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Richard Richardson, Licentiate of the Royal College of Physicians of Edinburgh, Rhayader, Radnorshire, and John Wickham Flower, Esq., Park Hill, Croydon, were elected Fellows.

The following communications were read :—

1. *On the SKIDDAW SLATE SERIES.* By R. HARKNESS, Esq., F.R.S., F.G.S., Professor of Geology in Queen's College, Cork. *With a Note on the GRAPTOLITES,* by J. W. SALTER, Esq., F.G.S., A.L.S.

CONTENTS.

1. Introduction.	4. Carrock- and Caldbeck-fells.
2. The Skiddaw Slates of the west side of Derwentwater, Bassenthwaite, and Binsey Crag.	5. The Skiddaw Slates of the eastern margin of the Lake-district.
3. The Skiddaw Slates east of Derwentwater and Bassenthwaite Lakes.	6. The Skiddaw Slates of Black Comb.
	7. Conclusion.

§ 1. *Introduction.*

THE several memoirs by Professor Sedgwick on the older Palæozoic rocks of the north of England, published in the 'Transactions' and 'Quarterly Journal of the Geological Society,' have indicated the nature and the arrangement of the older Palæozoic rocks as they occur in the Lake-district. Among these rocks, and forming the

base of the sedimentary series in the north of England, is a mass of strata designated the *Skiddaw Slates* by Professor Sedgwick, from the circumstance that these slates comprise the Skiddaw range of mountains. They have hitherto been regarded as all but unfossiliferous, the described organic remains consisting only of *two* species of *Graptolites* and *four* forms which have been attributed by Professor M'Coy to Fucoids.

The Skiddaw slates occupy a large area in the northern portion of the Lake-district. They also occur in the south-western extremity of Cumberland, where they form the mountain of Black Comb; and they are seen in Westmoreland on the eastern margin of the Lake-district, exhibiting themselves in *three* small patches. The object of this memoir is to point out in detail the circumstances under which they occur in their several areas, and to show that they are more fossiliferous than they have hitherto been regarded, and also to point out their equivalents elsewhere.

§ 2. *The Skiddaw Slates of the West Side of Derwentwater, Bassenthwaite, and Binsey Crag.*

The Skiddaw slates on the west of Derwentwater and Bassenthwaite Lakes, and Binsey Crag, form a portion of the area where they exhibit themselves in their greatest development, both geographically and geologically. The south-eastern boundary of this western part of the Skiddaw slates of Cumberland runs from the lower end of Derwentwater, by the Cat Bells, through Newlands to the head of Crummock-water. From thence it continues westward, and then, passing by the lower end of Ennerdale Lake, turns south-westward round the base of Dent Hill.

The western margin of this area is marked by the Carboniferous rocks of West Cumberland; and these rocks, in their eastern extension from Cockermouth, run along the northern edges of Binsey Crag and Caldbeck-fells, forming the northern limit of the older rocks of Cumberland.

The eastern boundary of the district under consideration is formed by the lower portion of Derwentwater, the River Derwent, Bassenthwaite Lake, and the ridges extending to Binsey Crag.

Commencing at Newlands, on the southern border of the Skiddaw slate area, we have, in the hills which lie south of Newlands, the greenish-grey rocks, containing lead-veins, which appertain to the series immediately overlying the Skiddaw slates. On crossing the Newlands valley northwards, the Skiddaw slates make their appearance at the southern base of the ridge of hills which contains Aiken Knot and Keskadale Knot. The strata here dip S.S.E., passing under the greenish-grey rocks, and consist of hard, slaty, grey shales, with interstratified coarser beds not exhibiting the same amount of cleavage as the finer deposits. On the north side of Keskadale Knot there are considerable masses of *débris* which have fallen from the outcrop of the Skiddaw slates. This *débris* is locally called "Scree," and among its fragments containing fossils are found. These "Scree" occur also on the south side of Keskadale Knot, and yield the same fossils as those

Fig. 1.—Map of the Skiddaw Slate District.

of the north side of this hill, viz. *Graptolites sagittarius* and a branching Graptolite. Tracks likewise are seen on the surfaces of some of the more flaggy strata.

On their strike, the rocks of Keskadale and Aiken Knots extend W.S.W. through Whiteless to the head of Crummock-water. At Whiteless they have afforded Professor Sedgwick *Graptolites latus* and *Chondrites informis**. From their position, and the relation which they have to the greenish-grey beds, the rocks of Keskadale Knot and Aiken Knot are among the highest of the Skiddaw slate series.

Fig. 2.—Section from Newlands to Sunderland (11 miles).

Northwards from the ridge just alluded to there occurs another, of which Causey Pike forms the highest summit, and in which a great development of slaty rocks is found. A short distance to the north of Causey Pike, and forming the southern side of the Coldale valley, is a lower ridge than that of which Causey Pike forms a part.

A portion of this ridge is known under the name of Outerside, and in its northern and more precipitous slope, facing Coldale, there is a considerable development of "Screes" under a rocky escarpment. The lower portion of this escarpment consists of cleaved rocks, the dip of the *cleavage* being N.W. Above these cleaved rocks flaggy strata are seen, dipping S.S.E. 30°. Among the "Screes" derived from the flaggy rocks fossils occur, and this is one of the localities among the Skiddaw slate series which, both in quantity and variety, is most prolific in organic remains. These fossils consist of Crustaceans, several forms of *Graptolites*, including the branching form which is seen at Keskadale, tube-like bodies apparently allied to the modern *Terebella*, and tracks.

East from this, at Hodgen-holm, near Portingscale, rocks of a flaggy character also occur, which, besides dipping S.S.E. at a high angle (60°), also contain evidences of animal life, usually in the form of tracks.

The Coldale valley, which lies N. of Outerside, affords no satisfactory dips among the strata, the rocks being for the most part of a slaty nature. North of this valley, inclinations are seen among the

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strata having an opposite direction from those on the south side, viz. N.N.W.

This valley seems to indicate the position of a well-marked anticlinal extending, in a W.S.W. direction, through the Skiddaw slates which lie to the westward. At Barff, which is situated near the head of Bassenthwaite, on the west side of the lake, these N.N.W. dips are very apparent. The south side of this hill, from the base for a considerable extent upwards, is covered with "Screes" composed of fragments of slaty rocks mixed with fragments of coarser flags, and with the outcrops of the Skiddaw slates well seen above them. These outcrops consist of slaty rocks interstratified with flaggy beds; and while the faces of the former are perpendicular, from the rocks exfoliating along the cleavage-planes, the latter have a regular N.N.W. dip at an angle of about 30° .

The "Screes" of the hill of Barff, like those of Outerside, afford abundance of fossils of a nature similar to those of the latter locality. Some of the fossils which occur at Barff were obtained by Professor Sedgwick at Scawgill, in Whinlatter-fells, which is immediately on the strike of the Barff strata.

These Scawgill fossils consist of *Graptolites sagittarius* and *G. latus*; and at Kirkfall, near Scawgill, *Palæochorda major* is found*.

The position and mode of occurrence of the fossiliferous strata of Outerside and Barff show that they are the representatives of the same zone on opposite sides of the anticlinal already alluded to, and their proximity to this axis leads to the conclusion that their horizon is low down in the Skiddaw slate series.

Northwards from Barff slaty rocks without very definite bedding occur. On approaching Wythop-fell from the south, the flaggy beds, having S.S.E. dips, again begin to make their appearance among the more slaty rocks. On the west side of Bassenthwaite Lake, a short distance south of the landing-place, near the Pheasant Inn, the flaggy beds with S.S.E. inclinations are seen intercalated among the slaty rocks; and immediately contiguous to the landing-place a thick mass of slate makes its appearance, underlying the flaggy rocks. On the northern escarpment of Wythop-fell, a short distance west of the Pheasant Inn, the slaty rocks with the intercalated flags are well seen, dipping S.S.E. 30° . There is every reason for inferring that the flaggy rocks seen here are the representatives of the fossiliferous strata of Barff and Outerside, and their opposite inclination to those of Barff shows the occurrence of a synclinal axis between the latter locality and Wythop-fell. North of Wythop-fell is the Embleton valley, which is about a mile wide, extending westward from Bassenthwaite Lake to the valley of Lorton, and is occupied by till and soil, exhibiting no rock *in situ*.

