

EXCURSION TO THE WEST RIDING OF YORKSHIRE.

JULY 17TH AND FIVE FOLLOWING DAYS.

Directors :—The PRESIDENT, and JAMES W. DAVIS, Esq., F.G.S.,
F.L.S., Secretary of the Yorkshire Geological and Poly-
technic Society.

(*Report by THE PRESIDENT,**)

The West Riding of Yorkshire exceeds in extent either Devonshire or Lincolnshire, yet in spite of its size the Carboniferous Rocks alone form a very large percentage of its area—a circumstance no doubt contributing largely to its wealth and importance. Thus, when people hear of the West Riding, visions of smoke and steam, of factories, collieries, forges and all the concomitants of a black country present themselves to the imagination. Yet the district visited on this occasion has none of these things, being purely agricultural or pastoral, mostly the latter; not densely inhabited, and constituting an agreeable tract of hill country which becomes mountainous towards the west. It forms part of a large block of older Carboniferous Rocks, which a series of east and west folds has brought to the surface between the Coal Fields of Durham and South Yorkshire, and is included within the wapontakes (hundreds) of Claro and Staincross, the latter being nearly coincident with the archdeaconry of Craven.

Claro commences where the first roots of the Pennine chain spring out of the Vale of York. Hydrographically it comprises the whole of the basin of the Nidd, together with small portions of the Ure on the north and of the Wharfe on the south. Harrogate, with nearly 10,000 inhabitants, is the largest town, but Knaresborough must be regarded as its historic capital. Excepting strips of Trias and Permian on the east, almost the whole of Claro is on Millstone Grit in parts covered by Drift. The surface ranges from 100 feet to 2,200 feet above sea level, and contains a considerable proportion of indifferent land, some of which, however, forms the best grouse ground in the county. There are wide upland plateaux with valleys of moderate slope: the hills never attain to the dignity of a peak, the most salient features being crags of gritstone, such as Almas Cliff (Kinder Grit), Brimham

* Some of the remarks made by the President at the previous meeting are incorporated with this report, especially in connection with the geology of Harrogate and Knaresborough.

Rocks (Third Grit), and the rocking stones on Roggan Moor so celebrated in the annals of shooting. The Millstone Grits of this district contain waters of remarkable purity, and the valley of the Washburn is now the storehouse for Leeds, just as Loch Katrine is for Glasgow.

On reaching the valley of the Wharfe at Bolton a different kind of country begins to appear, though Bolton may be regarded as partaking of the Millstone Grit scenery of Claro, and of the Carboniferous Limestone scenery of Craven, where the hills are usually tabular, but with here and there a peaked termination. The weathering of the Carboniferous Limestone has produced long scaurs or cliffs, such as those at Malham, Gordale, and Kilnsea. The climate being wet and the soil calcareous, Craven is given over almost wholly to grass, and forms some of the very best and most feeding pasturage in England. Skipton is the principal town, and has always been regarded as its capital.*

* It used to be said that a squirrel could go from Knaresborough Castle to Skipton Castle without once touching the ground. Those were the days when Knaresborough Forest was covered with "*silva minuta*," most of which has long since disappeared.

Knaresborough was about as far south as the marauding Scots ever reached in their numerous forays into the north of England. During the disorganization which succeeded the battle of Bannockburn their army ravaged the country up to the very gates of York (A.D. 1319). The people of Ripon paid black-mail and were let off. The men of Knaresborough, a royal burgh, stood the risk of battle, and were defeated. Part of the inhabitants took to the church tower, where the Scots tried to burn them alive; the marks of the fire are said to be still visible. The Scots returned home by way of Skipton, which was also harried and burnt. The route between the two towns was so desolated that the Forest tenants were partly excused their rent to the King under the plea of impoverishment.

The more modern history of Knaresborough commences with the grant by Edward III. to John of Gaunt (A.D. 1371), since which time the town and district may be said to have followed the fortunes of the Duchy of Lancaster. About the same period Skipton was granted to Robert, Earl of Clifford, the ancestor of that ruthless partizan of the House of Lancaster, who slew the boy Earl of Rutland at the battle of Wakefield.

We cannot doubt that, during the wars of the Roses, the district between Knaresborough and Skipton must have been strongly Lancastrian; and thus it came to pass that, when Henry VI. and Queen Margaret lay at York in the spring of 1461, an order was issued, in the name of the King, to summon all "liege men of the forest and demesne of Knaresburgh" to join the Lancastrian army. This was a few days before that fatal Palm Sunday which witnessed the complete triumph of the Yorkists at Towton on the banks of the Cock,

When the river ran all gory,
And in hillocks lay the dead;
And seven and thirty thousand
Fell from the white and red,

—a battle wherein more Englishmen died than any other that has yet been fought. Sir William Plumptre, the commander of the Knaresborough con-

We obtain our knowledge of the geology of the country round Harrogate chiefly from Mr. Fox Strangway's "Memoir," whilst the excellent work of Davis and Lees treats of the West Riding as a whole.

The PERMIAN rocks in the eastern part of Claro, though mostly unfossiliferous, are not without interest. The *Lower Marl* has a very slight development; but 5 feet of red and grey marls, belonging to this section, are to be seen in St. Helen's Quarry, south-east of Knaresborough. These are the marls to which allusion will presently be made in connection with the subject of rock staining.

The most important member of the series is the *Magnesian Limestone*. But few fossils have been found in this district, and those chiefly from the lower beds, though traces of *Axinus* may be seen in beds which are highly dolomitized. At Knaresborough the yellow earthy variety is most frequent. It lends itself to the formation of caves, and, owing to its peculiar colour, imparts a character to the gorges through which nearly all the rivers of the West Riding have to pass on their way into the Vale of York. Most of these earthy varieties contain probably about 25 per cent. of carbonate of magnesia; they are quite useless as building stones, but make excellent mortar. This porous, spongy sort of rock passes into yellow crystalline dolomite, frequently showing coloured bands; the more ferriferous varieties being studded with radiations of a metallic oxide, which is probably magnetite.* No purer form of dolomite than this would seem to occur in the Knaresborough district. But a few miles further south the crystalline dolomites of Huddleston Quarry are famous; there occurs also in Towton Field a form of Magnesian Limestone which is concretionary in small ovoids, almost resembling an oolite.

