striking points is the very small proportion of the numerous forms of variegation that can be accounted for by the mere altered state of combination of the iron *in situ*.

The occasional conversion of the red anhydrous sesquioxide, or the lower hydrates, into fully hydrous sesquioxide, the reduction of sesquioxide to protoxide of iron in the production of green slates, and the exceptional cases of the alteration of colour of red beds by the decomposition of bisulphide of iron complete the list of colour-alterations by simple chemical change.

Even the agency of organic matter in inducing chemical changes in the state of combination of the iron, will not in most cases account for the bleaching—the segregational motion of the colouring oxide, which is the ultimate cause of the variegation, being supplemental to the simple chemical changes of combination. The great majority of cases of variegation are independent of altered combinations, and more often than otherwise seem to have been induced by agencies not directly connected with chemical change. The transference of the colouring oxide from one part of the stratum to another has taken place by the simple mechanical agencies of infiltration and dissolution, as well as by segregation; but the latter, above all other agencies, has played the largest part in the variegation of ferruginous rocks.

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2. *On the* Older Rocks *of* South Devon *and* East Cornwall*. By Harvey B. Holl, M.D., F.G.S.

[Plate XVI.]

Contents.

I. Introduction.

In the course of last year I made an examination of the older rocks of South Devon and the adjacent portions of Cornwall, for the purpose of ascertaining the stratigraphical relations of the different beds, or groups of beds, with a view to their coordination with the more complete and better-known series in the northern part of the county. I was led to undertake this in the belief that, notwithstanding the many memoirs that have appeared on Devonian Geology, there was still a very great difference of opinion among geologists respecting

* This memoir is illustrated by an Ordnance Map coloured geologically, from which Pl. XVI. has been reduced.

the relations of the beds on the south side of the Culm-measures; and any one who is acquainted with the literature of the subject will, I think, admit the fact. Indeed the late Sir Henry De la Beche, subsequently to his last essay in the first volume of the Memoirs of the Geological Survey, regarded the succession of the rocks as still unravelled, and expressed his intention of taking an early opportunity of revising this portion of his labours*.

Many of the difficulties which stood in the way of the pioneers of Devonian geology have long since been cleared away, more especially by the publication of the Geological Survey-maps of Devon and Cornwall, the general accuracy of which is all the more remarkable as it was the first attempt at anything in equal detail in this country; and a great step was made towards a better understanding of the structure of the Devonian country when Prof. Sedgwick and Sir Roderick Murchison, in identifying the Culm-measures with the Carboniferous system, separated them from the underlying slaty rocks with which, under the name of Grauwacke, they had been previously united†. Nor need the general order of succession, as established by them thirty years ago, in the first of their memoirs, be greatly disturbed. But there are many matters of detail, not comprehended in their memoir, which are still open to inquiry, notwithstanding the elaborate and able report subsequently published by the Geological Survey‡. To this work the following communication must be regarded§ as supplementary, its object being to enter, in a general manner only, on the consideration of certain points in the physical structure of that portion of the country which lies to the south of the Carbonaceous rocks of Central Devon and adjacent parts of Cornwall.

II. Carbonaceous Rocks or Culm-measures.

The Culm-measures, as they occur on the southern side of the great synclinal trough of Central Devon, consist of argillaceous slates, with seams of grit and chert, and include beds of volcanic ash and limestone, the latter for the most part of dark colours. These limestones are precisely similar to those at the northern edge of the trough, near Bampton and South Molton; and the grit and chert beds resemble those of Coddon Hill; but the interstratified volcanic rocks, which are not met with in the north, occur here in considerable abundance; and as they are likewise abundant in the underlying

* See Sir Charles Lemon's Presidential Address, 1848. Trans. Roy. Geol. Soc. of Cornwall, 35th Annual Report, p. 13.

† Trans. Geol. Soc. 2nd ser. vol. v. p. 633. This first great reform in the classification of the rocks of Devonshire was made by Professor Sedgwick and Sir Roderick Murchison in 1836, and was communicated to the British Association in that year at Bristol. See Report of British Association 1836, Proc. of Sections, p. 95. All geologists, including Sir H. De la Beche, had previously considered the whole of the great Carboniferous tract of Devon to be part, and even a lower part, of that Grauwacke series which Sedgwick and Murchison assigned to the true Devonian, and which they had proved to underlie, and be wholly distinct from, the Culm strata. See also Trans. Geol. Soc. 2nd ser. vol. v. p. 701., where the term Devonian was proposed.

‡ Geological Report on Cornwall, Devon, and West Somerset, p. 56 *et seq.*

Devonian rocks, they give to the two formations a general facies more similar in the southern than in the northern part of the county; and their separation is consequently more difficult. But although much of these slaty rocks bears a strong resemblance in lithological character to those of the underlying series, and occasionally gives rise to much perplexity in deciding to which system particular portions should be referred, nevertheless they differ as a whole in a manner which is sufficiently obvious, but which it is difficult to convey in words. For instance, the underlying rocks along the southern border of the Culm-measures are almost entirely devoid of grits, and consist essentially of fine argillaceous slates, more or less mixed with volcanic matters, and often much affected by cleavage. The higher series, on the contrary, is distinguished more particularly by the thin seams of greenish-grey grit, varying from half an inch to 2 or 3 inches in thickness, which they contain. These grits sometimes become locally more developed, and then constitute beds of greenish or greyish sandstone of considerable thickness, separated only by thin seams of slate; while in other places the thin grits are represented by thinly bedded black, or black and white, chert interstratified with dark-coloured slate, both the chert and the slate having a tendency to become bleached in weathering. Carbonaceous matter is not by any means so generally distributed, nor so characteristic as might be expected; and cleavage, although not absent from the more purely argillaceous portions of the series, is not so frequent as in the lower rocks.

The southern limit of these Carbonaceous rocks ranges from the coast at Boscastle by Lesnewth to Hallworthy, and thence along the south side of Lancast Down, and the north of Trewen, to a north and south fault, which crosses the Launceston turnpike-road west of Kenners House, and is laid down in the maps of the Geological Survey. This fault throws down the Culm-measures on the eastward, and brings the line between them and the underlying slates southwards to Congdon. From Congdon the line passes by Bolathan to the north side of the brook at Does Houses, where a few beds of slate separate the Culm-measures from the northernmost of the three Petherwin limestones. The Culm-measures dip to the north, and preserve this dip, undulating at angles which vary from 5° to 15°, to within half a mile of Launceston, where it becomes reversed. A little further down the stream, on its north side, on the road from Launceston to Landlake, there is a quarry of dark-blue or nearly black slate, with thin seams of grey grit. The slates contain *Posidonomya*, and dip south at from 5° to 10°. On the opposite side of the brook are the fossiliferous grey slates overlying the limestone which has yielded the rich but peculiar Cephalopod fauna of Landlake. Both the slates and the limestone dip N. 30° E., at an angle of about 20°; while the Culm-measures dip towards them with a lower but somewhat undulating dip. A quarter of a mile, or rather less, to the S.S.E. of the limestone, black chert is quarried in a field on high ground, dipping E. 25° S., at a low angle, with much contortion; and a little further down the brook similar beds are exposed near the bridge under Hardow Down, overlain by dark-grey flags with plant-

remains. These beds rise gently towards the south; but the chert is much contorted. Yellowish or greenish Culm-measure sandstones, with plant-remains, are also seen in a small roadside excavation half a mile to the south-east of Hardow Down, opposite the turn-off to Burdown, dipping S. 40° E. From this place the line of junction between the two formations passes in a southerly direction to near St. Lavers; but a small outstanding patch of chert occurs in a field a little south-east of Trewarlet, resting upon slates which contain fossiliferous seams, which appear to be on the horizon of the Petherwin beds. These slates dip due south, while the chert in the field dips south-west at a low angle, and is underlain by thin grey grit exposed near the entrance to the field. Beyond the slates, and about halfway between the chert-quarry and St. Lavers, the lane is crossed by a fault running N.E. and S.W., which brings down a narrow strip of Culm-measure slate and grit, together with some calcareous volcanic ash, dipping S.W. On the south side of the little stream, however, we almost immediately come to pale-green slates belonging to the underlying series, dipping S. 20° E. at a rather high angle; and this dip is continued to beyond Lezant.

From St. Lavers the line passes south of Landue Mill, and across the Callington turnpike-road, in a south-easterly direction, at a spot where unconformability is noticed by Sir Henry De la Beche* (but which in reality is a line of fault, as his sketch clearly shows), and thence on towards Lowley Bridge. Before reaching Cudducombe, however, we again find Culm-measure slates and grits, the line between them and the underlying rocks recrossing the turnpike-road to Trekenna, whence a long narrow strip of Carbonaceous rocks runs along the northern slope of the ridge which extends from East Penrest to beyond Trebollets. Along this narrow strip the chert, which is well exposed in the quarries opened for road-stone, is for the most part white, and dips north-east; but the bedding is much contorted, and southerly dips occur lower down in the valley. On the high ground south-east of Lazant, near a place marked "Ruins" on the Ordnance Map, coarse thick slates are exposed in a roadside-cutting; but I could not satisfy myself whether they belonged to the Culm-measures or to the underlying series.

Descending the hill from Cudducombe to the Inny river, either by the Callington turnpike-road or by the lane which leads to Trehingstow, we pass over dark-coloured slates with thin grey grits dipping S. 20° W. These beds cross the river below Trecarrel Bridge, and are separated from the volcanic ash on the south side of the stream by a very inconsiderable thickness of the lower slates, as seen in the section on the road from the bridge to Linkinghorn; but unfortunately the actual contact is obscured by rubble. At Tregvis the beds dip S. 20° E., but halfway thence to Lower Trelabe they dip N. 25° E. at 5°. Between these two places occurs the axis of a synclinal trough occupied by Culm-measures, which here consist chiefly of slates, often of dark colour, and thin grey grits, with one or two inconsiderable bands of volcanic ash near Congdon. These beds run

* Rep. p. 107, and woodcut.

up by Coades Green, Congdon, and Trevadlock, and by the north of Nighton nearly to Alternan. The lowermost beds here appear to be argillaceous; and although sometimes black, as at Trevry, Trevadlock, and Trevage, they are liable to become whitened, or of a very pale colour, from exposure, and are then sometimes difficult to separate from the underlying rocks. North-east of Nighton the grey grits have been quarried at the edge of a wood near the turnpike road, where the beds dip N. 20° W. at 15°, and are in the same mineral condition as at Trelabe, and on the banks of the Inny below Trecarrel Bridge; and in some of the beds plant-remains are numerous. All the high ground on either side of the turnpike-road from the westward of Alternan to Coades Green is capped with these beds, the grits weathering to a greenish yellow colour, and becoming whitened on the surface, and the slates becoming pale and soft, and then so much resembling some of the underlying series that it is difficult to distinguish them lithologically. Near Trelask House there is a small off-standing patch of the Culm-measures dipping E. 10° N., overlying the ash-beds of Lawannick; and two other outliers occur on the opposite side of the Inny:—the one on the west of Pollinny, where the beds dip north-east, and rest on slates that contain *Spirifera disjuncta* and other fossils; the other to the south of that place, occupying the high ground on either side of the road to Larnick, with a dip a little to the east of south.

Lower down the Inny these beds are well exposed at Beals Mill, where they contain *Goniatites*, *Orthoceras*, and plant-remains, as noticed by Professor Phillips; and they include the grits of Mount Pleasant and Inny Foot, which are continued past the Swiss Cottage and Twowell Down towards Lammerton. These beds dip southerly, but, as they undulate on their line of strike, they deviate occasionally by 25 to 30 degrees from due south. Thus at Tregarvis the dip is S. 10° E.; at the New Bridge over the Inny on the Callington Road it is S.S.W.; at Beals Mill it is southerly; at Inny Foot S. 10–20° E.; while at the Swiss Cottage it is S. 35° W. This southerly dip is continued across the Inny for at least half a mile; but south of Tregvis, Norton, and Kingston the dip is reversed, and about Penpill we reach the southern limits of the Culm-measures, with the exception of an outlier which caps the high ground between Linkinghorn and Southhill.

From Penpill the line which limits the Culm-measures on the south follows the ridge of high ground by Venterdon and Stoke Climsland to Lidwell, and thence nearly to Horse Bridge. At the crossroad north of Stoke Climsland there are some black slates with chert bands, partly weathered white on the surface; and similar Carbonaceous slates, partly blanched from exposure, are seen half a mile to the north of this place on the road to Beal's Mill. These are followed by dark slates with grey grits quarried at Lower Down House and Row Down, similar to those of Lawannick Down and Tregvis. In descending the hill to Horse Bridge we pass from these dark slates and grits with a northern dip on to grey roofing-slates, dipping apparently to the west. These underlying slates, with the same westerly

dip, are also seen in the river above the bridge, and in a slate-quarry on the opposite side of the river. But a little further up the stream, opposite a place called Bridge Farm on the map, horizontal beds of dark-grey micaceous sandstones with carbonaceous slates occur, occupying lower ground than the roofing-slates in the lane ascending from the bridge to the quarry. These Carbonaceous rocks set in immediately beyond the copper-lode which has thrown them down on the north. The grits contain plant-remains, and resemble very closely those exposed at Lower Down House, west of Beal's Mill, and in the quarry north-east of Nighton. This copper-lode forms the southern limit of the Culm-measures all the way to Hartwell, beyond which the line of their outcrop curves northward with the high ground to Chipshop and Ottery. Westward of the latter place Carbonaceous slate with chert is seen in nearly horizontal position, although much contorted, while close by, in the adjoining field, the grey roofing-slates of Mill Hill quarry dip E. 40° N. at high angles. From the northern side of this quarry the Culm-measures are continued to Stiles Wick and Downhouse Farm, and thence, thrown down by a fault, they cross the Tavy at the southernmost of the three bridges at Tavistock to Challicot; but they are difficult to follow across Whitechurch Down from want of exposures and, as we approach the moor, from the alteration in the mineral character of the rock produced by the granite*. The Culm-measure slates with their thin grits are well seen in the bed of the river between the bridges at Tavistock when the water is low; and chert is quarried near the town and in the vicinity of Collytown, on the road to Merriville Bridge. These rocks are exposed also in a small section at the south end of the railway-station; and the black slates have been cut into in lowering the roads on the west of the town. A little north of the railway-station thick-bedded grits dipping north-west are faulted against a bed of highly calcareous volcanic ash dipping in the opposite direction. Westward of this is an anticlinal axis followed by a synclinal trough, which runs in a north-easterly direction by Tavytown, south of which the Culm-measures crop out on Whitechurch Down. The volcanic rocks, as they rise to the south on Whitechurch Down, consist chiefly of what appears to be compact chlorite with grains of quartz, and dip N.N.W. at an angle of 30°. The town of Tavistock lies in a synclinal trough running north-east and south-west. The rocks are much disturbed and contorted, and there are many small faults in the vicinity of the town.

At Pentre Cross, near St. Mullion, several miles to the south, there are two small outlying patches of these Culm-measures brought down by an east and west fault, with a downthrow on the north, which crosses the turnpike road a little south of the turn-off to Callington. There is no mistaking the character of these rocks, which consist of black carbonaceous slate with chert, and massive

* It may be possible that some of the altered rocks which skirt the granite and form the high ground south of Stamford Spiney, and east of Walkingham and Meavy, may belong to the Culm-measures, having escaped removal by denudation.

greenish sandstones with plant-remains. On the south side of the fault are the grey and purplish argillaceous slates of the older series dipping to the south-west at a high angle, while the grits opposed to them on the other side of the fault undulate off to the north; but as a whole the position of these Culm-measures is not very much out of the horizontal, while the underlying rocks are highly inclined. This is the most southern spot at which the Carbonaceous rocks have been observed, and it shows conclusively that they once stretched considerably further to the south, prior to their removal by denudation.

It has been necessary to be thus minute in describing the southern limit of the Culm-measures, in order that the relation between them and the underlying series might be clearly brought to view; and if we trace the line on the map (Pl. XVI.) it will be seen that although there is apparent conformability in some places, yet, when looked at as a whole, it is obvious that the upper group is not always resting on beds of the same age. From this it would appear that the forces which resulted in bringing up the granite of Dartmoor and the Camelford Hills, and which have thrown the beds into their present position, having been posterior in age to the Culm-measures, have acted equally on both formations, and, in producing the major and more manifest foldings and contortions, have somewhat modified and obscured the unconformability which originally existed between them. Following the lower beds as they trend up from the north of Hingston Down by Stoke Climsland to the north-westward, the overlying series crops out, and the lower rocks then occupy the whole of the country between the granite and the Culm-measures of Laneast Down, and show a clear succession from below upwards. Hence the Carbonaceous rocks of Nighton and Trevage cannot be resting on beds of the same age as do those of Laneast Down, unless all the evidences of superposition are to be disregarded. Before proceeding to the consideration of these lower rocks, however, it will be well to notice briefly the relations between themselves of those rocks which make up that portion of the Culm-measures included between the line of outcrop indicated above on the south, Dartmoor on the east, and the range of limestones which extend from Truscott near Launceston, past Lifton, Lew Trenchard, and Bridestow, towards Oakhampton, on the north.

Fully to understand the structure of this triangular area it is necessary to bear in mind that all the igneous rocks contained in it are of the character of volcanic ash and lavas, and were contemporaneous with the rocks among which they are included. There are compact and crystalline rocks among them, it is true; but they are associated in such a manner with other rocks of similar composition, that have a vesicular or schistose structure, as to leave no room for doubt upon this head; and not a single instance was noticed of a trap-rock of undoubtedly subsequent age*. In attempting to un-

* It would be premature to attempt to define the mineral character of these rocks until they have been analyzed. They appear, however, to consist of a felspar which is usually green, less commonly white, and of a dark-green foliated mineral which, as observed by Boase, is something between chlorite

ravel the structure of this intricate country this distinction becomes of importance, as these interbedded volcanic rocks afford great assistance, inasmuch as they serve to separate the slates and grits into horizons, and otherwise act as landmarks to the geologist.

If, now, we endeavour to picture to ourselves a broad sheet of lava, ash, and cinders spread out horizontally round about Brent Tor, reaching from what is now the Tamer to the Tavy, and southward to the parallel of Tavistock, and then imagine this sheet of volcanic rocks, together with those that underlie it, thrown into a narrow anticlinal fold along a line extending from Ramsdown past Dunterton to the Tamer—and a second such narrow line of elevation passing through Upperton towards Bowdon Down—and a third similar, but longer and yet narrower axis extending from the south of Milton Abbots and north of Lamerton towards Petertavy, at the same time depressing the area about Heathfield Down so as to trough higher beds, and raising that of Black Down on the east, we have a rough idea of the arrangement of the beds before us. Thus the volcanic rocks of Lamerton are a more southern portion of those of Milton Abbots and Charlhanger, thrown over a long sharp anticlinal axis,—narrow on the west, where they dip under the slates and grits of Twowell Down, and broader on the east of Lamerton, especially in the vicinity of Kilworthy and Wilminston, where they lie more horizontally. So with the volcanic beds of Upperton and Wick, which are a part of the same as the Milton Abbots beds rising up again from beneath the slate, chert, and grit of Heathfield Down, to be thrown over to the north at Quether. The ash extending from South Brent Tor to Burn, parallel to the railway, remarkable for its highly vesicular structure, appears to be the continuation of the Milton Abbots ash-bed faulted off at Burnford Farm, and thrown over to the westward of the anticlinal axis of Black Down; and the ash-bed of Rowdon belongs to the same geological horizon. The section (fig. 1, p. 409), across Heathfield Down, from the Mill Hill Slate-quarry, near Tavistock, to the Thistle Brook at Stowford, will show the general relations of these rocks.