* Barff, being only five miles from Keswick, and close to the high road leading from thence to Cockermouth, is by far the most accessible locality in the Lake-district for obtaining Skiddaw slate fossils. In such profusion do they occur here, that in the course of an hour I obtained a bagful. There is also a comfortable small inn, called "The Swan," at the base of Barff.

Besides the localities alluded to as furnishing Professor Sedgwick with fossils, there occur, S.W. of the places named, other localities in the area under consideration which also afforded him organic remains. At Knockmurton-fell *Graptolites latus* and *G. sagittarius* have been found. Here the dip of the Skiddaw slates, which are hard and flaggy and of a grey colour, is W. ; but this is a local dip. In this locality the Skiddaw slates yield iron-ore, one vein of which, about five feet in thickness, striking N. and S., and with an inclination towards the E., is here wrought.

To the east of this, at Blake-fell, Professor Sedgwick also obtained *Paleochoorda minor*; and at Lowes-fell, on the north side of Lowes-water, he mentions *Chondrites acutangulus* as occurring. Besides this, I have found here *Diplograpsus pristis*. The general dip of the strata in this part of Cumberland is N.N.W., and some of the fossiliferous rocks are on the line of strike of the beds of Barff and Whinlatter-fell. The anticlinal axis, previously mentioned as traversing the country W.S.W. from Coldale, seems to run to the southward of these fossiliferous rocks, and to cross Mellbreak, which is situated on the west side of Crummock-water, and is a hill having S.S.E. dips on its southern flank. In proceeding northwards from Crummock-water, down the Vale of Lorton, the mountains on both sides of this valley are made up of strata which correspond and conform with those on the west side of Bassenthwaite Lake, and are an extension W.S.W. of the rocks of that locality. There is an abundance of "Screes" on the flanks of the mountains on both sides of the Vale of Lorton, and also on Mellbreak, which would doubtless afford abundance of fossils if they were well examined.

On the north side of the Embleton valley are seen ridges of comparatively low hills, separating this valley from the vale of the Derwent. On the south side of these ridges there occurs at Lambfoot-fell a syenite which, when well exposed in its interior, is seen to be made up of very distinct crystals, but which near the outer margins becomes fine-grained and more trappean in its aspect. In this latter condition it is seen at the farm of Crag, near Bassenthwaite Lake, and eastward from Lambfoot-fell on its line of strike. Immediately north of this syenite, at Lambfoot-fell, are seen hard, flaggy Skiddaw slates, dipping N.N.W. 20°.

This inclination is the reverse of that which occurs on the opposite or south side of the Embleton valley, and indicates the presence in this valley of another anticlinal axis, parallel to the one which manifests itself to the southward. The Skiddaw slates of Lambfoot-fell incline towards a small valley separating this hill from the Hay, which forms part of another ridge north of the Lambfoot-fell range. In the Hay the Skiddaw slates are of a similar nature to those of Lambfoot-fell, and also have the N.N.W. inclinations. East from the Hay the ridge becomes higher, and forms Dunthwaite-fell, where, at Elba Plains, there are the same hard, grey, flaggy rocks, with intervening slaty beds, as seen at the Hay. Here also the dip is N.N.W. 35°, and the rocks, as well as the hill, slope away towards the River Derwent.

The rocks north of the Embleton valley differ somewhat in their mineral character from the Skiddaw slates which lie south of this vale, being harder, of a lighter colour, and having a greater affinity to the greywacke sandstones and shales of the Southern Highlands of Scotland.

North of the River Derwent, in the district between this and the margin of the Carboniferous rocks, the country is comparatively flat, and no good exposures of rock occur. In the course of a stream called Scalegill, which flows from the west side of Binsey Crag into the Derwent, there are seen at intervals small exposures of rock *in situ*. Several of these occur in the course of this rivulet through the flat moory country which lies between Binsey Crag and Sunderland, and exhibit soft black shales, considerably contorted, resembling the Skiddaw slates as they occur in the small areas of Westmoreland, rather than the rocks lying westwards of Bassenthwaite Lake and Derwentwater. Although considerably contorted, the prevailing inclination in this most northerly district of Skiddaw slate is N.N.W., and on the northern margin of this moory tract the Carboniferous formation makes its appearance, as seen at Sunderland.

With reference to the section extending from Newlands on the south to Sunderland on the north (fig. 2), no fossils have been obtained from that portion of the Skiddaw slates which lies north of the Embleton valley. There is, however, every reason to believe that, when the rocks in this portion of the area have been carefully examined, they too will furnish the same organic remains as occur in the strata lying on the south side of this valley. In the more southern portion of the area under consideration, the mode in which the rocks occur and the localities in which the fossils are found justify the conclusion that, notwithstanding the cleaved character of the great mass of the deposits, there are strata in which this structure is only very imperfectly developed, and which possess a well-marked flaggy nature. These flaggy beds occur at intervals through the whole of the Skiddaw slate series; and, wherever they present themselves, they yield fossils which are identical throughout the series, marking these deposits as palæontologically the same through the whole of the group.

§ 3. *The Skiddaw Slates of Cumberland, east of Derwentwater and Bassenthwaite Lakes.*

The north-eastern portion of the Lake-district is occupied by an extension eastwards of the Skiddaw slates which occur in the area already described. This portion has for its western boundary the eastern limits of the district just alluded to, being flanked on this side by the northern end of Derwentwater, the River Derwent, and Bassenthwaite Lake. Its northern boundary is the porphyritic rocks of Caldbeck-fells. On the east it is margined by Carboniferous rocks which skirt Carrock-, Bowscale-, and Mungrisdale-fells; and on the south the greenish-grey rocks which occur north and west of Matterdale, forming the northern flanks of Great Dod, White Pike, and Wanthwaite Crag, and, extending from the entrance into the

Vale of St. John westward to Keswick, bound the Skiddaw slates of this portion of Cumberland.

The southern portion of this area rarely exhibits the rocks *in situ*. The Skiddaw slates in this district occupy Flascow Moor, a large tract of barren country lying between the Keswick and Penrith Road on the north, and the base of the hills just referred to on the south. Two streams, having their origin among the greenish-grey rocks on the south, intersect this moory district in their course to the Glendermaken River, which flows into the Greta near Threlkeld. The most easterly of these streams, called Troutbeck, after passing over the greenish-grey rocks, reaches the moory country, and begins to exhibit in its course the Skiddaw slates. In a small brook which flows into Troutbeck from the west, these slates are considerably contorted, but have predominant S.S.E. dips. A short distance above the hamlet of Troutbeck this inclination is well seen, the angle being 40° ; and a gritty quartz-rock, strongly impregnated with iron-pyrites, is here seen associated with the Skiddaw slates. For a considerable distance below this hamlet, through the moor, no exposures of rock occur; but when the stream reaches near to the Keswick Road, parallel to which it flows for some distance, we have good sections of the Skiddaw slates, principally on the line of *strike*. The stream in this portion of its course is called Gills-beck, and here the Skiddaw slates, which are thin-bedded and of a dark colour, have prevailing N.N.W. dips. Intercalated with the strata are masses possessing the structure known as cone-in-cone, a feature which accompanies the Skiddaw slates in some other localities. In some portions of this section there are great contortions in the bedding, and quartz-veins are abundant, running along the lines of the contortions.

Fig. 3.—Section from Matterdale to Uldale (12 miles).

Westward from this stream we have the Skiddaw slates exhibited in the course of another brook, which also traverses Flascow Moor from the south. This, which is known as Mosedale-beck, rises from the northern flank of Great Dod, and its upper portion is likewise over the greenish-grey rocks. The junction of these with the Skiddaw slates in the course of this brook is not seen, in consequence of

the peaty nature of the country at the base of the crags of the greenish-grey rocks. Below this peaty interval the Skiddaw slates occur, and are seen in Mosedale-beck, consisting of contorted black shales, like those of Gills-beck, having the cone-in-cone masses imbedded among them.

The Skiddaw slates in the course of this stream have a prevailing N.N.W. inclination. They yield *Graptolites sagittarius* *.

