CHAPTER XXXIV.

CORNWALL, DEVON, AND WEST
SOMERSET.

By W. A. E. USSHER, F.G.S.

INTRODUCTION.

THE first of the long excursions of the Geologists' Association to Devonshire, in 1884, brings into strong contrast the views then obtaining in regard to the succession and relations of the Devonian sub-divisions in South Devon and Cornwall and the true succession and structure which was pointed out during the last visit at Easter, 1907.

The long excursion to Cornwall in 1887 gave the members the opportunity of inspecting the china clay district in the St. Austell granite, the lodes of the Camborne, Carn Brea, and Land's End districts, and of visiting the Lizard area and the Clicker Tor Serpentine, as also the Pliocene deposits of St. Erth. In this excursion the stratigraphy of the areas visited played a very subordinate part. The preliminary sketch by Mr. J. H. Collins deals mostly with the economic geology. He, however, describes the Ladock sandstones as Lower Devonian, and these he elsewhere traced on the south of the Helford river—an interesting fact, as these beds, under the name Grampound Grits, have, as forecasted by me in 1890, been taken by the Survey as the base of the Devonian, and traced across Cornwall, and their extension to the Helford district has been proved by Mr. J. B. Hill. To Mr. Hill is also due the inclusion of the pre-Devonian rocks, excepting the Lizard district, in the Ordovician.

The next excursion was to North Devon and West Somerset in 1896, when Dr. Hicks conducted the members over the Palæozoic area, maintaining the upthrust of more ancient rocks, represented by the Morte slates, along the strike of the Devonian series. Cannington Park and the Devonian limestones, slates, and grits of the Quantocks, and the Lias and Rhætic sections of Watchet and Blue Anchor were visited under the leadership of the Rev. H. H. Winwood. Mr. J. G. Hamling also conducted the excursionists over the Lower Culm Chert beds of Coddon Hill and the *Posidonomya* limestones of Venn.

The Cretaceous and New Red rocks, and traps associated with the lower part of the latter, were seen in the Easter excursion.

sion in 1899, when the coast from Lyme Regis to Exmouth and the country round Exeter were visited. In the following year the Easter excursion in the Torquay area enabled the members to become acquainted with interesting sections in the Bovey beds, and in the Devonian sub-divisions of the Torquay, Newton Abbot, and Chudleigh districts. Kent's Cavern was visited under the leadership of Mr. A. R. Hunt, who supplied the Association with a plan of the subterranean chambers. An enjoyable day on the Dartmoor Granite, near Lustleigh, was also arranged by him.

At Easter, 1901, the Lower Devonian rocks of the Kingsbridge area and the hornblende-epidote and mica schists of the Start and Prawle were seen. The little map accompanying the description foreshadows the anticlinal structure of the Dartmouth slates, proved by a comparison of the coast sections in the following year. In the Easter excursion to Plymouth in 1907 the Culm measures of the St. Mellion and Beer Alston outliers were seen.

In these excursions, therefore, all the rocks of the area from the Lizard schists to the Pliocene of St. Erth were visited by the Geologists' Association.

LITERATURE.

Sedgwick and Murchison blocked out the synclinal structures of the Culm measures of Central Devon in the years 1836, 1837, and 1840. They correlated these strata with the Coal measures; Prof. J. Phillips regarded them as Millstone grit, but Mr. Newell Arber has established the equivalence of the plant-bearing shales and grits to Coal measures. Murchison and Sedgwick separated the Culm from the underlying rocks, which they included under the term Devonian in 1840.

The finds of C. W. Peach established the age of the Gorran quartzites as Lower Silurian, or Ordovician as we should now call it.