The *Middle Marl* succeeds the Magnesian Limestone, and in some cases must overlap it. This sub-division consists of red marls, and soft red sandstone with much gypsum. Above it some

tingent, was taken prisoner, and his son slain along with many others of less degree, so that days of mourning fell upon the manor and forest.

The bloody Lord of Skipton, Shakespeare notwithstanding, had fallen in a preliminary skirmish, but his youthful son, afterwards known as the Shepherd Earl, found refuge under the care of Sir Launcelot Threlkeld in the wilds of Saddleback, whence he emerged to resume his rank and estates on the final triumph of the House of Lancaster.

The part played by the Royalist castles of Knaresborough and Skipton, during the Parliamentary wars, is too well known to require further mention.

* These markings, on examination, are seen not to be dendritic; they may, nevertheless, contain some oxide of manganese.

small remains of the *Upper Limestone* are visible in a cutting to the west of Knaresborough.

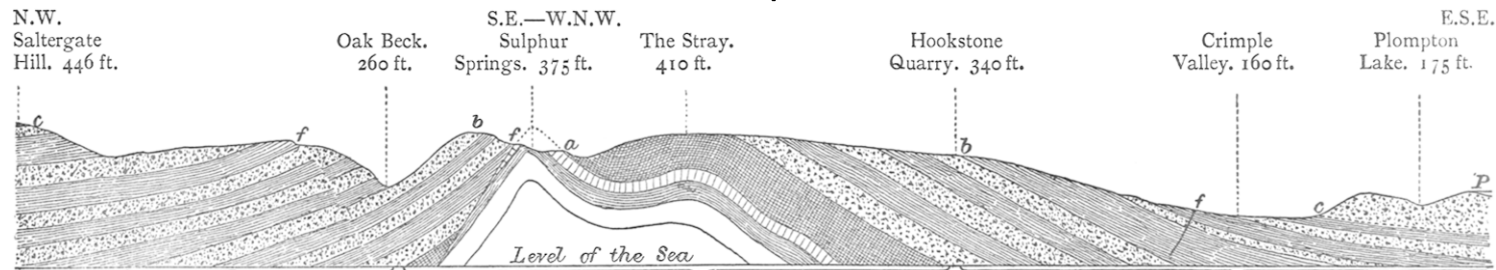
The association of gypseous marls with beds of magnesian limestone is worthy of attention as having an important bearing on the origin of magnesian limestones generally, regarding which there are so many rival theories. Is the double carbonate a contemporaneous product, or the result of subsequent dolomitization? Some are disposed to regard the formation of magnesian limestone as the result of precipitation in an inland sea, or at any rate of deposits due to streams charged with carbonate of lime and sulphate of magnesia, when, as Sterry Hunt has endeavoured to show, dolomite and gypsum would be the products. Prof. Green thinks that the palæontological facts noted in the Magnesian Limestone of Yorkshire favour this view, and he gives a history of the sequence of events, beginning with sandy deposits (the quicksands at the base of the Permian in South Yorkshire), which pass into sandy dolomites, and thence into pure dolomite. The fossils occur mostly in the lower beds, and, as the waters became more highly charged with saline matters, so life became scanty and dwarfed. He also looked to volcanic action as a source of supply for magnesian salts; but Mr. Lucas pointed out that the requisite materials might have been derived from the Yoredale Rocks and Millstone Grit of the neighbourhood, which were in all probability already above water. These questions have an additional interest as bearing on the probable position of the old shore line of the Permian Sea in these parts, and on the date of the Pennine upheaval.

The MILLSTONE GRIT Series is classified by Davis and Lees under the head of shore deposits with marine intercalations. The name serves to show the misleading character of a petrological title, as the group is full of shales, often with much ironstone, the smelting of which in former years had much to do with the disappearance of wood from Knaresborough Forest.

In the neighbourhood of Harrogate and Knaresborough the upper divisions of the Millstone Grit, including the "*Rough Rock*," are wanting, the highest beds now found belonging to the "*Third grits*." This circumstance is of course the result of pre-Permian denudation, which has not only removed the Coal Measures, but a considerable portion of the Millstone Grit likewise. Consequently, in this district, the Permians repose unconformably upon certain quartzo-felspathic grits, which are often of a red or purple colour. These are largely developed throughout many parts of the

DIAGRAMMATIC SECTION THROUGH THE HARROGATE ANTICLINAL.

Distance nearly 6 miles.



Millstone Grit Series on the North Side of the Anticinal.

Anticinal of Yoredale Rocks.

Millstone Grit Series on the South Side of the Anticinal.

Explanation of Signs.—*a*. Harrogate roadstone. On the north side of the anticinal this is forced against the principal fault (*f*). *b*. The Uppermost Kinder Grit. Quarried on the south side of the anticinal at Hookstone; on the north side of the anticinal forms Birk Crag. *c*. Approximate position of the fossiliferous band (Cayton Gill Beds) in the Millstone Grit on either side of the anticinal. *P*. Permian Beds (here Magnesian Limestone) resting unconformably on the Plompton Grits.

THE YOREDALE ROCKS are here composed of—*Lower Grits*, *Lower Shale*, *Calcareous Encrinital Grit* (Harrogate roadstone, *a*), *Upper Shale*.

MILLSTONE GRIT.—The three lowest Grit Beds with their accompanying Shales are called the *Fourth*, or *Kinder Grits*. A thick Shale intervenes. The upper series of Grits and Shales are referred to the *Third Grits*.