The interval of country between the Keswick Road on the south and the Glendermaken River on the north affords no exposures of rock. In the Glendermaken, as it flows along the eastern base of Souter-fell and south from Mungrisdale, the Skiddaw slates, of a dark colour, are seen at intervals dipping S.S.E. At Mungrisdale these Skiddaw slates are worked, and have a well-marked cleavage; but the surfaces of some of the strata very frequently show distinct tracks. Tracks similar to those of Mungrisdale also occur at Two-seats, near Threlkeld, on the south base of Saddle-back, which is on the line of strike of the Mungrisdale beds. The strata at Mungrisdale, some of which are flaggy, dip towards the S.S.E. at 55°.

With reference to the Souter-fell ridge, which lies between Mungrisdale and Saddle-back, on its south side it has a very regular slope, while on the north side it is more abrupt and marked by escarpments, from which results a considerable development of "Screes."

Among these "Screes," tracks are found resembling those of Mungrisdale, and the rocks which produce the "Screes" dip S.S.E. about 30°. On the opposite side of the valley of the Glendermaken, north of Souter-fell, the ridge known as Bannerdale-fell is seen. In the south spur of this ridge a considerable mass of chialstolite-slate makes its appearance, and has been extensively wrought here.

The first appearance of this mineral in the Skiddaw slates is marked by the occurrence of chialstolite in the form of very small dots, and some of the rocks so marked contain tracks. Following the southern spur of Bannerdale-fell northwards, the chialstolite is seen to become more abundant, and, on the higher portions of the hill, obtains to such an extent as to constitute chialstolite-rock; and rocks of this nature form the ridges which occupy the southern side of the Caldew valley. A southern spur from Bowscale-fell, called Tongue, parallel to the southern spur of Bannerdale-fell, exhibits similar rocks to those just described.

Following the Glendermaken, between Souter-fell and Bannerdale-fell, to its source, tracks occur, on the south-west flank of Bannerdale-fell, in the unchanged Skiddaw slates which dip S.S.E. Towards the north these slates become more black and glossy, and have spots of chialstolite in them. A short distance brings on the chialstolite-slates, and at the summit of the low ridge connecting Bannerdale-fell and Saddle-back the chialstolite-rock occurs.

* The streams which intersect Flasow Moor cut through a fine mass of glacial *débris*, consisting of sandy clays containing imbedded boulders of the several rocks which occur in the northern portion of the Lake-area. These boulders are often very beautifully striated; and on the surface of the moor large erratic blocks are very common.

From this ridge northwards, in passing into the Caldew valley, a still greater exhibition of the metamorphic changes produced on the Skiddaw slates by the influence of the granite of the Caldew valley is seen. In Black Hazel-gill, a stream which flows from the north side of Saddle-back into the River Caldew, the following changes in the metamorphic rocks occur. In the higher portion of the stream chistalite-rocks are found; below these there comes on dark-coloured hornblendic rock, which passes downwards into hornblendic gneiss, and in some cases into mica-schist, the whole dipping S.S.E.; and, in the bed of the Caldew, granite appears. A similar sequence of metamorphic rocks is seen in the course of other streams which flow from the southern ridges of the Caldew valley.

Professor Sedgwick has described a nearly similar sequence of metamorphic rocks as occurring on the south side of the Caldew valley.

On crossing the area occupied by the granite of the Caldew valley, and following the course of the streams which flow from its northern slope, we have the metamorphic series of the Skiddaw slates, but not so well developed on the north side of the River Caldew as on the south.

Wiley-gill is one of the tributaries of the Caldew from the north, and enters this river a short distance above the junction of Black Hazel-gill, flowing from the south. The lower portion of Wiley-gill is over granite, which forms the south base of the hill on its eastern side.

This granite is not seen in the stream, the lowest rocks shown *in situ* having a gneissose character; but the exposures of rock in this brook are by no means good. At the junction of a small stream which joins Wiley-gill from the east, slates having a chloritic nature are seen dipping S.S.E. at a high angle; and at the head of Wiley-gill rocks of nearly the same nature occur, having a glossy aspect and a light-grey colour. Here they are almost vertical, but still the prevalent dip is S.S.E.

On crossing over the watershed at the head of Wiley-gill, northwards, there is the head of a stream called Whitehouse-gill; ordinary Skiddaw slates of a grey colour, having a vertical cleavage and a well-shown S.S.E. inclination of 30°, here present themselves. The south side of the hill called Burn Dod, forming the northern side of the valley drained by Whitehouse-gill, is covered with small blocks of a coarse, gritty character, containing occasionally fragments resembling Skiddaw slate. Similar coarse rocks are alluded to by Professor Sedgwick as occurring in the mass of Skiddaw. At the south-west base of Burn Dod, Whitehouse-gill is joined by Frozen-gill, flowing from the north-east; and the hill called Cockup-fell, lying on the north side of this stream below the junction, exhibits the mode of association of the grits, which are seen covering the south side of Burn Dod, with the Skiddaw slates. On the south-west side of Cockup-fell, where these gritty beds have been wrought, they are seen interstratified with the Skiddaw slates, and dipping at a high angle towards the S.S.W. On the east side of Cockup-fell and in

the lower portion of Frozen-gill, these grits also occur under like circumstances.

In following up Frozen-gill to its source, the Skiddaw slates are well seen; they consist of grey beds considerably contorted, but with prevailing S.S.E. dips; and on both sides of the stream abundance of "Screes" occur, from which Graptolites were procured, including the branching form before alluded to, and also tracks.

North of the head of Frozen-gill, on the opposite side of the watershed, is the source of the Ellen, the river which enters the sea at Maryport. The banks of the stream, at its highest part known as Ellen-gill, afford exposures of rocks *in situ*, consisting of grey Skiddaw slates also dipping S.S.E.; and on following down its course, as it flows between Lowthwaite-fell and Mell-fell, the Skiddaw slate is again seen, dipping S.S.E. 35°.

There are numerous "Screes" on the sides of this stream yielding ordinary Graptolites and the branching form, the latter in considerable abundance*. The Skiddaw slates prevail down Ellen-gill for a considerable distance, when they are succeeded by rocks of a trappean nature, as these are exhibited in the enclosed ground on the north side of Lowthwaite-fell. East from this, at the head of Red-gill, and partially also at the head of Silver-gill, the Skiddaw slates make their appearance†.

The western side of the district of the Skiddaw slates under consideration is well seen among the rocks forming the western skirts of Skiddaw. In this portion of the district, to the north of a thick mass of quartz-veins known as "White Stones," above a plantation on the south-west side of Skiddaw, there is an escarpment of flaggy rocks; they dip S.S.E. 30°, and are associated with cleaved strata. Beneath this escarpment "Screes" are found which furnish *Graptolites sagittarius*, *G. tenuis*, *Diplograpsus pristis*, *Tetragrapsus* (the branching Graptolite before referred to), Crustaceans, Annelid-tubes, and tracks.

The whole of the fossils here have a great resemblance to those of Outerside, on the opposite side of Bassenthwaite Lake, and the position of the rocks here shows that they are an extension E.N.E. of the strata of that locality. Northwards from the escarpment of the south-west of Skiddaw, along the eastern skirts of the Dod-fell, although cleavage with a north-west inclination greatly prevails, the direction of the dip of the strata is on the whole S.S.E.; and the same dip may be seen on the road along the western base of Dod-fell, between Bassenthwaite and Keswick.

North of Dod-fell, which is the western spur of Skiddaw, on the side of the hill immediately north-east of Mirehouse, another escarp-

* On merely passing over the "Screes" of Frozen-gill and Ellen-gill, I found the fossils alluded to in considerable quantities, especially in the latter locality. There is every reason to infer that if these "Screes" were well examined, they would afford numerous fossils, some of which might probably prove to be new.

† Red-gill is the only locality in England which affords the rare mineral caldonite—the cupreous sulphato-carbonate of lead. This, however, is not obtained from the Skiddaw slates, but in igneous rocks occurring here which will subsequently be alluded to.

ment is seen, from which "Screes" have originated. The strata here are contorted, but on the whole the dip is S.S.E. They have a mineral nature like the rocks north of White Stones, and like them they also afford Graptolites, among which *Graptolites sagittarius* is most abundant*.

In the Skiddaw slate district lying east of Keswick Lake and Bassenthwaite Lake there is no axis distinctly shown. Sections along the western side of this area and along its eastern margin alike manifest a succession of S.S.E. dips from the northern portion of the Skiddaw slates almost to their southern limits. In this area also, wherever the Skiddaw slates occur, if they do not exhibit a highly metamorphic condition, nor a great development of cleavage, they yield the same fossils throughout the series.

