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INGLEBOROUGH.

PART II.* STRATIGRAPHY.

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The oldest rocks of which we have any representatives in this area are the great mass of green slates and grit and conglomerate which form the floor of Chapel-le-dale, and of Ribblesdale for about half a square mile near Horton. These so much resemble the old volcanic series described under the general title of "Green Slates and Porphyry" in the Lake District, and agree so well with them in their relation to the rocks with which they are associated, that, in default of any evidence to the contrary, they have been referred to the same horizon.

* Continued from Proc. Yorks. Geol. and Polytec. Soc., Vol. XIV., p. 150.

The rock consists, as far as the finer parts are concerned, of fine felspathic dust; the grit is composed chiefly of grains of quartz and pink orthoclase in a greenish matrix consisting of finer grit and the same material as the slate. There are also, but rarely, beds of breccia much like those in the Borrowdale Series. Iron pyrites occurs in beautifully perfect cubes, and as dendrites in the slates, while the iron pervades the whole as a green silicate which is especially conspicuous in some of the more crystalline quartz veins.

No fossil has ever been found in their equivalents in Cumberland; and, though these Yorkshire beds are more promising than those of the Lake District, no fossil has yet been recorded from them. The black marks seen on some faces of rock in the slate quarry north of Ingleton, which by their outline suggested graptolites, are merely segregations of mineral matter; while in other cases the combination of concretions and rock crushing have produced complex arrangements in which imagination has seen traces of trilobites and other organisms.

The succession as observed or inferred is shown in Section, Fig. 9. The coarser beds, known as "calliard," indicate the direction of the dip, and show, as pointed out by Professor Sedgwick,* that in the slate quarries "the planes of fission are parallel to the original laminæ of deposit." But in the absence of such bands it would be very difficult to make out the bedding. The apparent dips are generally high, from 70° to 90°, some, however, being as low as 50°. The strike is always N.W. and S.E.

The series would appear at first to have a fairly uniform dip to the S.W., the general differences of material showing a succession in that direction, and the details of the stratification at the S.W. end of the section where they can be made out indicating a coincidence of bedding and cleavage at about 80° to the S.W. (see Section, Fig. 9). Where, however, marked beds, such as the grits and conglomerate of Dale Barn and those recently exposed in the so-called granite quarry on the opposite side of the

* Quart. Journ. Geol. Soc., Vol. VIII., p. 45.

valley allow us to trace the bedding, it is sometimes seen that they are folded over in sharp plications of such a kind as it would be impossible to detect in the fine homogeneous slates. It may be, therefore, that the thickness of the series is not so great as would be inferred from this apparently regular succession at a high angle for $2\frac{1}{4}$ miles along the valley, but that with a general succession to the S.W. each portion is repeated in a series of sharp folds as shown in the diagram (Fig. 10). The pressure that produced these folds must have been in the same direction as that which produced the cleavage, but whether there is evidence of a cross strain in what looks like double cleavage or cleavage in two directions in the Ingleton quarries, or whether that is due to local readjustments to meet some accidental greater resistance we cannot now make out.

Fig. 10.

In the Ingleton "granite" quarry the coarse grit is excavated for road metal, the word "granite" being frequently used in commerce for any rock with a coarse grain. The more unyielding grit is here seen crushed into the associated soft slaty material, and, as there was much stretching of the mass, especially at the contact surfaces, when the mud was being squeezed out into a cleaved slate and the tough grit had to accommodate itself to the changed relations, there was a good deal of tearing and inclusion of fragments in the adjacent rocks, and it is not always easy to decide whether a given specimen is a part of the brecciated conglomerate or owes its character largely to brecciation in place and drag along the planes of readjustment.

When two consecutive formations of different character occur in a district which has been subjected to great and violent earth movement they are almost sure to give way along the line of contact, and when denudation attacks such a junction there is almost always a result which obscures the junction. Plenty of examples of this may be found among the overlying rocks in the steep precipices of Ingleborough, but we shall find the difficulty which arises from such conditions still greater when we are trying to make out the line of junction between such ancient deposits as the Green Slate Series and the Coniston Limestone and Shale.

This prepares us to find that junction sections between the two are exceedingly rare and obscure. In the gorge below Thornton Force the two series are seen in contact close to where the great fault leaves the bed of the stream and runs into the hill. Here there are thin papery shales presenting a somewhat intermediate character between the fine ash beds below and the calcareous shales above, but there is always the doubt that we may be here dealing not with true beds somewhat crushed, but with masses which owe their bed-like character to mechanical rearrangement during periods of movement long subsequent to their original deposition.