Several faults appear to traverse the country in the vicinity of Brent Tor. One of these crosses the Lyd river south-west of Coryton, and ranges by Monkstone to the west of the Tor. Another skirts the north-east side of the volcanic rocks of the Tor, extending from near Monkstone to South Brent Tor. These faults carry the country on the east further to the south, or rather south-east, and reverse the dips along the valley of the Tavy, where the beds rise to an anticlinal axis, which crosses the railway in a N.N.E. and S.S.W. direction, midway between Ford Gate and the Marytavy Railway Station.

and hornblende. Augite and hornblende are of less frequent occurrence, and then only in the more compact varieties. Many of these rocks are highly calcareous, the lime being sometimes diffused among the volcanic materials as a constituent of the rock; in other cases it has been merely infiltrated into the cavities of vesicles at a subsequent period. Near the granite these rocks have been altered both in their crystalline condition and in the arrangement of their elements; and of the resultant minerals hypersthene appears to be one. See further De la Beche, Rep. p. 119 *et seq.*

The volcanic rocks on the north of Dunterton and Quether pass under a belt of dark slates and chert, which ranges up from Landue, south of Launceston, by Greston Bridge to Staddon, and thence to Littonary Down, where, thrown to the south-eastward by the fault already mentioned, it is continued by Bowdon Down to East Longstone; and this in turn passes under the higher band of volcanic rocks of Bradstone, Chillaton, and West Longstone. It is this chert and its associated grit and slate which constitute the higher beds of Heathfield Down, on the west of the Brent Tor faults.

Still higher beds, consisting of dark-blue and greenish-grey slates, with seams of grit and nodules of ironstone, range up from the Tamer north of Bradstone, by Kelly and Marystow, and along the valley of the Lyd river to the Lydford railway-station, and thence pursue a north-easterly direction by Lydford and Downtown to the granite. These slates are finely exposed in the railway-sections between the Lidford and the Coryton stations. They are evenly laminated, dip northerly, and rest upon the volcanic rocks of Chillaton and West Longstone. The volcanic rock of Medwell appears to be the same as those of Bradstone and Chillaton, cropping out on the north side of a narrow synclinal fold which extends from Kelly to Green Cross, while the chert of Lawhitton, Hardow Down, and Kelland is the underlying rock of Staddon and Littonary Down again brought up to the surface, separated from the chert of Gordon Hill by the northern continuation of the Lyd-river slates, which range by Trenefell to the north of Tremale, where they are worked for roofing-purposes.

On the north of this belt of slaty rocks are the small lenticular deposits of dark-blue or black limestone of Cury Park, Poleat Corner, and Coryton Railway-station; and beyond these there is a range of chert-beds, which constitutes an important feature in the country, and forms a ridge of barren land which is easily followed. This chert forms the high ground of Gordon Hill, east of Launceston, where it is underlain on the north by black slate and the limestone south of Timber Bridge, and is continued east of the Tamer, by Sydenham and Leigh Down, to the Lew Water. It includes the volcanic ash-beds of Whitley and Leigh Down, and is exposed in quarries by the side of the railway west of Sydenham. A second patch of chert, which, although on nearly the same line of strike, appears to be disconnected from the last, is seen immediately to the north of the limestones of Poleat and Cury (some slates, however, intervening), and is continued on the north side of the road to Watergate, through Burley Down, to a farm marked Buddle Brook on the Ordnance Map. This chert occurs for the most part in rather thin beds; but they are contorted and crumpled to such an extent that the beds are often folded completely back upon themselves, and in looking at them it is impossible to avoid the conclusion that the more argillaceous slaty rocks cannot have escaped the influence of the forces which have contorted these harder rocks in so remarkable a manner, although it is not equally apparent in them. Slaty rocks lie to the north of the chert-beds similar to those on

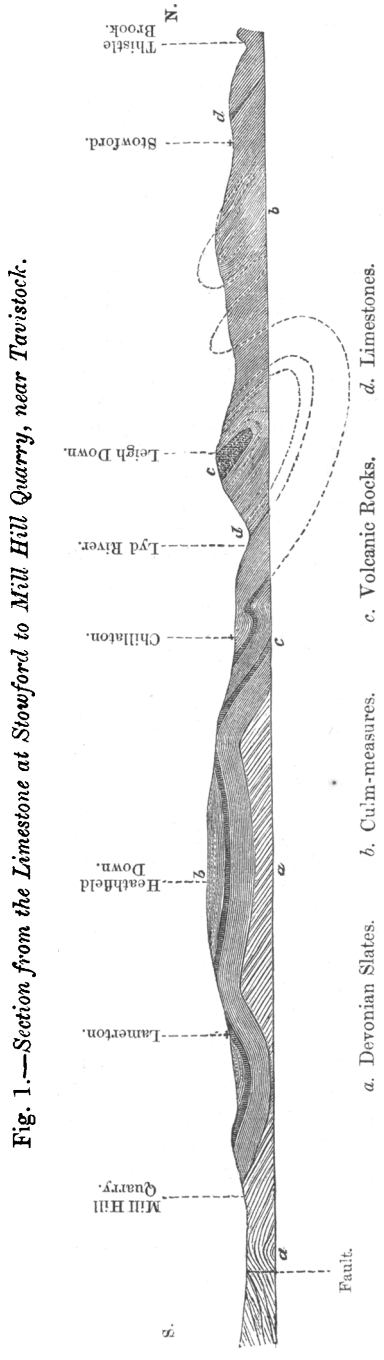


Fig. 1.—*Section from the Limestone at Stowford to Mill Hill Quarry, near Tavistock.*

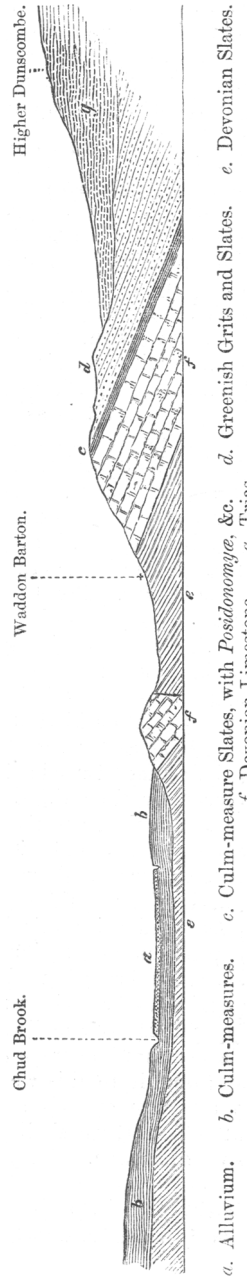


Fig. 2.—*Section from the Chud Brook through Waddon Barton to Higher Dunscombe.*

the south, beyond which are the southernmost limestones of Timber Bridge, near Lifton, and of Tinhay, and those of Lew Trenchard, Point Bridge, and Bridestow, which return by Thrastleton, Stowford, Thistle Brook, and the smaller patches north of Tinhay and Timber Bridge, the included area being occupied by the lower rocks of the Lyd river brought up to the surface by the anticlinal axis of Old Street Down.

The chert of Gordon Hill is not continued to the west on the same parallel; but on St. Stephen's Down, on the road from Launceston to Yeolm Bridge, similar chert occurs, and ranges westward towards Egloskerry. This chert occupies the centre of a synclinal trough, the underlying Devonian rocks being brought up to the surface along a narrow axis on the north, which extends from Underwood Farm to Yeolm Bridge, while a lower axis on the south ranges east and west through the town of Launceston. A bed of limestone, together with some volcanic ash, underlies this chert at Calvanna Park, near Lower Truscott, which bears the same relation to the siliceous rock above as the limestones of Coryton and Timber Bridge do to the chert of Gordon Hill and Sydenham. Between the anticlinal axis of Yeolm Bridge and the lower rocks of South Petherwin we appear to have, therefore, the whole of the Culm-measure series from the limestones downwards; but we miss from the rocks south of Launceston much of the volcanic ash, and most of the grit and chert which characterize the Carbonaceous system along the banks of the Tamer. Brent Tor, or its vicinity, as already suggested by Sir Henry De la Beche*, was probably the centre of volcanic action, and this may sufficiently explain the somewhat local distribution of the igneous products. The rocks forming the Tor are composed in great part of cinders, some of large size, mingled with ash, cemented into a kind of conglomerate, the vesicles being filled sometimes with carbonate of lime, at others with chalcedony. Neither in their mineral nor in their physical character do these volcanic rocks differ more than those of modern eruptions; the lavas are sometimes vesicular, at others crystalline and compact, the ashes more or less schistose and mixed with cinders, and the whole commingled in a manner that shows their common origin†.

It is difficult, therefore, where igneous and arenaceous rocks are intercalated so irregularly among the slates, to form even an approximate estimate of their thickness. If we take the distance from the lower rocks brought up by the anticlinal axis at Underwood Farm to the middle of the chert troughed in the synclinal fold on the south, at Upper Truscott, the distance is barely three-fourths of a mile, which, at a maximum average dip of 35°, would give little more than 2000 feet; and if to this we add half as much again for the increase of arenaceous materials and intercalated volcanic rocks on the banks of the Tamer, we shall probably arrive at as near an approximation as we can make.

* Rep. p. 122.

† The vesicular structure of some of these rocks would lead us to infer that they were accumulated, in part at any rate, on dry land.

The relations between the Culm-measures and the lower rocks north of South Petherwin are not altogether so clear as could be wished. The Carbonaceous rocks dip to the north; but the underlying slates are a good deal rolled, and their dip is not easily made out. Following, however, the line of outcrop from the Landlake quarry by St. Lavers to the south, the Culm-measures may be said to arch over the older rocks brought up between South Petherwin and Trekenna (see section fig. 3, p. 417), with minor east and west undulations; and in the deep synclinal trough of the Inny there are some of the higher beds (the slates south of Beal's Mill), which occupy the axis of the trough, corresponding probably in age with those of the Lyd river. The volcanic rocks, however, are absent, and the chert is for the most part replaced by grits.

Near Bridestow, the chert-beds of Watergate thin out, and the dark slates to the north and south of them are brought together, and are continued by Sourton and Oakhampton Park round the north side of the Dartmoor granite, which has pushed the Culm-measure beds to the northward, and brought them into vertical or highly inclined positions. It is not necessary, however, for the objects of this communication, to follow these beds further in this direction. I proceed, therefore, to notice briefly the relations existing between the lower Culm-measures and the underlying rocks as they occur on the east of Dartmoor.

Along the margin of the granite from East Down, near Lustleigh, to Skeriton, south of Holne, the Culm-measures consist of slates and grits with chert-beds very similar to those which occur north of Tavistock. The chert is perhaps not so abundant; but a siliceous rock, somewhat less flinty, is plentiful between Bickington and East Down; and volcanic admixtures occur near Ilsington, and become frequent further north between Chudleigh and Dunsford. Near the granite the rocks have become altered by it; and the resulting metamorphic rocks resemble those on the west and north-west of Dartmoor, showing their close similarity in mineral character. Near Ilsington they contain plant-remains, and Goniatites have likewise been found in them.

We may safely assume, I think, these rocks to be the equivalents in part of that portion of the Culm-measures which occurs south of the Lyd river, and to occupy a position at or near the base of the series. They dip, as a whole, away from the granite, to the east and south-east, but are much undulated and contorted, and hence counter dips are frequent. The line between the Carbonaceous rocks and the Devonian slates and limestones emerges from beneath the Bovey beds at Black Pool, and extends by the New Inn southward to Bickington. So far the line appears to be a line of fault, Culm-measure grits and slate very highly inclined to the eastward being brought against the Bickington limestone, dipping south-east at an angle of about 25°. This fault appears to run into another short fault, which extends north-west and south-east, and cuts off the Bickington limestone from its continuation with the Ashburton mass at Lemonford. From the factory north of Lemonford the line, as laid down on the

Geological Survey-map, then passes by Higher Way to the Druid's fault. The want of exposures, however, makes it very difficult to determine whether or not the slates at Alston and Way, which dip towards the Ashburton limestone, may not be Culm-measures brought against it by a fault parallel with the turnpike road. The nearly east and west fault which passes Rew Mill, and which is in part metalliferous, being now worked for copper at the Druids' mine, throws up the underlying Devonian rocks included between it and a nearly parallel fault which ranges from about a quarter of a mile south of Holne Bridge, past Christophers and Pridhamsleigh, to the south of Bulland. These lower rocks thus faulted up dip under the volcanic rocks and limestone of Ashburton; but about three-quarters of a mile from the town, on the road to Buckland-in-the-Moor, they appear to make a turn over, and become, first vertical and then reversed, at an angle of 65° to the south-east; and at the Druids' Farm they contain *Spirifera disjuncta*, *Chonetes sordida*, *Petraia bina*, and *Cyathocrinus pinnatus*? Following these fossiliferous beds along their line of strike to the south-west, we find them again in the descent to Holne Bridge, with abundance of *Spirifera disjuncta*. It would appear, therefore, that these beds are well in the Devonian rocks, and probably not very much below the base of the Ashburton limestone. If we follow them across the Dart, however, we find, just before entering Hembury Wood, that they abut against a mass of thick-bedded grits, with black slates which clearly belong to the Culm-measures. These rocks are highly flexed, and are confined to the east side of the river, where they form a steep ascent of some elevation. On the opposite side of the river the ground is low and consists of slate. Although the two series are not seen in actual contact, it is yet clear that they dip in opposite directions, and that they are brought into apposition by a fault. In all probability this fault runs into the Brook Mill lode south of Hembury Castle; and, in fact, it would appear that the north and south fault we are alluding to is itself metalliferous, as there are the remains of an old copper-mine on the banks of the river. Southward of the Brook Mill lode, it is impossible to draw the line with any approximation to accuracy, not simply from the want of exposures, but also from the country being covered with fragments brought down from the higher ground on the west; but to the eastward of a line thence by Skeriton we are clearly on the Devonian rocks*.

South of Newton Bushell there is a small outlying patch of these Culm-measure grits and slates, which occupies a depression in the Devonian rocks immediately to the east of the limestone of Og-

* The grits west of Bickington are succeeded by argillaceous slates, which undulate as far as Ramshorn Down, where they pass under the chert-beds of Combe. Now, in some of these beds, Prof. Phillips mentions the occurrence of fossils (Pal. Fos. p. 203); but I was not aware of this circumstance until too late, and therefore did not specially examine the locality with a view of ascertaining the position of these fossiliferous beds; if, however, they belong to the underlying Devonian series, they must be brought up to the surface either by a sharp anticlinal axis, or by a fault parallel to that of Bickington.

well. These beds rest unconformably on the older rocks, as noticed by Mr. Godwin-Austen*, who found at their base a conglomerate of rounded pebbles of quartz with angular fragments of the subjacent limestones†. Through these Carbonaceous slates and grits the limestone of Connator forms a protrusion, and on the east they are brought against the argillaceous slates of the Totnes turnpike-road (which underlie the limestones) by a north and south fault, with downthrow on the side towards Ogwell ‡.

Crossing over to the other side of the Bovey deposits, we find precisely similar Carbonaceous slates and grits, occupying the country north of the Kingsteignton limestone, overlain by Triassic conglomerate on the east, and by the Greensand and Bovey deposits on the west. Through these slates and grits, the limestone of Kingsteignton, Orchard Well, Ugbrook Park, &c. forms protrusions, the Carbonaceous rocks occupying the hollows between them. The slates south of the Kingsteignton limestone, much of which is purple or claret-coloured, belong to the Devonian system. They appear to rise from under the limestone and associated igneous rocks, which latter have altered them at the line of contact; and they occupy both shores of the estuary between Bishopsteignton and the Bovey beds of Newton.

North of Ugbrook Park there is a long curved strip of the older limestone, containing Devonian fossils, which appears to be faulted up, as the strike of this limestone is oblique to that of the Culm-measures, which occupy lower ground. At Waddon Barton this limestone is overlain by hard slates full of *Goniatites* and *Posidonomyæ*, above which are the typical Carbonaceous sandstones quarried at Ugbrook Park. Purplish and grey slates, with calcareous concretions, underlie this limestone, and are exposed in the hamlet of Waddon, where they are clearly seen to dip under the limestone. Beyond these, nearly midway between the cottages and the Chud Brook, there is an off-standing knoll of shattered limestone, which appears to be on a line of fault. The low ground through which the Chud Brook flows is partly occupied by alluvium; but we learn from Mr. Godwin-Austen that a well-sinking, which was formerly made here, passed through 15 feet of perfectly horizontal carbonaceous slate and sandstone resting on highly inclined slates, similar to those seen beneath the limestone at Waddon, and dipping in the same direction§. The section (fig. 2, p. 409) taken across the beds at Waddon Barton in a south-easterly direction, will serve to show the general structure of the country.

Northward of Chudleigh the Culm-measures undulate towards

* Geology of the S.E. of Devonshire, Trans. Geol. Soc. vol. vi. 2nd ser. p. 457.

† *L. c. suprà*, p. 458.

‡ Sir Henry De la Beche appears to have considered this fault an upcast on the east (*vide* Rep. p. 111). On the contrary, it appeared to me that this small patch of Carbonaceous rocks has been preserved where it is by having been brought down below the general level of the country, and so escaped denudation. The bedding of the Connator limestone appears to be vertical; but it may have been brought into that position before the Culm-measures were deposited.

§ *L. c.* p. 460.

Ashton and Dunsford, the direction of the bedding being south-west and north-east. The beds are broken through on the west by the granite of Dartmoor, and on the east by the limestone of Whiteway and Uppercot. Grits and volcanic rocks are abundant, the latter corresponding in general position to the similar rocks in the vicinity of Brent Tor; and near the granite they become crystalline and more or less altered, and lose all trace of their mixed igneous and mechanical origin.

It is not the intention in this communication to enter into a detailed account of the Carbonaceous rocks generally. For a further description of them, reference must be made to the original memoir by Sir Roderick Murchison and Professor Sedgwick, in the 5th vol. of the Transactions of this Society (2nd ser. Part 3, pp. 669 *et seq.*). It is to these authors that we are indebted for having first pointed out the true position of these rocks in the geological scale, when, by means of the included plant- and other fossil remains, they identified them with the Coal-measures of South Wales.

III. Devonian Rocks.

1. *Beds below the Plymouth and Torbay Limestones.*—The lowest rocks in the district to which this communication more particularly refers have been upraised around Hingston Down, and, between the granite of Dartmoor and the Tamer, in the vicinity of Buckland Monachorum, Beer Alston, and Roborough Down, near Bickleigh. On the confines of the moor, around Harrowbridge, Walkingham, and Meavy, the beds dip away from the granite at low angles; but to the south of Bickleigh Railway-tunnel, the granite has broken through the bedding, which ranges up to it, at right angles to its margin, with a southerly dip. These beds consist chiefly of pale greenish and grey argillaceous slates, sometimes soft and silvery, and often veined with quartz; but grit seams are not common. North of Harrowbridge and Buckland-Monachorum the prevailing dip is to the south-west; but the country is much disturbed by faults and metalliferous lodes, and southerly and westerly dips are not wanting.