§ 4. *Carrock- and Caldbeck-fells.*

Allusion has already been made to the granite of the Caldew valley, the Skiddaw Forest granite of Professor Sedgwick. This rock is seen extending down the course of the Caldew at intervals to near the junction of the stream flowing from the north, called Brandy-gill. It forms the south-east flank of the hill lying west of Brandy-gill, the surface of this flank being strewn over with granite-blocks.

From this hill it is well seen in the lower portion of the Brandy-gill rivulet, where it occurs in the condition of a fine-grained granite, much intersected with quartz-veins.

On the east side of Brandy-gill the same fine-grained granite is seen, forming the western spur of Carrock-fell, also much intersected by quartz-veins. From this spur eastwards, the crest of Carrock is flat, and covered with peat and vegetation, exhibiting very few traces of rock; but when the east side of the north spur of Carrock is reached, a very felspathic granite, approaching somewhat to porphyry, makes its appearance, and this forms also the summit of Carrock-fell. Although differing in its texture somewhat from the granite seen in Brandy-gill, I have little doubt of its being a continuation of the same mass, which, following the strike of the stratified rocks, extends W.S.W. into the valley of the Caldew, and E.N.E. through the northern half of Carrock-fell. On the south side of the granitic area there is seen, forming the southern mass of Carrock, and in close contact with the fine-grained granite of the western spur of Carrock-fell, a rather singular felspathic rock, consisting of two felspars, orthoclase and labradorite, and having an aspect greatly resembling that of a greenish-coloured syenite. This rock is not however confined to Carrock, but occurs also among the Caldbeck-fells†.

* The localities in the neighbourhood of Keswick which afford fossils, viz. Outerside, Barff, Skiddaw, Longside, and Mirehouse, were, I believe, first recognized as fossiliferous by Mr. Joseph Graham, mineral-dealer, Keswick.

† The quartz-veins of Carrock-fell are famous for the rare minerals which they afford. Besides wolfram, which is found in considerable abundance, they yield scheelite (tungstate of lime), apatite, telluric bismuth, molybdenum-glance, and also, to the north-west of Carrock, in Caldbeck-fells, fine specimens

On the north side of the granite of Brandy-gill, in the course of the stream, hard, grey, crystalline rocks devoid of bedding occur; and rocks of this character are seen likewise in the courses of Thief-gill, which flows from the north side of the western spur of Carrock-fell into Brandy-gill. Although devoid of bedding, these rocks often show traces of lamination, and they appear to be the representatives here of those gneissic rocks which are so well developed on the south side of the plutonic area. What they pass into northwards is not seen, the flat summits of the Caldbeck-fells being extremely peaty.

The interval between the north end of Carrock-fell and the south side of High Pike, the adjoining mountain, does not exhibit the rocks *in situ*, so that the relation between the plutonic masses of Carrock-fell and the igneous rocks of the Caldbeck range is not apparent. The brook-courses in the interval also afford no Skiddaw slate, and there is strong reason for concluding that no sedimentary rocks intervene between these plutonic and igneous masses.

High Pike itself is composed, for the most part, of claystone-porphry, which is well seen in the course of the Pottsgill-beck, a stream flowing from the north side of this mountain by Caldbeck into the Caldew. This claystone-porphry has a greyish-drab colour, and contains yellow crystals of felspar, which are generally partially decomposed. The stream which flows to the west of Pottsgill passes over rocks which have a similar nature.

In the upper portion of Roughten-gill, a stream which rises among the flat summits of Caldbeck-fells and flows northwards through these mountains, there is a more varied series of igneous rocks. On the moors at the head of this stream claystone-porphry, similar to that just alluded to, occurs; on passing down the stream, a mass of compact felspar makes its appearance; and this is succeeded by a considerable development of a rock composed of orthoclase and labradorite, like that forming the south side of Carrock-fell, and in which the lead-veins at Roughten-gill principally occur.

One of the best exposures of the porphyritic rocks of Caldbeck-fells is seen in the course of a stream called Charlton-wath, flowing between Brae-fell and Langlands-fell. The upper portion of this stream is over claystone-porphry, being an extension westwards of that at the head of Roughten-gill. Lower down the stream, and near the junction of a rivulet flowing from the south-west, a grey trap makes its appearance. For some distance below this junction no rock is seen; but after the barren interval is passed over, we come upon a fine-grained, greenish-grey, felspathic rock, beyond which is a small development of claystone-porphry. Still lower down the stream we meet with a rock having a singular aspect. This rock is much broken up in structure, has a mottled appearance, and seems to be composed of white and green felspars. It is usually partially decomposed, and its mottled character is well seen on its weathered

of phosphate of lead. There occur also arsenio-phosphates, sulphates, cupreous sulphates, and cupreous sulphato-carbonate of lead; and along with these are seen radiated malachite, brochantite, and other minerals.

surfaces. This mass of rock is probably the same as the double-felspar rock of Roughten-gill, with larger crystals, which appear to have undergone changes from chemical action. Below this mottled rock, in the course of the stream, we come upon a grey felstone, well developed, and succeeded by a purplish claystone which, on passing downwards, assumes a porphyritic nature, containing small white crystals of felspar. This last-named rock is seen immediately above the moor-road to Caldbeck, and a short distance below this road the Carboniferous rocks occur*.

The felspathic rocks extend still further to the north-west. The mottled rock is seen on the west side of Langlands-fell, and in it copper has been partially worked. The grey felspathic traps occur in Lowthwaite-fell, and from thence they extend to the north side of Overwater, being well seen at Latrig-fell, which lies immediately north of this small lake; they are also well exhibited in Binsey Crag, where they are principally of a porphyritic nature. Here sometimes they occur in the form of strata, and seem to be composed of masses of felspathic ash, containing fragments of felspar-porphry. When presenting this aspect, they have a conglomeratic nature, and are excessively hard. On the north side of Binsey a fine purple porphyry, with greenish crystals, is seen; to the north of this, on the ridge called Whitehouse Hill, hard grey rocks make their appearance, being succeeded northwards by the Carboniferous series. To the west of Binsey Crag and Whitehouse Hill there again occurs a flat moory country like that before described in connexion with the Skiddaw slates.

I believe that Professor Sedgwick is disposed to regard the felspathic traps of the Caldbeck-fells Range as the northern equivalents of the greenish-grey rocks which, to the south, succeed the Skiddaw slates.

5. The Skiddaw Slates of the Eastern Margin of the Lake-district.

At the lower end of Ullswater, a small stream called "Ellerbeck" enters the lake from the south; it crosses the road leading from Pooley to Howtown, and, at a short distance above, divides into two branches. The more southerly branch is known as Eggbeck; the lower portion of its course is over gravel and large blocks of stone derived from the boulder-clays of Doveack Moor. On ascending the stream, after passing through the enclosed ground, a plantation is reached which marks the boundary of the cultivated land, and above which rocks are seen, *in situ*, in the bed of the brook.

These rocks consist of contorted shales, dark in colour, thin-bedded, and having a great resemblance to the graptolitic shales of Dumfriesshire, but they do not present beds so highly anthracitic as those of the south of Scotland; as they are much broken up by closely approximated joints, they have a very shivery character.

On ascending the stream, above the dark shales others are seen

* I am indebted to Mr. Joseph Peat, of Caldbeck, for directing me to the several streams in this district where good sections occur, and also for information concerning the igneous rocks and mineralogy of Caldbeck-fells.

of a lighter colour, which are again succeeded by dark shales resembling those below, and containing Graptolites. Drab shales are seen above these in the course of the brook, having intercalated grey beds, the whole presenting a shivery aspect.

Above the foregoing shaly strata, for a short distance no rocks are seen in the bed of the stream; but a little above where the main road from Barton to Martindale crosses Eggbeck, a greenish-grey porphyry, with orange-coloured crystals of felspar, makes its appearance, and continues to occupy the bed of the stream to near its source, having occasionally ashy masses intermixed with it.

The Graptolites which occur in the dark shales of Eggbeck consist of *Graptolites sagittarius* and *Didymograpsus geminus*, together with the branching form previously referred to. These fossils are by no means abundant here, and, owing to the shivery nature of the strata, they are usually in a fragmentary condition.

Fig. 4.—Section from Ullswater to Wastdale Crag (11 miles).