There is no other junction of the Green Slate Series and the Coniston Limestone and Shale Series seen anywhere in the immediately adjoining area, though the two formations occur very close together in several places and in the same relative position. Some green slaty rock exposed at the surface in a weathered condition near Moughton Sike in the Crumnack valley may belong to this series, or to passage beds between it and the Coniston Limestone.

In the northern part of Ribblesdale the green slates are exposed in the bed of Douk Gill to the east of the village of Horton. They dip at a high angle in a southerly direction, and pass up into calcareous slates full of Bala fossils. About 150 yards down stream these turn up again in a synclinal fold broken at its west end by a fault* which cuts off the Bala Beds, bringing the green slates again to the surface.

* See Sedgwick, Quart. Journ. Geol. Soc., Vol. VIII., p. 49.

The Green Slate Series is seen in several sections, or on glaciated surfaces near Horton in Ribblesdale, but, except in the railway cutting south of the station, there is no continuous exposure for more than a few yards, so that it is difficult to correlate the horizons with those seen in Chapel-le-dale. It is, however, probable that it is the upper part of the series that is here represented from the occurrence of the Coniston Limestone Series so close to it on the south, and from the transitional character of the upper part of the series, which here contains much calcareous matter and even beds of limestone. The main mass, which succeeds in apparently descending section, consists of green slates, grits, and conglomerates not very unlike those which appear to underlie the passage beds in the gorge at the foot of Chapel-le-dale. The beds are generally inclined from 45° to 75° in a south-westerly direction, but they vary to such an extent and in such a manner in the direction and amount of dip, and are in places so crushed and veined, as to suggest that they are much folded and perhaps repeated, a supposition which is strengthened by the fact that all the pre-Carboniferous rocks are more and more intensely plicated as we follow them up Ribblesdale from south to north.

The Green Slate Series of Ingleborough is probably the "geological equivalent"* of the Green Slates and Porphyry of the Lake District and of the Bala Volcanic Series of North Wales. But there is a difference between the results of volcanic activity in these three areas. In North Wales there are lavas and volcanic breccias and ashes associated with fossiliferous marine deposits. It is clear that the volcanic masses were here built up on a sea floor, but that most of the lavas and ashes of successive great eruptions remain where they were first thrown out, and are not merely the volcanic material distributed far and wide over the bottom of the sea.

In the Lake District, on the other hand, there are lavas and agglomerates, and ashes, but no traces of fossiliferous sediments associated with the great masses of volcanic ejectamenta, nor is

* Whewell, History of the Inductive Sciences, Vol. III., p. 532

there any sufficient proof that the material was sorted by currents of water. For aught we can say at present the stratification may have been produced by the showering down of the coarser and finer, of the heavier and lighter material over a land surface, or into the sea, where it directly settled to the bottom, beyond the reach of wind, waves, and tides, but no signs of ancient land surfaces or of marine sediment with traces of life have yet been detected.

The Ingleborough district seems to have been still further from the region of volcanic activity. No lava flows appear to have reached it. There is a very large proportion of the finest material, and, where bands of coarser character occur, they consist of well-rolled sand and grit such as might be derived from a coarse granite, and, more rarely, some beds of breccia of doubtful origin. No signs of land surfaces, nor of the fauna or flora of a sea bottom, have so far been detected here, though we may hope that among the grit bands fossils may yet be found. On the whole it seems probable that we have here volcanic material transported from a distance, and quietly setting to the bottom of a lake or sea over which no coarser or heavier material than the grit of Dale Barn was ever strewn. We should not expect the thickness of beds to be as great as that which was attained by the cones nearer the sources of eruption, and this consideration, as well as observation of the nature of the folds where they can be detected, would support the suggestion (p. 325) that the apparent sequence along Chapel-le-dale is deceptive, and that the beds are repeated over and over again as shown in the diagram (Fig. 10).

We cannot attach much importance to the absence of fossils in a formation which has suffered so much deformation as has this Chapel-le-dale Series of green rocks. Almost all traces of organic life would probably have been entirely obliterated or been dragged out beyond all possibility of recognition, and, if they are found, it will probably be where protected by some of the more unyielding beds or on the turn of a fold where the distortion was not so violent.