In 1852 Sedgwick communicated an important paper on the Slate Rocks of Devon and Cornwall to the Geological Society.* He thus alludes to the latest work of Sir R. I. Murchison: "During the past year Sir R. I. Murchison, after an examination of certain fossils sent to him from Cornwall, has introduced some new colours into the geological maps of Cornwall and South Devon." [In a footnote, here referred to, a geological map of England published by the Society for the Diffusion of Useful Knowledge is mentioned, and the reference to Murchison's letter to Sir C. Lemon is given.] "Thus, he colours the great headlands between the Bays of St. Austell and Falmouth, *Lower Silurian*. Again, he colours a considerable part of the coast in the neighbourhood of Looe, etc., *Upper Silurian*; and the

* *Quart. Journ. Geol. Soc.*, vol. viii, p. 2.

same colour is extended to a portion of the slates of South Devon which skirt the north side of the Metamorphic rocks of Bolt Head and Start Point. The first change of colour is grounded on good evidence; for in the great headlands south-west of Austell Bay there is a development of rocks with a remarkable mineral structure, and with fossils which I should call Cambrian, and which Sir R. I. Murchison calls Lower Silurian. If I mistake not, there is, however, rather too great an extension given to the new colour in this part of Cornwall. As to the Upper Silurian colour, it was put in hypothetically, or on imperfect evidence; and I believe that both from Devonshire and from Cornwall it must be expunged as erroneous."

In this paper Sedgwick divided the Devonian rocks of Devon and Cornwall into three groups. The oldest or *Plymouth Group* included the Meadfoot Group, Staddon Grits, Plymouth Limestone, and the Slates between Liskeard and Bodmin, which were considered the oldest part of it. The equivalent in North Devon included the Ilfracombe Beds, Hangman Grits, and Lynnton Beds. His second, or Middle Devonian, group included under the name *Dartmouth Group* the rocks between Dartmouth and the metamorphic rocks of the Start and Bolt. This group was also said to occur on the north of the Plymouth Group, separating it from the *Petherwin* or highest group. The Dartmouth Group was correlated with the Morte Slates and Pickwell Down Beds.

In the *Petherwin Group* all the rocks from the New Quay to Tintagel on the north-west coast of Cornwall were comprised. The Petherwin Group was correlated with the Baggy Beds and overlying Barnstaple Beds (better known as Pilton Beds).

We are told of a mistake arising with regard to the Petherwin fossils in 1836, not cleared up until 1838, when their affinity to Carboniferous rather than to Silurian forms was recognised. He further records Griffith's establishment of the Carboniferous slate group in the South of Ireland on M'Coy's determinations of the fossils, many of which were considered identical with species found in the Petherwin and Barnstaple Groups. The Baggy Point sandstone is said to agree very closely with the Irish "yellow sandstone" mineralogically and zoologically. Though adhering to his original boundary, Sedgwick freely admitted the indefinite nature of the junction between Carboniferous and Upper Devonian. Here we have the embryo of the controversy afterwards raised by Jukes.

In accounting for the sudden termination of the Newton Abbot and Plymouth limestones against newer Devonian rocks on their borders, the writer unconsciously propounded a theory which had been advanced in the *Geol. Mag.*, dec. 2, vol. vi, 1879, pp. 296-298, by Mr. W. O. Crosby, as regards sedimentation on the borders of coral reefs.

In 1898 Mr. J. B. Hill advocated the inclusion of the rocks to the west of the strip then coloured as Silurian in the Ordovician; on the ground that the Portscatho, the youngest of the three groups (Portscatho, Falmouth, and Mylor) into which he divided them, passed into the Veryan Beds. These points his subsequent field-mapping enabled him to prove. (See Plate XXXII.)

The report of De la Beche in 1839 brings out most faithfully the nature, or spirit, of the geological evidence in Devon and Cornwall, the contradictions it so constantly presented to the explorer, the necessity for constant comparisons between the different parts of the area, and the falsity of correlating the rocks by lithological similarity, as was done in those days. The working out of the various correlations put forward, always tentatively, in the chapter on the Grauwacke, a term in which all the pre-Carboniferous rocks of Devon and Cornwall outside the Lizard and Start areas were then included, is a very good exercise of patience.

In North Devon and West Somerset the sequence of the pre-Carboniferous rocks given by De la Beche was not called in question before Prof. Jukes sought to establish a faulted repetition along the line of Morthoe in 1868—which, as subsequently pointed out by Etheridge, involved the representation of slates and grits with Upper Devonian fossils by slates with occasional grits with Middle Devonian fossils. The discovery of fossils in the Morte Slates by Hicks,* which were considered by him and by the late Mr. Whidborne to denote Lower Devonian rocks at Treborough, in West Somerset, and pre-Devonian rocks near Morthoe and Wiveliscombe, introduced the probability of a faulted complex in the comparatively regular and simple sequence of the Devonian rocks of the Northern outcrop.