At Morwellham Quay, on the Tamer, the beds are greatly contorted; and contortion is also seen in the valley of the Tavy, near Romans Lee, and on the east of Lumber Bridge; but easterly dips occur on Morwell Down and about Gulworthy, and north-easterly dips at Mill Hill quarry, thrown off from the granite of Hingston Down. From these twin granitic protrusions the beds dip away in all directions; those on the north, however, become horizontal at Latchley Ford, and then rise gently to the north, but are disturbed at Horse Bridge and Hartwell by a fault which has brought them against the Culm-measures. On the south of the down the beds range from the Tamer by Tiddeford to the north of Callington, with a southerly dip at an angle of from 25° to 30°, and pass under higher beds south of the town. On the south of Beer Ferrers and Bickleigh these green and grey slates pass under higher beds, which between Tamerton Foliot and St. Budeaux are partly blue and purple.

The country to the west of the Tamer is thrown down by the partially metalliferous faults of Calstock and Colete. A fault which ranges east and west by New Bridge, on the Notter, with upcast on the south, repeats some of the rocks between it and Callington; but the dip is to the south, and higher beds come in about Pillaton Down and St. Mellion, south of which a second nearly east and west fault throws down the country, and with it a patch of Culm-measures, at Pentre Cross. In a similar manner faults have brought down the area around Linkinghorn and South Hill; but lower beds occur on the west of the Notter, between it and the granite at Caradon.

The elvans, which are associated with these lower slates as we approach either of the great granitic masses of Dartmoor or the Camelford Hills, although sometimes parallel to the strike, have no relation to the plane of the bedding. Some of them may have been contemporaneous with the outburst of the granite, filling in fissures made by the same disturbing cause, as in the vicinity of St. Neot's and Blisland; but others, as near Redruth and Penryn, are seen to traverse the granite as well as the adjacent rocks, and must therefore be somewhat more recent. It is otherwise, however, with the volcanic rocks which are associated with the slates, and which occur more or less abundantly on certain horizons. They lie in the plane of the bedding, and were contemporaneous with the rocks among which they occur. Their structure is often schistose or vesicular; and many of them are rich in lime, which in the vesicular varieties has been infiltrated into the cavities. With this ash, whether schistose or vesicular, there is often intermingled more or less fused rock, in such a manner that it is very difficult, as observed by Sir Henry De la Beche, "to see where the one variety of igneous product ends, and the other commences"*. It is seldom that even the compact portions have produced any very obvious effects upon the subjacent slates.

As the rocks between Hingstown Down and the southern edge of the Culm-measures range by North Hill towards Alternan, they dip away from the granite at angles which do not appear to exceed 10°, and are often less; and in doing so they pass under the Culm-measures which extend by Coades Green to within a mile of the Penpont Waters, capping the higher grounds as they rise to the north-west. These lower rocks form a belt of country consisting of slates and ash-beds, which strike north-west and south-east, the angle of dip varying from 5° to 10° or 15°. At Holloway Cross and Trewen, westward of the line of fault, near Kneller's House, these ash-beds pass under overlying slates, which dip to the north-east with the same low undulating dip (under 15°), and include the limestone and fossiliferous slates of Trenalt and Tall Petherwin; and as the ground rises some 300 feet or so, we come rapidly upon higher beds, which are finally overlain by the Culm-measures. At Treguddick Mill some of the slates which underlie the ash are brought up by a short, sharp anticlinal axis, which throws the volca-

* Mem. Geol. Survey, vol. i. p. 82.

nic rocks over to the northward, after which they both dip under the higher beds of Tall Petherwin and Treguddick Farm.

To the eastward of the fault before mentioned, which runs down to Treveny, the country opens out in the direction of the Tamer; and north of Trecarrel Bridge lower rocks rise from beneath the Lewannick belt of volcanic ash, and form a ridge, which, commencing at East Penrest, where the beds emerge from beneath the Culm-measures of Cuddicombe, passes by Trebollets, Pollinny, and Trecugar to South Petherwin, and is then continued by Oldwell to the north of Trevoza, where these lower beds again pass beneath the Culm-measures. These lower rocks consist of evenly laminated pale-green slates, and are apparently unfossiliferous. As a consequence of the upheaval of the beds eastward of the Treveny fault, the continuation of the higher fossiliferous slates of Tall Petherwin and Trewen, with their included limestones, is carried to the northward, by Little Petherwin and the south of Doe's Houses, to the Landlake limestone-quarry, where they pass beneath the Culm-measures of Haldon Down. On the other hand, we have within this semicircular ridge, occupying the lower ground round about Trewarlet and Larrick, and on the eastward of Lower Linnick, some of the same fossiliferous slates with calcareous seams (see fig. 3).

These upper beds are less uniform in their petrological character than the pale-green slates below them. They consist chiefly of olive and brownish slates, more or less rust-stained on the surface, and often cleaved and splintery. Interstratified with them are thin ochreous seams, which occasionally contain fossils; and some of the olive-brown slates contain numerous minute points of ochreous matter, the remains of some decomposed crystals, which give them a speckled appearance. This is so frequent in the upper beds of this vicinity as to be almost characteristic. The still higher slate rocks, however, or those immediately beneath the Culm-measures, north of Holloway Cross and Trewen, are softer and thicker, and much of them is of a very pale colour and an even texture.

The limestone at the Landlake quarry dips N.N.E., at an angle of 20°; and it is from this spot that by far the larger part of the South Petherwin fossils have been obtained. The other two limestone patches appear to be less highly inclined; but there is some difficulty in making out the dip satisfactorily, as the rocks are here much rolled, and, moreover, they are affected by cleavage which in some places is inclined in an opposite direction to the bedding, as, for instance, in descending the hill from Little Petherwin. There appears to be no reason to doubt, however, that these three small calcareous patches are on the same line of strike, curved round to the northward of, and rising up to, the upraised lower rocks on the south. Some of the associated slates, in fact, may be seen capping the highest ground in the lane due east of South Petherwin, where the included ferruginous seams contain *Orthoceras ibex*, Phill., a *Clymenia* much flattened, and some other shells; *Spirifera disjuncta* and *Spirifera Urii* occur also abundantly in some slates halfway up the hill south of the Landlake quarry. In the quarry south of Doe's

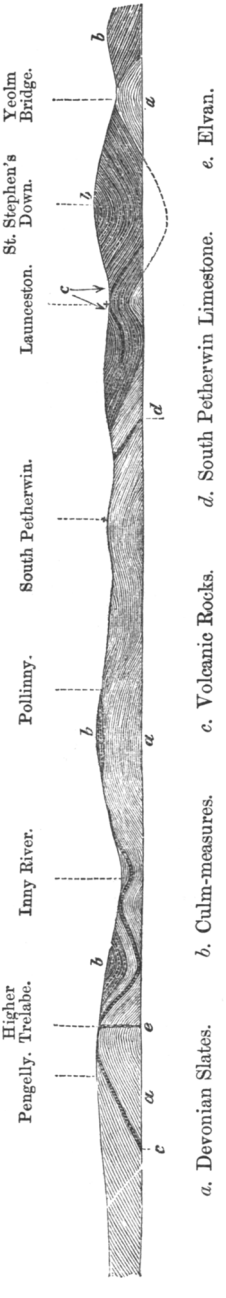


Fig. 3.—*Section from Yeolm Bridge to Pengelly, near Linkinghorn.*

Houses, fossils are specifically far less numerous than they are at Landlake, the only additions to the already known species from this locality being *Tentaculites annulatus*, Schloth., and a small undescribed species of *Serpula*; but the limestone at Little Petherwin, although in the same mineral condition, contains few or no fossils. Underlying these calcareous beds are two small patches of volcanic rock, the one a little north of South Petherwin, the other at Bolathan, a mile to the west of the former; and it is perhaps worth noting that these igneous rocks hold pretty much the same relative position to the Petherwin limestones that the larger band of Lewannick does to the limestone of Trewen, and may possibly be offstanding patches on the same horizon. Fossiliferous slates containing *Spirifera disjuncta*, *Cyathocrinus ellipticus*, and an *Orthis* occur in the lane leading from Trekellearn Bridge to Pollinny, about halfway up the hill; and the similar olive and speckled slates with ferruginous seams, which occupy the depressed country round about Trewarlet, and beneath which the pale-green slates of Brocka and Trevoza are seen to dip, are again fossiliferous at Larrick, Trewarlet, and the south of Laudue; and on the banks of the Inny below Round Bury, troughed among the beds which overlie the volcanic rocks on either side of the river at Trecarrel Bridge, a small patch of highly calcareous ash occurs, which appears to be sufficiently on the same horizon as the limestones and calcareous seams of south Petherwin and Trewarlet, to be regarded as belonging to the same group.

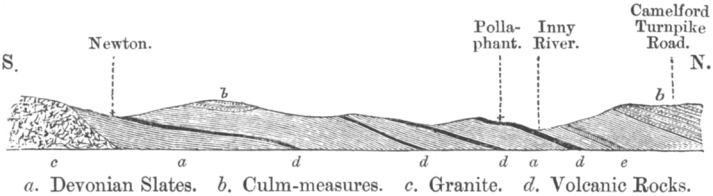
It would appear, therefore, that the place of the limestones and calcareous seams of South Petherwin,

Trewen, &c. is at a short distance only above the uppermost belt of volcanic rock, or that which extends from Trecarrel Bridge, by Lewannick, to Laneast. The overlying slates attain their greatest thickness in this vicinity, north of Holloway Cross and Trenalt.

Three miles to the north of South Petherwin, these lower rocks are again brought up to the surface by a narrow anticlinal axis at Yeolm Bridge, which extends westward by Underwood Farm. These slates are sparingly fossiliferous; but the few species that occur at this locality are all South Petherwin forms, with the exception of *Sanguinolaria elliptica* and *Bellerophon hiulcus*, of which latter, I believe, only a single very imperfect specimen has been met with, and this may have come from the overlying Culm-measures*.

The attempt to ascertain the relative position of the several beds of ash is attended with considerable difficulty, owing to the paucity of good exposures and the uncertainty regarding the true dip of the beds. The belt of volcanic ash which extends from Tregue Cross by Penhale to the south of Davidstow, appears to be the same as that which ranges up from North Hill to the west of Alternan, broken off and carried further to the northward by the granite of Brey Down; but the strip of Culm-measures which runs up from Coades Green to as far as Trebant, obscures in great part the older rocks which dip away from this igneous belt to the north-east; and the slates which further on rise up from beneath these Culm-measures, and range by Alternan and Tregue Cross, are altered by the granite. Crossing the country, however, from Trevillans gate by St. Clether, we have apparently a clear upward succession of strata, all the way to the Carbonaceous rocks of Coose Moor. The volcanic belt of St. Clether consists of an upper and a lower band separated by beds of more schistose ash (along which the river runs), and has a north-easterly dip, at an angle of about 20°. From this belt, a little further to the east, at Laneast, we have again apparently an upward series to the Culm-measures of Laneast Down, all the dips obtainable being north-easterly. The intermediate belt of igneous rock, or that south of Laneast, is highly calcareous, and has some beds of limestone at the top—a character which it possesses in common with the volcanic rocks of Titch Beacon, which strike up to an impure limestone at Grills, near Lesnewth, and appear to be on the same horizon.

Fig. 4.—*Section from Minwonnet by Pollaphant to the Granite near Newton.*



a. Devonian Slates. *b*. Culm-measures. *c*. Granite. *d*. Volcanic Rocks. *e*. Limestone.

* Phill. Pal. Foss. p. 139, pl. 58. f. 203.

The two masses of volcanic rock on either side of the Inny at Trecarrel Bridge appear to be portions of the same band, troughing some of the higher beds between them, as already noticed. A tolerably good section is seen in the lane leading from the bridge to Tregvis, the volcanic rocks rising as an arch, which throws off a thin covering of the higher slates; on the south these undulate for about a hundred yards, when the volcanic rock again rises, overlain by the slates. A little further on, these rocks are overlapped by the Culm-measures.

The belt of slates in which the volcanic rocks we have been considering are included is readily followed westward from St. Clether, by Davidstow and Lesnewth, to the coast at Trevalga, where they curve south-west to Tintagell, and are there associated with slates that contain *Petraia Celtica*, *Phacops latifrons*, *Strophalosia productoides*, *Spirifera disjuncta*, and its varieties *gigantea* and *inornata*, *Rhynchonella pleurodon*, *Pterinea subradiata*, and *Spirifera speciosa*, all of which, with the exception of the last two, are also met with at South Petherwin. The greenish-grey slaty rocks which support the volcanic belt of Tregue Cross and Penhale dip under it, and strike, by Trevillan's and St. Kitt's, round the north-westward of Cadon Barrow, lower rocks containing some thin grits being brought up south-eastward of the barrow, and about Camelford. To the westward of these lower rocks, and overlying them, there is a belt of similar greyish slates striking up from below the volcanic beds of Tregreenwell, east of St. Teath to Delabole, where the rock has long been worked for roofing-slates, and thence to the Trewarnet slate-quarries, where it curves round to the coast at Tregatta. The exact mode in which this range of slates is brought into contact with the higher rocks of Tintagell is somewhat obscure; but the abrupt change in the direction of the strike suggests the probability of a fault crossing the country somewhere betwen Tregatta and Tintagell. The dip of the Delabole and Tregatta belt of roofing-slates is to the west, south-west, and south, as they curve round to the coast; and if they are, as they appear to be, the same as those which support the volcanic rocks of Tregue Cross and Penhale, the higher beds of Delamear Down (under which these slates dip) must be the same as those of Davidston and St. Clether, but without the interstratified bands of igneous rock. These latter, however, again come in south of St. Teath, where the beds begin to widen out to form a broad shallow trough with minor axes; and as this trough trends round to the westward, it deepens, and includes higher beds, some of which are calcareous and correspond in geological position with the fossiliferous beds of South Petherwin. The slates which include these ash- and lava-beds, and support the higher rocks troughed in the synclinal axis, form therefore two belts:—a northern, which trends east and west from the south of St. Teath, at Treburget, to Pentire Point; and a southern, which is continued by St. Tudy and St. Mabyn, and then curves round to the Camel river at Egloshayle, beyond which it is continued without the volcanic bands, by the south of St. Breock and St. Ervan, to the coast at Bedruthen. Some of these volcanic bands

are no doubt the same beds repeated by the subordinate anticlinal and synclinal folds; and faults may have destroyed the continuity of a bed, and thrown it out of the line of strike, as is the case in the vicinity of Padstow. The limestones and fossiliferous bands range on either side of the axis of the trough, which trends from Constantine Bay, by Padstow and St. Michaels, to Lower Amble, round to the south-east of St. Kew; and some of these higher beds consist of purplish argillaceous slate very similar to some of that associated with the volcanic rocks of Saltash and St. Germans, to be noticed hereafter.

The fossils of the Padstow district occur chiefly at Permizen Bay, Dinas Cove, and Penquean, and consist of *Petraia Celtica*, *Phacops latifrons*, *P. laciniatus*, *Athyris concentrica*, *Atrypa desquamata*, and *Orthoceras Ludense*, Phill. (which are also South-Petherwin forms), *Spirifera speciosa*, *Pentamerus brevirostris*, *Streptorhynchus umbraculum*, *Stringocephalus giganteus*, *Cyathocrinus megastylus* (which are Middle Devonian), and *Spirifera hysterica*, which is a Looe and also a Lynton species, but is said to occur likewise in the limestone of Woolborough near Newton Bushell. From Bedruthen Steps, Mr. Pengelly has obtained specimens of *Pteraspis Cornubicus*, M'Coy; and this is the lowest horizon on which it has hitherto been observed. We have therefore six species occurring in the Padstow area in common with South Petherwin, and six in common with the Looe-river district, with two that belong to intermediate stations, viz. *Spirifera speciosa*, which occurs also at Tintagell, and *Phacops latifrons* at Liskeard. See Table III., p. 450.

These rocks rise, on the south of the trough, to the anticlinal axis of St. Breock's Down; and in all probability the slates which contain the calcareous and fossiliferous rocks of St. Columb Porth and New Quay, are the same beds repeated on the south side of the axis*. This axis extends from the coast north of Trenance Point, near Morgan Porth, to the Camel above Polbroke, and brings up lower rocks, which consist chiefly of thick pale-coloured slates with bands of hard grey grits, the whole much traversed with veins of quartz, fragments from which, mingled with those from the grits, are strewed abundantly over the surface of the down. Eastward of the Camel, the country to the south of the axis, about Bodmin and Lanivit, is thrown up by the granite of St. Austell, and the dip becomes northerly, at for the most part low angles. This upcast is aided by a line of fault which extends from the east of Bodmin, by the Black Pool Barrow, to the west of Lostwithiel. The crest of the St. Breock's-Down axis, which is formed by the arenaceous beds, thus becomes relatively depressed; and the country round about Bodmin, west of the fault, and between it and the Camel, consists chiefly of the thick slaty rocks which form the flanks of the axis, and some unimportant bands of grit, undulating off to the northward. At the quarries at Castle Canyke, and about Bodmin Down, the angle of dip is about 20°; south of Bodmin Down bands of grit rise to the south and crop out.

* See, further, De la Beche, Report, p. 88.

To the east of the fault which passes Lostwithiel, and which is probably continuous with the Tywardreath copper-lode, the country is upraised, and the rocks are similar to those of St. Breock's Down, much traversed with quartz veins, blocks and fragments of which lie about in abundance. The gritty and arenaceous beds form a narrow belt of country, which extends from the north of Black Pool by the Grey Mare and Rye Down, and between Boconnock and Broadoak, to Bucka-Barrows and Bury Down; and the grit beds south of St. Keyne appear to be the continuation eastward of the same belt of rocks. Opposite the Parsonage at St. Keyne these grits lie horizontally, and there can be no doubt about their passing under the argillaceous and calcareous rocks on the south; but it is not so clear whether they rise from under the slaty rocks on the north at St. Keyne, or whether they are faulted against them. These grits, with the thick slates which overlie them, together with those which form the high ground between the forks of the Towey River at St. Winnow, and the south-east of Lostwithiel, constitute a somewhat triangular area, having the Lostwithiel fault at its base, which separates and dovetails in between the higher rocks of the Liskeard synclinal trough as it crosses the tributaries of the Fowey, south of Warleggon, and St. Neots on the north, and the rocks of similar age as they strike from the Looe river below Tredinick by Lanreath and St. Veep to Trewardreath on the south. In this view, I am compelled to differ from the opinion of the late Sir Henry De la Beche, who held that the thick slates and grit beds of Boconnock and Rye Down are higher beds overlying the red slates of Lansalloes and Gregon*. The reasons against this will become more apparent when we have followed up the higher rocks from the eastward.