BALA BEDS.

In ascending section above the Green Slate Series and in descending section below the Silurian flags, grits, and conglomerates, we always find masses of roughly-cleaved shales with calcareous bands and concretions and beds of limestone. Notwithstanding the folded and faulted condition of the older rocks in this area the true sequence can generally be established in these beds, and the newer are found to occur next in succession below the Silurian, and the older next in succession above the green slates, though some members are here and there missing, being probably dropped out by faults. Some bands are highly fossiliferous, and the fossils as well as the position of the series makes it quite clear that this is the equivalent of the Coniston Limestone and Shale of the Lake District and the Bala Limestone and Shale of North Wales. The details, however, vary across this limited area, and, as might be expected, the exact correlation of subdivisions with those of more distant regions is at present very incomplete.

They are seen in the bed of the stream striking parallel to the great fault which traverses the gorge of the Twis or Greet below Thornton Force, as described above.*

The part of the series here exposed consists of a shale with layers of lenticular concretions of limestone. The lower beds are concealed by masses of drift and torrent *débris*—and that which is seen is so much crushed that all traces of fossils have been mostly obliterated, while the few that are found are generally so obscure to be almost unrecognisable.

However, there are fossils in it, and when the zones of the Bala Beds of this district come to be worked out in detail there may be enough palæontological evidence here to determine the exact horizon.

Sedgwick records the following fossils as having been found here near the upper dyke :—*Stenopora* (*Favosites*) *fibrosa* Gold., *Halysites*

* Proc. Yorks. Geol. and Polytec. Soc., Vol. XIV., pp. 146, 147. See Section Fig. 6.

catenularia Linn., *Orthis actoniæ* Sow.; to these I may add a *Petraia* (*Streptelasma*) *æquisulcata*. Near Twistleton Manor House the Coniston Limestone is seen in a roadway very much crushed and traversed by veins of calcite. It has evidently been much altered here and has a brown, earthy character, being probably dolomitized.

It crosses Dale Beck east of Twistleton Manor, but denudation has cut it down so much that it is generally covered by the alluvial gravel, except after a great flood, when portions are for a time left bare, or where baked portions are preserved in contact with the dykes, which stand out in reefs and buttresses having the same trend as those seen in the Greet.

A few small exposures among the roches moutonnées show that just south of Skirwith the same beds cross the eastern road to Chapel-le-dale and the stream below the farm.

At the lower end of Crina Bottom, whose waters drain into Jenkin Beck, there are shales and bands of concretionary limestone which weather into light, porous, gingerbread-coloured rock by the removal of the lime. These beds apparently dip at a high angle, but this is not clear, as there are only small exposures, and the beds deviate somewhat from the normal strike of the Coniston Limestone Series in the adjoining area, running E.N.E. and W.S.W. They are probably near a crush.

From this point for three miles to the south-west denudation has failed to reach down through the Mountain Limestone, on the upthrow side of the great fault, to the level of the Silurian and Bala. On the downthrow side of the fault the Mountain Limestone has nowhere been cut through.

As we have seen (p. 134) the base of the Carboniferous rocks is reached at different depths dependent upon the character of the underlying rocks, and the Bala shales seem always to have suffered more erosion than any of the other pre-Carboniferous rocks of the district. Therefore they have generally a greater thickness of Mountain Limestone above them. These depressions caused a larger gathering of subterranean waters in the fissured limestone, and thus valleys are apt to be opened up along them

in later times, and this again often results in their being deeply buried in glacial, alluvial, and terrestrial drifts. So that we have to study a very complex series of causes and effects to explain the present distribution of the exposures of these Bala beds. The ground-plan (Fig. 11) shows the relation of the Bala Beds and Silurian (Upper Silurian of Survey) to one another, and represents what we should see if all the Carboniferous and superficial deposits were swept off. Clapham Beck and its tributary torrent, Cat Hole Sike, have cut down to them, exposing a black shale with calcareous bands or nodules, and thin beds of limestone. Traces of fossils have been found in Cat Hole Sike, and it is probable that a small excavation in that watercourse would give an opportunity of collecting a sufficient number of species to determine the horizon.

Fig. 11.

GROUND-PLAN SHOWING RELATION OF SILURIAN AND BALA SERIES
BENEATH THE CARBONIFEROUS ROCKS.

