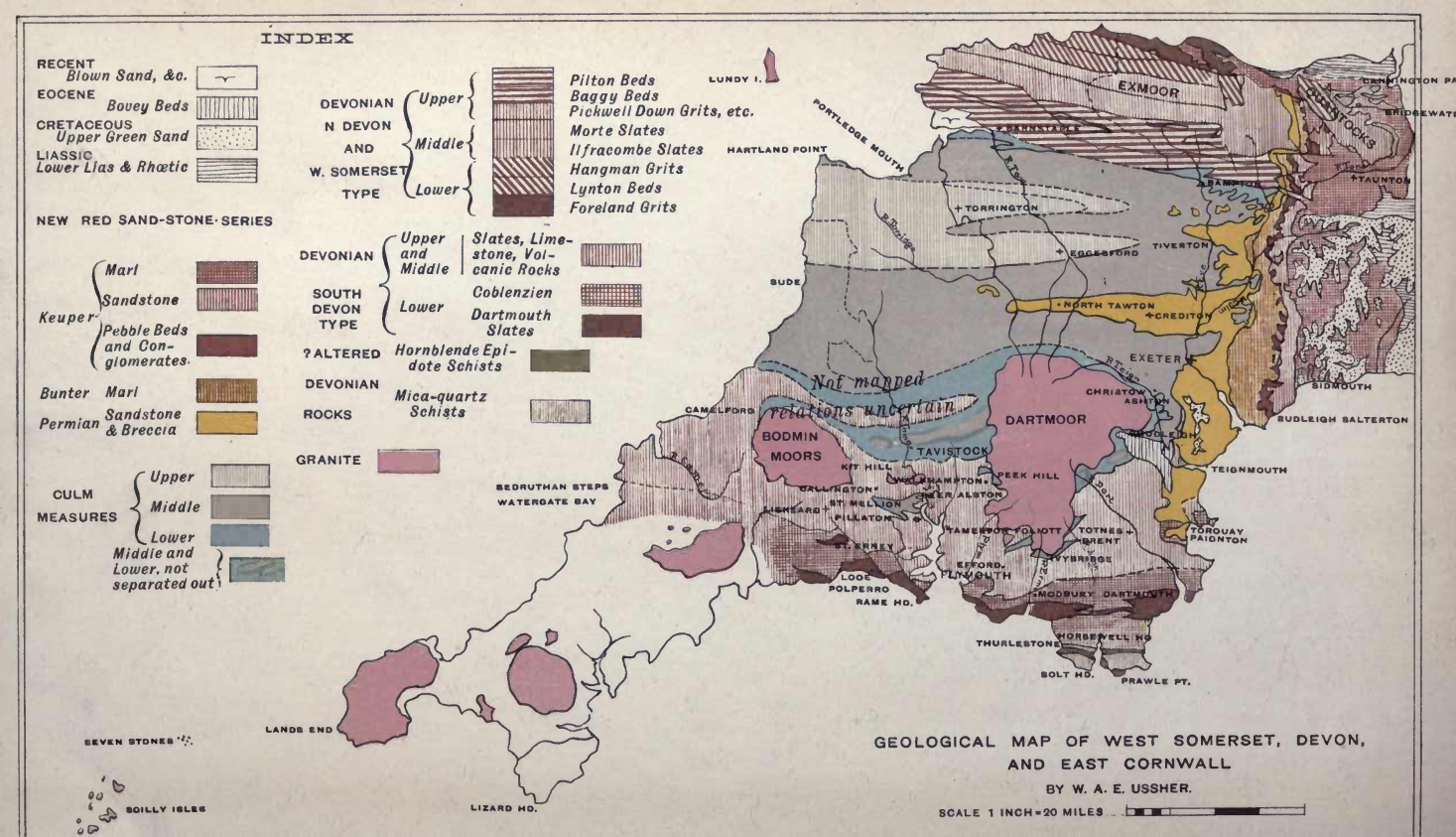
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GEOLOGICAL MAP OF WEST SOMERSET, DEVON, AND EAST CORNWALL
BY W. A. E. USSHER.
SCALE 1 INCH = 20 MILES

PROCEEDINGS

OF THE

SOMERSETSHIRE ARCHÆOLOGICAL AND

NATURAL HISTORY SOCIETY

DURING THE YEAR

1900.

PART II.—PAPERS, ETC.

The Devonian, Carboniferous, and New Red Rocks of West Somerset, Devon, and Cornwall.

BY W. A. E. USSHER.

(By permission of the Director-General of H.M. Geological Survey).

THE map accompanying this Paper is on too small a scale to indicate the positions of the smaller New Red pebble bed patches precisely, and to differentiate between Middle and Lower Culm in the St. Mellion outlier. Volcanic rocks have been also omitted for the same reason.

PREFACE.

THERE are two different methods which may be applied in the endeavour to unravel the geological structure of complicated areas.

The first, by a series of observations made during traverses across a district, furnishes the observer with a more or less numerous collection of facts, or apparent facts, which impress on his mind certain conclusions leading on reflection to more

or less rapid and brilliant generalization. This is pioneering work in stratigraphy, the personal coefficient counts in it of course, but the nature of the district counts still more.

Stratigraphical geology was built up in this way by William Smith, and the larger formations were established and sketched out by the great men who succeeded him.

The second method is a far slower process, involving great labour: the storing away of multitudes of facts, seeing everything, and following the evidence as it accumulates, weaving it into as many different hypotheses as it seems susceptible of, and allowing the progress of the work itself to point to the most reliable conclusion.

Stratigraphy, like every other branch of geology, has expanded enormously. The subdivision of formations, the discovery of structures undeciphered by the earlier workers, and the great advancement in palæontological research, whilst it gives less scope for investigation in the first manner, demands more and more of the exhaustive labour that characterizes the second. The geologist who traverses now over ground pioneered before is a free lance provided he does not hand down his ideas on a sketch map. The construction of a geological map, and more especially a government map, is a somewhat fearsome undertaking now-a-days, when there are so many eager amateurs on the look-out for sections which, if opened since the map was made may falsify it in places, or able to select the best time of year to visit districts which were mapped when crops and hedge-growths concealed the surface evidence.

Geological literature has accumulated so enormously that the results of special stratigraphical researches to attract the reader ought to be stated in the clearest possible manner, and summed up so that the maximum amount of information may be gleaned in the smallest possible compass. De la Beche's classic report on the geology of these counties is the exact opposite to this style of writing, and therefore perhaps seldom

read thoroughly or consulted as a work of reference, for which it is in many respects ill-adapted. Yet I make bold to say, that the great value of this report is in the absence of conciseness, precision, and clear statement of opinion from its pages. From beginning to end it is a reflection of the evidence presented to the author during the investigations made by himself and co-workers in the geology of the south-western counties. His report contains much more detail than his maps, because the evidence at his disposal was too meagre and too conflicting to lend itself to precise statement, and to be focussed in geological boundary lines, and the time taken was too short to produce more than a sketch map of the geology of these counties, which, considering the extreme difficulty of the area and the fact that the lines were often inferred from isolated observations, is a masterly production. Now that the detailed geological maps are being brought out, embracing my work in the New Red rocks, begun in 1871 and completed in 1880, and part of the Culm area, and the South Devon Devonian mapped since the year 1887, I think it may be useful to clear the existing literature on these three formations, for which I am personally responsible, of errors which the progress of the work has demonstrated, and to point out the principal papers, so saving the reader the trouble of referring to pamphlets in which the same subjects are treated in a more crude or less detailed manner.

The perversity of human nature often induces the chance reader to fix on some minor and local figure of description which were better suppressed than accentuated, and to ignore the many qualifications by which statements made from time to time are safeguarded.

The late Corney Grain, describing the recitation craze at "At Homes," pictured the dismay of the hostess when the reciter pointed unwittingly at the one grease spot or oil stain in her otherwise immaculate carpet, which she had hoped would escape detection; and so it may be that the one record

of early misconceptions which ought, like others of a like nature, to have been consigned as fragmentary MSS. to the oblivion of the dust heap, is selected for perusal.

As bearing on the allusion to the different methods of stratigraphical investigation, I may point out the skeleton in my cupboard as a warning. It is entitled, "The Devonian rocks between Plymouth and Looe," and appeared in *Trans. Roy. Geol. Soc., Corn.* This paper is the result of the study of the coast section, between the places mentioned, at a time when the resurvey of the Devonian rocks of South Devon was not contemplated, and when my knowledge of the Devonian was confined to North Devon and West Somerset. The deductions based on the observations are hopelessly wrong. I have spent ten years in mapping the Devonian rocks, and it has taken me this length of time to approximate to understanding the reading of this coast section: why this is so would take far too much space and time to relate, but on this section more than any other the reading of the stratigraphy of the Lower Devonian rocks of South Devon depends.

A summary of geological results was first incorporated by the Director-General of the Geological Survey, in his annual report for the year ending December 31st, 1892. This was continued down to the year ending December 31st, 1896, when it was superseded by a less condensed Summary of Progress, in which the results furnished by the respective officers were more nearly given in their own words. Taken in conjunction with the papers referred to, reference will be made to these reports, of which a list, together with the most important papers, will be given under the heading of the several formations to which they refer (the text of the reports in part at least being printed in the paper), together with the titles of minor papers partly redundant because embodied in those specially selected as works of reference, partly of local interest. I will conclude this preface by a quotation from the introduction to the Summary of Progress for the year 1897,

in which the Director-General thus refers to De la Beche's maps (on p. 5).

"The mapping which De la Beche began in the south-west of England was so rapidly executed by him, and the few assistants associated with him, that in a few years he had completed the geological investigation of the whole of Devon, Cornwall, and West Somerset. By the year 1839 the maps of this region, embracing no fewer than fourteen of the Ordnance Sheets, on the scale of one inch to a mile, were published, geologically coloured. These maps were not executed with the detail and precision now attainable on the larger scale employed by the Survey. They were, however, much more minute than anything that had preceded them."

CHAPTER I.

GENERAL STRUCTURE AND RELATIONS.

A LINE drawn from Minehead southward to Paignton, roughly speaking, separates the Palæozoic rocks on the west from the Secondary rocks on the east. The Palæozoic rocks run irregularly, encroaching eastward of this line between Williton and the Tiverton Valley, and forming masses or inliers surrounded by the Secondary rocks, the largest of which constitutes the Quantocks. Smaller inliers occur to the east of the Quantocks; at and near Westleigh; south of Collumpton, notably in Spraydown, and the Torquay promontory.

To the west of this line the Secondary rocks extend in the Tiverton Valley, and to a very much greater extent in the Crediton Valley; besides these encroaching tongues there are outliers, or isolated masses on the Palæozoic rocks, near Stoodleigh and Hatherleigh.

The Palæozoic rocks consist of the Devonian strata of the North Devon and West Somerset type, and of the South

Devon and East Cornwall type, and the great central area of carboniferous rocks of Culm Measure type which rest on them. The Culm and Devonian boundary runs along a line from Barnstaple by Brushford to Kittisford on the north, and in the south it forms an exceedingly sinuous and irregular line from near Boscastle to Tavistock and Cox Tor on the west of Dartmoor, and from Chudleigh to Ashburton and Holne on the east of Dartmoor.

Great masses of grit or sandstone rocks occur at intervals throughout the Northern Devonian area, marking conditions indicative of shallow water deposition. There are no volcanic rocks, and except at Holwell and Asholt limestones are scarce and impersistent.

The Southern Devonian area, on the contrary, contains very much less arenaceous materials, and these are confined to the lower beds, whilst at certain horizons volcanic rocks abound, and there are great local masses of limestone to the east of the Tamar.

Outliers of Culm Measures are, as far as I know, absent from the Northern Devonian area, and inliers of Devonian do not occur in the Culm. In the Southern area the case is quite the reverse. A considerable tract of Culm Measures forms an outlier with lesser detached fragments between Beer Alston and Quethiock, there are also small outliers near Tamerton Folliott, Saltash (Wearde Quay), and Efford (near Plymouth). There are inliers or detached exposures of Devonian in the Culm area at Chudleigh, Ugbrooke Park and Oldchard Well, and between Ilsington and Bickington on the west of the Bovey Valley—probably also near Lidford.

The Culm and Devonian rocks were subjected to great terrestrial movements, causing a contraction from south to north; in yielding to these their bedding planes were crumpled into an innumerable series of small curves or contortions with axes of plication running from east to west; the contorted strata were further bent into a series of undulations or broad

shallow basins and mounds or depressed ridges. The Culm Measures owe their central position to a broad shallow basin or synclinal curve from beneath which the comparatively shallow water Devonian rocks emerge on the north, and their deeper water representatives crop out on the south.

The stresses to which they were subjected affected the rocks very differently, according to their composition, mode of association, and general homogeniety. The thicker bedded grits were thrown into undulations and beautiful normal and inverted anticlines and synclines, such as may be seen in the Upper Culm Measures by the Torridge, near Torrington, and in the Clovelly and Hartland coast, and in the Lower Devonian grits in the North Devon and West Somerset area, and at Staddon and Mount Edgecumbe in the southern area. Interbedded shales and thin grits were often so broken and displaced by small slides along the axes of overfolds as to present no clearly plicated appearance, of this there are many examples in the Lower Devonian rocks of the southern area, and in places in the Culm rocks of the Exeter type. Hard thin bedded rocks, such as the chert beds of the Coddon Hill series in the Lower Culm are often broken and overthrust as in the case on Ramshorn Down,[1] where the appearances resemble false bedding, to which they were erroneously ascribed. Similar structures are frequent in thin bedded limestones or grits. In the argillaceous rocks of the Culm a tendency to cleavage is not uncommon, although pronounced slaty structure is rare; but in the Devonian it is very prevalent, as also fine secondary cleavage, and in places strain slip cleavage (Auswaschungs Klivage). In interlaminated shale and grit and interfilmed rocks, and in thinly laminated grits, which at certain horizons are locally frequent in the Lower Devonian of the southern area, cleavage has very rarely taken place, but the tendency to it is shown in the puckering of the planes into a series of minute contortions — described as gnarling. In the most

1. The British Culm Measures, p. 134.

southerly district of Devonshire, between the Start Point and Bolt Tail, the rocks correspond in types to those in the Lower Devonian area on the north of them, but they have been converted into mica and quartz schists, and the gnarling contortion and strain slips are much more frequent and intense.