To return to the beds which skirt the Camelford granite on the north-~~west~~. The volcanic rocks of Alternan and North Hill terminate near Kelbrook, being broken through by an elvan; the similar rocks of Bray's Shop, and Pengelly, although the continuity has not been actually ascertained, are probably portions of the same band disconnected by some local disturbances. The small patch at Treven connects this last with the larger patches of South Hill, Hay, and Callington, and these, again, with another small faulted patch at New Bridge, which last is not very far removed from the line of strike of the volcanic rock of St. Cleer. These patches do not form portions of a continuous bed; but it is probable that they all belong to the same horizon, judging from the general relations of the rocks of the district—the bed of volcanic rock at St. Cleer on the south bearing very much the same relation to the granite that that of Alternan does on the north, lower rocks being brought up in the interval on the east of the granite at Caradon, Notter Tor, and Bondwall's Mill. On the east of these lower rocks, the country around Linkinghorne and South Hill, which is on the line of upheaval between the Brown-Willy granite and Hingston Down, is thrown down by the faults at Hay and the Redmoor Mine, and with it a patch of the Culm-measures, in the same manner that

* Rep. pp. 80–81.

the faults of Cotele and Pentre Cross have thrown down the country about St. Mellion. To the south of St. Ives, however, we come into a belt of country the structure of which is very difficult to unravel, owing to the obscurity of the bedding, the planes of cleavage being so much more strongly marked than the lamination. Thus at Tencreek, near Liskeard, and at Hepple Mill, near Quethiock, vertical bedding, in which the stratification is shown by seams of ochreous material, is seen cleaved by planes which dip to the south at an angle of 12°; and at Pope's Mill horizontal beds are cleaved at an angle of 35°, dipping in the same direction; but in the great majority of the exposures it is impossible to ascertain whether the laminæ are those of deposition or of cleavage*. It would appear, however, that the argillaceous rocks, with their included beds of volcanic ash &c., are here thrown into a series of narrow east and west plications, which succeed each other in an oblique line extending from the neighbourhood of St. Neots to Saltash on the Tamer; but the details are involved in intricacy, as one anticlinal axis dovetails in between others in a manner that renders it difficult to follow the beds along their strike for any distance. A synclinal axis, however, crosses the Temple branch of the Fowey below Panter's Bridge, and runs eastward to Mount Coldwind, north of the Doubleboys railway-station, beyond which it ceases to be recognized. The rocks on the north of Quethiock and Liskeard dip to the south, under beds which are fossiliferous at the railway-station and at the slate-quarry south of Pope's Mill, where they include a bed of argillaceous limestone three feet in thickness, first noticed by the late Mr. Giles †. These beds rise again to an anticlinal axis at Menheniot, which runs eastward between the ash-beds at Combe; and this is succeeded by a synclinal trough at Tilland slate-quarry, in which the beds are highly inclined (60° to 80°), and the slates sometimes blue or purplish. A sharp anticlinal axis follows, which extends from Menheniot railway-station, by Molenick and Notter Mill, to Botes Fleming, beyond which there is a synclinal trough ranging from the north of St. Luke's by Landrake, and across the Tamer to the north of St. Budeaux, containing highly inclined grey, blue, and purple slates, which appear to form one or more subordinate anticlinal folds. One of these minor folds occurs at Stoketon, and is on the same line of strike as the axis south of Tamerton Foliot, noticed by Prof. Phillips ‡, and another at Trematon. The slates and volcanic rocks of Saltash and St. Stephens rise on the south of the latter trough, but they appear to constitute rather a series of plications than a single axis. It would appear, therefore, either that the lamination is deceptive and does not represent the true bedding, or that the plications must be very numerous, even more so in fact than the above description would imply; otherwise the prevalence of vertical and highly inclined stratification over a distance of three or

* The age of the cleavage is clearly subsequent to the period when the beds were brought into their present position, and therefore to the upthrust of the granite. See also De la Beche, Rep. p. 279.

† Thirty-sixth Ann. Rep. of the Geol. Soc. of Cornwall. ‡ Pal. Fos. p. 199.

four miles would imply a great accession of deposits unrepresented elsewhere. On the west these slate- and ash-beds appear to rise up over lower rocks; but on the east their relation to the argillaceous slates about Pillaton is not quite so clear, as the nearly W.S.W. fault from Pentre Cross may be prolonged across the Notter at Pillaton Mill, and, if so, would not be without its influence on the rocks of the Tiddi valley.

Assuming that the volcanic rocks of St. Cleer, New Bridge (on the Notter), Callington, Hay, South Hill, and Bray's Shop belong, as I believe, to the same geological horizon as the long belt which, bordering the granite on the north, runs up by North Hill to the south of Alternan, the beds which dip into the synclinal area of Liskeard, and undulate thence to Saltash and St. Stephens, represent in less force the higher group of Davidstow and Lewannick. Folded in among this upper group are some slate-beds locally fossiliferous, as at the Tregril slate-quarry, at Great Tressell north of St. Keyne, Doubleboys, Stoney Bridge, near Liskeard, and in the cuttings of the railway south of the town, and likewise at Saltash and St. Stephens. Among these fossils we find noticed *Pleurodictyum problematicum*, *Atrypa desquamata*, *Bellerophon bisulcatus*, *Fenestella antiqua*, an *Orthoceras*, two species of *Spirifera*, some undetermined *Cyathophyllidæ*, *Phacops latifrons*, and *P. punctatus*. The last species was found at Great Tressell by Mr. Pengelly, and is a characteristic Middle-Devonian fossil *.

South of St. Stephens the slates and ash-beds dip to the south. They include some calcareous bands, and pass under a thick series of argillaceous rocks of grey, blue, and purple colours, interstratified with ash-beds, which lead up to the base of the Plymouth limestone. These beds are laminated at a high angle, and apparently the lamination is in the plane of the bedding. East of the Hamoaze the beds seem to form a short synclinal trough, the slates, which are vertical along a line extending from Tor Point to Anthony, dipping northerly at high angles along the shore of Sango Lake. They are, however, again thrown over to the south at Wolsden House, and become undulated and contorted at St. John's, but again dip southerly at Mendinnick, and this dip is preserved all the way to the Rame Head, the slates south of Higher Tregantle being more or less hard and arenaceous, with uneven surfaces, and often interstratified with grit bands. At Wolsden House these contorted beds contain some calcareous seams, and a bed of volcanic ash occurs to the south of the park; a few grit bands may be seen between the village and Mendinnick, but the contortions which may be here observed die out before reaching the coast. The slates of Tor Point, which are there chiefly grey or blue, range past Anthony to Grafthole, where they become reddened and include thin bands of grit. If we recross the beds from the coast at Port Winkle to the limestone of St. Germans, which is on the same line of strike as the calcareous bands south of St. Stephens, we find that the variegated

* Fig. in Palæontographical Society's Monograph on Trilobites, vol. i. part 1, by Mr. Salter, pl. 1. figs. 17–19.

slates with thin grits, of Grafthole and Port Winkle, are succeeded by the grey slates of Polscove, and these again by the grits of Sheviock Wood, which strike E.N.E. towards Creep; but they are poorly represented, if at all, on the coast, and their place appears to be occupied by the hard reddish arenaceous slates of St. Germans Beacon. A considerable belt of slate occupies the country to the north of these grits, from Sconner to Polbathick and thence to St. Germans, and runs out to seaward between Downderry and the Flag-staff west of the mouth of the Seaton river, the dip being S. 20° E. at Polbathick, and becoming south-easterly on the coast. Beneath these slates are grit beds, which, striking down from Caracawn Cross to the towns of Looe, overlie or include a band of limestone north of the east town, and another at Hessen Ford. There is some difficulty in correlating this latter with the limestone of Milladon and St. Germans; but the beds at South Bake dip westerly, and it appears that some disturbing influence has been in operation in the vicinity.

If, however, we take the section up the Looe river a little further to the west, we find the grit beds and limestone of the town of Looe succeeded by a long downward succession of argillaceous slates, which are occasionally calcareous, as in Common Wood, at the pools opposite Trenant, at Terrers Pill, where we have the continuation of the Polpever limestone, and at the bridge at the foot of the ascent to Duloe. The section is not consecutive, and there are intervals, where no rocks are exposed, wide enough for concealed reversals of the dip to occur; but we miss from the series the gritty bands and reddish arenaceous slates so abundant between the base of the Hessingford limestone and the coast. Amid rocks, however, in which grits appear so irregularly, this circumstance loses much of its importance.

If we follow the strike of the calcareous beds south of St. Stephens by St. Germans to Milladon, and thence to Tredinick and Tremain, we have the northern limit of a group of beds which occupies the interval between the volcanic rocks of Saltash and the Plymouth limestone, deflected round to the south-east as we advance towards the Looe river, by, as I believe, the upheaval of lower rocks between Duloe and St. Keyne; and although, in the section of the argillaceous rocks of the Looe river, folds and repetitions of the beds may escape observation, there cannot be much ambiguity about the dip of the beds along the coast of Whitesand Bay, where the bedding is rendered clear by the seams and bands of interstratified grit. This belt of rocks, which on the Hamoaze occupies an interval of no more than about two and a quarter miles when followed to the Looe river, widens out to nearly three times that distance. This appears to be due partly to the lowering of the angle of dip, and partly to the addition of arenaceous materials which have come in from the south-west or south; at the same time there is the possibility of some concealed repetition of the beds between the Lyhner river and the coast.

The attempt to determine the relations of this belt of rocks west-

ward of the Looe river is not unattended with difficulty. It has been already stated that a fault extends from the west of Bodmin, by Lostwithiel, towards the coast. A second fault trends from the mining-district of Pembroke across the Gribbin promontory to Combe Hawne, near the mouth of the Fowey. This latter fault has thrown up the country on the north, and brought up at Pencarra Head, Fowey, and Tywardreath the rocks which passed down at Tredinick, Tremain, and St. Veep, forming a synclinal trough which contains the fossiliferous rocks of the Looe river, together with some red and variegated argillaceous beds which range up from the coast at Talland, by the north of Lansalloes and Gregon, across the Fowey, towards Tywardreath. These red slates appear to be a continuation of those which, trending down from Polbathick, become partially reddened at Narkurs and Treliddon, and reach the coast at the mouth of the Seaton river; and if the upcast of the coast-line between Talland Bay and Gibbin Head is not entirely due to the fault already noticed, but is partly owing to an anticlinal axis out at sea, south of Polperro, it is not impossible that such axis may curve round, parallel with the belt of variegated slates, and strike the coast of Whitesand Bay at St. Germans Beacon, accompanied by inversion of the strata, and terminate in the bed of the Lyhner north of Anthony. In that case, the grits of Sheviock Wood would be the same as those of Carracawn Cross, with the slates of Polbathick folded in between them.

Notwithstanding the apparent contrariety of the dips, and the consequent difficulty of obtaining satisfactory evidence, I believe that the argillaceous rocks of Lanreath and the north of St. Veep rise up from beneath the fossiliferous and purple slates on the south, and overlie the gritty beds of Boconock. Looking to the general structure of the country, and to the manner in which the slates with ash-beds of Saltash and St. Germans are carried north-westward by Liskeard and St. Neots, rising up over lower rocks on the one hand, while the calcareous and argillaceous rocks that overlie them are curved southward across the Looe river to the mouth of the Fowey on the other, it appears more consistent with probability that the grits and thick slates associated with them are lower rocks broadly elevated rather than higher beds troughed in a shallow basin. In mineral character they resemble those of the Bodmin district, and appear to be the same disturbed in their line of strike by the Lostwithiel fault, and have no resemblance petrologically to the higher rocks of the Plymouth country. Moreover the slates of the mouth of the Fowey, and of the coast thence to Polperro, which support the red rocks on the north, contain *Pteraspis Cornubicus*, M'Coy, which has been found also in the slates of Cliff on the Fowey, and in the vicinity of St. Veep; it occurs likewise on the same line of strike in the calcareous slaty rocks at Milladon, near St. Germans *.

The fossiliferous slates of Saltash and St. Germans, with their included volcanic ash-beds, brought down from the north-west by

* For a different interpretation, see De la Beche, Rep. pp. 80, 81.

repetitions oblique to their line of strike, join on the Hamoaze with the argillaceous rocks of Polbathick and Anthony, and range eastward by the south of Egg Buckland to Hamerton Ball and the vicinity of Ivy Bridge, where they are broken through by the granite of Harford. Much of this slate is red or claret-coloured, especially in the vicinity of Keyham, Stoke, and Ford Park; and the gritty bands associated with them further to the west appear to have entirely thinned out before reaching the Hamoaze. To the eastward of Ivy Bridge and the granite, the beds curve to the north-east, resting on the volcanic rocks of South Brent, which are altered by the granite; and they include, on the same line of strike, as we advance to the north-east, other bands of igneous rock, together with the limestones of Buckfastleigh, Ashburton, Bickington, and Ash Hill. These limestones dip to the east and south-east, at angles varying from 15° to 20°, but they are much broken by north-west and south-east faults. The slates on the west of the limestone are uniformly argillaceous, and often very evenly laminated, and appear everywhere to dip under the limestones. The manner in which these lower rocks are brought against the Culm-measures has been already described, as also the position of the beds west of Ashburton, which, near the town, dip towards the volcanic rocks and limestones; but at Horsehill and at the corner of the lane leading up to the Druids' Farm they are thrown over to the north, beyond which the bedding appears to be nearly vertical; and they contain *Spirifera disjuncta*, *Petraia bina*, *Athyris concentrica*, *Chonetes sordida*, *Orthis interlineata*, and a species of *Cyathocrinus*; and in all probability these light-coloured beds, thus thrown under the Culm-measures, may not be very far below the base of the limestones.

As we follow the slate-beds westward of the southern extremity of the granite at Ivy Bridge along their line of outcrop to the north-east, they become less and less inclined, as seen in the railway-sections between Ivy Bridge and Totnes; the lower beds, as they range northward, follow the course of the volcanic rocks and limestones of Dean Church, Buckfastleigh, Ashburton, and Bickington, dipping to the east and south-east at angles which do not average more than 12° or 15°, and seldom exceed 25°; while the higher beds pass by Black Hall, near New Bridge, on the Avon, where they are fossiliferous, to Sandwell, and thence to Dartington, north of Totnes. Thus the belt of rocks opens out, and the beds, being thrown down more or less horizontally by the faulting on the north-west of the Ashburton range of limestones, undulate broadly over the country towards the coast at Torbay, supporting the limestones of Dartington, Berry Pomeroy, Marldon, Ogwell, Kingskerswell, and Torquay, and the minor patches of Sandwell, Paytor, Woolstone Green, &c. Although occasionally purple, the beds are less frequently so than they are further to the westward, and grit bands appear to be absent.

The evidence of the superposition of the slates to the Ashburton limestones appears to be free from ambiguity, notwithstanding the faults which cross the beds on the line of strike. The limestones

occupy, for the most part, the low ground, and dip into the hills on the east and south-east, which are composed of slates and ash beds dipping in the same direction, and rising steeply 200 feet or more above the limestones. This is well seen at Pridhamsleigh, in the descent to Ashburton from Goodrington, and in the hills north of Bickington, where the limestone is overlain by volcanic rocks. Even supposing, therefore, that the lamination does not represent the true bedding, it will still appear that the slates are uppermost.

The relation of these slates to the overlying limestones will be considered in connexion with the latter.

2. *Plymouth and Torbay Limestones.*—The Plymouth mass of limestone commences on the west at Impacombe, south of Devonport, where it is overlain by the slates and red rocks of Mount Edgcombe; and slates, for the most part blue, pass under it on the north; but its relation to the rocks on the west is obscured by the waters of the Hamoaze and Sango Lake. I am unable, therefore, to bring this limestone into connexion with the contorted beds of St. John's, among which, as already noticed, there are some calcareous slates; but the higher beds of Impacombe appear to run out seaward by Millbrook and Withnoe, above the purple and greenish slates of Freathy, which include some bands of volcanic ash. It is the same with its eastern termination, which appears to thin out horizontally or nearly so. As observed by Sir Henry De la Beche, however, there is much ambiguity about the bedding of this limestone, although the general dip of the mass is to the south, so that its relations and thickness are difficult to ascertain. The joints are very regular, and in places where the rock is highly crystalline the true bedding is very obscure. There can, however, be little question that the limestone overlies the variegated slates of the north of Plymouth, and dips under the grey and blue slaty rocks of Mount Edgcombe, Plimstock, and Elberton; and between its outcrop and its dip under the higher rocks, it appears to form one or more undulations, so that its real thickness may be very much less than its superficial breadth and apparent dip would seem to indicate.

In following the line between the slates which underlie and overlie the Plymouth limestone to the eastward, we are assisted by the volcanic rocks of Hearston and Filham House, which lead up to the fossiliferous slates of Black Hall on the Avon. No limestone, however, occurs on this line of strike until we reach Sandwell, where there is a small patch overlain by volcanic rocks; and beyond this we have the somewhat larger patch of Paytor, which is brought down by a fault bounding it on the north; and apparently the limestone of Woolstone Green is also faulted down. There is a fourth small patch at West Ogwell, which together with those just named appear to form the thin western margin of the range of limestone, which becomes more largely developed immediately to the eastward of them. The great mass south-west of Newton Bushell, which constitutes the Ogwell and Ipplepen limestone, forms a tableland of slightly undulating beds, denuded and excavated in the vicinity of East Ogwell and in the valley of the Torbryan brook, so as to

expose the underlying beds, which at the former locality consist in part of volcanic ash. On the east of Ogwell this limestone is overlain by Culm-measures, as already stated when describing these Carbonaceous rocks, thrown down apparently against the nearly vertical limestone of Connator, on the east, by a fault. Three other small masses of limestone are seen to the north-east of Connator, one of which, near Woolborough Church, has afforded a fine series of organic remains, many of which are quite local*.

On the east of the Ogwell and Ipplepen limestone the lower slates are faulted up, and form high ground about Dainton School-house, and between the school and Whitborough on the east. These slates throw off the limestone of Kings Kerswell on the north, which dips under some higher slates at the village, and the limestone of Bulley Barton on the south. This latter appears to be the northern edge of the Marldon mass exposed from beneath the overlying New Red sandstone and conglomerate, the small protrusions of Compton, Combe Fishacre, and the narrow outcrop at Battleford showing their connexion beneath; and, the upcast on the east of the limestone of Ipplepen being much less than it is at Dainton School-house and the Two-mile Oak, the two limestone masses at Bow Hill are brought nearly into contact, a thin strip of slates only intervening. These slates dip to the south-east under the limestone of Bulley Barton as it curves round by Bow Hill, the Ipplepen limestone dipping against them. The mass of limestone which protrudes through the Trias at Compton, together with two other small protrusions at Gallows Gate, connect in a similar manner the Marldon limestone with that of the Torquay district; and this, again, has its deep-seated connexion rendered probable by the protruding mass south-west of Deccombe. The limestone of Kings Kerswell is manifestly a portion of that of Ogwell, separated only by the slates thrown up by the fault which bounds the Ogwell limestone on the east, as are likewise the smaller masses of Connator, Woolborough, &c., which occupy the faulted ground south of Newton Bushell.

The Torquay limestone need not detain us, as it is well known and has been described in detail in a special paper by the late Sir Henry De la Beche†. An anticlinal axis extending from Upton to the coast at Meadfoot Sands brings up the lower beds, which here contain some grit beds, resemble some of the equivalent beds of Whitesand Bay, and contain many of the same fossils as those from the Looe district—among others, *Pleurodictyum problematicum*, *Athyris concentrica*, *Spiriferina cristata*, *Leptæna laticosta*, *Orthis hipparionyx*, *Bellerophon bisulcatus*, &c. In the cliff between Meadfoot sands and the Thatcher rock two fine scales of *Phillolepis concentricus*, Ag., have been found by Mr. Pengelly, and are now in his

* I had an opportunity of spending a day in examining the rocks in this vicinity with Mr. Beete Jukes; and the conclusion we arrived at was, that the rocks to the east of the turnpike-road were not Culm-measures as they are coloured on our maps.

