
4. Areas where the Chalk is protected by impermeable beds, and in which therefore water does not sink into it.

Now, in colouring these maps in accordance with the above scheme, and in thinking over the colouring of others not yet to hand,

I have found only two certainties, that is, only two colours on our Geological Survey Maps that could at once be followed. These two are the outcrops of the bare Chalk (No. 1) and the areas of the London Clay, which latter of course range themselves under No. 4. Moreover, it is not only where London Clay is shown as occurring at the surface that this holds; but also over the tracts where it occurs beneath other beds, so that, for our purpose, the whole of the Bagshot Sands (mostly permeable though they be) are coloured with impermeable areas as regards the Chalk, and so also will be great part of the Suffolk Crag tract, although that Crag is highly permeable.

As far as I have yet carried the work, one other colour on the Survey Maps can also be followed, for the Boulder Clay can be included with impermeable beds. However, in some parts in which this work is not yet done, it is possible that there may be some tracts coloured as Boulder Clay over which that bed has been altered, by surface actions, so that some of the clayey matter has been lost and the Chalk dissolved away, the remainder forming a stony loam that is not quite impermeable. Indeed, the fact of such alteration occurring at all, produced as it is mainly by the infiltration of water, is in itself a proof that the Boulder Clay is to some extent permeable, and therefore where thin it may let some amount of water through to more permeable beds underneath. Moreover, on some of the higher ground of West Norfolk, it is not easy to distinguish a thin capping of Boulder Clay from the weathered surface of the Chalk itself, for the Boulder Clay in those parts consists sometimes of little else than Chalk, being mainly a mass of chalk pebbles in a chalky matrix, with a little admixture of sand, but with little clay. It follows therefore that some Boulder Clay cannot fairly be coloured as impermeable; but must be classed with the mixed beds (No. 3).

Of course with this Clay, as with the London Clay, it is not only where it crops out, but also wherever it underlies other beds, which may be highly permeable, that we have to take it into account; this however, is one of the things that is sometimes not shown on the Survey Map; but which must be shown from knowledge of the ground, or by inference, from the lie of the beds.

Having drawn your attention to the more certain parts of the work, it may be well to treat of the various beds in stratigraphical order, premising that in all cases (unless otherwise mentioned) only their area of outcrop is referred to, and not parts where they are covered by Drift, of whatsoever character; and I will begin at the bottom.

Thanet Beds. — This comparatively local base of the Tertiary Series is almost wholly a fine sand in Surrey and West Kent, and may then be fairly treated as on the whole permeable. When, however, the map of East Kent is taken in hand, a different condition will have to be dealt with, for then we find a mass of clayey beds in the sands, which may cause the greater part to be impermeable, or at all events not higher in the scale than the mixed beds (No. 3). In Suffolk the outcrop of this division is too narrow to be shown

separately, and it has been included with that of the overlying division. In Norfolk neither of these come to the surface.

The Woolwich and Reading Beds are very irregular and varying in their composition, sometimes all clay, sometimes all sand, sometimes alternations of clayey and sandy beds. As it would be almost impossible to pick out the permeable and impermeable parts, the whole has been classed as mixed. In Norfolk and in the neighbouring part of Suffolk, where these beds are everywhere thickly covered with Drift, I have extended the colour of the impermeable beds up to their presumed boundary, as a matter of safety.

The Oldhaven and Blackheath Beds, though of a highly permeable character, are nearly everywhere underlain by the last division, and therefore their permeability is of no effect, as regards the Chalk, so that they have to go with the last, except in the very small areas where they cut through to the Thanet Sand, and in the outliers that rest direct on the Chalk.

The London Clay has already been noticed; but it should be remarked that its basal beds are often rather sandy, and let some water through. The outcrop of these beds however is so small that it may be disregarded. All the beds overlying this thick and widespread mass of clay are put out of court, as I have already said, being cut off from the Chalk by it, and thus the Bagshot Beds and the Coral-line Crag are wholly disposed of.

The *Red Crag* of Suffolk, however, in part rests on the Chalk, and must then take its proper place among the permeable beds, though most of it is taken out from the fact of overlying the London Clay. With its representative in our county, the *Norwich Crag*, the case is somewhat different, as it rests to a much greater extent on the Chalk. As however, in the Geological Survey maps, some upper beds are coloured with this series that have not always been classed with it, we must take into consideration the occurrence of those clayey patches, generally thought to represent the more continuous *Chillesford Clay* of Suffolk, which locally cut off the gravel and sand above from the Chalk, as far as infiltration is concerned, and as some of these patches are too small to be shown on the map, though they may have much effect underground, this is a case where local knowledge comes in, and I have to thank Mr. H. B. Woodward for giving me the advantage of his knowledge in this matter. As a general rule the *Norwich Crag*, has been classed as permeable, even where the lower part is not seen, and where, though small lenticular masses of clay or loam may occur, these would have little effect, merely throwing off the water locally.