This section may be regarded as approximately correct as far as the surface is concerned. The folding of the Yoredale Rocks beneath the Stray is, to a certain extent, hypothetical. When the railway was made across the Stray the beds were observed to be so much disturbed that it was thought by some that the principal axis of elevation was at this point, rather than at the Sulphur Springs.

The Millstone Grit series consist very largely of Shale. It must not be supposed that the relative thickness of the Grits and Shales is accurately delineated in the diagram. Even the Plompton Grits, which form the highest section of the Third Grits in this district, are by no means free from associated Shales.

drainage area of the river Nidd, appearing in moderate elevations at Plompton, but rising to a height of nearly 1,000 feet above sea level in Brimham Rocks.

It is these Plompton grits which the older geologists were disposed to regard as the equivalent of the "Rothliegende," apparently from a general impression that the base of the Permian should be *red*, in order to correspond with the beds in Germany. The Red Rock of Rotherham, now known to be a member of the Upper Coal Measures, was for a long time classed with the "Rothliegende," in deference probably to the opinions of Phillips and Sedgwick. It is hardly necessary to repeat that, throughout Yorkshire, the unconformity of the true Permian to all members of the Carboniferous is one of the most marked features in the stratigraphy of the country. This was recognized by Phillips, and yet he persisted in regarding the Plompton Grits as "Rothliegende." Mr. Binney seems to have been the first to suspect, from the character of the few fossil plants occasionally found in these beds, that they were not of Permian age, whilst later on Mr. Clifton Ward and the Government Surveyors succeeded in establishing their true stratigraphical position as members of the Millstone Grit.

The coloration of these beds has also been the subject of much controversy. The causes which have produced rock-staining in the lower beds at the junction of the Permian and Carboniferous in these parts may not be all of the same nature. Mr. Ward thought that the prevalence of a red colour in the underlying rock might be due to some action exerted by the Magnesian Limestone on the percolations; and this notion has attained a certain degree of acceptance, though it is difficult on chemical grounds to see exactly what the nature of such action can be. Moreover it is quite an open question whether there really is any increase of red colour in the grits which lie beneath the Magnesian Limestone; indeed, that there is any such increase is denied by Mr. Lucas, who, as before mentioned, was inclined to attribute some of the red colouring to a lower marl now removed. In many parts of the Nidd valley the stratum of grit in actual junction with the Magnesian Limestone is often less highly coloured than the bed below. There can be very little doubt that much of the red colour of the Plompton Grits is due to the quantity of red felspar which they contain, so that possibly the principal causes were pre-existent within the rock itself.

The fossiliferous horizon known as the Cayton Gill Beds (c of the diagram, Fig. 1) is seen on both sides of the Harrogate anti-clinal. *Productus semireticulatus* is the most abundant fossil; *Streptorhynchus crenistria* is fairly plentiful, as also a very pretty *Fenestella*; the joints of Encrinites are very abundant.

Kinder-Grits.—The base of the Millstone Grit consists of three thick grit beds associated with still thicker shales. Some of these grits have been extensively used for building stone at Harrogate, but they are very porous. Though usually pretty free from strong colours, some of these beds are very purple in places, though exposure soon removes the tint. The outliers of the Millstone Grit Series in Craven mostly belong to this section.

Yoredale Rocks.—This is a group established by Phillips for a variable series of beds between the Carboniferous or Scar Limestone of Craven, and the Millstone Grit. It is well developed in Craven and throughout the west, consisting of shales, limestones, and peculiar grits, often calciferous. In the bed of the Hodder Yoredale Shales, with their limestones and layers of ironstone, give rise to springs containing sulphuretted hydrogen. In Bowland Forest these shales are dark and full of molluscan and fish remains. Near Skipton the Yoredale rocks consist of calcareous shales and limestones with many fossils, the beds sometimes being of a ferruginous and bituminous character; sulphur springs occur here in a position somewhat analogous to those at Harrogate. The attitude of the Yoredale Rocks at the latter place may be gathered from the diagram, Fig. 1. Very little is known about the shales of this group, but the Harrogate roadstone (a of the diagram) is a remarkable rock; below this are other shales and another peculiar grit.

The Yoredale grits at Harrogate are so peculiar that, being in some way connected also with the phenomena of the sulphur springs, a brief description may be useful before proceeding to consider the subject of the waters themselves. A large hand specimen from the Beckwithshaw quarry shows three different phases. Firstly, a fine-grained quartzo-felspathic grit without lime; secondly, a calciferous encrinite-grit, where the lime has mostly been removed, but where the structure of the crinoidal stem is better brought out in consequence; thirdly, a more calcareous portion. A hand specimen from the bottom of the sulphur well on Harlow Carr is a very fine-grained quartzo-felspathic grit with much white mica, and coaly matter in bands and blotches. In the Low Harrogate quarry (Cold Bath

HARROGATE WATERS.—ANALYSES.

No. 1.—OLD SULPHUR WELL (Strong saline SULPHUR). Thorpe, 1875.

| | GRAINS IN GALL. | GRAINS IN GALL. |
|--|-----------------|-----------------|
| Sodium Chloride | 893.7 | |
| KCl 9.6, LiCl 0.7, NH ₄ Cl 1, CaCl ₂ 43.5, BaCl ₂ 6.6, MgCl ₂ 48 | 109.4 | |
| Magnesium Iodide | 0.1 | |
| „ Bromide | 2.3 | |
| Calcium carbonate | 29.8 | |
| Magnesium carbonate | 6.0 | |
| Alkaline carbonates | | 1005.5 |
| Sulphates | | |
| Silica | | 35.8 |
| SODIUM SULPHYDEATE (NaHS) | | nil. |
| F, Sr, P ₂ O ₅ , Al ₂ O ₃ , and organic matter | | 0.7 |
| | | 5.2 |
| | | traces |
| Total solids | | 1047.2 |

GASES.