Lying west from Eggbeck is Barton-fell. At the top of this hill is a greenish, ashy-looking grit; and in the stream which separates Barton-fell from Swarth-fell, the hill still further westwards, the porphyries of Eggbeck are well seen, together with greenish rocks, which are not porphyritic, intercalated among them, but having no distinct bedding. The rocks here are rudely prismatic, and to the S.S.E. they seem to pass upwards into the greenish-grey rock above alluded to.

Eggbeck is the only spot in this neighbourhood where the Skiddaw slates are seen. To the north of Barton-fell and Swarth-fell, both of which rise boldly above Ullswater, exhibiting escarpments on their north sides, there is a comparatively low tract of country; but there no rocks *in situ* appear, the interspace from the south side of Ullswater to the adjoining hills being covered by soil and *débris*. The contour of the country, however, justifies the conclusion that the Skiddaw slates extend some distance along the northern base of Barton-fell and Swarth-fell, but that they soon become covered up by the porphyries, ash-beds, and green slates, which are so extensively developed along the margin of Ullswater, from Howtown to Patterdale, and also in the mountainous district lying southwards.

There are strong reasons for inferring that the presence of the Skiddaw slates at Eggbeck is the result of an anticlinal axis crossing this portion of the Lake-district and extending in a W.S.W. direction. Proofs of the existence of this axis can be seen in the neighbourhood of Patterdale. On the east side of this portion of Ullswater several slate-quarries have been wrought, at Blowick, along the western base of Place-fell.

These slates usually show very imperfect stratification, and the cleavage commonly intersects the bedding. In some localities, however, the dips are apparent, being S.S.E., generally at an angle of 30° , which is also the prevailing dip of the Skiddaw slates at Eggbeck. On examining the arrangements of the lines of lamination among the slates here, they also are found to conform to the dips of the strata. Among the more regularly stratified beds east of Patterdale, there is often a rapid thinning-out of the strata.

On the opposite side of the lake, in the face of the cliff looking towards Ullswater, immediately north of Patterdale Hall, the strata, which consist of a dark greenish-grey grit, spotted with red, so as to have almost a porphyritic appearance, dip towards the N.N.W. about 35° , an inclination directly opposed to that on the east side of the lake.

These features support the inference that the axis before referred to extends through Place-fell, and, crossing the upper reach of Ullswater, passes through Grisedale, from whence it runs in the direction of the granite-area in the lower part of Eskdale, in West Cumberland.

To return to the section along the eastern margin of the Lake-district. To the south of the porphyries and greenish-grey rocks associated with them in the higher portion of Eggbeck, we have in Heltondale a development of the greenish-grey grits with indistinct dips, but apparently inclining S.S.E. These also occur further south at Butterwick, where they are intersected by north and south joints; and here likewise the stratification is imperfect. Southward from this, at Bampton, the greenish-grey rocks are also seen, being worked here for building-purposes.

In this locality, besides the ordinary greenish-grey rocks, there occur others which contain angular fragments of a hard, grey rock, not unlike some of the harder varieties of the Skiddaw slates, imbedded in a greenish-grey matrix. A similar rock is seen on the road from Ullswater, leading over Kirkstone Pass, and is also worked for a building-stone in Borrowdale.

The rocks at Bampton dip N.N.W. about 40° , and in the interval between this and Butterwick a synclinal axis occurs. Southward from Bampton, in the neighbourhood of Thornthwaite Hall, situated on the stream which flows out of Haws-water, there is a large mass of the greenish-grey rocks; they continue southwards, forming the ridge called Scaleborrow, that separates the Haws-water valley from Swinedale. Here too the rocks are equally devoid of stratification, but are much intersected by joints, which often assume so regular an aspect as to look like bedding.

On the south side of Scaleborrow, in Rossgill-beck, which flows into the stream draining Swinedale, the Skiddaw slates are again seen; and here they were formerly worked for slate-pencils. In this locality the slates, which are somewhat shaly, are, by cleavage and fine jointing, cut up into long thin pieces. Intercalated with them are masses possessing the cone-in-cone structure, and which on decomposing produce abundance of hydrated peroxide of iron, showing their affinity in composition to iron-stone. The strata here are much contorted, but on the whole dip S.S.E.

Higher up Swinedale than the junction of Rossgill-beck, where the rocks become prominent on both sides of the dale, they consist of the hard greenish-grey grits, equally without distinct bedding with those lying northwards, and to such an extent cut by vertical joints that they have a columnar aspect. This exposure of the Skiddaw slates in Rossgill-beck is doubtless the result of another anticlinal, which, like that before alluded to, has a W.S.W. strike.

In the course of the River Lowther, southwards from the junction of Swinedale-beck, no rock is seen for a considerable distance. On the east side of the river occurs the Carboniferous series, which bounds the Silurians on the east. The lower part of the Carboniferous rocks is well seen in the escarpment on the east side of the Lowther, immediately above the ruins of Shap Abbey; here also the equivalents of the green slates and porphyries are seen in the stream, and, in consequence of having been stained by the beds of the Carboniferous series, they present a purple colour.

Above Shap Abbey, a small stream enters the Lowther opposite to the hamlet of Keld, and is called Keld-gill. Between this and the Abbey there are abundant exhibitions of rock in the course of the Lowther, all of which possess the greenish-grey colour and an imperfectly bedded character.

Southwards from Keld-gill, over that portion of Rafland Moor which lies between this and another small stream, called Thornship-gill, no good exposures of rock occur; and this remark applies also to the River Lowther in the interval between the junctions of these streams.

The lower part of the course of Thornship-gill is over gravel composed of small rounded fragments of Skiddaw slates; and on following up the stream for a short distance, these rocks are seen *in situ*. They consist of dark-coloured, shaly beds, like those of Rossgill and Eggbeck, enclosing masses which have also the cone-in-cone structure. The strata here are much contorted, but the prevailing dip is N.N.W. Quartz-veins intersect the beds, and have a N.W. and S.E. strike. The slates here, like those of Rossgill, are much broken up by cleavage and jointing; and they have also been extensively wrought for slate-pencils. This locality also affords fossils, among which we have *Graptolites sagittarius*, the branching forms, and others too imperfect to determine. In one locality on the N.E. side of Thornship-gill, porphyry is seen, which, from the dip of the slates, must overlie the latter, and here consequently we have the same sequence of strata that occurs at Eggbeck.

The appearance of the Skiddaw slates in this locality must be referred to the same cause to which those of Rossgill and Eggbeck have been assigned, namely, the occurrence of another anticlinal parallel to those already mentioned.

In following up the Lowther from the junction of Thornship-beck, we have at intervals many exposures of the imperfectly bedded, greenish-grey rocks. These are well seen at Cragg Mill on the north side of Shap Moor, and among the rocks here are found the masses which have the imbedded angular fragments already mentioned as occurring at Bampton and elsewhere. Like the same rocks at Bampton, it is probable that they mark the position of a synclinal, the rocks on their N.N.W. side having a S.S.E. dip, while in Wet Sleddale, on the south side of the Lowther, an opposite dip obtains. In the streams flowing from Wastdale Pike and Harrup Pike, which are tributaries to the Lowther from the south side of Wet Sleddale, the prevailing dips are also N.N.W.

On the high road leading from Shap to Kendal, owing to the moory nature of the ground, the greenish-grey rocks are not well seen in the interval between Shap Common and Wastdale Crag.

In this interval we have, however, at Blea-beck, a mass of basalt crossing the road, and extending north-eastwards to the Lancaster and Carlisle Railway, where, at the summit-cutting, this basalt and its relations to the Silurian and Carboniferous rocks can be distinctly made out (fig. 5).

Fig. 5.—Section at the Summit-cutting on the Lancaster and Carlisle Railway.

The principal mass of this cutting is the basaltic trap, which on its north side has greenish Silurian shales dipping N.N.W. at a high angle (above 50°). Upon them, and also upon a portion of the trap, conglomerates occur, made up of fragments of Silurian shales, quartz, chert, and trap, and dipping N.E. 10° . The conglomerates have purple grits above them, the total thickness of both being about 20 feet; and an irregular, nodular limestone, averaging a foot in thickness, lies upon the latter. On this irregular limestone, 8 feet of purple shales with limestone-nodules are seen, being succeeded by grey shales about 5 feet thick, having upon them another nodular limestone 18 inches in thickness, above which is a white grit, supporting the hard limestone which is wrought on Shap Moor.