† Trans. Geol. Soc. 2nd Ser. vol. iii. p. 161.

collection; and a scale from Meadfoot is figured by Prof. Phillips (Pal. Fos. pl. 57. f. 256), and referred to *Holoptychius*, which has also, judging from the figure, very much the appearance of *Phillolepis*.

It is less easy to ascertain the relations of the limestones to the north and east of Totnes, although there is no reasonable cause for supposing that these calcareous masses are other than portions of the same range of limestones. This arises partly from the extreme difficulty there is in getting reliable evidence respecting the dip of the beds, as much of the limestone exhibits no true bedding, and the lamination of the slates cannot always be relied upon.

The limestones do not afford much assistance. It is frequently extremely difficult to distinguish the bedding from the often very regular joints and planes of cleavage; and a bed of fossiliferous rock included between others that are devoid of fossils will sometimes show a true dip quite at variance from the apparent one. Moreover the limestones are sometimes much fractured and contorted; and in that case very little reliance can be placed upon a few local observations, which may yield very conflicting results. The junk-like termination of some of the limestones is another source of perplexity, their relation to the slates being such as to make it appear that, in the movements to which the rocks have been subjected, the limestones have been, as it were, dislocated from the slates, so that the former are bounded by what are virtually lines of fault.

It would appear, however, that higher rocks, which occupy a synclinal trough that trends up from Plymouth Sound by Halberton to the vicinity of Totnes, are thrown down by faults, one of which runs up from Sandwell Park, by Whiteley and Colt, to the Dart south of Dartington House, and is continued thence across the railway south of Forder Bridge, and another, skirting the limestone of Boston, is continued N.N.W. towards Bow Barn. The result of this downthrow has been to push the southern extremity of the Dartington limestone round to the north-west, and the Barton and Bunker Hill limestone to the eastward. The evidence of the former fault is to be seen in proceeding along either of the turnpike-roads from Totnes to Skinners Bridge. We there find similar thick slates to those which occupy the country between Totnes and Ashsprington, to be continued nearly to Colt with a south-easterly dip; but at Colt the dip of the slates conforms to that of the overlying limestone at Skinners Bridge, and is to the north-west. A third fault follows the bed of the Dart from Totnes to the south of Allabeer—the thick slates which strike up to the river at right angles to the stream with a southerly dip abutting against thinly laminated argillaceous slates which, with a variable dip more or less to the eastward, occupy the low ground on the opposite bank, near Weston. This fault carries the country on the east of the Dart somewhat to the southward. Another fault, extending from Longcombe Cross to True Street, bounds the limestone of Berry Pomeroy on the south. The limestone dips to the north, while the red slates on the south of it dip in the contrary direction

under the higher limestone of Longcombe, which, associated with some volcanic ash, ranges by Great Court and Howell towards the limestone of Boston. Other faults exist, some of which have been laid down on the map.

This faulting, or rather the force which produced it, has so contorted and fractured and, as already stated, so dislocated the limestones, that it is very difficult to distinguish in this neighbourhood the slates which were anterior from those which were posterior to the period of the limestone*.

The dip of the Dartington limestone, from the south of Staverton round by Skinners Bridge to Vineyard, is inward towards Dartington House as a centre. In the quarries at the two last-named localities the bedding is more than usually clear. South of Dartington, however, the outer edge of the limestone is thrown over and dips to the south-east. The two limestone masses on the opposite side of the Dart, the one west of Buckyatt, the other west of Little Hempston, are the continuations of the Dartington limestone faulted off. The former rests on volcanic rock, which has not altered it, and is overlain by slates with some ash bands dipping to the south-east. These rocks, therefore, are above the limestone, and presumably those also of Dartington House, as the limestone dips towards them. The other mass of limestone, west of Little Hempston, is traversed by a fault along its line of strike, which is continued on to the railway-cutting below Forder Bridge. This fault has brought some volcanic rock against the limestone on the west, while the slates on the east of the limestone dip off it towards Little Hempston. South-east of the village there is another faulted strip of limestone, the northern portion of which dips to the south-east at a high angle, while the southern half in the quarry and railway-section dips north-west towards the church. It appears, therefore, that all the slaty rocks between the Buckyatt limestone and that of Bunker's Hill and Gatecombe House are above the limestones; but it is not clear how they end to the north-east; there are, however, some appearances of a fault running north-west and south-east by Forder Bridge; and the dip of the Fishacre limestone, which appears to be the continuation of that west of Buckyatt, is reversed.

The mass of limestone extending from Boston, by Bunker's Hill, to Gatecombe House, appears to be thrown up by a fault; but there is great uncertainty respecting the relations of the slates on the west between Bunker's Hill and Berry Pomeroy, the dip of the lamination in the slate being often quite at variance with the bedding of the limestone. The same want of accordance between the bedding of the limestone and the lamination of the slates is again observed at Arton.

The lower slates and limestones are again brought up to the sur-

* Sir Henry De la Beche appears to have considered that these limestones may have had "their geological continuation consisting in slate." It is difficult, however, to fall into this view, seeing that the limestones are for the most part devoid of detrital materials, and would appear therefore to have been formed in waters free from muddy sediments. *Vide* Rep. p. 72.

face between Ash and Higher Yalberton on the north, and Sharkham Point, near Brixham, on the south. The great mass of limestone of Berry Head, which stretches inland to Walton, and of which the Yalberton and Stoke Gabriel limestones are but detached portions, forms an arch, which is depressed in its central portions between Walton and Fishcombe Point: while its southern margin is thrown over an anticlinal axis at Mudstone Sands, and is seen at Sharkham Point and Brixham dipping under the higher beds on the south, its northern edge, between Higher Yalberton and the coast, is doubled under with inverted dip. The Stoke Gabriel limestone is thrown up on the north-east by a fault, which extends from the village by Howell to the south-west of Ash, and has brought it against the higher beds which range up from Ashsprington. On the north, this limestone dips under the purple slates and grits of Windmill Hill, and near Higher Yalberton some slates are troughed in a fold of the limestone.

A long narrow anticlinal axis commencing at Yealmpton ranges by Broadway and Cornworthy, and thence to Brixham, where at Mudstone Sands it appears to be again narrowing to a termination; and a second anticlinal axis to the north of the former commences near Ludbrook and runs, by the north of Roster Bridge and between Perchwood and Tuckenhay, to the south-east of Stoke Gabriel. These anticlinal axes have brought up the lower slates with an overthrow to the north. If we follow the line of strike between the fossiliferous slates and the base of the overlying limestone from Brixham past Lupton House to the limestone of East Cornworthy, and thence to Middle Washburton and the Avon below Broadly and the north of Modbury, to the limestone of Palmer's Cross, which is clearly on the same line of strike as that on the south side of the anticlinal axis at Yealm Bridge,—and again in an opposite direction through Ermington and the limestone of Shilstone to the Avon at Beckham, and thence back by Fowlescombe to Ludbrook, and again from Ludbrook by North Hewish, Diptford, Harberton Ford, and Perchwood to the west of Stoke Gabriel,—such line will indicate pretty nearly the limit between the upper and lower slates, and the place of the Torbay limestones, which, however, in the part of the country between Totnes and the Yealm, are only feebly represented at a few points.

The limestone at Yealm Bridge is partly dolomitized. It forms the crest of the anticlinal axis, but is depressed on the south towards Torr. On the north it is underlain by a bed of volcanic rock, from off which it has been partly removed by denudation, the thinner edge at Ketley and the small patch on the north side of the axis at Yealm Bridge alone remaining.

There still remain to be noticed the several masses of Devonian limestone which protrude through the Culm-measures on the north-east of the Bovey basin; but there is no apparent reason for separating any of these masses from those of Ogwell and Kings Kerswell. The Chudleigh limestone has been already noticed when describing the Carbonaceous rocks, and perhaps from its position it might be regarded as belonging to the Ashburton range; but the fossils

associate it rather with that of Ogwell. The slates on either side of the Teign estuary are Devonian, and apparently they rise from beneath the limestone; but there is much difficulty in ascertaining this with certainty. They are entirely argillaceous, and in part red or claret-coloured, and are altered by the igneous rock at Colway Cross, which seems to rest upon them.

The fossils of these limestones are so well known by the lists of Phillips*, Godwin-Austen†, and Sedgwick and Murchison‡, that it is not necessary to enumerate them here. In the subjoined Table will be found the local distribution of the species which have been hitherto met with in the slates which immediately underlie these upper limestones of the south-east of Devon; but it is very far from complete, as the several localities, as well as some others not mentioned, have not by any means been thoroughly searched. The species from the vicinity of East and West Ogwell are given on the authority of Mr. Godwin-Austen§; the rest are from the 'Palæozoic Fossils' of Professor Phillips, and other sources‖.

TABLE I.

Species occurring in the beds immediately below the Upper South-Devon Limestones.

Species.	Localities.				
	East & West Ogwell.	Newton Bushell.	Meadfoot.	Mudstone Bay.	Black Hall.
Favosites dubia, *Blainv.*	...	...	*		
—— fibrosa, *Goldf.*?	...	...	*		
Alveolites suborbicularis, *E. & H.*	...	...	...	*	
Petraia Celtica, *Lonsd.*	*	...	*[7]	*	
—— pleuriradialis, *Phill.*	...	...	*		
Pleurodictyum problematicum, *Goldf.*	*	...	*	*	
Cyathocrinus megastylus, *Phill.*					
—— pinnatus, *Goldf.*	...	...	*	*	
—— nodulosus, *Phill.*	*				
Cheirurus articulatus, *Salt.*	*				
Homalonotus elongatus, *Salt.*	...	...	*		
—— armatus, *Burm.*?			*[7]		
Phacops granulatus, *Münst.*	*				
—— punctatus, *Stein.*	*				
—— lævis, *Münst.*	*	*[2]			
—— latifrons, *Bronn.*	...	*[2]	...	...	*[3]
Fenestella antiqua, *Lonsd.*	*				
Hemitrypa oculata, *Phill.*	...	...	*		
Retepora repisteria, *Goldf.*	...	...	*	*	
Athyris concentrica, *V. Buch*	...	...	*		

* Pal. Foss. p. 142. † *L. c.* p. 466. ‡ *L. c.* p. 703.

§ *L. c.* p. 469.

‖ This Table must be taken in connexion with Table III, which gives the distribution of species in the corresponding rocks in a different area, and together include, I believe, all the recorded species on this horizon.

Species.	Localities.				
	East & West Ogwell.	Newton Bushell.	Meadfoot.	Mudstone Bay.	Black Hall.
Spirifera undifera et var. undulata, *Rœm.*	...	...	*[4]		
—— lævicosta, *Val.*	*[7]				
—— speciosa, *Schloth.*	*				
—— disjuncta, *Sow.*	*[7]				
Spiriferina cristata, var. octoplicata	...	...	*[4]		
Rhynchonella pleurodon, *Phill.*	...	...	*[4]		
Atrypa reticularis, *Linn.*	*[7]				
Pentamerus brevirostris, *Phill.*	*[7]				
Rhynchonella cuboides, *Sby.*	...	...	*		
Strophomena rhomboidalis, *Wahl.*	*[7]	...	...	...	*[5]
Streptorhynchus umbraculum, *Schloth.*	...	...	*[4]		
—— gigas, *M'Coy*	*[7]				
—— crenistria, *Phill.*	...	...	...	...	*[5]
Leptæna laticosta, *Conrad*	...	...	*		
—— interstrialis, *Phill.*	...	...	...	...	*[5]
Orthis hipparionyx, *Vanux*	...	...	*		
—— resupinata, *Mart.*	*[7]				
—— granulosa, *Phill.*	...	...	*	*	
Chonetes sordida, *Phill.*	*	...	*		
—— simiradiata, *Sow.*	...	...	*[6]		
—— Hardrensis, *Phill.*	*[7]	...	*	...	*[5]
Aviculopecten polytrichus, *Phill.*	...	...	*?	*	
Pterinea anisota, *Phill.*	...	...	*		
—— subradiata, *Phill.*	*[7]				
Clidophorus ovatus, *Phill.* non *Sow.*	...	...	*		
Modiola scalaris, *Phill.*	*				
Pleurotomaria aspera, *Sow.*?	*[7]				
Trochus Boneii, *Stein.*	*				
Euomphalus serpens, *Phill.*	...	...	*		
Bellerophon bisulcatus, *Röm.*	...	...	*		
Porcellia Woodwardii, *Sow.*	...	...	*		
—— striata	...	...	*		
Orthoceras tentaculare, *Phill.*	...	...	*		
Cyrtoceras bdellalites, *Phill.*					
Phillolepis concentricus, *Ag.*	...	...	*[3]		
Scale of Holoptychius?	...	...	*		
Pteraspis (Scaphaspis) Cornubicus, *M'Coy*	...	...	*[3]	*	
Cephalaspis? Carteri, *M'Coy*	...	...	?		

[1] Murchison. [2] Salt. Mon. Pal. Soc. [3] Pengelly. [4] Davidson.
[5] Davidson, in Col. Pengellii. [6] Salter. [7] Jermyn-Street Museum.

3. *Beds overlying the Plymouth and Torbay Limestones.*—It has been already stated that a long narrow inclined synclinal trough extends from Plymouth Sound to Tor Bay. The beds contained in this trough consist of argillaceous slates similar to those which underlie the limestones north of Devonport. They are well seen on the coast at Jenny Cliff Bay between Mount Batten and Withy Hedge, of which a section has been given by Prof. Phillips*. South of Plimstock and Elburton this belt of rocks widens out to pass on

* Pal. Fos. p. 201, Nos. 3 to 5 inclusive.

both sides of the Yealmpton limestone; and it contains much dark-blue slate, and occasionally, as at Gooswell, some calcareous bands. These blue slates occupy the middle of the trough, and are quarried near Brixton and north of Ludbrook, &c. At Harberton the trough deepens, being thrown down on the north as already described, and higher beds occupy the interval between this place and the Dart. These latter consist of thick slates in which much volcanic matter is disseminated, interstratified with bands of grit; and for the most part they yield a red soil. Volcanic rocks are frequent; and on the east of the Dart there are some calcareous bands associated with them, as also much red and purple grit. Good sections of these rocks are to be seen in the vicinity of Totnes and in the descent to Bow Bridge; and the manner in which they have been brought into relation with the limestones of Dartington, Boston, and Berry Pomeroy has been already explained. The continuation of these rocks across the Dart is somewhat interrupted by the upthrown limestone of Stoke Gabriel, and by the southern portion of the Berry Pomeroy limestone, which is similarly thrown up at Longcombe Cross.

The variegated argillaceous slates (partly claret-coloured) which form the lower portion of this upper group rest upon the limestones of Berry Pomeroy, Arton, Loventor, and Marldon; and immediately above the limestones they are occasionally fossiliferous, as in Berry Park; but they have yielded little that can be determined, and the species do not appear to differ from those contained in the slates below the limestones. These beds dip to the east and south-east, and pass under the purple and greyish grits of Blagdon Cross, Beacon Hill, Ockham, and Cockington; while the beds thrown off the Stoke Gabriel and Yalberton limestones dip to the north under the grits of Windmill Hill and Collaton, thus forming a shallow basin which is occupied by the Triassic rocks of Painton. Much of the red colour appears to be due to the action of the atmosphere upon the bases contained in the rock, and beds which are light-coloured often yield a red soil; but the blue slate appears especially liable to become claret-coloured.

The rocks thrown off on the south of the anticlinal axis extending from Mudstone Bay to Yealmpton are precisely similar to the lower beds contained in the above-mentioned synclinal trough, and consist of grey and dark-blue argillaceous slates, the latter often changed to a purplish or red colour. These rocks are well seen in the railway-sections east of Greenway House, where they contain some beds of ash. From Greenway they are continued by Ditsham and Combe, where they have been quarried for slates, and by New House, on the Avon, to Modbury, and thence south of the Yealmpton limestone to Staddiscombe, near Plimstock, and to the coast at Withy Hedge in Plymouth Sound. Above these are beds of slate, much of which is reddish, containing bands of grey, yellowish, or purple grit. These grits, apparently, do not form continuous beds; at least they cannot be followed many miles on their line of strike. The following section is seen on the Torquay and Dartmouth railway between the tunnel at Greenway Farm, south of Galmpton, and the station at Kingswear.

Section from the Tunnel at Greenway House to Kingswear.

	Feet.
1. Volcanic ash resting on grey glossy slates sparingly fossiliferous . .	
2. Grey and bluish-grey slates (corresponding to viaduct)	
3. Purplish and greenish evenly laminated glossy slates. Dip S. 30° E. at 25°	200
Crush and contortion—perhaps a line of fault.	
4. Purplish and greenish glossy slates. Dip. S. 30° E. at 35° to 40°. .	160
5. The same, disturbed, and not truly *in situ*	160
6. Interval covered with vegetation—apparently slates with grit bands .	550
7. Red and greenish flags and grits, partly thick-bedded. Dip S. 20° E. .	250
8. The same, not *in situ*	90
9. Red and greenish flags and slates with thick beds of sandstone. Dip S. 20° E. at 35°	300
10. The same, tumbled about and not seen *in situ*	400
11. Red and greenish grey slates and grits, greatly folded and contorted .	260
12. Red slates and flaggy sandstones	60
13. Light-coloured and reddish slate	140
14. Reddish and brownish slates, with beds of sandstone much contorted and folded, the general dip being southerly at about 15°	470
15. Hard, coarse, and often reddish slate. Dip S. 20° E. at 50°, about .	350
Viaduct.	
16. Soft grey slates. Dip S. 20° E. at 50°	180
Viaduct.	
17. Light-grey slates, with numerous small quartz veins. Dip S. 30° E. at 35°	1240
18. Grey evenly bedded slates, dipping at an angle of 45° (opposite embankment)	370
"Floating Bridge."	
19. Light-grey slates. Dip S. 30° E. at 25° to 35°	100
20. Volcanic ash	55
21. Soft greenish slates	90
22. Blue slates. Dip S. 30° E. at 30° (opposite embankment)	160
Fault.	
23. Grey slates	110
24. Quartz vein	4
25. Slates, chiefly bluish grey, much veined with quartz. Dip S. 40° E. at 45°, but undulating and wavy	360
26. Grey thick-bedded sandstone. Dip S. 30° E. at 30°	*90
27. Blue, grey, and purple slates, with purple and grey grits, much undulated and contorted. General dip S. 30° E. at angles varying from 12° to 45° (opposite embankment), about	200
28. Hard grey and bluish slates, sometimes reddened; somewhat glossy and micaceous on the surface, and much veined with small quartz veins, and occasionally including thin bands of grit. Dip S. 20° E. at 45°, about	1200
Bridge.	
29. Hard reddish slightly micaceous slates with a few calcareous seams. Encrinites. Dip S. 20° E. at from 35° to 45°	250
Kingswear Railway Station.	