In the Torquay promontory the rocks are shown to be excessively contorted, vertical junctions with zig-zag folding being frequent. On the whole the Devonian rocks of North Devon and West Somerset are not nearly so thrust, contorted and broken, and are much more regular in their distribution than those in the southern area.

The irregularity in the boundary and distribution of the Culm and Devonian in the southern area has been already alluded to. This irregularity and the differentiation in the effects of the terrestrial movements seems to have been very largely, if not entirely, due to the obstructive presence of the granite masses among them during the movements. The apparent effects of these masses on the strikes of the Palæozoic rocks has been already discussed in another place,[1] and the illustrative maps then published bring out many of the points in the above description. The movements affecting the Palæozoic rocks took place during the long interval which elapsed between the final deposition of the carboniferous rocks and the formation of the earliest Secondary rocks, viz., the New Red sandstone series.

Not only were the Palæozoic rocks folded and contorted, but during that lapse of time they were so extensively denuded that the whole series of the Culm Measures were removed from the anticlinals as well as in places, the Upper, Middle, and part of the Lower Devonian, to permit of the deposition of the New Red rocks on the upturned edges of the Foreland grits at Porlock and Minehead, and of the Lower Devonian rocks at Paignton, Slapton, Thurlestone and Cawsand.

Taking the extreme discordance between the Palæozoic

1. The British Culm Measures. Part II.

rocks and the earliest deposits of the New Red sandstone series into account, and the unbroken sequence which that series presents from base to summit, although it is highly probable that the lower beds correspond to continental Upper Permian horizons, it seems to me, even if the base of the Bunter could be clearly proved, far better to group the rocks together, as De la Beche has done, under the old term, New Red sandstone formation or series, than to use a term for the lower beds, which, in a general sense, would seem to group them with the Palæozoic rocks from which they are as sharply marked off as possible, and to separate them from strata with which they are most intimately connected.

The northerly attenuation of the New Red sandstone series and the successive conformable overlap of its lower members, and their disappearance on the margin of the Lower Devonian rocks near Williton, seems unquestionably to point to a greater development in the English Channel valley. Whether as I believe the New Red of the South Western counties was in pre-Keuper times an isolated basin, at least as far as the other English New Red areas are concerned or not, is a speculative question, as also the manner of its deposition, and into the consideration of these I do not propose to enter.

In the lower beds of the New Red series basalts, andesites, etc., occur seemingly at different horizons. They form local clusters, each cluster representing fragments of a once continuous sheet of lava emanating from a local source, but there is nothing whatever to warrant the supposition that the clusters are relics of a continuous volcanic horizon, although proximous clusters may have been in some cases once connected. These patches of lava contributed materials to the breccias which were subsequently accumulated, so that it is difficult to gauge their former extension from the fragments spared by denudation.

The Olivine basalts of Dunchideock form the most southerly group, and lie almost directly on the Culm Measures. The

horizon at which they would occur, had the series been prolonged southward to the coast, is above the limestone boulder breccio-conglomerates of Watcombe and Petitor crags, which crop out from under the rubbly breccias with quartz porphyry boulders at the base of the cliff at Shaldon; so that, either through concealment by conformable overlap, or through attenuation northward, about 500 feet of strata have disappeared between Watcombe and Dunchideock.

The extreme irregularity of the boundary of the New Red at its junction with the Culm Measures north of Exeter, and the presence of the Culm Inlier of Spraydown, indicate deposition on a very uneven floor, whether fluviatile, fluvio lacustrine, or marine in its nature, it is probable that the scour of narrow channels would give rise to a slower rate of accumulation in them than in the broader areas of deposit, so that it is extremely difficult to ascertain any definite sequence in the rocks in which the traps of the Killerton, Silverton, Crediton, and Tiverton districts occur.

The most northerly patch of trap is met with at Coleford Lodge, in association with an outlier of Lower New Red which occurs on the high ground round Stoodley Beacon.

On the north side of the Crediton valley and from thence along the Culm to the Tiverton valley the marginal deposits of the New Red are of a more or less earthy and gravelly nature and of local derivation, they mantle irregularly upward encroaching on the Culm summits, and on the north of the Crediton valley form a chain of outliers from Stoodley Beacon eastward to the vicinity of Westleigh. How far these gravels may have extended over the Palæozoic area it is impossible to say, but it is legitimate to suggest that as torrential or fluviatile materials partly mixed with screes or weathered rubble they may have carried the drainage of the higher lands into the deeper areas of deposit; thereby accounting for the occasional presence of fossiliferous Devonian

fragments in the breccias.[1] From Westleigh northward the Lower New Red rocks exhibit as definite a sequence as the overlying members of the series, their boundary with the Devonian rocks up to their final disappearance through conformable overlap being comparatively regular.

By terrestrial movements in pre-cretaceous times the secondary rocks were tilted eastward, with local differentiation in the direction of the uplift, according to the obstruction afforded by the trend of the Palæozoic masses. Thus the general dip is eastward, but off the area between Stogumber and Porlock it is northerly. These movements, acting from east to west, broke the New Red rocks into a series of faults, trending generally north and south, but with local differentiation and cross faulting. Examples of this are well shown in the geological map and sections accompanying my paper published in 1889.[2] Very excellent examples of faults, chiefly on the strike, are to be found affecting the junction of the Keuper sandstones and Budleigh pebble beds, and frequently cutting out the latter altogether between Uffculme and Ottery St. Mary.

Between Wiveliscombe and Thorn St. Margarets, where my survey of the New Red sub-divisions began in 1871, faults prevented the recognition of the Lower Marl group as a definite sub-division, until a visit to the south coast section, a year or so later, had shown me their true position, and entailed the re-survey of about 80 square miles. The New Red district of West Somerset was re-investigated three times before the very satisfactory rendering shown in the map above referred to was arrived at.

In the Bridgewater area the faults affecting the New Red which are in this district of Keuper age, run chiefly from east to west, a differentiation due no doubt to the obstructive trend

1. *Vide.* Paper by Rev. W. Downes, Trans. Devon Assoc. for 1881, pp. 293-297.

2. *Proc.* Som. Arch. and Nat. Hist. Soc. New Ser. Vol. 15. 1889.

of the Mendips and Quantocks, which also accounts for the easterly and westerly strikes in the Bridgewater area and Polden Hills, etc.[1]

CHAPTER II.

DEVONIAN.

THE actual re-survey of the Palæozoic rocks was not planned before the year 1888. Prior to that date, in mapping out the lower sub-divisions of the New Red, advantage was taken of the necessity of investigating tracts of Culm rocks in the search for New Red outliers to study their character attentively. In following the alluvia of the streams, and more especially of the Taw and Torridge valleys northward from Okehampton to Barnstaple, chains of connected observations furnished me with ample opportunities for studying the Culm rocks during the years 1877 and 1878.

The mapping of such superficial deposits as were met with in the North Devon area afforded opportunities for the study of the coast section and traverses across the strike of the rocks up stream valleys a mile or two apart: I found the junctions thus obtained were sufficient to map out, by connecting them inferentially, all the main sub-divisions. I had never felt satisfied with my previous attempts at solving the structure of the New Red rocks between Porlock and Cothelstone, as the Devonian rocks on their borders being unexplored it was impossible to say how far the faults affecting them influenced the New Red rocks.

This problem I was permitted to attack from Minehead in 1879, and in a year's time had mapped the Quantocks and a considerable part of the area between the Stogumber valley, Dulverton, and Minehead. This work was done on the old 1-inch map, and although very much more detailed than any

1. See Map II in *Proc.* Som. Arch. for 1891. Vol. 36.

previous or subsequent stratigraphical work in the area, falls very far short of an exhaustive survey.

The late A. Champernowne, who at that time had mapped a part of the Devonian rocks of South Devon in the Totnes and Torquay area, having in a previous visit to North Devon warmly adopted the views put forward by the late Prof. Jukes in 1866, accompanied me on a series of traverses in West Somerset. These resulted in a complete reversal of his views, and, with that openmindedness which characterized him, he joined me in writing a paper descriptive of our expedition. This paper "On the structure of the Palæozoic districts of West Somerset" appeared in the *Quarterly Journal Geological Society* for August, 1879. Subsequent detailed examination of the ground having substantiated its general correctness, this paper, taken in connection with the following, which give the more detailed observations of the area described with the actual mapping, must be regarded as integral portions of the literature of the stratigraphy of the North Devon and West Somerset Devonian area. The papers referred to are, "On the geology of parts of Devon and West Somerset, north of South Molton and Dulverton," *Proc.* Som. Arch. for 1879; part ii of "The Triassic rocks of West Somerset and the Devonian rocks on their borders," *Proc.* Som. Arch. for 1889. A short general paper, "On the Palæozoic rocks of North Devon and West Somerset," which appeared in the *Geological Magazine* for October, 1881 (p. 441), may be taken as introductory to the three mentioned above.

After the Cardiff meeting of the British Association I went to Ilfracombe in order to visit the quarries in the Morte slates, in which the late Dr. Hicks had found fossils, and to see under his guidance the stratigraphical evidence on which his views were based, but in that respect I was disappointed, being shown nothing that I had not seen already.

When the Barnstaple and Lynton railway was sufficiently advanced for inspection, in company with Mr. J. G. Hamling,

of Barnstaple, I examined the cuttings. The results embodied in the "Summary of Progress" for that year (1897) are as follows :—

"The rocks appear to follow each other in ascending succession from north to south. The 'Lynton Beds,' as exposed in the railway-cuttings, consist of bluish-grey irregular slates, slaty limestone and even grits, with patches of decomposed brown material full of fossil casts. The embankment at Dean separates a cutting in Lynton beds from the Hangman series, well exposed in adjacent cuttings on the south, both series giving the same dip near their junction. The 'Hangman Series' is exposed in cuttings at frequent intervals from the embankment at Dean to St. Helen's Church cutting, Parracombe. It consists of buff-brown, green, yellow, and occasionally red and purplish mudstones, sandstones, and grits. The mudstones contain in places fragments of shale, probably indicative of contemporaneous erosion, or of the deposit of mud in surface irregularities of the sediments underneath. At half-a-mile north of Parracombe red grits occur in this series, which strongly resemble the Cockington and other grits in the Lower Devonian series of south Devon, whilst in the green mudstones a great similarity can be traced to rocks on the Wembury coast south of Plymouth, and on the south Cornish coast east of Downderry.

The junction between the Hangman and Ilfracombe series is not exposed in section. It seems to cross the line at about a quarter-of-a-mile south of St. Helen's Church, Parracombe.

The Ilfracombe series consists of bluish and silvery slates, occasionally calcareous and with limestone beds (as in cutting south-east of Parracombe and in Lower Rowley cutting), and hard brownish grits which seem by their decomposition to have been in part slightly calcareous, as in the Rowley Cross cutting, in which also quartz veins occur along the divisional planes. At Comer's Ground Quarry, near Westland Pound, calcareous shales or slates, mostly decomposed, rest on some

limestone beds. In the Westland Pound cutting, where there is an appearance of faulting, indications are to be seen of the former presence of calcareous lenticles or films, in which organic structure may occasionally be detected; in one spot the rock is very similar to varieties in the South Hams district. From the Westland Pound cutting, southward, it is not easy to say where a line could be drawn between the Ilfracombe and Morte slates, or whether such a line could be proved in the Westland Pound cutting. At half-a-mile south of Westland Pound, the slates include hard siliceous brown bands, the gritty material in one place showing crushed plication on a small scale. Crinoid structure was recognised at one spot. From this part southward to Sprecott, the slates are greenish, hard, and more or less siliceous. In the Sprecott cuttings very hard, greenish, slaty mudstones are exposed, and both here and near South Thorne there are signs of small thrust-faults.

From the Sprecott cuttings to Button Wood pale greenish slates of the Morte type prevail. Although often showing markings suggestive of small fossils, these strata only yielded recognisable traces of crinoids in two or three places. In general characters they resemble most closely the pale greenish Upper Devonian slates in some districts of South Devon.

Unfortunately, the Button Wood Junction cutting leaves much to be desired. Rubbly igneous rock of the Bittadon felsite type is exposed, the lower part of the section being concealed by talus. North of the felsite the cleavage of the shivered Morte slate seems to dip south at 70°, whilst on the south side dark purple slates, with occasional beds of grit, dip apparently north at 50°, so that unless these appearances can be accounted for by surface disturbances, such as root-intrusion and the like, the felsite may mark a line of fault, separating the Morte and Pickwell series. The felsite is also exposed in a quarry in Sloley's Wood, north of Smitha Park, the surface-evidence to south of it indicating Pickwell beds

similar to those exposed in the cuttings. The cuttings in the Pickwell series show dull purple, red, greenish, and brownish slates, slaty grits, grits, and arenaceous mudstones. Near Chumhill, shaly beds, with intercalated brown decomposed, and friable bands, suggest decomposition of calcareous matter; they may either belong to the Pickwell or Baggy series.

Green slates, or slaty mudstones (Baggy series), with arenaceous bands (resembling parts of the Hangman series) in the upper portion, pass under the brown micaceous grits of the *Cucullæa* zone. The green slaty mudstones recall Upper Devonian slate types in South Devon.