As regards the Culm rocks, in the report† of the Plymouth excursion, p. 88, an unintentional error, which also occurs in the recently published memoir for Plymouth and Liskeard, was made in omitting the name of Dr. G. J. Hinde in alluding to the Halton Quay section and in the bibliography.

STRATIGRAPHY.

The following is a table of strata in the area under consideration, in descending order:

* *Quart. Journ. Geol. Soc.*, vol. lii (1896), p. 254, and vol. liii (1897), p. 441.

† *Proc. Geol. Assoc.*, vol. xx (1907), p. 78.

CRETACEOUS.	PLEISTOCENE.	{	Alluvium, valley gravel, submerged forests.
			Head, stream-tin gravels, old alluvial flats.
			Raised beaches, cavern deposits.
	PLIOCENE.	{	Sands and clays of St. Erth and St. Agnes Beacon.
	EOCENE BAGSHOT.	{	Clay with seams of lignite and beds of sand.
			Gravels flanking and underlying the Bovey Basin.
		{	Gravels, capping Haldon, at Burnworthy Farm on the Blackdowns, and on Combpyne Hill.
			Clays and gravels of Petrockstow.
	CHALK.	{	Chalk with many flints. Zone of <i>Micraster cor-testudinarium</i> .
			Chalk rock. Zone of <i>Holaster planus</i> .
			White chalk with scattered flints. Zone of <i>Terebratulina gracilis</i> var. <i>lata</i> .
			Hard nodular chalk, Beer stone. Zone of <i>Rhynchonella cuvieri</i> .
			White chalk with few siliceous nodules, grains of quartz and glauconite. Zone of <i>Holaster subglobosus</i> .
			Fossiliferous nodules and phosphatic bed. Zone of <i>Hystrichoceras varians</i> .
	SELBORNIAN.	{	Glauconitic sandstone, or calcareous grit, sands, and chert beds. Zone of <i>Pecten asper</i> .
			Sands, including Fox mould and Cowstones of De la Beche. Zone of <i>Schloenbachia rostrata</i> .
	UPPER GAULT OR MALM-STONE.	{	Sandy clay, local, east of Honiton, and on Shute Hill.
	JURASSIC, LOWER LIAS.	{	Blue Lias, limestones, and shales. Zones of <i>Arnioceras semicostatus</i> , <i>Coroniceras bucklandi</i> , <i>Schlotheimia angulata</i> , <i>Psiloceras planorbis</i> .
	RHÆTIC BEDS.	{	White lias. <i>Cardium rhaticum</i> , etc.
			Black shales, with <i>Avicula contorta</i> .
		{	Grey, etc., Marls.
	NEW RED SERIES.	TRIAS.	Keuper Marls.
			Upper Sandstones (Lower Keuper and Upper Bunter).
			Pebble beds and Conglomerate—Bunter.
			Lower Marls.
		PERMIAN.	Lower Sandstones and breccia.
			Breccia of Dawlish.
			Rubby breccia of Labrador Inn.
			Conglomerates of Watcombe and Petitor.
			Clays of Watcombe and Petitor.
			Contemporaneous volcanic rocks in Exeter, Silverton, Crediton, and Tiverton districts.
CARBONIFEROUS. (CULM TYPE)	UPPER.	{	Plant bearing shales and grits—Middle Coal Measures.
	MIDDLE.	{	Plant bearing shales and grits with Goniatite nodules—Lower Coal Measures.
			Shales with limestone, <i>Posidonomya becheri</i> , <i>Glyphioceras spirale</i> —Pendleside beds.
	LOWER.	{	Chert beds and dark shales, and Limestone of Cannington Park—Carboniferous limestone.