NOTE.—The amount of free H₂S found by Thorpe dissolved in the water = 3.7 grains per gallon. In his paper in the "Journal of the Chemical Society" no other gases are mentioned. Hofmann in 1854 found carbonic acid 22 cubic inches, carburetted hydrogen 6 cubic inches, nitrogen 3 cubic inches. He also states that the bubbles rising from these waters spontaneously consist mainly of carburetted hydrogen and nitrogen.

Temperature.—In 1872 this was found to range between 46°F. and 52°F.

No. 2.—"MAGNESIA" WELL (Mild saline SULPHUR). Muspratt, 1867. Hospital Mild Sulphur.

| | GRAINS IN GALL. | GRAINS IN GALL. |
|--|-----------------|-----------------|
| Sodium chloride | 215. | |
| KCl 27.9, BaCl ₂ 1.2, MgCl ₂ 1.8 | 30.9 | |
| Iodides, &c. | traces. | |
| Calcium Carbonate | 18.3 | |
| Magnesium Carbonate | 13.0 | |
| Alkaline carbonates | | 31.3 |
| Sulphates | | nil. |
| Silica | | 1.6 |
| SODIUM SULPHYDEATE (NaHS) | | 1.6 |
| Sr. Fe. Mn. | | traces. |
| Total solids | | 280.4 |

GASES.

NOTE.—There seems to have been no separate estimation of the gaseous and alkaline sulphides. A moderate amount of Carbonic Acid was found, together with some carburetted hydrogen, nitrogen, and a little oxygen.

No. 3.—STARBECK SPA WATER (Pure SULPHUR). Fairley, 1879.

| | GRAINS IN GALL. | GRAINS IN GALL. |
|----------------------------------|-----------------|-----------------|
| Sodium chloride | 116.4 | |
| LiCl, BaCl ₂ | traces. | |
| Calcium carbonate | 10.0 | |
| Magnesium carbonate | 3.5 | |
| *Sodium carbonate | 14.5 | |
| *Potassium carbonate | 0.6 | |
| Calcium sulphate | | 1.9 |
| Silica | | 3.2 |
| SODIUM SULPHYDEATE (NaHS) | | 1.4 |
| Total solids | | 151.5 |

* According to Hofmann's analysis in 1854 the proportion of Na₂ CO₃ to K₂ CO₃ is nearly reversed. Gases not estimated.

No. 4.—"KISSENGEN" WATER (Strong saline CHALYBEATE). Attfield, 1879.

| | GRAINS IN GALL. | GRAINS IN GALL. |
|---|-----------------|-----------------|
| Sodium chloride | 674.5 | |
| KCl 21.5, LiCl tr, NH ₄ Cl .4, CaCl ₂ 87, SrCl ₂ 0.8, MgCl ₂ 65.5 | 178.8 | |
| Iodides, &c. | traces. | |
| Calcium carbonate | 9.0 | |
| Barium carbonate | 2.1 | |
| FERROUS CARBONATE | 9.6 | |
| Alkaline carbonates | | 20.7 |
| Barium sulphate | | nil. |
| Silica | | 0.5 |
| | | 3.7 |
| Total solids | | 874.6 |

Gases.—Principally carbonic acid in moderate amount, with oxygen and nitrogen.

No. 5.—ST. JOHN'S WELL (Pure CHALYBEATE). Hofmann, 1854.

| | GRAINS IN GALL. | GRAINS IN GALL. |
|----------------------------|-----------------|-----------------|
| Sodium chloride | 1.5 | |
| Iodides, &c. | traces. | |
| Calcium carbonate | 2.3 | |
| Magnesium carbonate | 3.0 | |
| FERROUS CARBONATE | 0.6 | |
| Sodium carbonate | 1.3 | |
| Potassium carbonate | 1.0 | |
| Calcium sulphate | | 2.3 |
| Silica | | 0.3 |
| Organic matter | | tr. |
| | | tr. |
| Total solids | | 10.0 |

Gases.—Principally carbonic acid, with some nitrogen, and traces of carburetted hydrogen and of oxygen.

Road) the crinoidal character is very prevalent, and where the soluble matter has been removed, it becomes a spongy, silicious, encrinite grit. The decomposition of this rock produces a good soil, but we may well believe that the surface beds have already parted with some of their constituents, and the iron-stained nature of the joint faces points in the same direction; it is in the stuff formed in these cracks that the little double-pyramid quartz crystals, known as Harrogate diamonds, have been deposited.

The Harrogate waters,* both sulphur and iron, occur in connection with a triangular patch of Yoredale rocks, of which a cross section is seen in Fig. 1. This patch is bounded towards the N.W. by the main fault, and extends for about three miles S.W. of Harrogate. There are about 80 springs in all. The strongest waters rise in the little valley of Low Harrogate between the Bog Field, 375 feet, to the Montpelier Spa, 335 feet. This is the nucleus of the sulphur waters; the strong iron waters are near, but usually occupy an outer area. It is evident that an iron water and a sulphur water are incompatible, yet they wait closely on each other, and must in some way be connected. One of the great puzzles is to understand how they are kept apart in the ducts which convey them to the surface. The very high angle of the beds, and the peculiar jointing of the encrinite grit have probably something to do with it.

The composition of the Harrogate waters has often been studied from a therapeutical point of view, but it has also its geological aspect, and recent observations have brought out some features of considerable importance in this direction. Henceforth there will be less difficulty in understanding the vein deposits of the Carboniferous Series, as here we have an opportunity of testing the vital fluids of the rocks, as it were, in the act of circulation. An inspection of the accompanying table may serve to illustrate this.