The succeeding cuttings from Cunnilear Wood, southward, expose the bluish-grey argillaceous slates of the Pilton series, with brown decomposed patches of organic remains, and occasional beds of hard fine grit and limestone, showing contortion in several places, as north of Cheffham Mill Viaduct, Northleigh Plantation, near Collard Bridge, and Snapper.

For the last mile the railway runs along the Alluvium."

The re-survey of the Devonian rocks was begun in the Chudleigh and Torquay districts in the year 1887, and carried westward into Cornwall as far as Polperro.

Traverse or hasty work was found to be quite useless, and even detailed mapping in many places gave unsatisfactory results.

Beyond the Looe and Liskeard area the Devonian work has been recently entrusted to the able hands of my colleague, Mr. J. B. Hill, who is engaged on the Falmouth area.

So variable are the rocks of the South Devon area, that it has been found necessary to pay the closest attention to all local types, and to check the work as it advanced by comparison with districts mapped before, searching for fossils no matter how decomposed, and collecting specimens showing the lithological variations.

The work of primary scientific importance was the general delineation of the three main divisions, viz., the Upper,

Middle and Lower Devonian. In the Torquay, Totnes and Newton Abbot area, in spite of the numerous faults which cut up the highly contorted strata, it was possible to do this owing to the discovery of fossils by Mr. Lee and Mr. Champernowne, and the extension of these discoveries to new localities; moreover, the development of the limestones greatly facilitated the work, which was confirmed by a visit in 1888 from Messrs. Gosselet, Kayser, Holet, Frech and Tschernyschew. Subsequently Prof. Gosselet, Dr. Kayser, M. Frech, Prof. R. Jones, Dr. H. Woodward, and the late Prof. A. H. Nicholson kindly assisted me by bringing their expert knowledge to bear on the fossils collected.

A paper was communicated to the Geological Society, entitled, "The Devonian Rocks of South Devon." *Quarterly Journal Geological Society*, August, 1890, p. 487. As stated on p. 490: "The area to which this paper more particularly refers lies north of the river Dart and east of Dartmoor." As will be seen (on p. 499): This paper was not intended to be a final communication as regards the relations of the components of the Lower Devonian, even in respect to the Torquay and Paignton area. There is no mention in it of the Dartmouth slate series, which forms the southern part of the Kingswear promontory. The relations of the Dartmouth slates had not then been worked out, and it was found impossible to dogmatize as to the sequence of the faulted Lower Devonian rocks of the Torquay and Paignton area, until in the further progress of the work sufficient evidence had been obtained. In the above paper (p. 490), and in the Report of the Director General for the year 1892 (p. 254), the Middle Devonian slates are said to pass downward into the Lower Devonian by intercalation of shales or slates and grits. This may locally be the case, but later researches have shown that appearances of intercalation may be produced by the repetition of sharp plications of grits at their junction with the slates, and, although it is quite possible that the uppermost Lower Devonian

strata may be slates or shales with beds of grit or sandstone in places, all statements which appear to give prominence to such a view were better suppressed than accentuated. The progress of the survey to the west of the Torquay and Paignton area permitted me to follow the Lower Devonian rocks up till the end of 1894, without, however, obtaining anything sufficiently conclusive to reconcile the numberless seeming contradictions that the local evidences of their sequence presented. The survey of the Lower Devonian, at that time carried on as far as Polbathick and Downderry, was then temporarily abandoned, with the numerous problems successively presented during the survey, unsolved.

In the Report for the year 1894, based on notes contributed by me to the Director General; there is some confusion in the statement of results, as will be seen in the following quotation: "Pushing the survey of the three great sub-divisions of the Devonian system across the south-west of Devonshire into Cornwall, he (Mr. Ussher) has been able to recognize and trace the continuation of the Lower Devonian, Lincombe and Warberry grits and slates. These strata extend through the southern part of the Devonian area, and are exposed along the coast line, as at Revelstoke, where they are traversed by intrusive felsitic rocks, while they also include Diabase sills and bosses. The general lithological characters of this sub-division are marked by the want of persistence of its different members, and the variations in the intercalation of the slates and grits. The slates and hard grit beds of the Kingswear promontory and Revelstoke are extensively developed, besides the grits and sandstones of the Lincombe and Warberry series."

In this paragraph the Lincombe and Warberry grits are confounded with the Dartmouth slates and grits, and said to occur on the Revelstoke coast in one place, whilst in the concluding sentence they are spoken of as two different groups. The concluding sentence is right. The Revelstoke grits and slates are the grits and slates of the Dartmouth and Kingswear

promontory series; but owing to faults of which I had then no clue, both in the Revelstoke area and between Plymouth Sound and Downderry, there was not sufficient evidence to enable me to separate them from the higher horizons, to which I had given local names. At the end of 1894, the Lower Devonian succession was as indefinite as it was left in the paper communicated to the Geological Society in 1890. I had been unable to piece together a Lower Devonian succession which would apply throughout the districts between Torquay and Downderry. During the years from 1895 to 1898 inclusive, my attention was devoted exclusively to Middle and Upper Devonian rocks and Culm Measures, the area surveyed taking in the south part of Dartmoor. This district produced a new crop of problems; so that when I was free to devote a part of the year 1899 exclusively to the continuation of the Lower Devonian rocks, by the survey of the Looe district between Downderry and Polperro, I had sowed, like Cadmus, an overwhelming array of conflicting materials to be subdued. But for the specimens collected as types during the progress of the work, it would have been impossible to remember the Lower Devonian types over so large an area with sufficient distinctness for comparison with those of the Looe area. Amongst these, whilst turning them over in connection with the preparation of Geological Survey memoirs, I had, by the aid of a paper of the late J. E. Lee, identified organisms found at Piskey's Cove in the Revelstoke coast, and at Portwrinkle on the Downderry coast, as the honeycombe layers of *Pteraspis* scales—an identification kindly confirmed by Mr. Smith Woodward; so that, prior to the survey of the Looe area, I was prepared to recognize the Dartmouth slates as an important subdivision and not surprized to find that the variegated purple, green, and buff slates of Polperro and Talland, with horizons of Pteraspidian remains, and hard beds of grit or quartzite were identical in character with the Dartmouth slates of the coast from Scabbicombe sands to Slapton sands,

with those of the Erme mouth, Revelstoke, and Wembury coast, and of the Portwrinkle and Downderry coast. However, with consistent perversity the Looe area gave conflicting evidence as regards the position of the fossiliferous Looe beds, which were said to be Gedinnien (that is, to belong to a lower series than had been recognized in the Lower Devonian of South Devon), and that of the Dartmouth slate group. The fossiliferous slates and grits of Looe recalled to my mind rocks in the Plymouth coast section, and rocks in the exceedingly difficult area around Kingsbridge, Slapton, and Torcross, and even displayed certain affinities to rocks in the Torquay promontory. In the Torquay promontory the Dartmouth slates are not represented, consequently the identification of the fossiliferous Looe beds there would prove them to be above the Dartmouth slates.

As far as the Looe District is concerned, the coast evidence, rendered unsatisfactory by fault boundaries, favours the idea that the Dartmouth slates or Polperro beds are the lowest member of the Lower Devonian in the area east of Polperro.

The inland evidence presents us with a mass of hard grits with *Pteraspis* remains, associated with the characteristic red and green Dartmouth slates on Bindown, dying out westward and with no apparent representation of the fossiliferous Looe beds on the north of it, such as one might expect to find were it an ordinary anticline. This counter evidence might be due to fault; but as it is, taken in connection with the age ascribed to the fauna, the sequence given further on must not be regarded as an absolute opinion, but simply as the best explanation to accord with all the stratigraphical facts at my disposal, and that entirely without prejudice to an entirely different complexion being imparted to the question by expert palæontological researches in the area, which are sadly needed.

The mapping of the Looe district necessitated the revision of a considerable part of the Lower Devonian area, as it enabled me to trace faulted boundaries and so to limit as far

as possible the horizon of the Dartmouth slates. In the course of this work the Torquay area was studied again with rather better results.

The more detailed account of the survey of the Looe area appears in the Summary of Progress for the year 1899.

During the progress of the Survey of the Middle and Upper Devonian rocks many a paper might have been written on the results obtained from time to time by tracing volcanic horizons and the discovery of badly preserved fossils, which taken in connection with stratigraphical facts and lithological characters, were enough to establish the existence of definite horizons. But the statements which appeared in the Official Reports and Summaries of progress were deemed sufficient.

They are as follows:—*Report of Director General of Geological Survey* for the year ending December 31st, 1893, pp. 256-257: "In the progress of the survey of the Devonian rocks of South Devon, the Plymouth area has been brought into connexion with those of Newton Abbot and Torquay, and the same sub-divisions have been found to hold good in it as have been established further to the east. Thus the presence of Upper Devonian rocks has been proved by the discovery of the characteristic *Entomides* near Tor Point, on the west or Cornish side of Plymouth Sound, in a series of slates which, developed on the north of the Plymouth Limestone, correspond in lithological character to the Entomis-slates of Torquay and Newton Abbot. The igneous rocks, so abundant in the eastern part of the Devonian area, have been traced westwards to Plymouth Sound. Those in the Upper Devonian series seem to be, as at Newton Abbot, for the most part intrusive. The Ashprington volcanic series has been traced continuously from the Totnes district, but in irregular and greatly diminished thickness."

Report of Director General of Geological Survey for year ending Dec. 31st, 1894, pp. 270-271: "The Middle Devonian group, as it is followed westwards, is found still to consist of slates

with occasional traces of volcanic material and local bands of limestone. Rocks probably representing in part the Ashprington volcanic series have been followed into Cornwall, where they are seen at St. Germans.

Upper Devonian strata have been found by Mr. Ussher to be largely developed in the southern parts of the counties of Devon and Cornwall. Thus they are found skirting the Dartmoor Granite, from Kingsbridge Road to Shaugh Prior, not far from Plymouth. In the Plymouth District, they consist of slates with local volcanic materials and a mass of porphyritic diabase at Ford, near Devonport. As they range into Cornwall, they present some specially interesting features. Besides retaining their evidence of contemporaneous volcanic action, they have yielded fossils which prove their stratigraphical position and allow of their being correlated with the Upper Devonian group of other regions. Thus the characteristic *Entomostraca* have been found by Mr. Ussher north-west and east from St. Germans, as well as abundantly at Carkeel, to the north-west of Saltash. The small *Goniatites* and *Bactrites* of Saltern Cove (marking the Büdesheim fauna, that is the Frasnian or lower part of the Upper Devonian group) have been detected by the same observer two miles E.S.E. from St. Germans. These discoveries, coupled with that of *Entomostraca* near Tor Point, in 1893, are of essential service in tracing the sub-divisions of the Devonian system across the ground. Taken in conjunction with the lithological evidence, they show that Upper Devonian rocks are continuous throughout Southern Devonshire and extend into Southern Cornwall."

Report of Director General of Geological Survey for year ending Dec. 31st, 1895, p. 7 : "The area in South Devon, surveyed by Mr. Ussher, stretches across the southern part of Dartmoor and includes a large tract of granite, together with the surrounding Devonian and Carboniferous strata, and the eruptive masses associated with them. The Devonian rocks appear to belong chiefly to the upper division of the system, but though

they occupy a large part of the area, they have proved to be singularly unfossiliferous. Certain contemporaneous volcanic rocks are probably to be referred to the Ashprington series. Limestones and slates in the area surveyed represent the Middle Devonian division, and have yielded *Pleurodictyum* at Staverton. No Lower Devonian rocks appear to occur within the area recently mapped."

From *Report of Director General of Geological Survey* for year ending Dec. 31st, 1896, p. 51 : "The only member of the staff engaged in mapping Devonian rocks is Mr. W. A. E. Ussher, who during the past year has been stationed in the extreme west of Devonshire and the borders of Cornwall. The oldest strata mapped by him are the Middle Devonian limestones of the Ashburton district. Certain schalsteins bordering the Ashburton limestone may belong to the same subdivision, and perhaps also a plicated band of calcareous slates at Landulph on the Cornish side of the River Tamar.

The Upper Devonian rocks surveyed last year are on the whole unfossiliferous, and as the grey, greenish, and red slates composing them are devoid of lithological landmarks, such fossils as have been found in them become of importance. Near Warren Point on the banks of the River Tamar north of St. Budeaux, the discovery of a few small *Goniatites* of the Büdesheim type points to the occurrence there of the lower horizons of the Upper Devonian groups, whilst higher strata are indicated by the presence of *Styliola* and of the characteristic *Entomides* on the shores of the River Tamar south of Warren Point, and on the Cornish bank near Weir Point. *Entomides* have also been found midway between St. Budeaux and Tamerton Foliot.

Bands containing *Spirifer disjunctus* occur, on the shores of the Rivers Tamar and Tavy just north of the latitude of Beer Ferris, in slates precisely similar to those containing the same fossil at Druid and Holne Bridge in the Ashburton district. This *spirifer*-horizon seems to represent the 'Petherwin Beds,'

From Meavy northward to Whitchurch Down no fossils except traces of crinoids, and *Aulopora* (?) in one spot, have been found in the slates. In the neighbourhood of St. Budeaux masses of bedded tuff and vesicular rock denote local volcanism in the Upper Devonian period.

Near Dousland and Walkhampton hard dark-grey or green rocks occur, which may be partly of igneous origin and belong either to the Culm Measures or Devonian system. They are possibly an altered representative of the volcanic products which appear to form an intermediate group in the neighbourhood of Tavistock."

In the Summaries of Progress for the years 1897 and 1898 the Devonian strata call for no further mention than is given in the quotations in the next chapter.

The Liskeard area is referred to in the Summary for the year 1899: The strata which immediately succeed the Lower Devonian grits of St. Keyne consist of "slaty mudstones, often splitting prismatically and with cleavage planes that dip generally at low angles, the bedding being frequently shown by vertically undulating suture-like lines." Calcareous slates, with slaty limestone, are exposed in the cutting of the new line, south of Liskeard station, but no persistent calcareous horizon can be traced.