		NORTHERN OUTCROP.	SOUTHERN OUTCROP.
DEVONIAN.	UPPER.	Pilton and Baggy Beds. { <i>Fammenien</i> and <i>Psammites de Condraz</i> type.	<i>Cypridinen Schiefer</i> , greenish and red slates with cyprids.
		Pickwell Down grits with slates.	Büdesheim and <i>Goniatite</i> beds, red and dark grey slates, with <i>Goniatites</i> and calcareous nodules, and beds of limestone.
		(?) Morte Slates in part.	Volcanic rocks, vesicular spilites (pillow lavas), massive limestones.
	MIDDLE.	(?) Morte Slates in part.	Massive and bedded limestones, mostly coralline, thin limestones, shales, and slates. Volcanic bands developed in the Ashprington series.
		Ilfracombe Beds. Slates with limestone bands and lenticles, locally developed, and grits, prevalent in the lower part.	Slates replacing limestone with occasional calcareous bands.
		Hangman grits and slates, with <i>Natica</i> and <i>Myalina</i> bed in upper part.	Staddon grits, slates, and shales.
	LOWER.	Lynton Beds. Calcareous slates and grits.	Meadfoot group. Calcareous slates, shales, and grits.
		Foreland Grits.	Dartmouth slates, mostly purple and green slates. Occasional volcanic bands in Meadfoot Group and Dartmouth slates.
	ORDOVICIAN.	{ Gorran Quartzite and Vryan Beds. Portscatho Beds. Falmouth Beds. Mylor Beds.	
OF UNCERTAIN AGE.	{ Dodman Phyllites, <i>incertæ sedis</i> . Hornblende-epidote schists of Hope and Prawle. Mica schists of Start and Bolt.		
PRE-ORDOVICIAN.	{ Hornblende schist. Mica schist.	{ of the Lizard.	

IGNEOUS ROCKS.

CONTEMPORANEOUS.	EXETER TRAPS	{ Traps ranging in composition from trachytes or orthophyres to basalts or melaphyres. Biotite trachyte—Killerton. Orthophyre—Knowle Quarry, near Crediton. Olivine trachyte—Pocombe. Quartz basalts—Ide.	
		{ Lavas and tuffs, in the Upper and Middle Devonian—porphyritic and amygdaloidal Diabases—the vesicular Spilites in the Upper Devonian of the Padstow and Plymouth areas displaying pillow structure. Occasional altered and decomposed basic rocks in the Meadfoot group and Dartmouth slates.	

INTRUSIVE.	{ SILLS, &C. }	BASIC.	{ Proterobases. Dolerites. Diabases.
			{ Picrites. Gabbro.
	{ DYKES AND VEINS. }	ACID.	{ Quartz-felsite—Bindown.
			{ Rhyolites, near Modbury.
			{ Diabase. Dolerite.
		BASIC.	{ Lamprophyre.
			{ Quartz-porphyry. Aplite.
		ACID.	{ Granite. Pegmatite.

The problems of Devonshire geology have been ably treated by Prof. A. W. Clayden in his charming *History of Devonshire Scenery*, 1906. In this work, p. 63, he advocates the formation of domes in the palæozoic rocks above the subterranean lava reservoirs which fed the Devonian and Culm volcanoes, through the crossing of the Hercynian by Pennine undulations, and thinks that the molten matter which ultimately became the granite bosses rose up into these domes. That (p. 77) the Dartmoor granite "was at one time crowned not only by a great mass of Culm strata, but also by extensive cones from which acid lavas were outpoured." Simultaneously he believed that basic and intermediate lavas were extruded communicating with deeper-seated portions of the magma by basic pipes similar to those intruded into the Lower Culm in the Teign Valley, or by similar pipes farther west. Worth's notion of Dartmoor being the stump of a volcano or volcanoes, from which the igneous materials so largely present in the Lower New Red Breccias of Crediton and the area south of Exeter were derived, is here modified and amplified.

When discussing the invariable preference of the granite masses for argillaceous rocks with Mr. Reid, he suggested the greater facilities afforded for the penetration of the molten rock by the shrinkage of argillaceous strata.