The Mountain Limestone is faulted against them on the south, and, though the actual line of fault is not exposed, its position is seen above the footbridge at the north end of the lake in Mr. Farrer's grounds at Ingleborough, near Clapham, and a line of depression up the hill side probably marks its course. The Mountain Limestone gets more and more crushed as we follow it towards the waterfall, which represents very nearly the north wall of the fault. Above this the stream tumbles over a succession of ledges formed by bands of limestone in shale. These beds have yielded a considerable number of ill-preserved

specimens of common Coniston Limestone fossils. The cleavage is irregular, owing to the irregular texture of the beds, and also, perhaps, partly to movements subsequent to the cleavage of the rock, but it is generally from 50° to 70° S.S.W. The joints are not very pronounced, the most conspicuous being nearly at right angles to the strike.

Whether it comes to the surface continuously between Spring Valley Sike and Norber Sike under the heavy masses of drift below Robin Proctor's Scar, on the north side of Thwaite Lane, is a matter rather of inference than of direct observation. In the neighbourhood of Austwick, Crummack, Wharfe, and Wood-end, all within an area of about two miles north and south, by one mile east and west, we have the best sections of the upper part of the Bala Beds seen anywhere in this district. Their general distribution is shown on the plan (Fig. 11), and their relations to one another and to the overlying formations are shown in sections.

There is no exposure of the underlying Green Slate series in this area unless we suppose that some of the shales south of Wharfe may represent it, being muddy sediment deposited further away from the focus of volcanic eruption; but the occurrence near Horton in Ribblesdale of Green Slates of the same character as those of Chapel-le-dale goes against this suggestion, while the beds of coarse tuff seen in the shale in Wharfe Mill Dam and elsewhere in that neighbourhood show that the products of eruption still reached this area either directly from the crater or drifted as ordinary sediment from unconsolidated cones of volcanic ash.

A very instructive traverse may be made by turning into Norber Sike at the Sheepfold by the bend of the road from Austwick Town Head to Norber Brow. The Bala shales can be followed almost continuously along the stream to the spring thrown out at the base of the Mountain Limestone. They consist of a strongly-cleaved calcareous mudstone, yet not so evenly cleaved as to yield slates.

In the upper part of the section bands of flat concretions of limestone lie with their larger surfaces adjusted to the cleavage

planes. These represent part of the Coniston Limestone. From this point the basement bed of the Mountain Limestone runs nearly east for about $\frac{1}{8}$ mile. If we leave it here where it turns to the north and cross the field in a south-westerly direction, a distance of about 150 yards, to where the road to Crummack takes the corresponding turn to the north, we find a road-cutting in the shale from which during several excursions my party have collected a large number of well-preserved fossils. It was here—about the middle of the cutting—that Mrs. Hughes found the first specimen of *Dindymene* recorded from this district.

The fossils* found in this cutting, which we will refer to as the Norber Road Section, are:—

- Diplograptus* (like *pristis* His.).
- Diplograptus truncatus* Lapw.
- Dicellograptus anceps* Mch.
- Stenopora* (*Favosites*) *fibrosa*.
- Tentaculites anglicus* Salt.
- Ateleocystites* sp.
- Agnostus trinodus* Salt.
- Ampyx nudus* Murch.
- A. rostratus* Sars.
- Staurocephalus* (*Sphærocoryphe*) *unicus* Thom.
- Trinucleus seticornis* His.
- Dindymene Hughesiæ* Roberts.
- Cybele Löveni* Linnrs.
- Lichas laxatus* M'Coy.
- Turrilepas* sp.
- Phacops* (*Pterygomætopus*) sp.
- Phillipsinella parabola* Barr.
- Leptæna transversalis* Wahl.
- Leptæna sericea* Sow.
- Orthisina* sp.

* Cf. Marr, Rept. Brit. Assoc., 1881, p. 650; Proc. Yorkshire Geol. Polytec. Soc., N.S., Vol. VII., p. 397; Geol. Mag., Dec. III., Vol. IV., No. 1, 1887, p. 35; ib., Vol. IX., No. 333, p. 97. Reynolds, Geol. Mag., Dec. IV., Vol. I., p. 108.