The junction between the greenish-grey rocks and the porphyritic syenite of Wastdale Crag is nowhere very apparent. There is seen,

however, on the east side of the high road, a small quarry in which a felstone occurs, intermediate in character between a syenite and the greenish rocks; and a similar rock is also seen south-west from Wastdale Crag in the direction of Long Sleddale, where it is known under the name of "flint." It is probably a mass of plutonic rock having the same origin as the Wastdale Crag syenite, but possessing a less crystalline nature in consequence of more rapid cooling from having been in immediate contact with the greenish-grey rocks.

§ 6. *The Skiddaw Slates of Black Comb.*

The most southerly position occupied by the Skiddaw slates in Cumberland or in Westmoreland is Black Comb, a mountain rising abruptly to the height of 1919 feet, in the south-west of Cumberland; it is surrounded on all sides, except the west, by the greenish-grey rocks which succeed the Skiddaw slate series in the north of England. On the west side, Black Comb is margined by a comparatively low and flat tract of country, composed of the Trias sandstones extending southward from St. Bee's Head, and flanking on the west side the Silurian rocks and their accompanying granites and syenites.

To the south of Black Comb there is a flat tract of country which separates this mountain from the greenish-grey craggy rocks of Millom, and in which no rocks are seen, the area being covered with till and soil. Still further south, greenish-grey rocks occur, exhibiting their usual broken outline, and presenting bold escarpments towards the north—a feature generally accompanying their line of outcrop, while on their dip they present commonly a less rugged aspect. To the S.S.E., at Millom, these greenish-grey rocks pass under the Coniston limestone and Coniston flags, which also dip S.S.E.

Fig. 6.—Section across Black Comb (5 miles).

On the north side of the Whicham valley (the flat interspace just alluded to, where the southern flanks of Black Comb exhibit the Skiddaw slates) the beds dip N.N.W.

Portions of the southern escarpments of this mountain have been wrought for slate; and among the *débris* of the quarries *Graptolites* may be found, though from the Black Comb beds I have obtained only one species, namely, *Graptolites sagittarius*. The position of the strata here shows that they are very low down in the Skiddaw slate series.

The rocks on the southern flank of Black Comb consist of strata with slaty cleavage, interstratified with flaggy beds, the latter yielding fossils and dipping N.N.W. Along the course of the stream flowing from near the summit of Black Comb southwards, and which is known as Black Comb Beck, a coarse slaty cleavage prevails among the rocks, which also dip N.N.W. These rocks abound in quartz-veins, in which cobalt has been sought, but without profitable success.

Towards the south-west side of Black Comb, a little above Whicham Church, the Skiddaw slates are also seen. Here they are hard, and possess somewhat the nature of flinty slate. In this locality also cobalt has been attempted to be worked. Continuing along the west side of the range, the Skiddaw slates still have the N.N.W. inclination, but at varying angles; they are well seen at Whitebeck and also at Foss-beck *.

North of Foss-beck, near Hole-beck, and on the south side of the latter stream, a fine-grained grey granite occurs, which has been worked; but it seems in no way to affect the general arrangement of the Skiddaw slates. This granite was described as occurring here by Mr. J. G. Marshall at the Manchester Meeting of the British Association, 1861. The Skiddaw slates of Black Comb continue northward to near Bootle, where the porphyries associated with the greenish-grey rocks begin to make their appearance.

The Skiddaw slates of the Black Comb range do not extend northwards beyond the parallel of Bootle, the road from this place over the hills to Broughton exhibiting no Skiddaw slate. At Fell Green, a mile east of Bootle, on this road, the greenish-grey series and the accompanying porphyries are seen, and the country between this and Stoneside-fell is composed of rocks of a similar character. At Stoneside-fell, on the south side of the road, a dark porphyry with light-grey crystals appears in this greenish-grey series; and the outline of Corney-fell, a hill on the north side of this road, indicates that the rocks which compose it also belong to the same greenish-grey series. At the Druids' Temple, about a mile south-east of Stoneside-fell, they also occur, while at Swineside, a short distance to the west, the Skiddaw slates make their appearance, dipping N.N.W. 40°, and having a greyish-drab colour.

The section of the Skiddaw slates of Black Comb shows an almost continuous N.N.W. inclination, from their appearance on the southern flanks of this range until they are succeeded by the greenish-grey rocks of Stoneside-fell. Their relation to the greenish-grey series on the south, at Millom, is seen in Professor Sedgwick's section †.

In the Whicham portion of the section there is a great fault, from which the rocks dip in opposite directions. The continuous exposures of N.N.W. dips in the Skiddaw slates of the Black Comb range, from the southern flank for about three miles N.N.W., lead to the conclusion that on the south side of this range some of the lowest

* There are abundant "Screes" on the west side of the Black Comb range; and, if well examined, they would no doubt afford fossils.

† Quart. Journ. Geol. Soc. vol. ii. p. 111.

beds of the series are exposed. This conclusion shows that Graptolites occur very low down in the series,—an inference which is justified by the sections of these rocks as seen in other localities.

§ 7. *Conclusion.*

The lithology of the Skiddaw slates varies considerably in the several areas where they occur, and, with reference to geological position, there is in some cases a difference in their mineral nature. This, however, is not of so uniform a character as to admit of this series being divided into subgroups marked by mineral aspects. The fossil contents are even less applicable for subdivisions than mineral nature, since, as already stated, the same organisms are disseminated through the whole of this portion of the Lower Silurians as they occur in Cumberland and Westmoreland. Under these circumstances, I am induced to look to other evidence for relative position among the strata forming the Skiddaw slates.

The physical geology of the various areas under consideration shows that in all of them, except that which lies west from Derwentwater and Bassenthwaite Lake, axes are by no means well exhibited. Even in that large area south of Caldbeck-fells there is no well-defined axis, but a continuous S.S.E. dip from the northern limits of the Skiddaw slates almost to their southern margin. The area west of Derwentwater and Bassenthwaite affords two well-marked axes; and the nature of the rocks between them shows that the Skiddaw slate series is made up of fine indurated shaly beds with well-developed slaty cleavage, having intercalated through them coarser strata almost devoid of cleavage, possessing a flaggy nature, and affording fossils.

From Newlands, where the upper members of the Skiddaw slates are seen with the superposed greenish-grey rocks, to Coldale, where the most southern of the axes just alluded to occurs, the distance is less than three miles measured along the dip, which averages 30°. This portion of the section (see fig. 2, p. 116) would give a thickness of Skiddaw slates, from the greenish-grey rocks above to the lowest beds exposed at Coldale, of about 7000 feet; and this is probably their average thickness where best seen in the north of England.

The thickness of the succeeding greenish-grey rocks is not so easily made out. There are, however, circumstances which render it probable that these latter rocks do not exceed in thickness those of the Skiddaw slate series; so that between the base of these latter and the Coniston limestone, the equivalent of the Bala limestone, there is a varied mass of rocks of 14,000 feet in thickness, the lower half consisting of rocks of a sedimentary nature, while the upper half is composed of rocks which had an igneous origin, and which consist principally of porphyries and ashes. This thickness of rocks, which in Cumberland and Westmoreland lies below the Coniston limestone, corresponds with the thickness of the Llandeilo flags*.

The Skiddaw slates yield some forms of Graptolites which occur in the southern Highlands of Scotland, indicating some palæontological

* 'Siluria,' 2nd edit. p. 194.

affinity between the rocks of these areas. There is, however, in the former, so far as we yet know, an absence of the genus *Rastrites*, which is well represented in the south of Scotland; but we miss in the Scotch deposits the genera *Dichograpsus* and *Tetragrapsus*, which make their appearance in the Skiddaw slates. But with reference to the fossils from this series, their nature and the evidence they afford as to age are discussed in a note which Mr. Salter has kindly added to this memoir.

If we take into consideration the direction of the *strike* of the strata in the north of England and in the south of Scotland, we find in this a great conformity, the *prevalent strike* in both countries being W.S.W. and E.N.E.; and, with reference to the dips, the direction generally obtaining north of the Border is N.N.W., while to the south thereof the most common inclinations are S.S.E. The physical geology of the older rocks of the north of England and south of Scotland supports the conclusion that the disturbing forces which acted upon them operated in both areas at the same geological epoch; and also, judging from the arrangement of the metamorphic rocks of the Highlands proper, that the strata of the north of Scotland owe their elevation to the same period.