Purple and green Upper Devonian slates occur round Menheniot, and have yielded the characteristic *Entomostraca* near Doddycross and Padderbury.

No boundary between Upper and Middle Devonian can be drawn, and it is probable that these strata are displaced in the Liskeard district by the prolongation of the fault which cuts them off on the west against Lower Devonian rocks, south-east of Menheniot station. Shalsteins and vesicular igneous rocks occur on the east of Liskeard. The Clicker Tor Serpentine is an Ophitic dolerite apparently intrusive.

So far the stratigraphical literature of the Northern and Southern Devonian areas has been treated separately. I have

now to consider those papers which deal with the Devonian areas generally; of these only two claim attention, viz.: "The Devonian Rocks of Great Britain," *Brit. Assoc. Tran. of Sections* for year 1889, and "The Devonian Rocks as described by De la Beche, interpreted in accordance with recent researches," Proc. Roy. Geol. Soc., Corn., Nov., 1890. It must be remembered that the actual materials at my disposal, when these papers were written, were, as far as the Southern Devonian area is concerned, derived from the actual survey of the Torquay, Newton Abbot and Totnes districts, and from observations of the cuttings of the S.W.R. between Plymouth and Tavistock.

The British Association paper gives a classification in which the country to the west of the Torquay and Totnes area, is treated separately under the heading of the Western area. As far as my actual survey enabled me to classify the rocks, the table is right, but beyond this, that is as regards the so-called Western area, it forms a good example of the hopeless confusion that is likely to result from basing any ideas as to structure and succession on traverses and disconnected observations, even with an intimate knowledge of the representatives of the same strata in a contiguous area. In this classification the Dartmouth slates are put at the top of the Lower Devonian "(probably.)" Their true position has since been proved to be below the Meadfoot Beds. By a printer's error, or rather through the exigencies of space, the Meadfoot Beds are paralleled with the Gedinnien, instead of with the Coblenzien (Untere Coblenz Stufe) as was intended. With these two corrections and the elimination of the Western area altogether, this classification may be taken in connection with the Geological Society paper on "The Devonian Rocks of South Devon," in which no general table of classification is given.

In the second part of the paper on West Somerset, *Proc.* Som. Arch. for 1889, a general classification of the rocks of N. and S. Devon will be found. In this table by reason of

space, probably, the term "Gedinnien" has been put a line above its proper position, and the query to the position of the Dartmouth slates may be done away with.

To follow De la Beche's descriptions on the old one inch geological map is no light task: following his correlations scattered through the chapter brings to light contradictions which are the inevitable outcome of an attempt to correlate faulted and contorted rocks from insufficient evidence over so wide an area. The paper based on his descriptions of the Devonian rocks brings out, I think, his tremendous powers of observation, far better than either the casual reading of his report or the study of his maps can do. That an individual, whose ignorance of the succession of the rocks of the area west of Totnes has been shown to be profound, should by the careful perusal of chapter iii of De la Beche's report, be enabled to construct a geological map of Cornwall, giving the sub-divisions, which could in any way advance our knowledge of the Devonian and form a basis for future work, is a remarkable tribute to the skill and acumen of De la Beche's powers of observation.

The fault shifting the Lower Devonian subdivisions from the latitude of Plymouth to that of Liskeard has since been proved on the ground by actual mapping, and that alone is sufficient to entitle the paper to a foremost place in the stratigraphical literature of the Devonian. The run of the subdivisions from the absence of sufficient observations is in many cases entirely wrong in the area to which I can speak from personal knowledge, but the correlations of the beds from the Dartmouth slates, *i.e.*, Talland beds, upwards is in the main correct. The classifications given in part ii of the paper are a distinct advance on that previously published (1889), and in the correlation of the slates of Talland and those of Watergate Bay with the Dartmouth slates—one of the actual results of my survey of the Looe district—is foreshadowed, and further confirmed by Mr. Fox's discovery of *Pteraspis* at

Watergate Bay.[1] The contrast between the difficulties presented by the North Devon Devonian area and that of South Devon and Cornwall is also clearly brought out.

The problems left unsolved in Devonian stratigraphy may be summed up in the expression of the need I have always felt for definite palæontological evidence. Fossils are plentiful on certain horizons, but their distorted, fractured, and decomposed condition does not tempt the palæontologist to desert the well-worn paths to quarries in rocks, whose position in the Devonian series is comparatively defined for areas where stratigraphy affords two or more equally plausible interpretations, a balance of evidence which the discovery of a recognizable fauna would overturn. A careful study of the Looe fauna, taken in connection with the red fossiliferous beds in the Plymouth coast section between Boveysand Bay and Audurn Point, with the fossiliferous shales and grits of the Kingsbridge area at Ringmore Churchstow, Slapton, Beeson, Ford, and Tinsey Head, and of the Lincombe Hill, New Cut, and Smuggler's Cove beds of the Torquay promontory, is urgently needed. I select these localities from a host of others in which fossils occur, as but for the older date ascribed to the Looe fauna, I should be inclined to consider that the Looe beds were represented in them, and prove to be in the Coblenzien, either above or in the Meadfoot beds as a horizon locally distinguishable, in which case the Lower Devonian rocks represented in the districts east of Looe would consist of Upper and Lower Coblenzien and the Dartmouth slate series, the latter being the oldest subdivision.

As far as the Start and Bolt rocks are concerned, they have been shown by the survey of the area to have originally consisted of sediments similar to those in the Devonian area, and of igneous rocks which were originally of basic origin. They do not appear to have undergone the stress of any terrestrial movements anterior to those experienced by the Devonian

1. Trans. Roy. Geol. Soc., Corn. Vol. 12, part 5. 1900.

rocks, although much more intensely distorted and folded. As far as a minute survey enabled me to judge, the boundary between the altered and unaltered rocks was not a persistent stratigraphical line and betrayed no evidence of being due to faults or unconformability. In inclining to regard these rocks as metamorphosed Devonian sediments and diabases, I would rather accentuate than suppress the fact that the line of metamorphism which suggests the contrary view is very clearly marked.

In the Report of the Director General for 1892, pp. 254-255, this area is referred to. I give the Report *in extenso* here, as it contains opinions which were modified by the subsequent progress of the work: "The Maps of Devon and Cornwall were the first on which the Geological Survey began its operations. The region which they represent, besides the importance of its mineral industries, is one of great geological complication, which could not be properly worked out on maps of so small a scale as one inch to a mile, and so inaccurate in their topography. Moreover, at the time when these maps were made, geological science was far from being so well equipped as it now is for attacking such problems as are presented by the rocks of the south-west of England. It has long been recognised, therefore, that a total re-survey of that region was needed; but the state of progress of the survey of other parts of the country has hitherto prevented this work from being undertaken on an adequate scale. But as the eventual re-survey, which must sooner or later be carried out, will be greatly facilitated by an accurate determination of the stratigraphical horizons of the Devonian rocks, and a detailed mapping of these in some one district, Mr. Ussher has been employed in conducting these operations in the South of Devonshire. By a sedulous scrutiny of the ground he has been enabled to detect the presence of organic remains previously unnoticed, and by their aid to distinguish and trace the three great divisions of the Devonian system over the district

between Newton Abbot and Plymouth. According to his observations, the following grouping may now be considered as established both by palæontological and stratigraphical evidence :—

1.—*Upper Devonian.*—Slates, lying on Goniatite limestone in the limestone areas, and with local volcanic rocks.

2.—*Middle Devonian.*—Slates, limestones, and volcanic rocks. The Limestones are developed in a local or sporadic manner, and in the intermediate districts they are replaced by volcanic rocks (the Ashprington Series), while their basement beds are represented by occasional calcareous bands and lenticles in the slate bounding the volcanic series.

3.—*Lower Devonian.*—Red and grey grits, sandstones, and shales, apparently passing upward into the Middle Devonian slates by the irregular intercalation of grits with slates.

The strata have been so excessively folded, fractured, and cleaved that their true order of sequence is difficult to trace upon the ground. But the existence of certain well-marked groups of rock, characterised by special fossils, has enabled Mr. Ussher to trace a zone of Lower Devonian grit, extending from Staddon Point, near Plymouth, to Sharkham Point, near Brixham, and to recognise certain belts of rock in the Middle Devonian group, closely resembling each other, to the north and south of that zone. One of the most interesting portions of this region includes its most southerly promontories from the Bolt Tail to the Start Point, where a series of mica-schists, quartz-schists, and other crystalline metamorphic rocks has long offered some difficult problems to geologists. Mr. Ussher has observed that among these rocks some green schists, probably altered diabases, present much resemblance to certain decomposed calcareous and volcanic materials, locally forming the base of the 'Ashprington Series.' He

finds no signs of discordance or dislocation at the junction of the schists with the comparatively unaltered slates. He thinks the varieties of mica-schist, to be comparable to the Devonian Slates and interlaminated grits and shales on the north, though greatly more gnarled and plicated. He believes that the Lower Devonian grits form an anticlinal range, re-appearing between Beeson and the Thurlestone coast amongst a series of Middle Devonian slates, volcanic rocks, and passage-beds between the Middle and Lower Devonian; and he concludes that in all probability the green rocks, mica-schists and quartz-schists are really metamorphosed Devonian sedimentary and igneous rocks.

During the progress of the field-work in South Devonshire, a large series of specimens, sent up by Mr. Ussher, has been sliced and subjected to microscopic investigation, by the petrographer to the Survey, Mr. J. J. H. Teall, F.R.S., who reports that the detailed examination of the rocks from the metamorphic area of South Devon has brought to light the fact that the previously published descriptions of the green varieties of rock were very imperfect. The specimens which have been least altered by surface-agencies consist essentially of hornblende, albite and epidote. In altered specimens hornblende is more or less replaced by chlorite; and when this is the case calcite is usually present. The hornblende is either uralitic or actinolitic in character, never compact. The felspar is water-clear, and usually without any trace of cleavage or twinning. It has been definitely determined to be albite in one case, and from its uniform character in all the slides examined there can be no doubt that this is the dominant if not the only species present. The association of albite with hornblende, epidote, chlorite and calcite has been described by Lossen in his various papers relating to the modification of the diabases associated with Devonian rocks in the Hartz. Quartz, which had previously been supposed to form an important constituent of these rocks, appears to be comparatively scarce.

Besides studying the rocks of the metamorphic area, Mr. Teall has examined many others both of sedimentary and igneous origin, from the Devonian and Culm areas; but the only points which in his opinion appear to be of sufficient importance to deserve mention in the present Report are (1) the recognition of quartz-albite veins and (2) the proof that certain dolerites have been rendered schistose by dynamic action without the conversion of the augite into hornblende."

In the above grouping, as I have already mentioned, the existence of a passage series of slates and grits between Middle and Lower Devonian has not been proved. The Lower Devonian consist of sandstones and hard grits (the Staddon series), with shales and slates, dark slates with hard grits and calcareous bands locally stained red (the Meadfoot series), and of variegated slates with hard grits (the Dartmouth series). The Beeson grits may be synclinals, and in any case the opinion above given must have been qualified by such phrases as "may or might possibly." I cannot without palæontological evidence prove that Middle Devonian rocks occur in the Kingsbridge and Torcross district, so the correlation of the Ashprington series with the Hornblende epidote schists is not justified.

CHAPTER III.

CARBONIFEROUS.

Between the years 1869 and 1871 I made my first acquaintance with carboniferous rocks in the field, and from Yatton, Midsummer Norton, Frome, Cheddar, and Axbridge, mapped most of the area covered by that formation from the Lower limestone shales upward to the Coal Measures as far as included in sheet 19 of the old series Geological Survey Map. In after years in carrying on my work in the New Red sub-

divisions I mapped the Cannington limestone, the Westleigh and Spraydown inliers, and in 1877 and 1878 carefully studied the Culm Measures along the river valleys from Okehampton to Barnstaple. No attempt was made to map out any subdivisions in the Culm Measures, or to follow the Lower Culm rocks along their margin, the Culm area being investigated officially solely for the purpose of ascertaining the presence or absence of New Red outliers, and of mapping the alluvia and old gravels, etc., of the principal rivers and their tributaries. Between the years 1880 and 1887 I was engaged on Jurassic rocks, Lias, Rhœtic, and Keuper, in Lincolnshire, Worcestershire, and Warwickshire, and on drifts in Sussex.

Fearing lest the results of my study of the Culm rocks might altogether be lost, I obtained leave to bring them forward at the meeting of the British Association in 1886, and an abstract of the paper appeared in the Transactions for that year. The paper was subsequently published in the *Geological Magazine* in January, 1887. In the summer of 1887 I had an unexpected opportunity of renewing my acquaintance with the Culm rocks, in completing the parts of the old one-inch Geological Survey Map which had not been investigated since De la Beche's Survey; Lower Culm rocks were then noted, but no attempt was made to draw a boundary for them. However, by the year 1892 I thought it advisable to bring together the results I had obtained from actual survey, and so to amplify and extend the previous communications as to supersede them. This paper, entitled "The British Culm Measures," appeared in the *Proceedings* of the Somerset Arch. and Nat. Hist. Soc. for 1892. It was divided into two parts: the first, dealing with the literature stratigraphy and extension of the Culm Measures in England and on the Continent; the second, discussing the probable causes of the abnormal distribution of the Culm and older rocks of the south-western counties in the areas surrounding the granite masses of Devon and Cornwall.

The use of one or two unhappy phrases[1] in the latter part of the paper led to an entire misconception of its scope and meaning, and to a display of hostility, for which I was for a long time unable to account.