The Norber Road beds strike in an east-south-easterly direction, but the wide extent of ground from north to south over which the series here extends, and the high angle of dip, suggest that, unless it has a much greater thickness than we are justified in believing, the beds must be repeated by folds. Accordingly we find that instead of the north-north-easterly dips of the Norber Road section and of the Sike head, we have south-south-westerly dips further down the Sike and along Wharfe Gill Sike, near Woodend, where all the fossils found, namely, *Atleocystites* sp., *Phacops* (*Pterygomotopus*) sp., occur also near Staindale, in the Norber Road Section. Further north, also along Crummack Lane, southerly dips prevail. An anticlinal

Fig. 12.

- a. Striped sandy shale.
- b. Conglomerate.
- c. Cleaved mudstone.
- d. Felspathic ash-like beds, similar to those seen south of the barn in the field on the west.

fold is seen also west of Wharfe Mill Dam between the two barns, and another in the bed of the stream north of the Dam House Bridge Fault (see below). Although, therefore, the true dips are not so easy to detect in the Bala beds as in the overlying Silurian, still it can be made out that the beds are thrown into large spoon-shaped anticlinals and synclinals, with smaller adjustment folds and faults on the margin.

As the result of this the calcareous shales in which *Trinucleus* is fairly common, and which we saw striking in a south-south-easterly direction at Norber Brow, are thrown off to the north and south by the time we reach Crummack Beck, where

older beds of the series are brought up in the anticlinal arch, as seen between the two barns near Dam House Bridge (Fig. 12) and in Wharfe Mill Dam (Fig. 13). These older beds consist of mudstones which break into larger prism-shaped fragments and slabs than the overlying calcareous shales. There are also beds of fragmental felspathic and other rocks such as are usually called volcanic ash, but whether they are lapilli showered down into the sea directly from eruptions or only the waste of distant still unconsolidated beds of volcanic ash distributed over the sea bottom it is impossible now to tell.

Fig. 13.

- a. Striped sandy shale not much cleaved.
- b. Conglomerate not well seen in the line of this section.
- c. Cleaved shale with subordinate calcareous band.
- d. Felspathic ash-like beds and yellow porcellanous rock with subordinate black bands, one very conspicuous. These are probably the beds seen under the bridge.
- e. Slate strongly cleaved 70° S.S.W.
- f. Felspathic, speckly, ash-like beds exposed at the gate for a horizontal distance of about 8 feet.
- g. Very tough, granular, crystalline rock, with small sago-like grains of transparent quartz, about 10 inches seen.
- h. Limestone, with a knobby, irregular surface, about 2 feet seen.

The strike of *e*, *f*, *g*, *h* is clear, but not the dip; indeed, it may be that between this and the barn we have crossed the axis of the fold, and that we are already on the southern limb of the anticlinal.

Fossils occur both in the mudstones and in the ash, and especially in the intermediate rock in which there is a mixture of the ash and mud. The fossils found here are *Calymene blumenbachii* Brongn., *Illænus davisii* Salt, *Trinucleus seticornis* His., *Leptaena transversalis* Wahl., *Strophomena*. The large *Strophomenas* are so conspicuously the most abundant form that, although they are not

peculiar to this horizon, they characterise it by the numbers of individuals in proportion to other species, so that for convenience of local reference I formerly called these beds the *Strophomena* Shales. The same remarks apply also to the name *Trinucleus* Shale by which I referred to the overlying beds. Closer work will doubtless by-and-by divide the series into many palæontologically distinguishable zones.

The whole series is nipped out by faults near Wood Lane and is not seen again to the E.

The section is much complicated by a fault which may be seen crossing the stream a little above Dam House Bridge. The direction of this fault is slightly oblique to the strike of the Bala Beds, having a little more north and south in it, so that it brings the Silurian rocks against lower and lower beds of the Bala series as we follow it to the east-south-east. The beds of both series are similarly folded on the north or downthrow side of the fault, but, owing to the downthrow being on the north, higher beds of the Bala series are found in the tops of the anticlinal folds on the north side of the fault than are exposed in the corresponding and contiguous folds on the south of it. Thus in the stream close above the small waterfall which marks the exact position of and is due to the Dam House Bridge fault there is a small subordinate anticlinal which throws off the basement bed of the Silurian on either side, so that black shales are exposed between two bands of conglomerate, the one with a northerly, the other with a southerly dip (see Figs. 12 and 13). It is probable that this is a pre-Carboniferous fault.

In these black shales the following fossils have been found :—

Orthis testudinaria Dalm.

Strophomena siluriana Dav.