The five waters, whose analyses are there given, are representative of the chief varieties. Technically the *Sulphur waters* are divided into strong saline, mild saline, and pure, the latter term being merely relative. It may also be noted that No. 3, selected as a type of the "pure sulphur," is situated at some distance from the triangular patch of Yoredale Rocks previously mentioned, and very near the junction of the Millstone Grit Shales with the Middle Permian Marls. At the same time it is not improbable

* For further details consult "The Harrogate Waters," by George Oliver, M.D.—H. K. Lewis, London.

that this spring may represent an overflow from a spring at Bilton, which is more in the direction of a slight prolongation of the anticlinal axis. In consequence of the absence from this water of the chlorides of the alkaline earths, there is a fair amount of alkaline carbonate, and the same is the case with the spring at Harlow Carr on the other side of Low Harrogate. In fact the further away from Low Harrogate the less amount of chloride occurs in the sulphur springs.

The Old Sulphur Well yields a pretty uniform supply, amounting to about 12 gallons per hour, though in the very dry year, 1868, there was some mention made of a threatened deficiency. The temperature is evidently pretty nearly that of the air, so that no appreciable amount of extraneous heat can be detected. Indeed it may be said that all the waters of Harrogate are "cold," and, with one exception (the Alum Well), they all have a markedly alkaline reaction. Calculating roughly, the Old Sulphur Well would yield seven tons of chlorides per annum, including 100lbs. of Barium Chloride,* and 37lbs. of Magnesium Bromide, with some Iodide. It also would produce 240lbs. of Sodium Sulphydrate (NaHS).

The origin or source of these abundant impregnations has naturally been a matter of considerable difficulty. The most probable explanation is that the springs, though not superficial, are far from being deep-seated, and that the water supply comes mostly from the Harlow Hill district, which attains 600ft. elevation, and attracts a rainfall that cannot well average less than 35 inches annually. That the supply is not superficial may be inferred from the fact that the drainage of the Bog Field had no effect on the delivery of the waters, and thus the notion, held by Phillips, as to the bog origin of the sulphur waters would seem to be untenable. The large quantity of chlorides looks very much as if a portion of the water of the sea or of an estuary† had been

* Barium Chloride was not noticed by Hoffman in 1854, and that chemist only found traces of Bromides and Iodides. Improvements in methods of analysis may account for the difference.

† Comparing the total solids of the Mediterranean with those of the Baltic, the following differences may be noted:—

| | MEDITERRANEAN. | | | BALTIC. | | |
|-------------------|----------------|-------|-----|---------|-------|-----|
| Solids in 100 | ... | 3.77 | ... | ... | 1.77 | ... |
| Haloids per cent. | ... | 89.5 | ... | ... | 94.5 | ... |
| Sulphates | ... | 10.2 | ... | ... | 5.2 | ... |
| Carbonates | ... | 0.5 | ... | ... | 0.3 | ... |
| | | <hr/> | | | <hr/> | |
| | | 100 | | | 100 | |

evaporated and the salts incorporated with the Yoredale Rocks during their formation. There is abundant evidence, both in this neighbourhood and elsewhere, of the quantity of organic matter, chiefly of vegetable origin, locked up in the Yoredale Rocks. Hence it is not, unreasonable to believe that the putrefactive distillation of such organic matter, acting very slowly and through long periods of time, more or less effects the complete deoxidization of the sulphates, and that to this we owe the quantity of sulphide present in the Harrogate waters. The considerable quantity of carburetted hydrogen and of nitrogen found by Hoffman all favour this view, which is much strengthened by the almost complete absence of oxygen, showing that the nitrogen present is due to organic decomposition. At the same time the very slight traces of phosphoric acid would show that this mainly arises from vegetable matter.

EXCURSION.

Monday.—The London contingent arrived at Harrogate early in the afternoon, and having secured quarters at the Prospect Hotel, re-assembled with the other members of the party at the Old Sulphur Well. Here they tested the quality of the water for which the place is celebrated, and availed themselves of the permission which was given to them to descend underneath the floor of the building to inspect the springs which supply the pump-room above. The President, who on this occasion was the director, offered a few remarks on the chemical composition of the water and of several of the sulphur waters of Harrogate. He was enabled to illustrate his observations by means of a number of specimen tubes containing the saline contents of one gallon of each of the various waters to be found in the town, and by this method the different volumes were at once perceived. These very interesting tubes had been prepared from evaporations conducted by Mr. Davis, chemist, of Harrogate. They are the property of the Harrogate Improvement Commissioners, who kindly lent them for the occasion. Mr. W. H. Wyles (the Clerk to the Commissioners), and Mr. W. W. Harry (the engineer) afforded the party every facility in the examination of the specimens. Whilst the company were thus engaged, Dr. Oliver, who is well known as the author of a valuable work on “The Harrogate Waters,” appeared at the wells and supplemented the President’s observations. Dr. Oliver dwelt more especially upon the geological conditions under which the water finds its way

to the surface in connection with the very remarkable anticlinal which is known to exist at Low Harrogate.

The singular stratigraphy of Harrogate arrested the attention of geologists a long time ago. Mr. Wm. Smith, the father of English geology, was the first to appreciate the peculiarity, but although he recognised that there was an anticlinal or upthrust of lower rocks, extending from Harlow Hill to Low Harrogate, he appears to have thought that within that anticlinal there was a synclinal basin towards which the springs gravitated. Later on, his nephew, the late Professor Phillips, who for forty years had given great consideration to the peculiarities of the geology of Harrogate, drew the attention of the Geological Society of London to the very remarkable features of the district, the difficulties in regard to which had been to some extent cleared up by the making of the new railway across the Stray. The subject of the anticlinal was treated generally in a diagram in the paper brought before the Geological Society by Professor Phillips, and the relation of the Millstone Grit beds on the north and south of the Yoredale rocks beneath was made very clear. At the same time Professor Phillips seems to have had a notion that there was a sort of synclinal towards the apex of the anticlinal, and his section at this part of the diagram is somewhat obscure and difficult to comprehend.