Since the British Culm Measures was written, I have had ample opportunities of tracing the rocks in the field in districts

1. The phrases to which I allude will be found on pp. 206 and 207 of the Somerset Arch. *Proceedings* for 1892, and are italicized in the following quotations: "Whatever may be the derivation of the Palæozoic rocks of Devon and Cornwall, their extent and development points to the removal and redistribution of very great masses of pre-existing rocks, and as no rocks other than the granites seem to exhibit an unconformably inlying position amongst them, from Bristol to the Land's End, it is difficult to resist the suggestion that granites, *or rocks capable of conversion to granite* by *in situ* metamorphism, were actually levied under contribution to supply part at least of the materials."

The second passage referring to the age of the granite, taken in respect of the probable subterranean connection of the various masses, is as follows:—"The second restriction, for reasons before stated, renders the post-carboniferous upheaval or eruption almost unthinkable, and would almost necessitate the *genesis of granite (in its present form) in situ by the remelting of a pre-existent rock.*"

A paper was written by General MacMahon to combat what were supposed to be my views on the genesis of granite.

The then President opened the discussion by crediting me with a knowledge of petrology, which I regret to say I do not possess. Passing over divers hard things said, I take this opportunity of thanking my friends, Messrs. Teall and Watts, for standing up and trying to point out that the drift of my observations was quite misunderstood.

I could not defend myself for the simple reason that I was ignorant of the *casus belli*. To me the General was simply tilting at a windmill, and trying to be facetious over the north and south movements. The sense of injustice is apt to rankle, so at last I wrote to Mr. Hudleston, and enquired what it was all about. To my horror he told me that I was credited with the belief that the Devon and Cornish granites might have resulted from the *in situ* metamorphism of ancient rocks that were not granitoid, and might even have been stratified rocks.

Going through the Paper I saw that the phrases italicized would bear that interpretation, from which, as it appears, the quotation from the late J. A. Phillips, on p. 206 (viz., the statement "that neither granites nor elvans could result from the rearrangement, by heat or otherwise, of the constituents either of one or of any number of such slates" as are given in his table of analyses), had not sufficiently safeguarded me.

I do not believe, or ever did believe, that the theoretical pre-existent masses were other than granite "of sorts." But in regrettable ignorance of the vagaries of the petrological mind, I put in the objectionable alternatives for possible disciples of metasomatosis, that I might "by all means gain some."

My friend, Mr. A. R. Hunt, with characteristic chivalry, came forward in defence of the oppressed, thereby demonstrating the absurdity of crediting a man with ideas as to genesis of granite who confounds melting and fusion. He is right. Messrs. Teall and Watts were right. The General's paper was not written as a contribution toward the solution of this simply stratigraphical and mechanical problem, it was not meant to throw any light on it, and it didn't. The admirable paper "On Rocks of igneous origin on Dartmoor," by the same author, Q.J.G.S. for Aug., 1894, renders this the less regrettable.

before unknown to me. To Mr. Fox I am indebted for most of these. The announcement of his discovery of *Radiolaria* in the Chert beds of the Coddon Hill series, attracted attention to the Lower Culm Measures specially, although that discovery does not facilitate the actual mapping of the subdivisions of the Culm rocks. In 1897, for the first time, the sub-division of the Culm was attempted on 6-inch maps in the area north of Tiverton.

In this area and in the Culm districts of Ashton and Trusham, I found that a line between the Lower Culm Measures, which do not contain grits, and the shales and grits above them is comparatively easy to trace, whilst no absolute line of demarcation can be drawn between the different types in the areas composed of shales and grits.

Hence, although there are some reasons for including shales and grits, locally, in the upper part of the Lower Culm [*Goniatites*, in Mr. Vicary's collection, having been obtained in the Bonhay Road section, between St. David's and St. Thomas' Stations, Exeter, and in grits and shales near Pinhoe Church], the inclusion of the Exeter type in the Middle Culm Measures is more desirable than in the Lower, in which it is bracketed in the classification in the British Culm Measures, p. 115.

Mr. Fox[1] has shown that the term grit is inapplicable to any of the beds of the Coddon Hill series. He has also pointed out that my ascription of plication fractures to false bedding in the illustration of the Ramshorn Down section is quite wrong. For both corrections I am his debtor.

As regards Herr Dalmer's views as to the relative age of the Wildenfels and Chemnitz Hainischen Culm (in p. 177 British Culm Measures) there is a serious error of transcrip-

1. Messrs. Fox and Hinde. Quart. Journ. Geol. Soc. for Nov., 1895. Vol. 51, p. 615 and p. 625. The Lower Culm were not sub-divided prior to 1897. The Ramshorn Down district was mapped on the old 1-inch in 1887. I have had no opportunity of revising it in detail as has been done at Ashton, &c., this year, on 6-inch maps.

tion, the part of the sentence referred to should be "Herr Dalmer considers the Wildenfels Culm *older* than the Chemnitz Hainischen."

In the above respects "The British Culm Measures" needs emendation, otherwise it merely needs amplification as far as the results of subsequent work given in official reports tend to the solution of problems left unsolved in 1892. So that the following notes may be regarded as a sequel to it.

British Culm Measures. *Part III.*

1.—Extension of the Culm Measures. 2.—Sub-divisions of the Lower Culm. 3.—Altered Lower Culm Measures. 4.—Volcanic rocks associated with Lower Culm Measures. 5.—Relations of the Middle and Lower Culm Measures.

1. Extension of the Culm Measures.

Beer Alston and St. Mellion.

It was not until the year 1897 that the progress of the work allowed of the tracing out of the Culm rocks discovered in 1888 in the S.W.R. cutting near Beer Alston. On the Devon side of the Tamar south of Calstock, and on the Cornish side north of Calstock, and at Pentillie, they form outlying masses of shales and sandstones on the Upper Devonian slates, but in the district surrounding St. Mellion they cover an area of from 8 to 9 square miles, extending from the Tamar at Cothele and Halton Quay on the east, to Crendle Down and Hammett Down on the west. One of the most marked features in this tract is the conical flat-topped hill of Lower Culm rocks called Cadson Bury. The boundaries of the Culm with the Devonian are frequently faulted, and in many cases where the sinuous trend of the boundaries seems to denote natural junctions, the direct superposition, or apparent superposition, of the sandstones and shales (locally

containing plant traces) on the Devonian, seems to suggest irregular fault boundaries or thrusts cutting out the Lower Culm rocks, which are in places tolerably well developed in their natural position. In parts of this complex tract, the Culm boundaries, with an apparently natural trend along the contours separate sandstones and shales from the Devonian in places, and chert beds or other hard members of the Lower Culm in places. I suggested an unconformable junction to account for these anomalies in the Summary of Progress for 1897, but the further extension of the work does not quite bear out this explanation. The occurrence of Culm rocks in the vicinity of St. Cleer is possible, but it involves evidence which has not yet yielded satisfactory results.

Tamerton Foliott.

A small patch of black cherty Coddon Hill beds, penetrated by filaments of quartz, and greatly disturbed, is exposed in a quarry on the summit of the hill immediately south of Tamerton Foliott. This little outlier is probably based by a thrust fault, it hardly extends beyond the exposure, the surrounding slates are Upper Devonian, and have yielded in one spot characteristic *Entoms*. South of Warleigh Barton and west of Tamerton Foliott, hard dark Lower Culm shales form a narrow outlier, resting on the Upper Devonian slates on the summit, and descending the wooded slope toward the creek in a south-easterly direction. In Tor Wood they appear to be bounded in part by decomposed volcanic rock, and may also be faulted. These outliers are about two miles south of the latitude of the southernmost extension of the St. Mellion Culm Measures, and were mapped in 1896.

Wearde Quay and St. Erney.

South of Saltash, and opposite Bull Point, where the Lynher joins the Tamar, there is a most interesting coast section of Devonian slates and volcanic rocks. Interbedded with the latter, but only visible in one place, five chains N. of Henn Point, are several hard dark cherty beds, with irregular corrugated surfaces. The little patch of rock in which this interesting phenomenon is displayed,

is bounded by V-shaped coalescent faults, hence its preservation is most probably due to the fracture and lowering of a mass of higher beds subsequently removed by denudation. The presence of volcanic bombs or cinders and coarse tuffs in the volcanic rocks, in which the vesicles show fluxion lines, justifies the belief that the centre of eruption was not far off. On nearing Wearde Quay we encounter hard, even bedded, grey brownish weathered grits or sandstones, with shaly partings, evidently an overlying series, a little further west these beds are found to rest on a hard igneous rock, exposed in a quarry by the coast. In the adjacent Railway Cutting they are also exposed, and in one place may possibly overlie conformably the uppermost beds of the Lower Culm ; this, however, is not reliable, as the beds I took for Lower Culm were not well exposed. The hard sandstones, to a depth of over twenty feet, are very well shown in a quarry on the north side of the railway, by the lane, on the map. In one part of it the upper beds are rather coarse in grain and seem to contain occasional cherty fragments. They can be traced westward to Forder Lake, where they may be detected in one spot in the vicinity of the greenstone quarry. I call these beds the Wearde sandstones. They occur on the north of St. Erney, from thence to the banks of the Lynher, near Poldrissick, and south of Bagmill. But from Bagmill to Forder Lake, although visible at Trehane, their continuity cannot be proved, and from the character of the surface evidence, it is impossible to draw accurate boundaries, as they make no distinctive feature, and occur in a tract in which Devonian slates and volcanic rocks are inextricably blended. For a long time I hesitated to regard the Wearde sandstones as Culm Measures, but thought they might possibly be indurated siliceous tuffs. The subsequent mapping of part of the Tavistock volcanic Devono-carboniferous rocks, and the assurance of Professor Watts that they may be regarded as true grits caused me to include them in the Middle Culm, and the occurrence of simi-

lar sandstones in the St. Mellion and other Culm tracts has confirmed this view.

Efford and Crabtree near Plymouth.

Prior to the discovery of the Wearde rocks in 1894, in mapping Plymouth and its environs in 1893, I encountered even bedded felspathic grits or sandstones with shale partings, which were in part beautifully interlaminated with sandy materials, these rocks occur on the south of Efford and east of Lower Compton. At Efford they are exposed in a quarry showing several folds, and appear to rest on dark shales or slates, which may be Culm or Devonian, there being no characters sufficiently definite to discriminate by. On the south the sandstones are bounded by volcanic rock and Upper Devonian slates. Traced east and west their termination is as indefinite and unsatisfactory as that of the Wearde sandstones of St. Erney. These rocks must be classed with those of Wearde, and like them, are exactly comparable with grits and shales in the Beer Alston and St. Mellion Middle Culm Measures. They extend from the valley just south of Compton to the Plym estuary south of Crabtree, a distance of about a mile-and-a-half. The question of the southerly extension of the Culm within or on the margin of the aureole of metamorphism round the granites is so bound up with the constitution of the Lower Culm that it must be treated under that head.

2. SUB-DIVISIONS OF THE LOWER CULM.

Northern Outcrop.

In the area between Tiverton, Burlescombe and Dulverton, there is no evidence of any unconformability between the hard grits and shales of the Middle Culm Measures and the Lower Culm. The highest beds of the latter group are exposed in Duvale Quarry, south of Bampton Station, and consist of blackish shales containing plant traces weathered white, and small *Posidonomya*. There is no means of proving the persistence of this type at the top of the series,

so I do not mention it specially in the following succession which appeared in the Summary of Progress for 1897.

Middle Culm.—Sandstones and shales lying on grits and shales.

Lower Culm.—Limestones with mudstones and bands and lenticles of Chert, either replaced by or resting on hard shales with Chert (Coddon Hill series). Dark slates or shales.

The limestones are often so siliceous that they enclose chert segregations, they are often quite decomposed to a tough brown or orange brown friable residue. In the upper beds, traced from east to west, their occurrence is variable, but detailed mapping has not been carried far enough to demonstrate their persistence.

In the Coddon Hill series the chert beds may occur in a group, or so irregularly that their presence or absence can only be proved by the knife test. As it is impossible to apply this test to all the beds in all the sections in which they occur, their inclusion under Phillips' term, "the Coddon Hill Beds," seems to me to be advisable. As the area around Coddon Hill has not been mapped in detail, I do not profess to define the upper limit of the Coddon Hill beds. The dark slates or shales at the base of the group constitute the greatest difficulty in mapping it, as it is extremely difficult to obtain a defined boundary between them and the slates of the Upper Devonian (Pilton Beds).

Southern Outcrop.

To turn now to South Devon and Cornwall. Where the series is complete the sequence appears to be very much the same as that given above, but the limestones are apparently local and impersistent.

In the tunnel at Perridge, on the Teign Valley Railway, now in course of construction, the top beds of the Lower Culm form an anticlinal ridge under the over-arching intercalations of thin grit beds and broken shales of the Exeter type of the Middle Culm. They consist of dark mudstones, containing *Goniatites* occasionally, and in character resembling

"the clift" of the Somerset Coalfield. In places they appear to be banded faintly by fine arenaceous material. This occurrence, coupled with that at Baldoak, about two miles to the northward, and the *Goniatites* from Cocktree Moor, near North Tawton, (see The British Culm Measures, p. 137) proves the superficial extension of the Culm Measures to be rather due to constant repetition by plication than to any great thickness.

As in North Devon, there is no means of testing the persistence of an argillaceous topmost zone in the Lower Culm of South Devon, and, moreover, the *Goniatites* in Mr. Vicary's collection, obtained many years ago from the shales and grits of Bonhay Road, Exeter, and near Pinhoe Church, constitute a considerable difficulty, as I failed to find any traces of Lower Culm in either place, and the Pinhoe *Goniatite* specimens were embedded in grit in several cases. In the Ashton and Trusham district, where I have mapped out their boundary, the sequence is as follows :—

Middle Culm.—Shales and grits of the Exeter type.

Lower Culm.—(1) Hard and soft shales, occasional cherty bands, and hard dense mudstones, with occasional local bands of pale grey siliceous limestone. *Posidonomya* found. The Waddon Barton beds and the *Goniatites spiralis* beds, generally, belong to this group.