They therefore represent the highest beds of the Bala seen in this district, and are the equivalent of the *Strophomena siluriana* beds so largely developed in the tributaries of the Rawthey, especially in Sarley Beck, some 15 miles N.N.W. of Wharfe. It was on specimens collected in Sarley Beck that Davidson founded the species *siluriana*. In the Lake District their equivalent is seen in the shales of Ashgill, near Coniston.

About three-quarters of a mile north of the section near Wharfe which has just been described, where the principal feeder of Crummack Beck issues from the base of the Carboniferous rocks (see Plate L.), the stream has cut down on to the top of another anticlinal fold which brought Bala Beds within reach of recent denudation (Fig. 14). This interesting spot is known as Austwick Beck Head, from the name of the stream into which the water eventually finds its way, though the tributary which immediately receives it is known as Crummack Beck. Just below the junction of the stream from Austwick Beck Head and Moughton Sike the Coniston or Bala

Fig. 14.

DIAGRAM ILLUSTRATING THE MODE OF OCCURRENCE OF THE STRATA
AT AUSTWICK BECK HEAD.

- a.* Mountain Limestone.
- b.* Basement bed of the Mountain Limestone.
- c.* Silurian.
- d.* Basement bed of Silurian.
- e.* Bala Shale and Limestone.

Limestone is seen dipping south. It is at the surface in Moughton Lane with a similar strike and under the Mountain Limestone scar on the east is again seen dipping south at about 50°.

Close to the keld or springhead the basement bed of the Silurian is exposed resting on the Bala Shale. This section is not very clear owing to the creep-forward of the basement bed of the Carboniferous for some distance down the side of the stream; in fact, we have here an example of the occurrence of a depression along the outcrop of the Bala Beds which I referred to above (p. 331). It is increased somewhat in this case by a crush and some faulted ground along the

Photographed by Godfrey Bingley, Healdingkey, Leeds.

AUSTWICK BECK HEAD, GRUNMACK DALE.

Proc. Yorks. Geol. and Polytec. Soc., Vol. XIV., Plate L.

junction between them and the more tough and unyielding Silurian. The depression in the pre-Carboniferous surface was filled with limestone and conglomerate, and, moreover, as usual in the case of the deeper hollows, caused the conglomerate to be made up almost entirely of fragments of the underlying rocks, so that it is easily confounded with the thin line of basement bed of the Silurian which is also composed of fragments of the Bala series. As the subterranean denudation of the Mountain Limestone went on this depression determined that the spring should come out here, and resulted also in this deeper portion of the basement bed of the Carboniferous being prolonged further out into the valley. A little care, however, and, after floods, a little clearing of the torrent *débris*, enables us to distinguish and work out the relations between the two basement beds.

In Ribblesdale, the next valley on the east, the Coniston Limestone series is exposed at Crag Hill and west of the village of Horton. The section at Crag Hill is full of interest for the stratigraphist and palæontologist, and would well repay careful detailed work. The beds are brought to the surface by a sharp anticlinal fold, the axis of which runs about 10° S. of E.

The fall of the ground to the east is greater than the inclination of the anticlinal axis in the same direction, and therefore we find higher and higher beds of Bala series as we ascend the hill, and at last see the Silurian beds folding over the Bala series 100 feet or so below the base of the Mountain Limestone, as shown in the diagrams (Figs. 15, 16, 17) in which are given a ground plan (Fig. 15), a section along the axis (Fig. 16), and another at right angles to it (Fig. 17).

Behind and above the farm there is a fine section exposing a large cliff of limestone and calcareous shale split off so as to expose the upper face of the rock. On this numerous well-preserved specimens of characteristic Bala fossils were to be seen weathered out. Most of the more obvious of these have been long ago collected, but plenty may still be found with a little care and trouble. The following is a list of those determined :—

Heliolites interstinctus Wahl.

Stenopora (Favosites) fibrosa Goldf.

Petraia (Streptelasma) æquisulcata M'Coy.

B

Fig. 15.

Fig. 16.

Fig. 17

Cheirurus bimucronatus Murch.
Cybele verrucosa Dalm.
Illænus bowmanni Salter.
Phacops ? obtusicaudatus Salt.
Discina.
Leptæna sericea Sow.
L. transversalis Wahl.
Lingula ovata M'Coy.
Orthis Actoniæ Sow.
Orthis biforata Schloth
Orthis calligramma Dalm.
Orthis elegantula Dalm.
Orthis flabellulum Sow.
Orthis vespertilio Sow.
Rhynchonella.
Strophomena grandis Sow.
Modiolopsis antiqua Sow.
Murchisonia.