The general arrangement of the older rocks of the north-west of England shows that not only have the Lower Silurians been subjected to elevations producing a W.S.W. and E.N.E. strike, but also that the succeeding Coniston limestone, Coniston flags, Coniston grits, Ireleth flags, and Kendal group of Professor Sedgwick—deposits occupying the horizons of the Caradoc, the Llandovery, the Wenlock, and the Ludlow series of Sir R. I. Murchison—were elevated at the same time as the older Silurian deposits.

In Cumberland and Westmoreland, the older palæozoic rocks are succeeded unconformably either by the Upper Old Red Sandstones or by the Carboniferous strata, both of which have *strikes* totally at variance with the older rocks; and consequently we are led to infer from this evidence that the elevations of the Silurian series, both in the northern and southern Highlands of Scotland and in the north of England, took place during the earlier portion of the Old Red Sandstone epoch.

Denudation has removed from the northern Highlands probably all the Upper Silurians (the metamorphic character of most of these rocks does not allow of their being assigned to very definite Silurian zones), and in the southern Highlands nothing remains of the older palæozoic rocks except the Lower Silurian series. In that portion of the north of England which most nearly approximates to the Silurian area of the south of Scotland, we have also only the lower members of this series represented, while further to the south, denudation not being so powerful, the whole of the Upper Silurian rocks occur.

The eastern edge of the older palæozoic rocks of Cumberland and Westmoreland had suffered a considerable amount of denudation antecedent to the deposition of the Upper Old Red series, for, in these latter, fragments of Skiddaw slates are, in some localities, very abun-

dant. The exposure of the Skiddaw slates at Black Comb also shows that the south-west margin of the area of the older palæozoic rocks has likewise been subjected to great denudation.

As concerns the age of the Skiddaw slate series, the sequence of the strata above it, its position, and also its depth below the Coniston limestone would lead to the inference that it occupies the horizon of the Llandeilo flags; and the fossils corroborate this conclusion. Mr. Salter has already pointed out the affinity of these fossils to those of the lower portion of the Llandeilo series*; and in a note he informs me that the Skiddaw slates are referable to "that group which is best represented in the rocks of Shelve, and which occurs in North Wales overlying the Tremadoc group, and *underlying* the mass of the Llandeilo,—a series containing the earliest and most varied forms of Graptolites, and which is at once the birth-place and metropolis of the family, as nowhere else are there so many genera or such complex forms." This evidence, combined with the sequence of the rocks in the Lake-district, distinctly places the Skiddaw slate series on the horizon of the Lower Llandeilo, and also places the Quebec group of Sir William Logan, as suggested by Mr. Salter, in the same position.

Note on the SKIDDAW SLATE FOSSILS. By J. W. SALTER, Esq., F.G.S.,
A.L.S., of the Geological Survey of Great Britain.

THE persevering labours of Prof. Harkness have been again rewarded. But little was known, notwithstanding the old explorations by Prof. Sedgwick, of the fauna of the Skiddaw slates till within the last three years, when, at my request, Mr. Bryce Wright took advantage of a short residence each year near Skiddaw to search for organic remains in what proves to be a rich formation. The Museum in Jernyn Street and the Cambridge Museum have received, since that time, many accessions through Mr. Wright's labours. The fauna proved to be of a newer date than had been assigned to it in Prof. Sedgwick's table of classification: not, indeed, relatively to the other rocks of the Lake-district, for the Professor has put it in its right place with respect to them; but instead of being, as suggested, an equivalent of the great formation of the Lingula-flags, its fossils indicate it to be of the age of some part of the Llandeilo-flags; and I shall endeavour to show that it must be the lower portion of that formation.

Two species of Graptolites and some imperfect remains (considered as sea-weeds by Prof. M'Coy) were the fossils known to Prof. Sedgwick at the time of the publication of his great work in 1851†.

Mr. Wright fortunately discovered at least six more Graptolites, and a Crustacean with a curious, elongated carapace of two valves, which I shall here term *Caryocaris* (fig. 15), as it has long wanted a name. An obscure figure of it appeared in the 'Geologist' of February 1861, together with a figure of the most remarkable of the

* 'Geologist,' vol. iv. p. 74.

† 'Synopsis of the Classification of the Palæozoic Fossils in the Woodwardian Museum.'

new Graptolites—a doubly and triply branched form which I termed *Dichograpsus*, after ascertaining its identity with those remarkable fossils discovered by Sir W. Logan near Quebec, of which he sent drawings to England many years back, and which, admirably engraved, were to be seen in the Canadian Department of the Great Exhibition.

There were also with these forms some foliaceous Graptolites, which I have referred to *Phyllograptus*, Hall, together with the now well-known species *Graptolites sagittarius* and *G. tenuis*, the latter very abundant. Mr. W. West, of Wimpole Street, has since made some notable additions to this list, and some of his specimens are figured on p. 137.

Prof. Harkness has not only added to our correct knowledge of the beds from which these are obtained, but has also furnished a few new forms to the British list; among them, especially, the beautiful *Didymograpsus caduceus*, a swallow-tailed form, formerly described by myself, from Canada.

Indeed, the most interesting point about these collections is the positive identity that appears to obtain between the fossils of the Skiddaw slates and those of the Quebec group of Canada. In both we have the ordinary genera of Lower Silurian Graptolites—*Graptolites*, *Diplograpsus*, and *Didymograpsus*; but mixed up with these are some others peculiar to this horizon, viz. *Phyllograptus*, the *Dichograpsus* mentioned above, and a kind of double *Didymograpsus*, for which it is perhaps admissible to form a new genus—*Tetragrapsus*.

The series of forms in the Graptolite group is now so perfect, that it may well be surmised that we have pretty nearly exhausted the variations.

There are simple Graptolites with a single row of cells, unbranched or only irregularly proliferous—*Graptolites*. Straight Graptolites with a double row of cells—*Diplograpsus*. Twin Graptolites, having a single row of cells only on each branch, the bifurcation taking place from the root—*Didymograpsus* (figs. 13 a to 13 f); again, a form in which this bifurcation takes place twice, the branches patent or nearly close—*Tetragrapsus* (figs. 8 a, 8 b); *Phyllograptus* (Hall), also composed of four stems, i. e. doubly branched, but the stems close together, and giving the appearance of a cruciform *Diplograpsus* (figs. 7 a, 7 b). *Tetragrapsus* comes near to the Canadian genus *Dichograpsus*, which is doubly branched, and again dichotomous more than once, in most of the species. But the main character which distinguishes *Dichograpsus* is the presence of a corneous plate which envelops all the lower part of the branches (fig. 10), and which is not known in any other genus of the group; it has not, indeed, been seen in more than two or three species of *Dichograpsus*, but it may not have been preserved in all cases. I still believe that the best analogy for this plate is in the basal plate of *Defrancia*, a Bryozoon compared with it several years back by Huxley. Lastly, we have the extremely branched form *Dendrograpsus* (Hall), the name of which sufficiently expresses its ramose character. The branches in this

Figs. 7-15. *Sketches of Graptolites from the Skiddaw Slates. (Natural size.)*

7. *Phyllograptus*, Hall. 8. *Tetragraptus*, gen. nov. (*a*. is the typical form; *b*. may possibly be a form of *Dichograptus*). 9. *Dichograptus aranea*, Salter. 10. *Dichograptus*, Salter, with its corneous cup (from Logan). 11. *Dichograptus Sedgwickii*, Salter. 12. Branchlet of *Dichograptus*. 13. Several forms of *Didymograptus*. 14. Branching *Bryozoon*? 15. *Caryocaris Wrightii*, Salter.

genus have no connecting bars; but in *Dictyonema*, which is the oldest form of the Graptolite group, the rods are held together by very regular processes, that give the whole frond, which is tubular, exactly the aspect of a *Fenestella*. The presence of the projecting Graptolitoid cells and the horny texture, however, prevent its being confounded with that genus; but the resemblance is very close, and I think we have here a real affinity,—a conclusion strengthened by the general agreement of the long-celled Graptolites with recent genera of the *Tubuliporidae*.

I herewith give figures of the new species of *Dichograpsus*, *Tetragrapsus*, &c.; and I subjoin a list of all the known Skiddaw slate fossils. Those marked W. were collected by Mr. Bryce Wright; those marked H. are due to the researches of Prof. Harkness; and those marked 'West' are from that gentleman's collection.