(2) More or less cherty siliceous rocks, locally fairly thick bedded, dark cherts, intercalated in or representing the whole series. Local evidences of vulcanicity at about this horizon, such as bands of tuff, etc.

(2*a*) Very hard dark blue-grey bedded mudstone, with thread-like whitish banding at intervals.

(3) Dark shales or slates.

I cannot be certain whether Upper Devonian does or does not occur between Ashton and Dartmoor, owing to the difficulty in distinguishing between Culm-shales, which may be slaty in places, and Devonian slates, which may locally be dark coloured. In the western parts of the St. Mellion area,

where the Lower Culm beds are in unfaulted relation to the Middle Culm sandstones and shales, they exhibit characters sufficiently marked to distinguish them, but not to make out a definite sequence. In the upper beds, near Newton Ferrers House and elsewhere, dark blue-grey white-banded mudstones, with a tendency to cleavage occur in them. Also claystones, weathering to a pale-green tint, resembling Upper Devonian beds. No limestones or fossils have been found, although there are hard rather siliceous even-bedded mudstones which suggest the presence of the *Posidonomya Becheri* and *Goniatites spiralis* horizons. The more siliceous rocks with cherts seem to underlie these materials.

Near Painter's Cross, Pillaton, etc., the Lower Culm, in spite of very imperfect representation, present distinctive characters, such as hard dark shales and chert beds.

On the north side of Halton Quay, in the small space of two hundred yards, Middle Culm sandstones and shales, hard siliceous Coddon beds and slaty brownish mudstones, with numerous examples of *Posidonomya Becheri* are represented.

For the occurrence of *Radiolaria* the reader is referred to the papers of Messrs. Fox and Hinde,[1] in which numerous localities throughout the Culm areas are given.

In spite of the variety in their types, it is well to remember that the Lower Culm rocks are throughout a dark colored, finely levigated argillaceous series, in which, through the occurrence of calcareous and siliceous organisms, or through some other differentiations in the character of the mud, hard bedded rocks of different types have resulted, hence in view of the extremely difficult character of the evidence, it is unsafe to infer from the absence of the calcareous fauna, or of developments of Radiolarian Cherts, or of beds of marked lithological character, that such absences are indications of breaks in the series. Messrs. Fox and Hinde have proved that *Radiolaria* are not confined to the actual cherts.

1. Quart. Journ. Geol. Soc., Nov., 1895. Trans. R.G.S. Corn., 1896. Trans. Devon Assoc., 1896 and 1897.

Coddon Hill beds occur at Holne, on Ashburton Down, where they contain pale coloured cherts, and in other places in that district. Banded cherts and cherty rocks were also noted at Ilsington in 1896. Masses of banded chert occur in places in the Ashton and Trusham Lower Culm area, and elsewhere. They form a natural introduction to the consideration of the banded and porcellanized rocks of the Peak Hill type. In fact, Mr. J. G. Hamling has shown me dark and pale banded flinty rocks in the Coddon Hill beds, on the N. side of Coddon Hill, which are identical with types of these hard rocks.

3. ALTERED LOWER CULM MEASURES.

Mr. Champernowne showed on his MS. maps a band of "porcellanized rocks" not far from the granite boundary near Brent. In the official report for the year 1895, these rocks are referred to in the following quotations:—"The banded siliceous rocks of Kingsbridge Road (Wrangaton) and Brent have their exact counterparts in varieties of the Lower Culm Cherts north of Ashburton. Again the dark altered rocks, containing chiastolite, on the borders of the granite near Brent and Ivybridge, closely resemble the dark shaly Lower Culm strata which cover an extensive area north of Ashburton Down. It is worthy of note that the type of metamorphism exhibited by these carboniferous rocks has not been observed among Devonian strata where they come in contact with the granite. . . . Intruded igneous rocks pierce the Culm Measures north of Brent."

In the official report for 1894, the "hard porcellanized grits" on the south of Dartmoor are referred to. The term grit was then erroneously applied to them. In the vicinity of Brent these rocks contain scapolite. While engaged on the survey of the borders of Dartmoor in 1896, I found these hard banded rocks on the summit of Peak Hill, east of Dous-

land, and traced them on the borders of the granite, both there and at Walkhampton. In 1887, as stated in the Summary of Progress for that year, p. 106, I obtained evidence of the occurrence of similar hard banded rock, near the granite of Bodmin Moors, south of Alternun, and at Camelford, where it is broken up for road metal. It is quarried for a similar purpose on the slope of Peak Hill and near Wrangaton. "The flinty shales" described by De la Beche, as occurring "at Helstone, near Camelford," are probably altered Lower Culm shales.

On the borders of Dartmoor, near Dunsford, masses of hard-banded rock occur on the margin of the granite, and at Waterfall, near Canonteign, Christow, and other places, varieties of the Lower Culm beds may be recognized in the vicinity of the granite. The hard-banded rocks, although easily recognizable, differ in colour and arrangement of banding and in the texture of the bands, and that this should be the case, where the variously indurated mudstones and cherty rocks of the Lower Culm, in certain localities associated with igneous rocks, came within the periphery of the granite zone of metamorphism, is only natural. Four types of these rocks, from the vicinity of Walkhampton and Dousland, were submitted to Mr. Teall for examination. I quote the results from the official report for 1896, p. 52:—

"One of these specimens (2762) (1) consists of two parts. One is evidently a sedimentary rock which has been cleaved and subsequently indurated. It is compact and of a dull purplish colour. The other portion is a dark green, fine-grained crystalline rock. Under the microscope the altered sediment shows micro-flaser structure. Numerous lines of opaque granules wind round elongated lenticles, which are comparatively free from these granules. Minute scales of sericitic mica and aggregates of typical contact-biotite form a large part of the rock. Brown, green, and blue tourmaline occurs. There is also a sub-stratum of crypto-crystalline

material, probably quartz. Mr. Teall is not able to determine the nature of the original rock. It was certainly a very fine-grained sediment, possibly a cherty shale or very impure chert. The dark green fine-grained rock is an aggregate of green hornblende. It shows a parallel structure of the same kind as that seen in the sediment, and the lines pass through the hornblende individuals without interruption, thus proving that the growth of the hornblende was subsequent to the cleavage. The rock, which is now an amphibolite, was probably in the first instance a greenstone. The specimen proves that the sediment and the igneous rock have been subjected in the first place to dynamic action which developed cleavage, and subsequently to metamorphic action which produced hornblende in the latter and biotite and tourmaline in the former. Hence the rocks may be designated as a tourmaline-biotite-hornfels and amphibolite.

Another specimen (2763) (2) is a schistose rock, mainly composed of bands and streaks of a compact greenish yellow substance. A patch of light brown massive axinite is seen on one surface. Under the microscope the yellowish green substance proves to be an aggregate of epidote. The impersistent dark streaks and lenticles are formed of green hornblende. The axinite, a boro-silicate of aluminium and calcium, forms a coarsely crystalline aggregate, the individuals of which often measure one millemeter across. It is crowded with inclusions, small indeterminable flecks, grains of epidote, and patches of green hornblende, which are arranged parallel to the cleavage of the rock and traverse the large individuals of axinite without any reference to their crystallographic orientation. There is no doubt that the axinite has been formed out of the materials of the rock, with the addition of boracic acid derived from the granitic magma or exhaled after the main intrusions of granite had taken place. The rock may be termed a schistose epidiorite with axinite.

A third specimen (2764) (3) appears to the eye as a green-

ish gneissose rock with patches and lenticles of brown garnet. When examined with the microscope the greenish portion of the rock is seen to be a foliated aggregate of scapolite and pale-green augite, with sphene as an important accessory constituent. The foliation is defined not only by the arrangement of the main constituents, but also by thin streaks of sphene-granules which traverse the large crystalline plates of scapolite without interruption. The brown patches are aggregates of grossularia-garnet with which some of the pale-green pyroxene is associated. This is a remarkable rock, which so far as Mr. Teall is aware, has not been recognised amongst contact-products of Palæozoic or later date. It occurs amongst the crystalline schists of Scotland in Forfarshire, Perthshire and Caithness, interbanded with crystalline limestones.

It is very important that the original rock, of which this is the metamorphic product should, if possible, be discovered. If a sediment it must have been calcareous. It may possibly have been igneous, but judging from what he knows of the other occurrences, Mr. Teall thinks this improbable. He defines the rock as a foliated scapolite-pyroxene rock.

A fourth specimen (2765) (4) appears to the naked eye as a dark foliated rock with irregular patches, lenticles and streaks of brown garnet. When examined, microscopically, it is found to be an aggregate of garnet and hornblende with some carbonate, epidote, and green pyroxene.

The hornblende shows a tendency to aggregate itself in tufts as in many greenstones which occur in the contact zone. Mr. Teall is inclined to regard this rock as an altered greenstone, and he classes it as a foliated garnet hornblende rock."

It must be borne in mind that the rocks above described[1]

1. Mr. Teall has recently furnished me with the following brief description of the Walkhampton rocks:—"At Walkhampton the Lower Culm Measures have been much altered, and include biotite-hornfels with tourmaline, schistose epidosite containing axinite, garnet-hornfels and a peculiar rock essentially composed of pyroxene and scapolite, allied to the '*gneiss à wernerite*' of French authors. The minerals characteristic of contact action are tourmaline, axinite, garnet and biotite, to which in all probability scapolite pyroxene and hornblende must be added."

were taken from a district not far removed from the Tavistock volcanic series, and near Brent there are both intrusive and volcanic rocks—and the most ordinary type does not appear to have been included in the specimens sliced and examined.

In the official report (*op. cit.* p. 51) I described the hard dark-grey or green rocks near Dousland and Walkhampton, as probably partly of igneous origin and belonging either to the Culm or Devonian. "They are possibly an altered representative of the volcanic products which appear to form an intermediate group in the neighbourhood of Tavistock."

The Summary of Progress for 1898 contains the following passage, p. 96 :—"Since 1893 the occurrence of rocks of this nature near Brent, Wrangaton, Ivybridge, and Cornwood, has been a source of perplexity owing to the apparent intercalation of inconstant bands among Upper Devonian slates in a railway-cutting south of Brent, and to the occurrence of a similar collocation in the upper part of a slate-quarry 2¼ miles east of Tavistock. These appearances might be explained by contortion, but if, as there seems now to be little reason to doubt, the Peak Hill rocks are altered representatives of the volcanic series and basement Culm-Measures of Tavistock, the local association of bands of volcanic rock with fine calcareous matter in the uppermost part of the Upper Devonian slates need cause no surprize."

4. VOLCANIC ROCKS ASSOCIATED WITH THE LOWER CULM.

On this subject the Brentor Memoir and *Geol. Soc.* paper by my friend, Mr. F. Rutley, occupy a position of the first importance. The volcanic rocks of the Tavistock area may, roughly speaking, be taken as contemporaneous with those of Wearde Quay near Saltash, as suggested by Mr. Rutley in 1880[1], and with the evidences of contemporaneous vulcanicity in the Lower Culm districts of Ashton and Trusham. The

1. Quart. Journ. Geol. Soc., May, 1880, pp. 286 and 288.

following is adapted from the Summary of Progress for 1898: In the Tavistock area the Upper Devonian strata consist of very unfossiliferous fine-grained, pale, greenish slates, with planes of schistosity often nearly horizontal, and very seldom highly inclined. This tendency to horizontality in the schistosity is the rule in the area west of Dartmoor. It is also apparent in the volcanic rocks and Culm-Measures, in which it is due to the sharp irregularly zigzagged structure of the smaller folds. The bedding may, therefore, be in reality frequently vertical in the limbs of the larger repeating folds. The relations of the Devonian slates to the volcanic rocks and Culm Measures are so disturbed by faults that no actual succession could be obtained in the area surveyed, and within the altered zone near the granite it is seldom possible to draw precise boundaries. The volcanic rocks consist of more or less vesicular shalsteins, the vesicles being often filled with calcite. Bands of compact greenish limestone are locally associated in the volcanic materials, and may be impersistent calcareous deposits of Upper Devonian age formed during the lower and earlier emissions. Good examples of this association are visible by the River Tavy, on the south side of Abbey Bridge, Tavistock, and by the high road W.N.W. of Tavistock, at the turning to Langford.

Such an association suggests an alteration product comparable with No. 2764 in Mr. Teall's description.

At and near Tavistock, for instance, in the road cuttings near the S.W.R. station, the blending of hard, dark, sometimes cherty Lower Culm with the volcanic rocks is so intimate as to suggest lenticular intercalation, but the effect may be due to the intersection of zigzag plications.

Cox Tor Moor exhibits masses of altered greenstone (epidiorite) and hard banded rocks of the Peak Hill types, and hard dark shaly beds. These rocks have been admirably described by General MacMahon (*Quart. Journ. Geol. Soc.* Vol. 50. August, 1894. pp. 351-360), as also those of Sourton

Down and Brentor. This paper forms an indispensable part of the literature of the Culm.

Through the presence of volcanic rocks it is impossible to obtain any sequence of the Lower Culm and their emission probably continued at more or less frequent intervals during their deposition, but had ceased before the formation of the shales and sandstones of the Middle Culm. There are evidences of the alteration of the latter near the granite on Cox Tor Moor.

In the Ashton and Trusham Lower Culm districts there are occasional evidences of fine volcanic interbanding, the igneous rocks seem to be tuffs coming in generally at the horizon specified in a previous section, and dolerites which may be in part interbedded. In view of the publication of the geological maps with the most recent investigations in the Ashton and Trusham Culm districts it is unnecessary to enter into details. It may, however, be pointed out that the evidences of contemporaneous vulcanicity in the Lower Culm are feeble when compared with those of the Tavistock area, and they do not represent, as far as has been ascertained, the lower parts or Upper Devonian emissions of the Tavistock area. As regards the Culm rocks of Wearde Quay, with the exception of the indurated mudstones or cherts locally preserved in interbedded relations with the volcanic series, and irregular appearances suggesting the association of rocks which may belong to the Lower Culm in the igneous rocks of the adjacent Railway Cutting, and at Forder Lake, and further west, there is no evidence to prove that vulcanicity took place during the Lower Culm, beyond the negative evidence furnished by the Wearde sandstones and those of Efford being present where the Lower Culm rocks are practically almost absent. As this relates to the last section of the chapter it will be referred to later on.