These gritty bands come to the coast at Man Sands and Scabbacombe Bay. If we follow the arenaceous rocks on the north of the "Floating Bridge" to the westward we find them to range by Little Combe, and by Tidaford and Woolcombe to Collaton, Morleigh Down, Black Down, and Lee Moor, and then to curve south-west by Stubston, Sherlangston and Torr, to near the mouth of the Erme.

* The above figures refer to the distances along the railway, measured by the intervals between the sleepers, which was 10 feet, and not to actual thicknesses.

If in like manner we follow the more southern belt of arenaceous rocks from the north of Kingswear, we find purple and grey grits south of Ditsham Cross at Bugford and south of Blackauton; and hard reddish slates, similar to those at Kingswear, occur on the same line of strike at Loddeswell and Hatch Bridge; and with these slaty and arenaceous beds are associated some bands of a peculiar volcanic rock consisting of felspar and a foliated greenish mineral resembling chlorite. These two belts of rock, therefore, become separated, west of the Avon, by argillaceous slates which occupy the country between Heathfield and Aveton Giffard, and between Kingston and the mouth of the Avon; and as they dip under the beds which strike up from Loddiswell and East Allington to Aveton Giffard and Bigbury, we must presume that they are lower beds brought up; but in what manner is not very clear. With the grit-beds which strike down to the mouth of the Erme from Heathfield Down there is some rock composed of quartz and felspar; but I did not meet with this rock *in situ*, although heaps of it were lying by the roadsides, and I was unable, therefore, to ascertain its character or relations; but the rocks on the east of this band of quartz and felspar at Bednick, Broom Hill, and Wakeham dip south towards a mass of igneous rock, which at the quarry at the eastern extremity of the mass appeared to be a bedded rock, dipping south and graduating upwards into the slates above. The variegated argillaceous slates, which underlie the grits of Black Down and Lee Moor, widen out as they trend round by Modbury, and with a lessened angle of dip, and probably some undulation, range by Holberton towards Newton Ferrers, and occupy the whole of the country between the Yealmpton limestone and the coast. It would almost appear, therefore, that some line of fracture extends up from near the mouth of the Erme towards Heathfield Down, and has cut out part of the belt of arenaceous rocks which ranges up from Morleigh Down and Lee Moor on the east.

It is difficult to bring the argillaceous rocks on the east of the Yealm satisfactorily into connexion with those on the west of the river, without supposing a line of fault to run up the stream from the coast south of Worswell. The beds which range down from the south of Holberton appear to run out to sea at Stoke Point, and the grits which strike down to Erme mouth were not met with again on the east of the Yealm. Light-coloured grits, however, occur in the hill north of Knighton; but it is not certain that they are a continuation of those of Staddon Point, although only grey and blue slate was met with between the grit at Knighton and the limestone at Plymstock, without any appearance of the red grits of Staddon Point.

These grey and blue slates strike up from across the Yealm south of Kitley Park, and from the north of Brixton, and appear on the shores of Plymouth Sound between the limestone and Withy Hedge, and contain some calcareous bands, especially near Gooswell. To the south of these are the red grits and slates of Staddon Point, which range inland to the south of Staddiscombe *, and, if continuous with

* No. 6 in Prof. Phillips's section, *l. c.* p. 201.

the grits of Knighton, must curve round to the south-east; but if they do so, the dips in the argillaceous rocks of Down Thomas and Longdon must be deceptive. The red grits of Staddon Point are much folded, and some of the beds inverted, but the general dip is southerly; and above them are the grey and bluish slates, with thin grey grits, of Bovey Sand Bay; and these are succeeded by reddish slates, partly argillaceous and partly hard and micaceous, like those of Kingswear. The general appearance of these rocks along the shore of Plymouth Sound reminds one of the section on the Dart river.

These rocks are continued across Plymouth Sound without any material variation. The argillaceous slates which overlie the limestone at Mount Edgecombe correspond to those of Jenny Cliff Bay, but west of Millbrook they become interstratified with bands of grit. Red arenaceous rocks like those of Staddon Point succeed these at Marker Church, and are continued southward as far as the Barracks, where a mass of reddish felspathic rock * separates these grits from the grey slates of Kingsand and Cawsand. This mass of igneous rock appears to have carried the grits somewhat to the north of the general line of strike; but the latter are not continued across the promontory to Whitesand Bay in exactly the same mineral condition, their place on the coast being occupied by coarse slates with thin grit-bands. The rocks of Kingsand and Cawsand are similar to those of Bovey Sand Bay; and similar rocks, sometimes reddened, are continued to Penlee Point and the Rame Head. The dips are all southerly, at angles varying from 35° to 45° or more.

Returning to the Kingsbridge promontory, we find coarse reddish slightly micaceous slates, similar to those of Kingswear, extending all along the shores of Start Bay, from the mouth of the Dart to Slapton Bridge, dipping southerly at angles varying from 30° to 60° or more. On the west, on the other hand, soft argillaceous grey, blue, or purple slates occupy the whole of the distance between Aveton Giffard and the metamorphic rocks at Hope. At Aveton Giffard there are some blue and green evenly laminated slates, the laminæ of which dip S. 20° E. at 70° or 80°; and to the south of these a long belt of argillaceous rocks, apparently an anticlinal axis, which includes a band of similar roofing-slates, ranges about N. 10° E. from the coast between Rigmore and the mouth of the Avon, past Churchstow, to Buckland Tout-Saints and Netherton, and thence towards Coles Cross and Heathfield. In an opposite direction coarse reddish slates, mingled with others that are more argillaceous, but for the most part red, trend westward from the north of Slapton by Hartston, to the grit beds of Marlston, north of Sherford, and thence to Kingsbridge. All these beds dip to the south at high angles; but along a line extending from Hurleston by the north of Charleton and Stokenham to Slapton Sands the dip becomes reversed, and the beds rise to the south; and with them a band of dark bluish-grey roofing-slate, similar to that of Buckland Tout-Saints, and Netherton, which crops out along a parallel line crossing the Kingsbridge inlet south of Charleston, and strikes thence by Frogmore to the south

* Apparently intrusive.

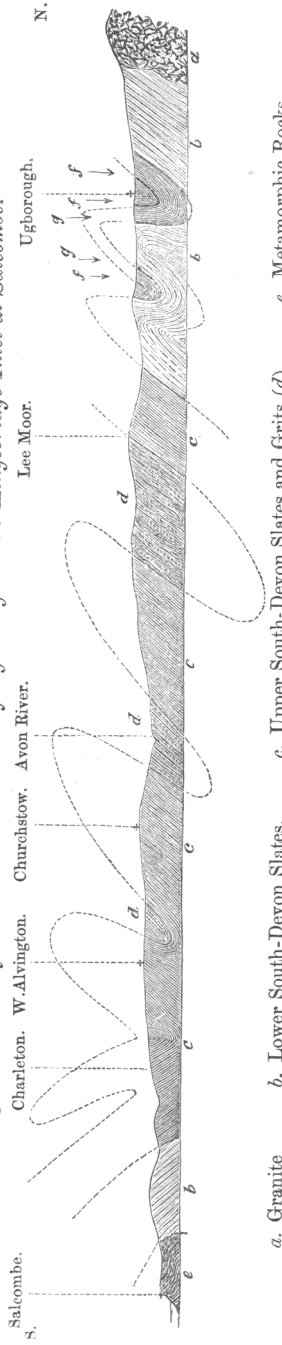


Fig. 5.—*Section from the Granite North of Ugborough to the Kingsbridge Inlet at Salcombe.*

a. Granite. *b.* Lower South-Devon Slates. *c.* Upper South-Devon Slates and Grits (*d*). *e.* Metamorphic Rocks. *f.* Volcanic Rocks. *g.* Torbay Limestone.

of Torr Cross. Other slates, not very dissimilar except in their less even lamination, succeed these, with the same northern dip, and lead up to the metamorphic rocks of Salcombe and the Bolt.

The relation of the soft variegated argillaceous rocks to the somewhat coarser and less regularly laminated reddish slates on the shores of Start Bay north of Slapton is a question not very easily decided, except inferentially, which, of course, is not the most satisfactory method. But the reddish slates of Start Bay precisely resemble those at the southern extremity of the Dart-river section at Kingswear, to which they appear to form a consecutive series; and if we trust to the dips as representing the true succession of the beds, they will appear to be clearly above the grits of the Dart river opposite Dartmouth, and of Bugford. The variegated slates on the west, between Aveton Giffard and the altered schists of the Bolt Tail, on the contrary, resemble those which are seen to pass beneath the grits on the north at Modbury, and at the viaduct near Greenway House on the Dart. Following the strike of the beds from Dartmouth by Woodleigh and Aveton Giffard to Regmore, and from Stokenham to Thurlestone, we find that the included rocks occupy on the shores of Bigbury Bay not more than half the breadth of country that they do on the opposite coast south of the Dart; and therefore it would appear that the sharp anticlinal axes are on the west, and the synclinal axes on the east. As the dips are all southerly (from S. to S. 20° E.), at high angles, these axes must be thrown over to the north, and we thus have the same beds repeated again and again. That these inclined anticlinal and synclinal axes are not purely hypothetical will, I think, appear when we consider that if we were to measure the distance from the Ditsham limestone to where the dip becomes reversed between Stokenham and Friscomb, we should find it amount to rather more than seven miles, which, at an angle of 35° only, would give a thickness of up-

wards of 20,000 feet for the relatively small portion of the South-Devon series which overlies the Torbay limestones,—an estimate which would be beyond all probability.

This higher group of rocks is only very sparingly fossiliferous. A few fossils are stated to have been found in the cliffs of Plymouth Sound; and Encrinites occur in the calcareous seams at Kingswear. Mr. Pengelly has seen traces of them in Scabbacombe Bay and at Beeson Cellers, near Torr Cross; but these remains are in such a wretched condition that, with the exception of *Petraia Celtica*, Lonsd., I am not aware that any of them have been determined.

IV. Metamorphic Rocks of the Salcombe district.

These rocks consist chiefly of mica-slate and of a mixture of granular quartz with a mineral allied to chlorite, and have been fully described by the late Sir Henry de la Beche in his 'Report of the Geology of Devon and Cornwall'*, and by the authors of the 'Devonian System,' in the memoir already quoted †, to which reference must be made for mineral details. As observed by the latter authors, mica-slate prevails most towards the south, and the chloritic rocks towards the north; but the different varieties are so commingled that they cannot be separated into two formations‡. Although greatly undulated and contorted, they have a general dip towards the argillaceous-slate system on the north, which has likewise a northern dip; but the actual contact is nowhere seen, and the manner in which the altered and unaltered rocks are brought into apposition is somewhat obscure. The argillaceous rocks are high up in the Devonian system; nevertheless no clear evidence of a line of fault between them and the metamorphic rocks has been observed. Assuming that the latter belong to some earlier epoch, it is possible, perhaps, that they may have been thrust up from below, breaking through all the lower beds of the Devonian series, while they carried up and threw off to the northward the higher beds of the Kingsbridge district. Such an hypothesis is quite consistent with what we know of the general relations of the slaty rocks of South Devon, and may assist in explaining the relative positions of the beds, as the metamorphic rocks might then have formed a counter-force to that which brought up the granite of Dartmoor, and have contributed to the production of those long narrow anticlinal and synclinal folds into which the intervening slaty rocks have been thrown. At the same time, it must be observed, these altered rocks of Start Point and the Bolt have not a very ancient aspect, and the dark-blue slates of Hopes Cove exhibit that minute crumpling and abundant intersection with veins of red and white quartz so frequently observed in slate rocks at the point of commencing metamorphism. Moreover the rocks appear on the whole to be more highly crystalline, and the effects of metamorphic action seem to increase progressively, as we proceed towards the south; and it appears to me more probable that these micaceous and chloritic rocks are altered depositions of Devonian age, mantling over a granitic mass,

* P. 27. † Pp. 658 and 661. ‡ *L. c.* p. 659.

like that of Dartmoor, more deeply seated. The dynamical effects on the slate rocks which occupy the interval between Salcombe and the Dartmoor granite at South Brent and Ivy Bridge would still be much the same, as there is pretty good evidence to show that all these great granitic masses of Devon and Cornwall belong to one epoch *, and have been the direct cause which has brought the slaty rocks into their present position.

V. Granite of Dartmoor and of Brown Willy (Camelford).

The Dartmoor granite has been also fully described by Sir Henry De la Beche †, Sir Roderick Murchison and Prof. Sedgwick ‡, Mr. Godwin-Austen §, and other writers of earlier date. It will be sufficient, therefore, for my present purpose merely to restate the relations these masses bear to the surrounding rocks, in order that their influence in bringing about the general disposition of the latter, above described, may not be overlooked.

The Dartmoor granite has pressed the Culm-measures to the northward, bringing the beds into nearly vertical positions. On the east, between Dunsford and Bovey Tracey, it has broken through the beds, which range up to it more or less at right angles to its margin, and the volcanic rocks interstratified with them are altered and rendered crystalline. South of Bovey Tracey, however, and thence to Skeriton, the granite throws the Culm-measures off to the south-east. At its southern extremity, near Ivy Bridge, it has broken through the Devonian rocks; but around Cornwood the latter form a shallow basin between the granite at Harford and the offstanding protruding mass of Crown Hill Down. Westward of Crown Hill Down, and, in fact, along the whole south-western border of Dartmoor, as far as Meavy, the granite has broken through the bedding, which trends up to its edge; but thence northwards, almost to Bridestow, the beds dip away from the granite at for the most part low angles, and occasionally they are nearly horizontal, as in the neighbourhood of Petertavy.

The granite of the Camelford Hills throws off the beds to the south, which dip at moderate angles towards Liskeard. On the north it has carried the beds which range up from the north of Hingston Down to the north-east, and beds on the same geological horizon dip off the granite on the west at tolerably high angles. Lower beds, however, are brought up on the east and north-west of the granite. Those on the east dip away from its margin somewhat irregularly; those on the north-west stretch away towards Cadon Barrow, throwing off higher beds to the north-east and west.

The rocks contiguous to the granite are altered by it; and the resulting metamorphic rock, of course, varies with the original constitution of the rock acted upon. Generally the effects are very feeble at a distance of a quarter of a mile from its margin; but it extends further where the beds dip off from the granite than where they

* See also on this point Sedgwick and Murchison, *l. c.* p. 685, and De la Beche, Rep. p. 165.

† Rep. p. 157 *et seq.* ‡ *L. c.* p. 685. § *L. c.* p. 476.

trend up to it, for obvious reasons; and it varies also with the relative fusibility of the rock, the volcanic rocks being the first to exhibit any alteration, which they do by becoming crystalline and altered in the arrangement of their elements, as near Petertavy and on the east of Dartmoor. Among the Culm-measures the resultant metamorphic rock is commonly either a minutely crystallized black schorl-rock of uniform texture, or a mixture of this with semivitrified grit in alternating layers, or a uniform mixture of small schorl-crystals and quartz-grains. Some of the rocks, however, are rendered micaceous; and among the older rocks this result is the more common effect; but occasionally crystals of chiastolite, more or less perfectly developed, appear in the slates, as on the north of Ivy Bridge. None of these altered rocks, however, exhibit a high degree of metamorphism, but the contrary; and we pass abruptly from these slightly altered rocks to highly crystallized coarse-grained granite, without any intervening rocks which would indicate a gradation from the unaltered Carbonaceous and Devonian rocks into the granite. The truly igneous character of these granitic masses is therefore as clearly shown as any geological phenomenon can be; and around the margin of the moor the granite has thrown out veins, both large and small, into the adjacent rocks. Whether the elvans, which at Blisland and St. Neots also appear to have emanated from the molten mass, really did so or not, we need not stop to inquire.

VI. General Remarks.

It follows from what has been stated that neither the highest nor the lowest portion of the Devonian system, as seen in North Devon, occurs on the south side of the Culm-measures, and that the slate rocks which pass under the Carbonaceous series on the north are not the same as those that rise from beneath them on the south. There is, no doubt, a good deal of similarity between them, as there is between much of the slaty rocks of Devonshire; and this, together with the fact that both are locally fossiliferous and contain some organic remains in common, has led to the inference that the opposite sides of the trough are symmetrical. So far as the Culm-measures are concerned, this appears to be the case; and although the local admixture of volcanic material may have somewhat augmented the thickness of these beds in the south, the small patches of limestone at a certain distance from the base of the series, both in the north and in the south, appear to indicate a well-marked horizon on which there existed a change of conditions; and hence the subdivision of the Carbonaceous system by Sedgwick and Murchison into a lower and an upper series is a natural one *. But in the south there is complete unconformability between the base of the Culm-measures and the underlying Devonian rocks. If we follow the southern range of Culm-measure limestones from Launceston eastward, round the margin of the Dartmoor granite, by Bridestow to Drewsteignton, and thence to the north of Dunsford, we find that the interbedded volcanic rocks between Dunsford and Chudleigh correspond in their relative position,

* *L. c.* p. 670.

as regards both the range of limestones and the base of the measures, with the similar volcanic rocks of the Brent Tor district. There is more grit, perhaps, on the east side of the Dartmoor granite than on the west, though even this may be questioned; but in the abundance of chert-beds, and in their general petrological aspect, they are precisely similar. Now the base of these lower Culm-measures does not everywhere rest on the same part of the underlying Devonian rocks. The beds which underlie them at Penter's Cross and Whitechurch Down are considerably lower than those on which they rest at Petherwin and Trewen; while on the east they lie directly on the denuded surfaces of the Torbay limestones, which are probably more than two thousand feet higher in the series; and if the Culm-measures of the Ilsington and Holne district are not, as I believe, brought into contact with the older rocks by faults, then they rest on successively lower and lower beds as we pass from Bickington to Skeriton, near Dean Church. Nor has this want of conformability altogether escaped observation; for it is noticed by Prof. Sedgwick as occurring "near Launceston"*, and by Godwin-Austen in the Newton Bushell district†. As already stated, on the west of Dartmoor the great undulations into which the upthrust of the granite has thrown the beds has affected both systems; but nevertheless the minor contortions and crumplings of the higher series have no relationship to those of the lower, and, moreover, the angles at which the beds of the two formations rest are commonly altogether different. Now this unconformability on the southern side of the Culm trough is so considerable that it throws doubt upon the reality of the apparent regular succession on the north, and leads to the suspicion that the conformability which is there supposed to exist may be more apparent than real. The late Mr. Thomas Weaver did not, in fact, consider the Culm-measures to rest conformably on the underlying rocks; for he says, "The Wavellite schists and sandstone (7), and culmiferous shales (8), though apparently in some places in parallel (conformable) position with the Trilobite slates ‡ (6), do, when thoroughly examined upon the line of outcrop in the district, form a break with No. 6, and are unconformable thereto" §. That there is some difficulty in detecting any want of conformability is due to the similarity in appearance of the slaty rocks of the two series and the absence of those interstratified beds of volcanic ash which are so serviceable in enabling us to follow the lines of strike in the south. But if, as I believe, the Culm-measures have been laid down on the denuded surface of the older rocks, then there is a break in the sequence and a lapse of time to be accounted for.