When the party left the Old Sulphur Wells they proceeded to verify the stratigraphical facts in connection with the anticlinal, and for this purpose walked to the well-known road-stone quarry in the Cold Bath Road. This stone is one of the hard beds of the Yoredale rocks, and may be described as a calciferous grit very largely charged with the remains of encrinites. In the Cold Bath Road quarry these rocks are to be seen dipping at a considerable angle in a south-easterly direction. In the bed of the stream, just at the back of the sulphur well, the same rock is observed to dip in a direction somewhat to the north of east, and a little further up the hill, underneath Cornwall House, this same bed dips at a very high angle indeed, nearly due north. These facts are taken to indicate that there exists an anticlinal dome, which is here seen to be dying out to the eastward, and the north side of the anticlinal is very much steeper than the south—in fact, the anticlinal itself is fractured a little on the north-west side of what may be presumed to be its principal axis by a great fault which causes the road-stone to be brought into juxtaposition with the lower beds of the Mill-

stone Grit. There are geologists at Harrogate who consider that the axis of this swelling or anticlinal is to be found beneath the Stray rather than at the sulphur springs, and this view receives some substantiation from the appearances which were noted when the railway was made across the Stray. The probable explanation is that the Harrogate road-stone and its accompanying shales are bent into more than one series of curves, and that one of these curves very nearly reaches the surface in the railway cutting. A northerly dip of the beds near the Low Harrogate Church is further evidence of the probability of this view.

The party having satisfied themselves as to the reality of the anticlinal axis, were conducted to the Bog Springs, where there are something like 34 different sources of sulphur and iron waters. Dr. Oliver here indicated the peculiarities of the position and the nature of the several waters, and deduced from his observations the fact that, as a rule, the sulphur springs occupy an inner position, and that the iron springs are without, on either side of the main axis of upheaval. The nature of the several wells was pointed out, and attention was especially drawn to the very abnormal water known as the "Alum Well." It may be mentioned that one of the characteristics of the sulphur waters at Harrogate is the absence, more or less complete, of sulphates. This peculiarity enables many of the Harrogate waters to act as carriers of salts of barium and strontium, which would otherwise be insoluble. In the "Alum Well," however, a large quantity of sulphates exists. The probability is that this is due to the shallow origin of the spring, whose waters become oxidised, and this may account also for the acid reaction so exceptional to the waters of this neighbourhood.

Having spent some time at the springs, the company walked to Birk Crag, where they had an opportunity of looking from that very picturesque ridge of Millstone Grit over the wild and dreary scenery of Haverah Park, which consists entirely of the grits and shales of the Millstone Grit group. These rocks are noted for the purity of their waters. Oak Beck, which flows through Haverah Park, has been utilized for the purpose of supplying the town of Harrogate with pure water, just as the Washburn river has been adapted for supplying Leeds. The remainder of the evening was spent by the party in walking round by Harlow Carr and the back of Harlow Hill to Harrogate. They afterwards met at the Prospect Hotel, and were very kindly welcomed to Harrogate by Mr. Richard Carter, F.G.S., of Spring Bank, Harrogate, who, with Mr. Harry

and other gentlemen, had done much to facilitate the success of the excursion.

Tuesday.—The party left Harrogate for Knaresborough by an early train, and after a brief inspection of the old castle at the latter place, descended to the foot of the cliff on which what is left of the ancient pile stands. Here the unconformable junction of the Magnesian Limestone upon the Millstone Grit was pointed out by the Director (the President of the Association) and verified by the members. From this point the party crossed the river for the purpose of visiting the Dropping Well, which is too well-known to need describing here. The Director took occasion to explain the nature of the waters which flow over the rock. The stream supplying these waters springs out of the adjacent cliff, and represents the drainage of a hollow originating in the high ground towards Belmont. This ground is chiefly made up of the Middle Permian Marls, and it is to the salts in these marls that we must trace the impregnation of the Dropping Well waters. The following is an old analysis of the water :—

| | | Grains to the Gallon. |
|----------------------|-----|-----------------------|
| Carbonate of Soda | ... | 6 |
| Carbonate of Lime | ... | 23 |
| Sulphate of Lime | ... | 132 |
| Sulphate of Magnesia | ... | 11 |
| | | — |
| Total | ... | 172 |
| | | — |

The deposits upon the sponges and other substances which are placed at the well, consist almost wholly of carbonate of lime, the amount of sulphate of lime deposited being very small indeed, notwithstanding the very large quantity of sulphate of lime found in the water. Mr. Simpson, the lessee of the Long Walk and the Mother Shipton Inn, recently possessed himself of some magnificent specimens of sponges, which show the action of the deposit remarkably well from their porous nature. Some time was spent by the party in examining the various caves in the valley of the Nidd, and in listening to stories about St. Robert and Eugene Aram, after which they crossed the river at Grimbald Bridge, and finally took leave of the Magnesian Limestone where the romantic Grimbald Crag is terminated by a small fault on its western side. Plompton Rocks—a mile and a half distant—were very soon reached. These rocks are interesting to geologists from having

been regarded in former days as constituting a portion of the Permian series—equivalent to the German “Rothliegende.” The researches of the Government surveyors in recent years have shown that these rocks are really nothing more than the highest beds of the Millstone Grit series, as developed in this district, and that they are unconformably overlaid, just as at Knaresborough, by the Permian rocks. The extraordinary action of the weather upon these curious grits afforded matter for endless speculation. In this respect the Plompton Rocks, which belong to the same bed of grit which forms the Brimham Rocks at a much greater elevation, are possibly more singular and grotesque than even the Brimham rocks themselves.