The *Drift*, as you must expect, has a very varying effect, from its varying character. The Boulder Clay has already been noticed, and there is no need to recur to it; but the gravels and sands that often underlie it, though in themselves permeable, are sometimes cut off from the Chalk by clayey beds, whether thin local layers of Boulder Clay or masses of brick-earth. With regard to this Glacial brick-earth too there is much variation, for whilst most of the small isolated masses in the south are practically impermeable, when we get to the

northern part of our county some parts of the large sheet of brick-earth are sandy, and therefore fall into the Mixed division. Here, again, I have drawn on Mr. Woodward's knowledge; but nevertheless I can only look on part of the Norwich map as an approximation or a compromise.

When we come to the later, or Post-Glacial Drifts, as before, the gravels and sands range themselves in the permeable beds (of course I mean only when not underlain by impermeable or mixed beds); but the brick-earth is rarely impermeable, being generally of a sandy nature, and therefore classed as Mixed.

On the broad Chalk tracts of some of our more southern counties that rock is to a large extent hidden, over the higher grounds, by a very irregular mass of brick-earth, usually with a more clayey layer, known as the "clay-with-flints," at the base. Now this brick-earth is also sandy, and though the underlying clay would seem at first sight to be fairly waterproof, yet the fact that it has been formed simply by the gradual dissolving away of the Chalk, by the infiltration of carbonated water, is enough to show that water has sunk through to the Chalk in large quantity—the clayey matter being indeed simply a filtrate, the solid residue left after very long continued action. I have therefore classed these loamy and clayey tracts as Mixed; but they need not trouble us here, as they do not occur in Norfolk.

Alluvium.—It might be expected that the deposits of our marshes and river-flats would be impermeable, from their generally clayey nature; but I have thought it advisable as a rule to class them in the Mixed group. The reasons for this are that some alluvium is of a sandy nature, that some is very thin, and that the water-courses in many places cut through the alluvium to the gravel and chalk beneath; so that on the whole it is best to class it amongst the doubtful beds.

With regard to the four divisions adopted in these maps the first two, Bare Chalk and Chalk covered by permeable beds, naturally group themselves together, as also do the latter two, the areas taken up by mixed beds and by impermeable beds. It should be noted, however, that there are large tracts of the last division in which the natural drainage is outward, towards the chalk, in consequence of which much of the rain falling on such tracts of impermeable beds flows across them to the Chalk, or to permeable beds over the Chalk, and then in many parts wholly sinks into the ground, and in others partially sinks; so that these areas contribute to the supply of water in the Chalk. In some of the newer maps exhibited I have divided the area of the impermeable beds into two, distinguishing the part that drains away from the Chalk from that where the drainage flows to the Chalk.

Of course to make use of these maps it is needful to measure the various areas, and a very hasty look at the maps will show you that this will be a very troublesome task. It has been done however on the older maps exhibited, by engineers with the proper appliances for such work; but I have not ventured to attempt such measurements on the new maps.

The general result of the maps is to show that over large areas, coloured on ordinary geological maps as Chalk, that rock is covered by beds impermeable to water, the drainage of great part of which moreover flows away from the Chalk, and therefore cannot in any way contribute to the water therein.

I may here allude to the enormous error in all but the latest maps, in colouring the whole of East Norfolk and the northern part of East Suffolk as Chalk (except for Crag), whereas we know, from well-sections, that there is a mass of the older Tertiary beds (London Clay and Reading Beds) between the Drift or Crag and the Chalk along the whole of the Suffolk coast and the eastern coast of our county.

REVIEWS.

I.—**GEOLOGICAL SURVEY OF SOUTH AUSTRALIA.** Report of the Government Geologist, HENRY Y. LYELL BROWN, F.G.S., Adelaide, South Australia, August 1st, 1883; with four chromolithographic plans. (Adelaide, Government Printing Office.)

THE Government of South Australia is to be congratulated on its wise decision to establish a Geological Survey of its Territories, the investigation of which has been hitherto left wholly to the energy of private individuals. First settled by a company, in 1834, it was not formed into a regular colony until 1841, and received the right of self-government in 1856. Its original area was about 300,000 square miles, but in 1861 its western limit was extended to 129° E.; and in 1863, the Northern Territory, reaching to the sea between 129° East and 138° East, was added, by which the area of the Colony was trebled. Hitherto South Australia has been chiefly distinguished for its valuable mines of copper, but its staple industry is wheat-growing, in which it is pre-eminent over its neighbours. It also has extensive sheep-runs, and since 1874 the number of sheep has never been less than 6,000,000.

Of course the great desire of every new country is to discover coal, and for the interior districts, water is indispensable to enable the large areas, seemingly well adapted for pasturage, to be occupied as runs.

The exploration which forms the subject of the present report was directed to the area comprised between 26° and 32° S. Lat. and 138½° and 141½° E. Long. The chief objects of this journey were to ascertain the extension from New South Wales into South Australia of the gold-bearing rocks of Mount Brown, and the Cretaceous formation in which artesian and other water has been found. The gold-bearing rocks were not found to extend across the border into South Australia, as far as could be ascertained. The Flinders range is the nearest point in this colony where rocks likely to prove auriferous outcrop, the intervening country being covered over with Cretaceous and Tertiary formations. There may, however, be some low outcrops occurring amongst the sand hills, but this is not very likely, and they cannot exist in any great extent. The extension of the Cretaceous