It is obvious that the true position of the Plymouth and Torbay limestones in the general mass of the South-Devon rocks is a matter of great importance to the correct interpretation of the structure of the country. Looking at the map, the question might suggest itself whether or not the limestones which range by Bickington and Ashburton to Dean Prior might not be the same as those of Ogwell, Ipplepen, and Dartington, thrown over a broad anticlinal axis of the

* Proc. Geol. Soc. vol. ii. p. 681. † *L. c.* p. 458. ‡ *I. e.* the Pilton group.
§ "Geological Relations of North Devon," Proc. Geol. Soc. vol. ii. p. 589.

lower slates to the north-west. This view, no doubt, would have the merit of simplifying the structure of the country south of the Culm-measures, inasmuch as it would bring the limestones of South Petherwin, Padstow, the Looe river, and St. Germans into relation with those of Plymouth and Torbay on one horizon; and, as will be shown hereafter, although the distribution of organic life in these rocks is very irregular and often local, nevertheless palæontological records would not altogether discountenance it. But however plausible this interpretation may appear at first sight, all the direct evidence obtainable, as already stated, is entirely against it; and whether we cross the country from Bickington by Hobbin Wood to Chircombe Bridge, or from Ashburton by Woodland to Torbryan, or, further to the south, from the granite by South Brent to Black Hall, near North Hewish, we appear to have a clear upward succession of the beds; and in the two or three instances in which the volcanic rocks were observed to have exerted any influence on the contiguous slates, it was on the Ashburton side only *.

There is equal difficulty in regarding the Plymouth limestone as the same as those of Milladon and the Looe river, brought up to the surface by an anticlinal axis with the intervening beds troughed in between them, notwithstanding the apparently horizontal thinning-out of the limestone at each extremity, and the contortion seen at St. John's. This view would, of course, require the beds contained in the synclinal trough west of the Looe river, as they trended up to the Lyhner and the Hamoaze, to become inverted, and in this position to range eastward to the granite north of Ivy Bridge, where, partly by the granite and partly by faults, the continuity of the belt of rocks became destroyed. But we cannot assume this view without doing violence to the apparent relations of the bedding on either side of the mouth of the Seaton river; and there is, in fact, no direct evidence to bear it out. Moreover it would bring these beds into relationship with the rocks which certainly overlie the limestones of Plymouth and Brixham on the south, and occupy the whole of the Dartmouth and Kingsbridge district, with which, notwithstanding a considerable resemblance in lithological character, there is no palæontological evidence to connect them; whereas the rocks which are seen beneath the limestones at Mudstone Bay and Meadfoot Sands are related to them by similarity of fossil contents, and more especially by their fish-remains. On the other hand, the slates which occupy the country between the Ogwell and Ashburton limestones resemble, both petrologically and in the abundant association of volcanic rocks, the beds which, brought down from the Liskeard district by St. Germans and Saltash, and from the coast by Polbathick and by Anthony, are continued by Plympton to the southern extremity of the granite at Ivy Bridge.

But a directly opposite interpretation has also been suggested respecting the stratigraphical relations of these beds, viz. that the

* In this I am borne out by Mr. Godwin-Austen, who regards the limestones of Ashburton and St. Germans as a lower range. (Trans. Geol. Soc. vol. vi. p. 462; also Sedgwick and Murchison, *l. c.* p. 653.)

red rocks of Staddon Point, Morleigh Down, and the Dart river have been brought up from below the Plymouth limestone by an inverted anticlinal axis; and I believe Mr. Beete Jukes is inclined to favour this view. There appears to be, however, on the east shore of Plymouth Sound, south of Mount Batten, and from the limestone of Brixham, along the river Dart, and the coast at Mann Sands, an upwards series, through grey, blue, and purple slate, to the red grit, which rocks succeed each other conformably; and the limestone of Berry Pomeroy and Marldon are overlain by variegated argillaceous slates, surmounted at Blagdon Cross by red grits like those of Staddon Point and the banks of the Dart. No similar rocks, however, are seen rising up from below the limestone among the lower rocks north-west of Dartington and Ogwell; nor are any such again brought up to the surface from beneath the limestone in the long downward succession of the beds between Plymouth and the Harrowbridge station, on the Tavistock railway.

The fossiliferous rocks of South Petherwin appear to be commonly held among geologists to be Upper Devonian, and are placed by Mr. Salter on the horizon of the red slates of Morte Bay *. Looking, however, to the relations of the beds which surround the granite of the Camelford Hills, and following, as I have done, the volcanic rocks of Alternan and Lewannick, which support the Petherwin limestones, round to the westward by St. Clether, Davidstow, and Tintagell, to Delabole and St. Mabyn on the one hand, and by Stoke Climsland, South Hill, Callington, and New Bridge, to St. Cleer and the vicinity of Liskeard on the other, there seems to be no reasonable doubt that we are following the same range of beds, and that the granite, in breaking through and carrying up the Devonian rocks, has done so without producing so great an amount of disturbance as to destroy the general relations of the surrounding rocks, although some lower beds are brought up on the south-east and north-west of the granitic mass, and carry these volcanic rocks further from its margin. There appears, therefore, to be evidence, as clear as we can expect to find among rocks of this kind, that the igneous rocks which are seen to dip away from the granite on all sides except that towards Bodmin, all belong to a single group; and that the band of volcanic rocks at Alternan, on the north, holds the same relative position as regards the granite that the smaller, but similar, band at St. Cleer does on the south—in other words, that the igneous rocks of Alternan and St. Cleer, and the more horizontal masses further to the east at South Hill and Callington, are on the same, or nearly the same, geological horizon. Now we have a tolerably clear upward succession from the beds which are thrown over to the north of the Hingston Down granite, and which range up to Alternan, across the strike to the limestones of South Petherwin—and an equally clear downward series from Whitechurch Down, along the Tavistock railway, to Plymouth. If, therefore, the Petherwin limestones were really

* "Upper Old Red Sandstone and Upper Devonian Rocks," Quart. Journ. Geol. Soc. vol. xix. p. 484, 1863.

above the Plymouth and Torbay range, where is the place of the latter and of the red grits which overlie them at Staddon Point and Blagdon Cross, on the north of Hingston Down? There can be no question about the rocks of Hingston Down and the vicinity of Buckland Monachorum being the lowest in the line of country between South Petherwin and the coast at Whitesand Bay; and admitting that the rocks of the St. Breock's anticlinal axis are, as I believe, somewhat lower in the series, we still find no trace of the red rocks of Staddon Point and the Kingsbridge district, between them and the volcanic beds of St. Clether and Tintagell, as they curve round by Delabole to the coast at Pentire and Padstow; and although it is possible that they may have thinned out before reaching Bodmin, that could hardly be the case as regards the country north of Plymouth. There really appears, therefore, to be so little ambiguity about the stratigraphical relations of these different beds, that it becomes necessary to examine the evidence afforded by organic remains which has led to a different opinion.

The following Table (Table II.) gives the distribution of the 76 species from the fossiliferous rocks of South Petherwin. The list of species is extracted from Table II. of Mr. Etheridge's elaborate memoir in the 23rd volume of the Society's Journal *. The columns headed "Europe" and "Carboniferous" are likewise extracted from Mr. Etheridge's lists. These Tables have been used also in compiling the other three columns, there being only two species in column 5 which are not contained in his Tables; and they are introduced on the authority of Prof. Phillips and Mr. Davidson. For the rest I am indebted to the writings of Prof. Phillips and Messrs. Godwin-Austen, Salter, and Davidson, and to some unpublished information derived from the last two authorities through Mr. Pengelly. The 6th column includes all the localities named in Table I. (p. 432), together with those of Walton, Rowdown, near Washburton, and Yealmpton Creek; but the list is very incomplete. The 7th column is likewise very incomplete, but comprehends the calcareous and fossiliferous rocks which range by Ashburton and Newnham Park to St. Germans and the Looe river, and thence on towards the Fowey. It may be observed, however, that some of the Petherwin fossils, collected many years ago, before the limits of the Culm-measures were clearly defined, may not really belong to the underlying rocks. This is the case with *Loxonema tumidum*, *Poterioceras fusiforme*, and perhaps *Murchisonia angulata*, as none of these species, except the last, are known to occur elsewhere in Devonian rocks†.

* P. 616 *et seq.* Three species have been omitted, as *Orthoceras ibex*, Phill., is the same as *O. Phillipsii*, D'Orb., and *Athyris indentata*, Sow., is the *A. concentrica*, V. Buch (*vide* Sow. in Trans. Geol. Soc. 2nd ser. vol. v. p. 784); *A. decussata*, Sow., is likewise a synonym of *A. concentrica*, according to M'Coy and De Koninck. (See Davidson, Mon. Palæont. Soc.: Brachiopoda, vol. iii. Part 6. No. 1. p. 17; consult also Phill. Pal. Foss. p. 70, and Morris, Cat. Brit. Foss. p. 130).

† The lowermost beds of the Carbonaceous rocks on the south side of the Culm trough are locally fossiliferous. They contain Goniatites, Orthoceratites, and some other fossils, and, near Landlake and Chudleigh, *Posidonomyæ*. The fossils named above, as also *Orthoceras striatum*, *Sanguinolaria elliptica*, &c., may have come from these lower beds.

TABLE II.

Species.	Devonian.															Carboniferous.
	Peculiar to Petherwin *.	North Devon.			Middle and South Devon.			Europe.			In any area.					
		Upper.	Middle.	Lower.	Upper limestones.	Slates. Meadfoot, &c.	Lower limestone range.	Upper.	Middle.	Lower.	Upper.	Middle.	Lower.			
Petraia Celtica, *Lonsd.*	...	*	...	...	*	*	*	...	...	...	*	*				
Hallia Pengellyi, *M.-Edw.* ‡	...	...	...	...	*							*				
Amplexus tortuosus, *Phill.*	...	...	*	...	*	...	*?	...	*	...	...	*				
Cyathophyllum cæspitosum, *Goldf.*	...	...	*	...	*	...	...	...	*	...	...	*				
Cyathocrinus ellipticus, *Phill.*	*															
—— variabilis, *Phill.*	...	*	*	...	...	...	...	...	...	...	*	*	...	*		
Phacops laciniatus, *Rœm.*	...	...	...	...	*	...	*	*	*	...	*	*				
—— latifrons, *Bronn*	...	*	...	?	*	*	*	*	*	*	*	*	*			
—— granulatus, *Münst.*	...	*	...	...	*	*	...	...	*	...	*	*				
Entomos serrato-striata, *Sandb.*	†	...	...	...	...	...	...	*	*	...	*	*				
Fenestella antiqua, *Goldf.*	...	*	*	*	*	*	*	...	*	...	*	*	*	*		
Polypora laxa, *Phill.*	...	*	...	...	*	...	...	...	*	...	*	*	...	*		
Athyris concentrica, *V. Buch*	...	*	*	...	*	*	*	*	*	...	*	*				
Spirifera Verneuillii, *Murch.*	...	*	*	...	*	...	*[3]	*	*	...	*	*				
—— Urii, *Flem.*	...	*	...	...	*	...	...	...	...	...	...	*	...	*		
—— lineata, *Mart.*	...	*	...	...	*	...	...	*	...	...	*	*				
Atrypa desquamata, *Sow.*	...	?	*	...	*	...	*	...	*	...	...	*				
—— reticularis, et var. aspera	...	...	*	...	*	...	*	*	*	*	*	*	*			
Rhynchonella pleurodon, *Phill.*	...	*	*	...	*	*	...	...	...	...	*	*	...	*		
—— pugnus, *Mart.*	...	*	*	...	*	...	...	*	*	...	*	*	...	*		
—— reniformis, *Sby.*	...	*	...	...	*	...	...	...	...	...	*	*	...	*		
Camarophoria rhomboidea, *Phill.*	...	...	...	...	*	...	*	...	*	...	...	*				
Orthis striatula, *Schloth.*	...	*	*	...	*	...	...	*	*	...	*	*				
—— interlineata, *Sow.*	...	*	*	*[1]	...	...	...	...	...	...	*	*				
Streptorhynchus crenistria, *Phill.*	...	*	*	...	*	*	*[2]	*	...	...	*	*	...	*		
Strophalosia productoides, *Murch.*	...	*	...	...	*	...	...	*	...	...	*	*				
Productus subaculeatus, *Murch.*	...	...	...	...	*	...	...	*	*	...	*	*				
Sanguinolaria sulcata, *Münst.*	...	*?	...	...	*	...	*	...	...	...	*	*				
Ctenodonta elliptica, *Phill.*	*															
Orthonota semisulcata, *Phill.* non *Sow.*	*															
Modiola amygdalina, *Phill.*	*															
Schizodus deltoideus, *Phill.*	...	...	*	...	...	...	...	...	...	...	...	*				
Aviculopecten granulosus, *Phill.*	*															
—— transversus, *Sow.*	...	*	...	...	...	...	...	*	*	...	*	*	...	*		
—— alternatus, *Phill.*	*															
—— granosus, *Sow.*	*															
—— arachnoideus, *Phill.*	*															
Avicula subradiata, *Phill.*	...	*	...	...	*	...	...	...	...	...	*	*				
—— exarata, *Phill.*	*															
Pterinea ventricosa, *Goldf.*	†	...	...	...	...	...	...	...	...	*	...	...	*			
—— spinosa, *Phill.*	...	...	...	*	...	...	*	...	...	...	...	*	*			
Cardiola retrostriata, *Keys.*	†	...	...	...	...	...	...	*								
Euomphalus serpens, *Phill.*	...	*	*	...	*	*	...	...	...	...	*	*				
Natica nixicosta, *Phill.*	†	...	...	...	*	...	...	*	...	...	*	*				
Pleurotomaria cancellata, *Phill.*	...	*?	...	...	*	...	?	...	...	...	*	*				
—— aspera, *Sow.*	...	*?	...	*	*	...	...	...	...	...	*	*	*			
—— antitorquata, *Phill.*	...	...	...	...	*	...	...	*	*	...	*	*				

TABLE II. (*continued*).

Species.	Devonian.														Carboniferous.
	Peculiar to Petherwin *.	North Devon. Upper.	North Devon. Middle.	North Devon. Lower.	Middle South Devon. Upper limestones.	Middle South Devon. Slates. Meadfoot, &c.	Middle South Devon. Lower limestone range.	Europe. Upper.	Europe. Middle.	Europe. Lower.	In any area. Upper.	In any area. Middle.	In any area. Lower.	
Loxonema nexilis, *Phill.*	...	...	...	...	*	...	...	...	*	...	...	*		
—— sinuosa, *Phill.*	*													
—— tumida, *Phill.*?	†	...	...	...	...	...	...	.	...	...	...	...	...	*
Murchisonia angulata, *Phill.*?	...	*	...	...	...	...	...	*	...	...	*	...	...	*
Bellerophon bisulcatus, *Rön.*	...	*	*	...	...	*	*	...	.	...	*	*		
Orthoceras cinctum, *Sow.*	...	?	...	...	*	...	...	...	...	...	...	*	...	*
—— laterale (O. undulatum)	...	...	...	...	*	...	...	...	...	...	...	*		
—— striatum, *M'Coy*?	...	*	...	...	...	...	...	...	.	...	*	...	...	*
—— Ludense, *Phill.*	...	...	...	?	*	...	...	..	...	...	...	*	?	
—— striatulum, *Sow.*	*													
—— Phillipsii, *D'Orb.* (O. Ibex, *Phill.*)	†	...	...	...	...	...	...	...	*	...	...	*		
Poterioceras fusiforme, *Sow.*?	†	...	...	...	...	...	...	...	...	...	...	...	...	*
Cyrtoceras rusticum, *Phill.*	...	...	...	...	*	...	...	...	...	...	...	*		
Goniatites biferus, *Phill.*	†	...	...	...	...	...	...	...	*	...	...	*		
—— vinctus, *Sow.* (G. insignis, *Phill.*)	...	*	...	...	...	...	...	...	...	...	*			
—— linearis, *Münst.*	†	...	...	...	...	...	...	...	*	...	...	*		
—— subsulcatus, *Bronn*	*													
Nautilus megasipho, *Phill.*	*													
Clymenia lævigata, *Münst.*	...	...	...	...	*	...	...	...	*	...	...	*		
—— striata, *Münst.*	†	...	...	...	...	...	...	...	*	...	...	*		
—— linearis, *Münst.* (C. undulata, *Phill.*)	...	...	...	...	*	...	...	*	?	...	*	*		
—— bisulcata, *Münst.*	*													
—— fasciata, *Phill.*	*													
—— sagittalis, *Phill.*	*													
—— plurisepta, *Phill.*	*													
—— valida, *Phill.*	*													
—— Münsteri, *M'Coy*	*													
—— Pattisoni, *M'Coy*	*													
—— quadrifera, *M'Coy*	*													
Total ..... 76.	21* 10†													
	31	27	16	4	37	9	14	18	24	3	33	48	6	14

* The asterisk in this column indicates that the species is peculiar to South Petherwin. Those species marked thus †, although not peculiar to South Petherwin, are not found elsewhere in British Devonian rocks.

‡ Coll. Geol. Soc. et Edw. & Haime, Monograph Pal. Soc. p. 223.

[1] Phillips, Pal. Foss. [2] Davidson, in Col. Pengelly. [3] Murchison, Siluria, p. 395.

If from the 76 species recorded in the above Table we deduct 21 species as being peculiar to the locality, *i. e.* not found elsewhere in Britain or the continent of Europe, and 10 others that are not found elsewhere in British Devonian rocks, making 31 in all, we have only 45 species left for comparison with other British localities.

Now, of these 45 species, 27 are said to occur in the upper group of North Devon; but, on the other hand, there are in the Upper North-Devon group 78 species which do not occur in the Petherwin beds. But there are 37 species in common between Petherwin and the Torbay or South-Devon limestones; and if to these we add 3 additional species from the Middle North-Devon or Ilfracombe group, this will make 40 species, and two others from the beds which underlie the Torbay limestones will give a total of 42 species out of 45 as common to the Middle Devonian and the Petherwin rocks, against 27 in common between Petherwin and the Upper North-Devon group. This leaves but 3 species that are not found in the Middle Devonian rocks of Devonshire, exclusive of the 31 that are peculiar, viz. *Avicula transversa*, *Murchisonia angulata*, and *Orthoceras striatum**, which are Upper-Devonian and Carboniferous species. The affinity, therefore, of the Petherwin fauna with that of the Upper North-Devon group is not so strong as it is with that of the Middle group of South Devon.

If we compare the Petherwin fauna with those of the Upper and Middle groups of the European continent, the results are nearly the same. Deducting from the 76 Petherwin species the 21 not found elsewhere, we have 55 species remaining, of which 18 occur in Continental Upper, and 24 in Continental Middle Devonian rocks. And if we compare the same 55 species with the fauna of the Upper and Middle groups of all areas collectively, we have 33 for the Upper and 48 for the Middle group in common. Of these, 3 species are met with common to Petherwin and the Upper Devonian group that do not occur in the Middle group, against 18 species common to the latter and Petherwin that do not occur in the Upper group, but of which two species, viz. *Poterioceras fusiforme* and *Loxonema tumida*, occur also in Carboniferous rocks, and, possibly, do not really belong to the Petherwin lower fauna†.