5. RELATIONS OF THE LOWER AND MIDDLE CULM.

The relations of the Exeter type of Culm Measures to the sandstones and shales and conglomeratic sandstones of Ugbrooke Park being unknown when "The British Culm Measures," *vide* p. 117, was written, constituted an obstacle to classification, which has been since partially removed. The thin hard brown weathered grits, intercalated with broken and often splintery shales which characterize the Exeter Culm type, are very well shown in the cuttings of the Teign Valley Extension Railway, from Leigh Cross northward. In one spot, near Leigh Cross, there are two small intrusions of decomposed igneous rock, probably dolerite, in them. At Perridge Tunnel, as before stated, they form an anticline over the uppermost horizon of the Lower Culm. As to their perfect conformability to the uppermost horizons of the Lower Culm I entertain no doubt. This type changes imperceptibly at first as we proceed southward from Leigh Cross and Ashton, in places the lower beds are found to consist of shales, with very occasional beds of sandstone of a more irregular character than is normal to the type; near Huxbeare Barton the grits are coarser and more thick-bedded, and by degrees we find the type presented by the road section on the south side of Bellamarsh Wood, not far from Chudleigh Station, where irregular masses of sandstone are associated with dark shales, or rather slaty mudstones, in a manner more consistent with the irregular beds of the Morchard type. These sandstones occur in mass with shaly partings, or sparsely in dark shales or irregular shaly or slaty mudstone. They are occasionally conglomeratic. In "The British Culm Measures," pp. 140-141, some of the localities where the coarser materials are found are specified: "In the conglomerates of Ugbrooke Park and Rydon Ball small pebbles and subangular fragments of quartz are most abundant, but they also contain decomposed felspar (?) and dark cherty rock, suggesting the denudation of

the cherty beds of the basement Culm Measures." Mr. Somervail's discovery of granite in these conglomeratic beds confirms the occurrence of felspar doubtfully mentioned in the above passage.

From Chudleigh southward the Exeter type has more or less completely disappeared, and has been either conformably overlapped or replaced by these dark shales and sandstones. The shales are often banded with sandstones and the banded associations as well as banding in the sandstones themselves often show false bedding. The sandstones are generally micaceous, and so frequently mixed with felspathic materials that I have been tempted to describe them as approaching to arkoses.

Here and there throughout their extension all the above characters are observable. At Efford, near Plymouth, the interbanding of sandstone and shale is well shown, and also at Wearde, where the occurrence of fragments of chert or hard mudstone in the coarser beds is worthy of note.

The sandstones of Calstock, Beer Alston, and St. Mellion display the same characteristics, and although the conglomeratic sandstone is rather local, the beds vary from a comparatively fine to a coarse grained rock, and I have occasionally found fragments of shale, or rather hard dark rock, which might denote contemporaneous erosion or derivation from subjacent upper horizons of the Lower Culm. As the fossiliferous upper horizons of the Lower Culm are developed in the vicinity of the Ugbrooke Park beds, the denudation of the chert beds could only refer to cherty bands in the upper beds of the Lower Culm and not to chert beds below them. The most extreme case is perhaps that of Efford, near Plymouth, where the sandstones and shales seem actually to rest on Upper Devonian, and at and near Wearde and St. Erney where they seem to occur amongst slates and volcanic rocks of presumably Upper Devonian age. That there was an irregular shoaling after or even in some places during the

formation of the upper beds of the Lower Culm is hardly questionable, but whether such movements were sufficiently irregular to allow of the local overlap of the Middle Culm sandstones upon Upper Devonian slates and volcanic rocks without any intervening representation of the deeper water Lower Culm beds, either through original impersistence or subsequent denudation, is merely a suggestion, though perhaps more or less in accordance with the fact that in parts of the area the deposition of the Lower Culm beds was preceded and subsequently partially interrupted by volcanic outbursts, whilst in contiguous areas no such interruptions took place. As it is generally the Lower Culm rocks that occur in contiguity to the granite, the opportunities for studying the effects of contact alteration on the sandstones and shales of the Middle Culm are rather local, but in the vicinity of Foxworthy and near Cox Tor Moor they are presented. As I do not believe in the post-carboniferous Upheaval of the Granite, I must plead guilty to seeing no great difficulty in the suggestion of the source from which the felspathic sandstones of the Middle Culm might have been derived.

That there must have been a general elevation of the sea bed either after or during the deposition of the Lower Culm rocks is certain ; that this elevation, through the local prevalence of volcanic action preceding and during the deposition of the Lower Culm, should be very irregular and unequal is probable. That the Middle Culm sandstones were deposited in shallow water is certain. For these reasons I think it is a difficult matter to generalize on the relations of the Lower and Middle Culm, as I believe over a large part of the area they are perfectly conformable, namely, in the northern districts and where the Exeter type prevails in the southern.

The presence of fragments in the Middle Culm rocks of the St. Mellion districts, Ugbrooke Park, and elsewhere, distinctly referable to the dark shaly and cherty beds of the Lower Culm, justifies the belief that even where the members

of the Lower Culm are fairly represented a certain amount of denudation had taken place.

In regard to the Middle Culm rocks of Wearde and Efford, either the Lower Culm were only very partially deposited through the elevation of the sea bed accompanied by vulcanicity, or the Middle Culm are largely made up of the triturated materials of the Lower Culm volcanic rocks, with such sediments as might have been associated with them, their position on Upper Devonian slates and volcanic rocks represents a considerable unconformability, in either case.

The question naturally arises, is the Exeter type a lower part of the Middle Culm than the Ugbrooke, Wearde and St. Mellion sandstones. On this subject see "British Culm Measures," pp. 140-145.

In the Bonhay Road section referred to, with illustration for "The British Culm Measures," (p. 138), the association of shales and grits is not nearly so distinctive as in the Teign Valley Extension Railway Cuttings, and is in part undistinguishable from other Middle Culm types; in North Devon the distinctive thin-bedded alternations are not sufficiently pronounced to be referred to as the Exeter type, so it would appear that the prevalence of that type is local.

The discovery of *Goniatites* in the Bonhay Road section, between St. David's and St. Thomas' Station, and near Pinhoe Church, has been already referred to. These discoveries were made many years ago, but from an examination of the specimens in Mr. Vicary's collection, there seems every reason to conclude that the *Goniatites* were obtained in grits as well as shales. On recently revisiting both localities I failed to find proofs of the presence of Lower Culm rocks, or of any traces of *Goniatites*. Still their discovery must be taken as a sign of the local passage of the Middle Culm shales and grits into the Lower Culm, and as a distinct qualification to the statements that grits do not occur in the Lower Culm Measures. The *Goniatites*, obtained by Mr. Vicary on Cocktree

Moor, near North Tawton, are of similar type to those obtained in Bonhay Road, and probably to the small spherical specimens from Baldoak, near St. Mary Tedborn.

CHAPTER IV.

NEW RED ROCKS.

In 1869, Mr. Whitaker, omitting details, gave the first correct section of the New Red rocks as exposed in the south coast, where they attain their maximum development (*Quart. Journ. Geol. Soc.* Vol. 25, p. 152). In this paper he rightly uses the term "New Red," instead of Triassic rocks. I have already given reasons for the advisability of using this term for all the Secondary rocks below the Rhœtic beds in the south-western counties. In my papers, on the contrary, they are termed Triassic rocks. This I freely admit is unjustifiable in view of the great probability that the lowest sub-divisions in which the trap rocks occur are contemporaneous with Upper Permian rocks in Germany.

My first Paper on the New Red Sub-divisions appeared in the *Geological Magazine*, Dec. II, Vol. ii, No. 4, April, 1875. It is a mere summary of results obtained in the prosecution of the Survey up to that time. There are, as far as I can see, three errors in it. The first is contained in this sentence in the section dealing with: "5. The Lower Sandstones and Breccias. Some varieties of the Breccia series so much resemble the gravels resting on the older rocks and frequently obscuring their junction with the Breccia, that, in the absence of good sections they are hardly distinguishable from them."

During the survey of these gravel districts a line was actually drawn to separate them from New Red, and it took a long time to convince me by the progress of the work that these gravels were not drifts, but actually the marginal deposits of

the Breccia, and that they dovetail or pass horizontally and very irregularly into it.

This error was again perpetrated in the Paper in *Quart. Journ. Geol. Soc.* for Nov., 1876, p. 392, in the passage beginning—"To what extent the Triassic beds," etc.

The next error is as regards the thicknesses of the subdivisions, as applied to the south coast section, the thickness of the Lower sandstone is too little, the same estimate is repeated in the 1876 Paper, p. 392. Outside this particular, the thicknesses given in the *Geol. Mag.* Paper may be taken as a minimum and those in the *Geol. Soc.* Paper as a maximum estimate, and considering the uncertainty occasioned by faults an even greater margin is quite permissible.

The third error in the *Geol. Mag.* Paper is the misprint of Langsant for Langstone in the footnote on last page.

The paper of Nov., 1876, above referred to, includes everything in the *Geol. Mag.* Paper, and gives sections across the strike of the rocks in four places, thus affording a good general idea of their structure and lithological variation. This paper may be regarded as Part I of the stratigraphical literature of the New Red Rocks.

The subsequent discovery of the true position of the Watcombe Clays was announced in the *Trans. Devon. Assoc.* for 1877, in a Paper "On the Age and Origin of the Watcombe Clay." This little Paper is an indispensable addition to the 1876 Paper.

For many reasons the Paper "On the Triassic Rocks of West Somerset," etc., in *Proc.* Som. Arch. etc. for 1889, should be regarded as the sequel to the 1876 Paper or Part II. In the first place it deals with the most difficult tract in the New Red area, which formed the greatest obstacle to the completion of the work, and in the second it gives a detailed map beside illustrative sections. The difference between this and the 1876 Paper is the result of work completed, compared with the results of work in progress.

The Paper which I regard as next in order, and entitled to be considered as Part III of the 1876 Paper, appeared in the *Quart. Journ. Geol. Soc.* for August, 1878, under the title "On the Chronological Value of the Triassic Strata of the South Western Counties," pp. 459—470. This amplifies some general deductions given at the close of the 1876 Paper, and is in some respects an advance of it, for instance, on p. 468, the gravels which had previously been regarded as drift are placed in their true position in the Lower New Red. The full sequence of the Lower sub-divisions, with estimates of their respective thicknesses, is given on p. 467. Perhaps the best point in this Paper is the treatment of the Fifth Proposition, pp. 461, 462: "That from the presence of numerous fragments of igneous rocks (Quartz porphyries) in the basement beds of the South Devon *Trias* [New Red], and from the absence of any known rocks in the county to which they could be readily referred it appears probable that the cliffs and bed of the *early Triassic sea* [areas of deposition], were partly composed of igneous rocks of similar character to the foreign fragments. That any portions of such rocks left undestroyed would be likely to occur (1) under the *Triassic* [New Red] beds in the vicinity of Dartmoor, (2) concealed by the *Trias* [New Red] between Newton Abbot and Seaton, (3) in the area now occupied by the English Channel."

In this passage I have italicized certain expressions, adding the words in brackets which should be substituted for them. Nine years after this paper was written, in mapping the Chudleigh area (1887), I discovered a small patch of quartz porphyry identical in character with the boulders in the Teignmouth, etc. Breccias. This little patch was observed in a field south of the village of Christow, at the bottom of the letter P in the words Christow Pound on the old 1-inch map. In the lapse of subsequent years, though always bearing it in mind, I was too much occupied to attach much significance to it. This year, however, revision of Culm work for the inser-

tion of boundaries gave me the opportunity of revisiting the spot and verifying the discovery as an *in sitû* rock. My colleague, Mr. Jukes Browne, with whom I was staying at the time, on seeing the specimens immediately commented on the identity of the rock with the quartz porphyry boulders in the New Red of Teignmouth, and advised me to record it specially. As bearing on the above-quoted proposition I now do so. For here we have a rock in the neighbourhood of Dartmoor which strongly confirms the notion that the large blocks of quartz porphyry in the New Red of Ide, and near Dunchideock, and at or near Ringmore, and in many other places, which are too large for transport except by gravitation or ice flotation, were in all probability fragments disintegrated from their parent intrusive bosses almost *in sitû*, and to quote De la Beche[1], "may readily have formed portions of igneous masses covered up by the red sandstone series." In referring, under the same heading, to the destruction of parts of the traps and their incorporation in the overlying Breccias, I go on to say "nor does it appear impossible that the eruption of quartz porphyries may have been in some way connected with their appearances." On this point also fresh evidence has been brought to light.

During the Survey of the Kingsbridge area in 1891, in mapping the small outliers of Lower New Red rocks at and near Thurlestone Sands, I found that the larger one, near Horswell House, was flanked at its termination by a patch of igneous rock intrusive in altered Devonian rocks and exposed in a quarry. In the centre and more deep-seated part of the quarry the rock presented the appearance of a quartz porphyry, whilst in the upper part it was found to be a mica Andesite. Occurring at such a distance from known granite, and in the immediate vicinity of New Red rock, this phenomenon[2] is of special interest. But it does not stand altogether alone.