The party now divided, some returning to Harrogate in carriages, others walking along the road. In the afternoon they were joined by Mr. J. W. Davis, when about a dozen of the most enthusiastic members, including that gentleman and the President drove to inspect the new quarry of Harrogate road-stone at Beckwithshaw, where the effects of contortion are very finely displayed. A small spring of sulphur water has recently been discovered near here by Dr. Oliver. In the evening the President congratulated the members on the arrival of Mr. Davis, and placed the direction of the excursions for the remainder of the week in his hands.

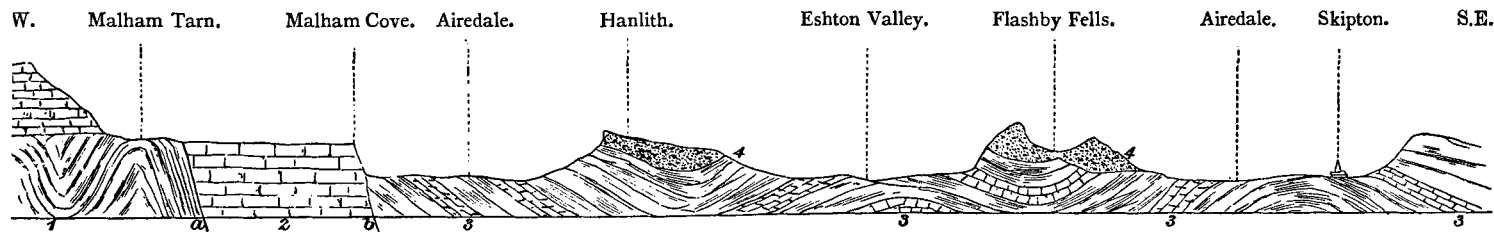
Wednesday.—This was an important day for the excursionists as they had to transfer themselves in conveyances from the base of operations at Harrogate to Skipton, *vid* Knaresborough Forest and Bolton. The early part of the journey was sufficiently dreary, the scenery of this portion of Knaresborough Forest being somewhat tame and uninteresting. A number of fossils were discovered on the stoneheaps near the Little Wonder Inn, coming from the well-known quarries in the Millstone Grit series near Hampsthwaite, on the horizon known as the “Cayton Gill Beds” (see diagram No. 1). The excessive rarity of fossils in the Millstone Grit makes their occurrence in this bed of considerable interest. The species appear to differ but slightly from such as are known to occur in the Carboniferous Limestone. Having safely passed the “dangerous corner” the Director and his followers descended into the valley of the Washburn, where the extraordinary size of the artificial lakes provided for the Leeds water-supply, struck everyone with astonishment. The Pass of Kexgill, the next object of interest on the route, shows traces of the anticlinal axis by the

way in which the grit rocks dip on either side. Having reached the summit of this pass the party drove rapidly down the descent to Bolton Bridge, and at about half-past twelve arrived at the Devonshire Arms, where a substantial lunch, for which the excursionists were well prepared, was served. About four hours were devoted to Bolton Abbey and the Strid, where many of the gentlemen from the south saw for the first time one of the most beautiful and interesting spots in Yorkshire; indeed, so fascinated were they with the charms of this delightful valley, that it was rather late when the journey was resumed. It may be stated that the Strid is cut through what is known as the Kinderscout grit, or lowest grit of the Millstone Grit series. Opposite Bolton Abbey there is a very fine section in the Yoredale shales, showing both faults and contortions. This is on the north side of the anticlinal. The stratigraphical phenomena between Bolton and Skipton are of the most marvellous kind. (See diagram, fig. 2, S.E. side, for the general structure of the Skipton Anticlinal). The long system of disturbance extending from the neighbourhood of Clitheroe to Harrogate, here assumes a most striking phase, and the quarries in consequence exhibit some extraordinary sections. The first quarries visited are known as the Hambleton Rock Quarries, where the Skipton rock, supposed to be Mountain Limestone, has been forced into a vertical position, and is variously contorted. Continuing the drive towards Skipton, the party made a diversion in the direction of Draughton Quarry, an excavation in the Yoredale rocks, where the most remarkable phenomena of rock-curvature may be seen to great advantage. Some of the choicest of these have been photographed by the Yorkshire Geological Society, and form beautiful pictures apart from their supreme geological interest. The excursionists had considerable difficulty in finding their carriages again. Skipton was not reached until a late hour in the evening, and it was some time before the party was settled in their various quarters; but, thanks to the admirable arrangements made by Mr. Davis, everything was finally put to rights.

Thursday.—This morning the party, accompanied by a few members of the Yorkshire Geological Society, travelled from Skipton to Bell Busk, and most of them walked from that Station to the village of Malham, a distance of nearly five miles. The hillocky character of the intervening country is chiefly due to the prevalence of glacial deposits. Malham Cove is situated not far from the south branch of the Craven fault. (See diagram, fig. 2, N.W.

FIG. 2.

DIAGRAMMATIC SECTION FROM MALHAM TO SKIPTON. Distance 12 miles.



Explanation of Signs.—1. SILURIAN GRITS. 2. MOUNTAIN LIMESTONE. 3. YOREDALE SERIES. 4. MILLSTONE GRIT. a. North branch of Craven Fault; b. South branch.