To pass to particular species, it may be observed that some importance has been attributed to the occurrence of *Cypridina* (*Entomos*) *serrato-striata*, Sand., in the Petherwin rocks, as it was formerly supposed to be a characteristic fossil of the Upper division of the Devonian system; but it is now known to occur likewise in the Middle division. The *Clymeniæ*, again, have been appealed to as evidence of the Upper-Devonian character of the Petherwin beds; but of the 11 species that have been met with in that locality, 8, according to Mr. Etheridge's lists, appear to be unknown elsewhere, and therefore tell us nothing. Of the 3 remaining species 2 are true Middle-Devonian forms, and the other is a Middle-Devonian species in South Devon (and on the Continent?), and an Upper-Devonian form in France. On the other hand, the genus *Cyrtoceras* is not known in true Upper Devonian rocks, nevertheless

* This last is not contained in Prof. Phillips's lists.

† In a paper "On the Geological and Chronological Distribution of the Devonian Fossils of Devon and Cornwall," published in the 'Geologist' for 1862, Mr. Pengelly arrived at the conclusion that the Petherwin beds were "somewhat more ancient than those of Barnstaple."

it occurs in the Petherwin beds; and, lastly, there are 6 Brachiopods named by Mr. Etheridge* as being characteristic of the North-Devon Upper Devonian rocks, and not occurring below them, viz. *Athyris oblonga, Discina nitida, Lingula squamiformis, Productus scabriculus, Terebratula sacculus* and *Rhynchonella acuminata* †, none of which are known in the Petherwin beds.

These results, so far as they go, are, I believe, in accordance with those of Mr. Salter‡, who, reasoning from the mixed character of the Petherwin fauna, consisting partly of Upper- and partly of Middle-Devonian forms, assigned to these beds a middle position between the fossiliferous zones of the two upper divisions of the Devonian system, or, at any rate, a place below the Marwood beds; and he gave, among other reasons for doing so, the presence of *Clymenia* and *Cardiola rostrata*. This method of reasoning, however, can hold good only so long as there is no evidence of stratigraphical superposition. That *Cardiola rostrata* lived in Upper-Devonian times on the Continent is no evidence that it did not exist in Middle-Devonian times in Britain; and perhaps a rigid comparison of the Devonian fauna of North America and elsewhere with that of Devonshire and continental Europe might throw some additional light on our knowledge respecting the migration of species, and their distribution in time and space.

The beds brought up by the narrow anticlinal axis at Yealm Bridge may perhaps be rather higher in the series than the Petherwin rocks; but of this there is no evidence. The fossils are *Phacops latifrons, Entomos*? (*Cypridina*) *serrato-striata* §, and *Petraia Celtica*, which are likewise Petherwin fossils, with *Sanguinolaria elliptica*, Phill., and *Bellerophon hiulcus*, Sow.; but these latter, as we are told by Mr. Pattison‖, were found in the loose upper layers; and it is not quite clear whether or not they may belong to the Upper or Carbonaceous system.

In endeavouring to determine the position of the fossiliferous rocks of Liskeard and the Looe-river district by means of their organic remains, we are embarrassed by the want of evidence; for although vast numbers of casts of fossils have been observed, they are mostly in such a wretched condition that only a few of them have been identified specifically. Besides the forms enumerated in the following Table (Table III.), species of *Orthoceras*, of Brachiopoda, and of Cœlenterata have been noticed in the neighbourhood of Liskeard; and it was from within this area that Mr. Pengelly obtained the *Phacops punctatus* figured in Mr. Salter's monograph¶. In the Looe-river district, including Polruan, Fowey, &c., and the shores of Whitesand Bay, other species, not included in the Table, have been found, of the genera *Aviculopecten, Avicula, Ctenodonta,*

* *L. c.* p. 668.

† *L. c.* p. 668. A seventh is given in the text, viz. *Spirifera Urii*; but this species occurs at Barton, and is recorded as a Middle-Devonian species in Tables 2 & 9 of the Memoir.

‡ Quart. Journ. Geol. Soc. vol. xix. p. 483.

§ On the authority of Mr. S. R. Pattison.

‖ Trans. Royal Geol. Soc. of Cornwall, 35th Ann. Rep. p. 64.

¶ Palæont. Soc. Mon. Trilobites, pt. 1. pl. i. figs. 17–19.

Orthoceras, and *Goniatites*, with some Trilobites not fully identified, and many species of Cœlenterata*. But as far as the known species at present go, they do not bear out the view generally prevalent among geologists, that these Looe-river beds are the representatives in time of the Lower Devonian or Linton group of North Devon; and the fine Ichthyodorulites from this locality, in the collection of Mr. Pengelly, have the oblique ridges appertaining to the Carboniferous type†.

The 42 species from the Looe district entered in Table III. do

TABLE III.

Fossils of the Looe-River, Liskeard, and Padstow districts compared with those of Petherwin, and with the Upper, Middle, and Lower Devonian Groups of Britain and Continental Europe respectively.

Species.	Localities.									
					British.			Europe.		
	Looe-River District.	Liskeard.	Padstow.	Petherwin.	Upper.	Middle.	Lower.	Upper.	Middle.	Lower.
Caunopora ramosa, *Brass.*	*†	...	...	...	...	*				
Petraia Celtica, *Londs.*	*	*	*	*	*	*				
—— pluriradialis, *Phill.*	*	...	...	...	*	*‡	*	...	...	*
Favosites dubia, *Blainv.*	*[1]	...	...	...	...	*	...	...	*	
—— fibrosa, *Goldf.*?	*†	...	...	...	...	*	...	...	*	
Heliolites porosa, *Goldf.*	*	...	...	...	...	*	...	...	*	
Pleurodictyum problematicum, *Goldf.*	*	*	...	.	...	*	...	*	*	*
Cyathocrinus megastylus, *Phill.*	*[2]	...	...	...	...	*				
Phacops laciniatus, *Rom.*	*	*[3]	*	*	...	*	...	...	*	*
—— punctatus, *Stein.*	...	*[4]	...	...	...	*	...	...	*	
—— latifrons, *Bronn*	...	*	*	*	*	*	...	*	*	*
Fenestella antiqua, *Goldf.*	*	*	...	*	*	*	*			
Athyris concentrica, *V. Buch*	...	...	*[5]	*	*	*	...	*	*	
Atrypa desquamata, *Sow.*	*	*								
—— reticularis, et var. aspera, *Schloth.*	*	...	...	*	...	*	...	*	*	
Chonetes Hardrensis, *Phill.*	*	...	...	...	...	*	...	?	?	
Leptæna laticosta, *Conrad*	*	...	...	...	...	*‡	...	...	*	*
Orthis arcuata, *Phill.*	*	...	...	...	...	*	*			
—— resupinata, *Phill.*	*[9]	...	...	*	*	*	...	*	*	
—— hipparionyx, *Vanux.*	*	...	...	...	...	?				
Rhynchonella Pengelliana, *Dav.*	*									
Spirifera primæva, *Stein.*	*	...	...	...	...	...	...	...	*	*
—— curvata, *Schloth.*	*[5]	...	...	...	...	*	...	...	*	
—— hysterica, *Schloth.*	*	...	*	...	...	?	*	*	*	*
—— lævicosta, *Valen.*	*	...	...	...	...	*	*	*	*	
—— speciosa, *Schloth.*	*	...	*	...	...	*	...	...	*	*
Spiriferina cristata, *Schloth.*	*	...	...	...	*	*				
Pentamerus brevirostris, *Phill.*	...	...	*[9]	...	...	*	...	...	*	
Stringocephalus giganteus, *Sow.*	...	...	*[5]	...	...	*	...	...	*	

* The corals enumerated by Mr. Couch, Trans. Roy. Geol. Soc. of Cornwall, 33rd Ann. Rep., are not included, as their specific determinations were made many years ago, before the genera and species had received their modern definitions.

† The *Pteraspides* and *Cephalaspides* of Padstow and the Looe-river district are not specifically the same as those of the Lower Old Red.

TABLE III. (*continued*).

Species.	Localities.									
					British.			Europe.		
	Looe River District.	Liskeard.	Padstow.	Petherwin.	Upper.	Middle.	Lower.	Upper.	Middle.	Lower.
Streptorhynchus gigas, *M'Coy*	*									
—— crenistria, *Phill.*	*	...	...	*	*	*	...	*		
—— persarmentosa, *M'Coy*	*									
—— umbraculum, *Schloth.*	*?	...	*	...	...	*	*	...	*[10]	
Strophomena rhomboidea, var. analoga, *Phill.*	*[9]	...	...	...	...	*				
Pterinea spinosa, *Phill.*	*	...	...	*	...	...	*			
Loxonema lincta, *Phill.*	*[6]	...	...	...	...	*				
Bellerophon bisulcatus, *Rom.*	*	*	...	*	...	*‡				
Pleurotomaria cancellata, *Phill.*	*[7]	...	...	*	*					
Orthoceras Ludense, *Phill.* non *Sow.*	...	...	*[8]	*	*	*				
Serpula, n. sp.	*[9]									
Pteraspis (Scaphaspis) Cornubicus, *M'Coy* ..	*	...	*	...	...	*‖				
Cephalaspis? Carteri, *M'Coy*	*									
And remains of several other species of fish.										

[1] De la Beche, Mem. Geol. Surv. vol. i. p. 101. [2] Phill. Pal. Fos. p. 32. [3] Pengelly in Davidson's Monograph, Palæont. Soc. [4] Salter in Col. Pengelly. [5] Etheridge, *l. c.* table ii. p. 621. [6] Murchison, Trans. Roy. Geol. Soc. of Cornwall, 33rd Ann. Rep. [7] Couch on Foss. of Cornwall, Trans. Roy. Geol. Soc, of Cornwall, 33rd Ann. Rep. [8] Pattison, Trans. Roy. Geol. Soc. of Cornwall, 35th Ann. Rep. [9] Coll. Mus. Pract. Geol. [10] Siluria, 4th Edit. p. 399. † and at Ashburton. ‡ Meadfoot. ‖ Mudstone Bay.

not, as already stated, include all the forms; and of these 42 species, 5 have not been meet with elsewhere, leaving therefore 37 species for comparison, all of which, with the exception of two, viz. *Orthis hipparionyx* and *Pterinea spinosa* are known to occur in Middle Devonian rocks, either of Britain or Europe, and all, with the exception of the above, and *Spirifera primæva*, and perhaps *Spirifera hysterica* (the occurrence of this latter species in South Devon being not quite certain), are met with in British Middle Devonian rocks. On the other hand, only 8 of the 37 species are known in the Linton beds, and these, with the exception of *Pterinea spinosa*, which occurs at South Petherwin, and the doubtful *Spirifera hysterica*, Schloth., before alluded to, all pass up from the Linton group into the middle division of the system, either in Britain or on the Continent of Europe It would appear, therefore, that the chances against these rocks being Lower Devonian are as 35 to 2.

The fossil evidence respecting the position of the Padstow rocks is still more meagre; but as they are, I believe, admitted to be Middle Devonian, no question here arises. *Orthoceras Ludense*, Phill., which is also a Petherwin fossil, is said to be abundant here, and Goniatites are stated to occur*.

* Pattison, Trans. Roy. Geol. Soc. of Cornwall, 35th Ann. Rep.

It must be admitted that the connexion between the rocks of the Liskeard and Looe-river range, on the one hand, and those of South Petherwin, on the other, by means of their fossil contents, does not appear at first sight to be very strong; but the lists of species compared are small, and of that of the southern areas one-third of the species are in common. Moreover it must be remembered that nearly the whole of the Petherwin fossils come from the single locality of Landlake; a few occur in the quarry at South Petherwin; but the other limestone deposits are unfossiliferous, a very few only occurring in the slates above them, and the continuation of the range to the coast affords only the following species:—*Petraia Celtica*, *Phacops latifrons**, *Pterinea subradiata**, *Strophalosia productoides**, *Rhynchonella pleurodon*, *Spirifera disjuncta*†, and var. *gigas*, and *inornata**, and *S. speciosa**. With the exception of the latter, these are all Petherwin fossils. Nevertheless we arrive at the conclusion that the Petherwin beds are not high up in the series, even from these data (independently of stratigraphical considerations), from their palæontological connexion with the higher group being so much less strong than it is with the middle group.

The unequal distribution of organic remains above alluded to in reference to the Landlake quarry appears to obtain very generally throughout the Devonian rocks of South Devon, although not always to the same extent; and it is, perhaps, what might be partly expected when we take into consideration the isolated position of many of these calcareous deposits; for whether we assume their coral-reef origin or not, they are still patches separated by intervals, more or less considerable, of, probably, muddy sea-bottoms. Mr. Godwin-Austen, long ago, drew attention to this local association of genera and species‡, one form of Cœlenterata prevailing in one locality, while another is the dominant species in a neighbouring one. Some of these calcareous deposits appear to contain little else than one or two species of Corals and a few Amorphozoa. Others teem with Brachiopoda like those of Woolborough and Barton. At the same time the limestones of Woolborough, Ogwell, and Barton have been, no doubt, more diligently searched, especially Woolborough, and for the reason, as Mr. Godwin-Austen states, that the fossils at that quarry are extracted more easily and in better condition than at any other, and it is therefore a favourite spot of collectors. But the Woolborough colony is in fact no less remarkable than that of Landlake, and has alone afforded 139 species. Woolborough and Barton are equally rich in Brachiopoda, viz. 38 species, but only 26 species are common to the two localities. Woolborough has 20 Brachiopods in common with Dartington, 19 with Hope's Nose, 18 with Plymouth, and 13 with Ilfracombe. Barton has 18 Brachiopods in common with Dartington, Hope's Nose, and Plymouth respectively, but only 10 with Ilfracombe §. Nevertheless all these localities are in Middle Devonian

* Mus. Geol. Soc. † Mus. Pract. Geol., Jermyn St.

‡ *L. c.* p. 465.

§ Vide Mr. Pengelly's tables. Trans. of the Devonshire Association for the Advancement of Science, Literature, and Art, 1867.

rocks, and, with the possible exception of Ilfracombe, are all on the same horizon.

The abundance of species of *Cyrtoceras* at the Woolborough quarry is quite as remarkable as that of species of *Clymenia* at Landlake. Of the 13 species which have been found at Woolborough, 9 are peculiar to the locality. One, *Cyrtoceras rusticum*, occurs likewise at Landlake, and three species occur in the Middle Devonian rocks of continental Europe. The Tetrabranchial forms, therefore, constitute a colony singularly restricted in range, and in consequence of these and the many other peculiar forms of extinct life associated at this spot, it has been suggested that this small mass of limestone, which here protrudes through the Culm-measures, may be of a different age from the rest of the Torbay limestones; and that the Woolborough and Landlake beds may have been synchronous, and referable to the lower part of the Upper Devonian series*. Against this view it may be urged that not one of the 13 species of *Cyrtoceras*, and only one of the 11 species of *Clymenia*, and one only of the 4 species of *Goniatites* met with in one or other of these two localities are known to occur in Upper Devonian rocks in any area.

But there is another and more fatal objection to this view, inasmuch as it assumes the existence of a fault with a downthrow of several thousand feet, and of course of an extent proportionate to such an effect; whereas there are only a few small faults in the vicinity with a throw of a hundred feet or so, perhaps less; for the Connator fault, if continuous with that of Bow Hill at all, has the downthrow on the other side, towards Ogwell and Ipplepen, or what amounts to the same thing, an upcast on the east, *i. e.* on the Woolborough side.

No further than Marldon, a few miles to the south, we see the Torbay limestones overlain by a great thickness of red slates and grits almost devoid of fossils; and the character of the rocks which overlie the upper limestones of South Devon is further seen in the succession of beds southward of Brixham, where they attain a thickness of several thousand feet; and there are not, and cannot be, any such faults as would cut out this great mass of red rocks and bring yet higher beds down among the Torbay limestones without producing more obvious effects than are visible on the country through which it passed.

The identification of the *Steganodictyum Cornubicum*, M'Coy, with the genus *Pteraspis* by the Rev. W. S. Symonds, of Pendock, which has since been confirmed by Prof. Huxley, has an important bearing upon the question of the age of the rocks of South Devon and Cornwall; for although it affords us no further aid by which to coordinate these rocks with any particular portion of the Old Red system, either of the Silurian area or of Scotland, the species being specifically different from any at present known in the Old Red, it throws additional weight on the views of those geologists who hold the two systems to be equivalent in time. The species is somewhat widely distributed; and I learn from Mr. Pengelly that it occurs at

* Salter, Quart. Journal Geol. Soc. vol. xix. p. 483, footnote.

intervals on the coast all the way from the mouth of the Fowey river to the towns of Looe, and thence along the shores of Whitesand Bay to the Rame Head, and up the river Towey to as far as Cliff and the parish of St. Veep. I have found it in the slaty limestone of Milladon near St. Germans; and Mr. Pengelly has met with it in Mudstone Bay, and at Bedruthen Steps near Padstow. It ranges, therefore, through the whole of the beds from the calcareous rocks of St. Germans to the base of the Plymouth and Torbay limestones. The genus, therefore, although more particularly characteristic of the Lower Old Red, appears to pass up*. In the fine series of fish-remains in the collection of Mr. Pengelly, I noticed at least four or five other species, exclusive of the *Phillolepis concentricus*, all from the Looe-river group of beds; and these remains appear to indicate an epoch during which, from their frequent occurrence, fish must have been abundant.

I leave the coordination of these rocks with the typical groupings of North Devon to those who are better acquainted with the latter, the chief object of this communication being rather to endeavour to establish the relations of the beds, or groups of beds, south of the Culm-measure trough among themselves; and as regards the results, stated generally, they accord pretty nearly with those of the authors of the Devonian system as enunciated in the first of their memoirs †, although differing somewhat in details,—the whole of the beds, from the St. Germans and Ashburton range of limestones to the top of those of Plymouth and Torbay inclusive, corresponding with their group No. 2, the red argillaceous and gritty beds which are seen passing under the Triassic rocks of Painton, and which occupy in force the whole of the Kingsbridge promontory, exclusive of the metamorphic rocks, being represented by their groups 3 and 4.

But, assuming that the rocks included between the base of the Ashburton and the top of the Torbay limestones (the group No. 2 of Sedgwick and Murchison) represent the calcareous portion of the Ilfracombe group of North Devon ‡, then the red rocks of Blagdon Cross and the Kingsbridge promontory would in all probability correspond in position, as they do to some extent in lithological character, with the Upper and Morthoe portions of the same series; while the rocks brought up around Hingston Down and in the vicinity of Buckland Monachorum would represent the lowermost portion of the Ilfracombe group, and the yet older rocks of St. Breock's Down would find their analogues in the Hangman Grits.

* Both *Pteraspis* and *Cephalaspis* occur in the Old Red high up in the Great Skirrid Mountain, and in the town of Abergavenny, in beds which, unless some great undiscovered fault exists, cannot be more than 1000 feet below the base of the Carboniferous slate of the South Welsh coalfield.

† *L. c.* p. 668, *et seq.*

‡ Vide Mr. Etheridge's Memoir, previously cited, pp. 604 & 605.

Geological Map of SOUTH DEVON & EAST CORNWALL,

by

Harvey B. Holl, M.D., F.G.S.

Bovey Deposits
Upper Greensand
Trias
Culm Measures
Upper South Devon Group
Elvan
Lower South Devon Group
Limestone
Volcanic Rocks
Metamorphic Rocks
Granite
Faults

SCALE OF MILES.
1 2 3 4 5 6 7 8 9 10 miles

J.W. Lowry fc.