The grey crystalline limestone (e) is taken for the present at any rate as the basement bed of the Silurian, and will be described by-and-by.

The Coniston Limestone and Shale are again seen a short distance north-east of Horton-in-Ribblesdale. The stream issuing from the Mountain Limestone in Dow Gill, about 100 yards below its source, has cut through the basement beds and exposed the green slates dipping at a high angle a little west of south. They are followed in apparently conformable succession by the Coniston Limestone and Shale which are here highly fossiliferous. About 150 yards down stream they begin to turn up to a fault thus lying in a broken synclinal.

S U M M A R Y .

THE ARENIG SERIES.

This forms the base of the group, and in the typical areas of North Wales and the Lake District consists of black shales, here and there more sandy or streaked with sandy layers. It has a very distinctive fauna, with indications in the upper part of the commencement of

volcanic outbursts somewhere not far off. At the base there is sometimes a coarse grit.

In the Lake District, where this division is well developed, its base and its top are still not well defined. Around Ingleborough it is not represented at all, unless it may be among the lowest parts of the volcanic series of Chapel-le-dale.

In all such questions of correlation it must be borne in mind that volcanic accumulations are from the nature of the case of more limited extent than ordinary muddy or sandy sediment, and that among them we must expect to find, though we cannot often hope to identify with certainty, synchronous beds of very different character in closely adjoining areas. This is what Whewell* referred to in his remarks upon "Geological Equivalents," and what was further developed afterwards under the head of "Homotaxis."

THE BALA SERIES. Volcanic Stage.

The great masses of green and grey slates, and grits and brecciated conglomerates of Chapel-le-dale, are referred to this horizon from their similarity to the Borrowdale beds of the Lake District, and because of their constant occurrence below the Calcareous stage of the Bala series, the horizon of which is determined by abundant fossil evidence.

THE BALA SERIES. Calcareous Stage.

This is the horizon of the beds, the distribution and character of which I have been describing in this part of my paper.

There are three places where the fossils are numerous and well-preserved, and the relative position of the beds can be made out—

1. The stream courses north and east of Horton-in-Ribblesdale (see p. 341).
2. The slope west of Crag Hill up to the base of the Mountain Limestone (see p. 339), and, best of all,
3. The area which lies across the southern end of Crummack Dale, between Austwick and Wharfe Gill (see p. 333).

Other areas have been mentioned above, but in them either the exposure is so small or the beds are so crushed that the sequence is obscure and the fossils generally unrecognisable.

* Op. cit.

My aim in this paper is to offer some notes which may be helpful to the field geologist on and around Ingleborough, and with that view I will conclude this part of it with a few practical hints.

These are the most easterly exposures of the upper portion of the Bala Beds to be found in this district. It is a variable series, and some knowledge and experience would be required in order to establish the true sequence in each area and correlate the several zones exposed in the different sections. But if anyone wants a very interesting and useful, though difficult, piece of work to do let him make out the details of the above three areas, stratigraphically and palæontologically, zone by zone. It will take a long time to do it properly, but it is not one of those heart-breaking districts where no definite results follow long and careful work. There are plenty of exposures and plenty of determinable fossils, and it only requires careful observation of the succession and discrimination of exact horizons where fossils have been found. In such cases all the specimens should be fully labelled in the field.

I gave many years ago in the Proceedings of this Society* and in the Geological Magazine,† a tentative classification, which I think still holds good as far as it goes, but I never visit the district without learning something new about it.

Now as to the best centres to work from. The village of Horton-in-Ribblesdale is close to the two first-named areas, or, if a more luxurious base of operations is preferred, the train from Settle will set the traveller down and pick him up at Horton Station.

For the third area Austwick or, but little further off, Clapham are most convenient.

If the home-life and folk-lore of the people interest our geologist, let him try to get taken in at one of the farmhouses that lie nestled in the snuggest corners of this margin of the Fells, and I feel sure that, if he is a man of the right sort himself, he will carry away with him a pleasant picture of the best side of old English country life.

(To be continued.)

* Proc. Geol. Polytech. Soc., W.R. Yorkshire, 1867, p. 565.

† Geol. Mag., Vol. IV., Aug., 1867, p. 346.