This section is designed to give an approximate idea of the position and contorted character of the rocks in the vicinity of the Craven Fault, and for many miles southward. The surface of the valleys is for the most part thickly covered with glacial clays, sand and boulders; but where exposures of the rock are met with they always exhibit a more or less contorted section. At Malham Tarn the Mountain Limestone extends in more or less horizontal beds on the upturned edges of the Silurian rocks. The grit rocks which occupy the higher ground at Hanlith and Flashby Fells are in the form of synclinals, whilst the summits of the anticlinals occupy the lower parts of the valleys. At Skipton a Limestone is quarried, which is supposed to be equivalent to the Mountain Limestone at Malham, but this is by no means certain.

side). The Director having arrived at the foot of that remarkable cliff, just where the river Aire springs from the base of the precipice, drew attention to the geological characteristics of the scene, more especially in connection with the underground course of the water which disappears a little to the south of Malham Tarn. The party retraced their steps in the direction of the village of Malham, and thence walked towards Gordale Scar, some of the gentlemen visiting Janet's Cave on the way. The gorge at Gordale is an excavation in what is known as the Scar Limestone, which is the lowest member of the Carboniferous Series in this district. The visitors were scarcely prepared for such an impressive scene, and nearly all agreed that it is one of the most remarkable spots, not only in Yorkshire but in England, and that probably no part of the Carboniferous Limestone, not even excepting the celebrated Cheddar Cliffs, can compete with Gordale in wonder and magnificence. The stream which flows through this extraordinary cañon, by its numerous waterfalls, adds largely to the interest of the scene. There can be very little doubt that this excavation is almost entirely the result of water action, aided to a certain extent by rock-jointing in the first instance. The scramble up the gorge is a somewhat difficult undertaking, but was safely accomplished, and the whole of the party finally stood on the limestone pavement of the moors above. From thence a rather rough walk led them to within a short distance of Malham Tarn, which is said to be situated on Silurian rocks and Boulder Clay.

At the place where the water sinks, to reappear, as already stated, at the foot of Malham Cove, Mr. Davis read a very interesting communication from Mr. Walter Morrison with reference to the underground course of the water, which disappears at this point. The Director expressed his opinion that the water at once falls into the north branch of the Craven fault, which crosses the moors about this spot. The kindness of Mr. Morrison in offering the party the use of boats and other facilities was duly acknowledged by the President, and Mr. Davis was requested to convey the thanks of the Association to that gentleman. Here the party divided. A number of them returned at once towards Malham, and thence to Bell Busk, whilst the other portion, under the guidance of Mr. Davis, took the road across the moors for the Victoria Cave and Settle. Owing to the inequalities of the ground, the latter party became subdivided, though both sections arrived at the Victoria Cave about the same time. Certain observations relative

to the position of the great north fault were made by some of the gentlemen present. This party finally descended into Settle by a very precipitous route. After a hurried visit to the museum at Giggleswick, where many of the objects found in the Victoria Cave are arranged, including the largest specimen of the grizzly bear which was ever found, the excursionists got to Settle Station just in time to catch the train for Skipton.

Friday.—The weather, which had hitherto favoured the excursionists in a most remarkable manner, changed for the first time during the week on Friday morning, when in a heavy shower the party proceeded from Skipton to Clapham. On the arrival of the party at the latter place the clouds broke, and it was comparatively fine for a few hours. This enabled Mr. Davis to take his trusty followers through the grounds belonging to Mr. Farrer, where the effects of one of the great faults are very well shown in the gorge of the stream. A section of the party then visited the celebrated Clapham Caves, whilst a smaller number proceeded up Trout Gill to Gaping Ghyll Hole. It is very well known that the waters which are collected on the southern flanks of Ingleborough, and which flow as an ordinary beck up to this point, suddenly disappear in the yawning limestone, just as one might imagine a river turned into a pit shaft. The waters are doubtless those which reappear close to the Clapham Cave. At some time or other the course of this stream was on the surface, and the lines of the old valley are still to be seen, though the stream no longer excavates that portion of the valley between Gaping Ghyll Hole and the place of its final emergence into daylight at the Clapham Caves. It may be as well here to draw attention to the readiness with which water sinks in these limestone districts—a circumstance due partly to the jointing of the rocks themselves and partly to their ready solubility in carbonated waters.

Both branches of the party ultimately returned to Clapham, where they re-assembled at lunch, which was liberally provided by the landlord of the New Inn. Before leaving the table the President took the opportunity of tendering the thanks of the Association to Mr. Davis for the admirable manner in which he had conducted the excursions. He spoke of that gentleman's extensive knowledge of the geological features of the district, and referred to the trouble which he had taken in making the arrangements which had given so much satisfaction to the visitors. Mr. Davis made a suitable reply, in the course of which he expressed his gratification

at having made the acquaintance of so many gentlemen, whom he facetiously described as the jolliest set of geologists he had ever met with.

The rain was now coming down in torrents, and under these depressing circumstances very few of the members or their friends showed any anxiety to carry out the programme to its final completion. Only ten were found bold enough to enter upon the undertaking, including the President and the Director. These gentlemen, well armed with umbrellas and waterproofs, walked, in a pouring rain which did not cease for a moment, first of all to Norber—a distance of over a mile—where they saw the magnificent display of ice-borne boulders of Silurian rocks resting on Mountain Limestone. By the hamlet of Wharfe the small party walked round Moughten Fells to Foredale. At Combe Quarries they had to be satisfied with a glimpse at the section, rendered classical by the splendid photograph of the Yorkshire Geological Society, where the Mountain Limestone lies unconformably on the upturned and folded edges of the Silurian slates and grits. A hurried walk took them to Horton-in-Ribblesdale, where they had the good fortune to catch the 6.43 train to Skipton.

Saturday.—The contemplated excursion to Raygill Quarries was abandoned, partly in consequence of the threatening nature of the weather and partly because many of the members were anxious to return to their homes in good time. It may be mentioned that at Raygill Quarries there is a fissure recently excavated by the Yorkshire Geological and Polytechnic Society. The bones of elephant, hippopotamus, rhinoceros, bear, hyena, lion, bison, and other animals have been found in the quarries, and are now in the museum of the Leeds Philosophical Society.

The excursions gave great satisfaction to the visitors, and were the means of introducing many persons for the first time to a district remarkable alike for its geological features and its fine scenery. There were few opportunities for obtaining fossils, but some of the younger and more active members of the party applied their hammers at various points with considerable success.