1. Report on the Geology of Corn., etc., p. 217.

2. The Director-General called attention to it in 1891, after visiting the spot.

In the Lower Culm area, south of Ashbrittle, there are two or three rather small patches of igneous rock, evidently intrusive. Mr. Teall considers them to be undoubtedly allied to the Exeter traps. Many miles south of this I lately discovered a similar rock in the Lower Culm, near Doddiscombsleigh. At Hannaborough, if my memory serves, a somewhat similar rock is intrusive in the Culm, between Hatherleigh and Okehampton. In all these cases the intrusive rocks occur not far from the New Red rocks, and they were doubtless once covered and concealed by them. I think, therefore, that it is extremely probable, almost certain, that the igneous fragments in the Lower New Red, which cannot be explained by the destruction of the former extension of the existing traps, may reasonably be referred to intrusive dykes, pipes, or necks, which were connected with this Permian epoch of vulcanicity. All references to the New Red of the Midland Counties in this Paper are taken from the Geological Survey Memoir of that district, not being based on personal knowledge, but the contention that below the Uppermost beds there is no basis for correlation I still maintain.

Mr. Vicary obtained good-sized weathered pebbles and subangular fragments of Devonian limestone, resembling the coralline limestone of Lummaton in the Breccias of the Crediton valley at Sollon, near Exbourne, and at Westacot, near North Tawton.[1]

As to the grouping of the New Red rocks, a short note entitled, "Permian in Devonshire," appeared in the *Geol. Mag.*, Dec. III, vol. ix, no. 336 p. 247, in June, 1892, and may be regarded as a supplement to the Paper last under consideration.

This note is, of course, as regards correlations tentative and provisional. In the maps now being published, which show my work in the New Red sub-divisions, the Index rightly

1. One of these containing Stromatopora is about 6in. by 5in. by 3in. in size.

brackets the sub-divisions as Trias and Permian, without indicating a division between them, for unquestionably such a separation must be regarded as very unsatisfactory at present.

In a Paper "On the Triassic Rocks of Normandy," the result of a careful perusal of a memoir on the Geology of La Manche and Calvados, by the late M. Bonissent, I discussed the relations of the New Red of those Provinces, as far as I was able to investigate the few and partial exposures on the ground, and what I conceived to be their relations to the Devon and Somerset rocks during that period.

The Paper appeared in the *Quart. Journal* Geol. Soc. for May, 1879, pp. 245—267. It was accompanied by a map constructed from M. Bonissent's descriptions, which, however, was not published. The Paper was subsequently translated into French by M. G. Lionnet, and appeared in the *Memoirs* of the Geological Society of Normandy, but the map was again omitted. As this map, tested by the French map of the region subsequently published, bears out in a remarkable degree the general accuracy of M. Bonissent's observations, its non-appearance has always been a source of regret to me. The views as to the age of the Normandy New Red Rocks, which I expressed, have not been endorsed by the French geologists, who are best qualified to form an opinion, still the Paper may be taken as a contribution toward the Stratigraphy of the New Red of the South Western Counties; and a short Paper entitled, "A Chapter on the Budleigh Pebbles," which appeared in *Trans.* Dev. Assoc. for 1877, may be included with it.

In all the Papers (except in the Note on Permian), above cited, a great want will be found, namely, the absence of any connected or detailed description of the Trap rocks. I have, therefore, specially alluded to them in the general notes after the Preface to this Paper. As regards description, however, from Polwhele's time (1797) down to the present, they have

been so often referred to that this want may not be felt. It is only natural to single out the Paper by Mr. Vicary,[1] and the more recent elaborate petrological researches of Mr. Bernard Hobson in *Quart. Journ.* Geol. Soc. Vol. xlviii (1892), pp. 496—507.

It is unnecessary to allude here to the stratigraphy of the Traps rocks, as this will be found treated more or less minutely in the memoirs accompanying the New 1-inch Geological Maps. The Memoir on the Exeter sheet, 325, having gone to press, descriptions of the major part of these clusters of Trap patches will appear shortly, together with petrological notes.

As regards the New Red rocks, with the exception of the small parts of their area to be found south of Chudleigh, which have been re-mapped in part on the 6-inch scale, in carrying on the Survey of the Devonian the work was done on the old 1-inch ordnance maps, and completed in 1880.

In conclusion, I would point out some lines of research which might lead to good results in amplifying the work of the Geological Survey, and clearing up those stratigraphical problems which yet remain to be solved.

The area occupied by the Lower Marl series, extending northward from the coast between Exmouth and Straight Point to Whimple, cannot be too carefully investigated for the occurrence of sandstones in or under the Marls; these are shown on the map wherever evidence of their occurrence was obtained, and their anomalous appearance may be due to faults which are very numerous on the coast, but cannot be traced far in this series inland. The coast evidence would lead one to infer that the sandstones of Straight Point [which are partly brecciated and contain calcareous (probably dolomitic) concretionary matter in one part] are above the Marls, with occasional intercalations of thick even-bedded

1. "On the Feldspathic Traps of Devonshire." Trans. Dev. Assoc. Part iv, p. 43. 1865.

sandstone which form the coast between Straight Point and Exmouth. The natural inference that the Marls are based by a passage series of Marls and sandstones is discounted by the nature of the evidence as we endeavour to trace them northward; for beyond Whimple no proofs of such an intercalated series is presented until we approach the Milverton district where sections of an intercalated series of Marls and sandstones have been noticed near Polehill.

These appearances are explainable on the assumption of the impersistence of the sandstones in the Marls, coupled with eliminating faults, which in a homogeneous series cannot be detected on the ground. On the south coast these sandstones are worthy of a special study, and careful search for traces of organisms is desirable. I believe them to be an important factor in the classification of the rocks.

The Pebble beds of Budleigh Salterton will also repay a minute study, which by revealing the gradually diminishing percentage of foreign pebbles and their composition in different parts of their northerly extension, and the character of the sand matrix as contrasted with the grain of the overlying sandstones may bring new facts to light. About Blue Anchor, north of Talaton, the evidence was not satisfactory.

In Mr. Vicary's collection are several decomposed pebbles of Devonian origin crowded with Brachiopods, such as *Streptorhynchus crenistria*, *Athyris*, etc., and crinoids which were obtained in the Pebble beds at Uffculm.

The opening of any new exposures in the Lower Marl area flanking Spraydowns, north of Broadclyst and Whimple, might throw considerable light on the relations of the Marls to the Lower series (Sandstone), which in that district were exceedingly obscure.

An extended comparison of the grain of the Upper and Lower Sandstones as to angularity or roundness would be of value.

As regards the three formations dealt with in this paper,

the three main outstanding questions requiring positive settlement may be summed up thus :—

Devonian. Position of fossiliferous Looe beds with reference to Dartmouth slate series.

Carboniferous. The exact relations of the Middle and Lower Culm in Volcanic areas.

New Red. The relations of the Lower Marls and intercalated Marls and Sandstones to the underlying Breccias and Sandstones.

APPENDIX.

LIST OF PAPERS, ETC., ON DEVONIAN ROCKS.

* "On the Structure of the Palæozoic Districts of West Somerset," by A. Champernowne and W. A. E. Ussher. *Quart. Journ.* Geol. Soc. for Aug., 1879, pp. 532—548.

* "On the Geology of Parts of Devon and West Somerset, North of South Molton and Dulverton." *Proc.* Som. Arch. and Nat. Hist. Soc. for 1879.

* "The Triassic Rocks of West Somerset and the Devonian Rocks on their borders." Part II. *Proc.* Som. Arch. and Nat. Hist. Soc. for 1889.

† "On the Palæozoic Rocks of North Devon and W. Somerset." *Geol. Mag.* for October, 1881, p. 441, etc.

* Summary of Progress of the Geological Survey of the United Kingdom for 1897. Pp. 76—78.

* "The Devonian Rocks of South Devon." *Quart. Journ.* Geol. Soc. for Aug., 1890, p. 487.

*‡ Report of the Director-General of the Geol. Sur. for 1892. Pp. 254, 255.

Important.* Unimportant.† Partly erroneous.‡ Condemned.||

LIST OF PAPERS, ETC., ON DEVONIAN ROCKS—*continued.*

* Report of the Director-Gen. Geol. Sur. for 1893. Pp. 256, 257.

‡* Report of D.-G. Geol. Sur. for 1894. Pp. 270, 271.

† Report of D.-G. Geol. Sur. for 1895. P. 7.

* Report of D.-G. Geol. Sur. for 1896. P. 51.

* Summary of Progress of the Geol. Sur. of the United Kingdom for 1898. Pp. 95, 96.

* Summary of Progress of the Geol. Sur., etc., for 1899.

‡ "The Devonian Rocks of Great Britain." Rep. Brit. Assoc. Trans. of Sections for 1889.

* "The Devonian Rocks as described by De la Beche, interpreted in accordance with recent researches." *Trans.* Roy. Geol. Soc., Corn., 1890.

‡ "The Devonian of the Western Region and Geology of Tavistock." *Trans.* Dev. Assoc. for 1889, pp. 437—451.

‖ "The Devonian Rocks between Plymouth and Looe." *Trans.* Roy. Geol. Soc., Corn.

‖ "On the Geology of S. Devon." *Proc.* Geologists' Assoc. Vol. 8, no. 8.

Important.* Unimportant.† Partly erroneous.‡ Condemned.‖

LIST OF PAPERS, ETC., ON CARBONIFEROUS.

† "The Culm Measures of Devonshire." British Assoc. Rep. Trans. of Sections, 1886. Published *Geol. Mag.* Decade III. Vol. 4. No. 1, p. 10. Jan., 1887.

* "The British Culm Measures." *Proc.* Somerset Arch. and Nat. Hist. Soc. Vol. 38. 1892.

Most Important.* Redundant.† Faulty.‡

LIST OF PAPERS, ETC., ON CARBONIFEROUS—*continued.*

* "On the probable nature and distribution of the Palæozoic Strata beneath the Secondary Rocks, etc." *Proc.* Som. Arch. and Nat. Hist. Soc. Vol. 36. 1891. Refers to Culm, pp. 12—18.

‡ "The Devonian of the Western Region and Geology of Tavistock." Partly wrong. *Trans.* Dev. Assoc. for 1889.

Rep. of Director-Gen. Geol. Sur. for 1894.

Extract: "The limits of alteration usually extend to about half-a-mile from the visible edge of the South margin of the Dartmoor granite. Though no apophyses from that rock have been met with in ground recently surveyed, there is distinct evidence that the general body of the granite does not plunge vertically downward from its exposed margin, but stretches outward for some way, under a variable thickness of Culm Measures and Upper Devonian strata. Two inliers of it are to be seen at Hemerdon Ball. The aureole of metamorphism varies in breadth in such a way as to indicate that the granite probably approaches nearer the surface in some parts of the altered belt than in others."

Rep. D.-G. Geol. Sur. for 1895. P. 7.

"In the prosecution of the revision of Devon and Cornwall, Mr. Ussher has been able to extend the area of Culm Measures much further south than they have hitherto been supposed to reach. He now believes that Culm rocks rise along the margin of the granite, or occur in faulted or folded contact with Upper Devonian slates near the eruptive mass as far south as Ivybridge, and he thinks that they may even run on round the granite to near Bickley. The banded siliceous rocks of Kingsbridge Road (Wrangaton) and Brent have their exact counterparts in varieties of the Lower Culm cherts north of Ashburton. Again the dark altered rocks containing chiastolite on the borders of the granite near Brent and Ivybridge, closely resemble the dark shaly Lower Culm strata which cover an extensive area north of Ashburton Down. It is worthy of note that the type of metamorphism exhibited by these Carboniferous rocks has not been observed among Devonian strata where they come in contact with the granite. With the exception of a few small *Goniatites*, similar to those of Ven, near Barnstaple, which have been found at one spot near Ashburton Down, no fossils have been detected in the Culm Measures of the area now reported on. Intruded igneous rocks pierce the Culm Measures north of Brent, and likewise the Upper Devonian strata of the Buckfastleigh and Ashburton area. The aureole of metamorphism around the southern end of the Dartmoor granite rarely exceeds a mile in width, while in some places it is hardly more than half-a-mile."

* Rep. D.-G. Geol. Sur. for 1896. Quoted in Chapter III.

* Summary of Progress for 1897. Results given in Chapter III.

* Summary of Progress for 1898. Results given in Chapter III.

Most Important.* Redundant.† Faulty.‡

LIST OF PAPERS ON NEW RED ROCKS.

† "On the Sub-divisions of the Triassic rocks between the coast of West Somerset and the south coast of Devon." *Geol. Mag.*, Dec. II, Vol. II, No. 4, April, 1875.

* "On the Triassic rocks of Somerset and Devon." *Quart. Journ.* Geol. Soc. for Nov., 1876, pp. 367—394.

* "On the age and origin of the Watcombe Clay." *Trans.* Devon Assoc. for 1877.

* "On the Triassic rocks of West Somerset," etc. *Proc.* Som. Arch. and Nat. Hist. Soc. for 1889. Part 1 of the Paper.

* "On the Chronological Value of the Triassic strata in the South-Western Counties." *Quart. Journ.* Geol. Soc. for Aug., 1878, pp. 454—470.

* "Permian in Devonshire." *Geol. Mag.*, Dec. III, Vol. IX, No. 336, p. 247, June, 1892.

"On the Triassic rocks of Normandy," etc. *Quart. Journ.* Geol. Soc. for May, 1879, p. 245, etc., and Mem. Soc. Geol. de Normandie.

"A chapter on the Budleigh Pebbles." *Trans.* Dev. Assoc. for 1877.

‡ "A Classification of the Triassic rocks of Devon," etc. *Trans.* Devon Assoc. for 1877.

‖ "On the Geology of Paignton." *Trans.* Dev. Assoc. for 1878.

‖ "The Geology of Dawlish." *Trans.* Dev. Assoc. for 1881.

‖ "On the Mouth of the River Exe." *Trans.* Devon Assoc. for 1878.

Most Important.* Redundant.† Redundant and Faulty.‡ Local.‖