FOSSILS.	LOCALITIES NEAR SKIDDAW.
Radiating Worm-burrows.....	Skiddaw, Longside (H., West).
Annelid-burrows	Hodgson, Holm (W.), Keswick, &c.
Nereites.....	Skiddaw, Longside (H.).
New Crustacean— <i>Caryocaris Wrightii</i> , n. s., fig. 15.	Outerside, Barff, Skiddaw, Longside (W., H., West).
Graptolites sagittarius, <i>His.</i>	Scawgill, Hakengill, Mirehouse, Braithwaite Brow (W., H.).
— <i>tenuis</i> , <i>Portl.</i>	Keswick (W., H.).
— <i>Nilssoni</i> , <i>Barr.</i>	Braithwaite Brow (W.).
— <i>latus</i> , <i>McCoy</i>	Braithwaite Brow, Whiteless, Scawgill (Sedgw.).
— sp.	Keswick.
<i>Diplograpsus pristis</i> ?, <i>His.</i>	Braithwaite Brow (W.).
<i>Didymograpsus sextans</i> , <i>Hall</i>	Braithwaite Brow (W.).
— <i>hirundo</i> (MS.), fig. 13 <i>f</i>	Ellengill (W., H.).
— <i>geminus</i> , <i>His.</i> , fig. 13 <i>c</i>	Eggbeck, Ullswater (H.).
— <i>caduceus</i> , <i>Salter</i> , fig. 13 <i>a, b</i>	Keswick (H.).
— sp. like <i>G. Pantoni</i> , <i>McCoy</i> , fig. 13 <i>e</i> (<i>D. V-fractus</i> , MS.)	Keswick (West).
<i>Phyllograptus angustifolium</i> , <i>Hall</i> , fig. 7 <i>a</i> , 7 <i>b</i>	Barff, Keswick (W., H.).
<i>Dichograpsus Sedgwickii</i> , fig. 11	Braithwaite (W.).
— sp., small branches, fig. 12	Keswick (H.).
<i>Tetragrapsus byronoides</i> , <i>Hall</i> , fig. 8 <i>a</i>	Frozzengill (H.).
— <i>crucialis</i> , n. s., fig. 8 <i>b</i>	Keswick.
<i>Dichotomous Bryozoon</i> ?, fig. 14	Barff, Keswick.

A few words will suffice to show the relations of this fauna with that of the corresponding beds in other countries. In the grouping of the Graptolites of the Skiddaw slates there is the closest resemblance to that group discovered by Logan near Quebec, and which is known to some authors under the name of the Taconic system. All the forms are representatives in the two cases, and several of the species are, I believe, identical; but as the Canadian figures have not yet received their long-desired publication, we cannot identify the names except in a few instances.

Moreover, there is a remarkable coincidence, even to minutiae of character, between the Skiddaw slates and the Graptolite-bearing rocks of Melbourne, Australia. In the collections sent over by

Prof. M'Coy and Mr. Selwyn to the International Exhibition, a large series of Graptolites appeared; and these agreed, genus for genus, and almost specifically, with our North-of-England forms. I cannot think this accidental, and believe, therefore, that there is a peculiar zone or horizon of the Llandeilo rocks of which these genera of Graptolites are characteristic*.

The mass of the Llandeilo strata is not tenanted by such compound forms. The species of *Didymograpsus* known in the Upper Llandeilo have the branches diverging at a moderate angle, while the strata known as Lower Llandeilo in England have the widely diverging forms of this genus, and such are found in the Skiddaw slates.

In Canada the age of the Quebec series is still under discussion; but all agree in placing it low down in the Silurian series†. Here the association of these Graptolites with Trilobites is such that we must either refer them to the Primordial group itself, which is unlikely, or allow that they represent the lowest beds of Lower Silurian rocks, the passage-beds from the Primordial zone to the Llandeilo flags,—the age, in fact, of the Tremadoc slates and Lower Llandeilo.

With regard to the so-called sea-weeds, fucoids, &c., I have shown elsewhere reason for believing that nine-tenths of these are due to the action of marine worms. In the Skiddaw slate series there are found abundant traces of these markings.

CARYOCARIS, gen. nov. C. WRIGHTII, sp. nov. Fig. 15.

A long, pod-shaped, bivalved carapace (with distinct hinge-pits), rounded anteriorly, subtruncate behind, and with the back and front subparallel. The surface is smooth, or with only oblique wrinkles near the margins, but with no parallel lines of sculpture. Body? Telson and appendages?

All I know of this pretty little Crustacean, an inch long, and rather more than one-third of an inch wide, is contained in the above note. I was fortunate enough to find the tubercles (Huxley found them also in *Ceratiocaris*), which I suppose indicate teeth (and corresponding pits) at each end of a short hinge-fulcrum. They are marked *a*.

The shelly carapace is solid for its size: it appears to have a good deal of lime in its composition. The genus is evidently distinct, though so little is known of the entire form.

Loc. Everywhere in the Skiddaw Slate district. I have named it after Mr. Bryce M. Wright, of Great Russell Street.

DICHOGRAPSUS, gen. nov. Figs. 9 to 12.

Frond repeatedly dichotomous from a short basal stipes into 8, 16,

* There is even a Crustacean, apparently of the genus *Caryocaris*, which M'Coy has done me the favour to name *Hymenocaris Salteri*.

† Hall has definitely added (see Proc. Amer. Phil. Soc. 1862) his opinion to give weight to the idea that the Quebec Graptolite-group (including the Hudson slates west of the river, as decided by Logan's discovery of the great fault) implies simply a different condition of the Calciferous Sandstone. "Quebec group" would surely be a better term; or why not "Skiddaw group"? It is the oldest.

24, or more branches, each with a single row of cells—not a double row as supposed by Prof. Hall, who must have seen the ends of the cells crushed vertically upon the narrow stipes.

TETRAGRAPSUS, gen. nov. Figs. 8*a*, 8*b*.

Fronds twice dichotomous near the base, of simple, long-celled stipes; the base of the branches not connected by a corneous plate (the branches sometimes patent, sometimes closely reflected: M'Coy, *in literis*).

PHYLLOGRAPTUS, Hall. Figs. 7*a*, 7*b*.

There are two species of this beautiful genus in the slates; but I prefer to leave the description of them open for the present. Prof. Wyville Thomson is hard at work on this group, and it is a pleasure to put good materials in the hands of so good a naturalist.

Two of the most remarkable of these Graptolites (see figures 8 and 13) were drawn from specimens in the collection of Mr. W. West, of Wimpole Street. I refer specially to the rare *Tetragrapsus crucialis*, and the *Didymograpsus* marked *c*, fig. 13, which is exceedingly like *D. Pantoni*, M'Coy, from Victoria. I have called it *D. V-fractus*. In truth, no one can collect in this region without doing some good; for the Skiddaw slate is the metropolis of the Graptolites.

2. On FOSSIL ESTHERIÆ and their DISTRIBUTION. By T. RUPERT JONES, Esq., F.G.S., Professor of Geology and Mineralogy at the Royal Military College, Sandhurst.

Introduction.—In 1856* I offered to the Society some remarks on the probably Crustacean character of the little fossil that used to be termed *Posidonomya minuta*, on its Estherian relationship, and on some points in the geological distribution of *Estheria*†. Much of the material that I have used for my 'Monograph of Fossil Estheriæ,' published by the Palæontographical Society, was then in my hands, but much information and very many specimens have been contributed since by friends, abroad and at home, so that I am now enabled to recognize fourteen fossil species, with several varieties. These are from the freshwater or brackish-water deposits of the Devonian, Lower and Upper Carboniferous, Permian, Triassic, Rhætic, Oolitic, Wealden, and Tertiary formations.

Though often imbedded in shales or marls in close proximity to other beds containing truly marine organisms, and even near beds impressed with casts of salt-crystals, yet the fossil *Estheriæ* have

* Quart. Journ. Geol. Soc. vol. xii. p. 376.

† In this paper *Estheria* was erroneously referred to as a marine Crustacean; and a mistake was made in the allusion to a *Silurian* Nummulite. The limestone containing this Nummulite is Carboniferous; but, coming from a Silurian district in Shropshire, it was at first mistaken for Aymestry limestone.