Dr. Teall (*Exeter Memoir*, p. 83) says: "In comparing the Exeter traps with their continental equivalents in age, the fact that they are but feeble representatives of the Permian Volcanic episode is strongly emphasised. In bulk they are insignificant in comparison with the Permian igneous rocks of Rhenish Prussia (Saar-Nahe district), the Thuringer Wald, and the Grandes Rousses. Not only is the amount of igneous material much larger on the Continent, but the rocks are also of a much more varied character. In Rhenish Prussia, for example, we find quartz-porphyrries, porphyrites (andesites), and melaphyres (basalts) in great abundance and rich in varieties. Rocks of the Killerton and Knowle types appear to be comparatively rare. Under these circumstances it is interesting to note that the Permian breccias of South Devon are, as Mr. Worth has shown, much richer in varieties of volcanic rocks than the Exeter traps. Quartz-porphyrries, rhyolites, spherulitic felsites, and andesites occur, in addition to the rocks above described. Thus Mr. Worth was doubtless right in maintain-

ing that important volcanoes existed in the West of England when the breccias were formed, although he may have been wrong in regarding the granitic mass of Dartmoor as the denuded stump of one of those volcanoes."

The most succinct description of the basic igneous rocks is, I think, the following, extracted from a paper by Dr. Teall read before this Association in 1887 :*

"The basic igneous rocks of the West of England—the so-called greenstones—are of exceptional interest on account of the extent to which they have been metamorphosed by the post-Carboniferous earth-movements, and by the intrusion of large masses of granite. Devon and Cornwall, together with Brittany, constitute a part of an old chain of highlands which formed a marked feature in the physical geography of northern Europe during Mesozoic times. The Devonian-Carboniferous and pre-Devonian rocks, of which this chain was composed, are concealed at intervals by Mesozoic and Tertiary strata, but wherever they come to the surface, as is the case in the Ardennes, the Eifel, Westphalia, Thuringia, and the Hartz, they present similar palæontological, stratigraphical, and petrographical characteristics. The chain acquired individuality towards the close of the Palæozoic epoch in consequence of the extensive crumpling of the Palæozoic sediments and their associated igneous rocks. The final relief of the intense stresses which produced this crumpling appears to have been afforded by the intrusion of granite at many points along the chain. The basic igneous rocks, associated with the Devonian and pre-Devonian sediments, are partly intrusive and partly contemporaneous (lavas and tuffs). They present essentially the same characters wherever they occur. The rocks of the Hartz and the Fichtelgebirge are often undistinguishable, either in respect of their original or secondary characters, from those of Devon and Cornwall. For our present purpose it will be convenient to separate the basic igneous rocks of the Lizard district from those of the rest of Cornwall and Devon. The latter are associated with Devonian-Carboniferous and Lower Palæozoic strata, and they have been metamorphosed in late Carboniferous or post-Carboniferous times: the former are associated with serpentine and various schists, and the period of their metamorphism has not, as yet, been determined.

"We are principally indebted to Messrs. Allport,† Phillips,‡ Rutley,§ and Worth|| for the information we possess as to the petrographical character of the 'greenstones' associated with

* "The Metamorphosis of Basic Igneous Rocks," *Proc. Geol. Assoc.*, vol. x, p. 69.

† *Quart. Journ. Geol. Soc.*, vol. xxxii, p. 407.

‡ *Ibid.*, vol. xxxii, p. 155, and vol. xxxiv, p. 471.

§ *Mem. Geol. Surv.*, "The Eruptive Rocks of Brent Tor"; also *Quart. Journ. Geol. Soc.*, vol. xlii, p. 392.

|| *Trans. Plymouth Inst.* (1886).

Palæozoic strata. The classification of these rocks is attended with considerable difficulty in consequence of variations in structure and composition in one and the same rock mass.

"These greenstones admirably illustrate the impossibility of separating rocks into sharply defined groups. We can describe the rocks, but to give each specimen a name, which shall denote its character, is impossible.

"The variations in structure are partly original and partly secondary. The most important secondary structural characters are those which depend on the development of foliation. The passage of a massive into a foliated rock has already been referred to. The variations in composition are also partly original and partly secondary. The most important secondary characters depend upon the development of chlorite or some form of hornblende at the expense of augite, of leucoxene, and ultimately granular sphene, at the expense of the titaniferous iron ore, and of water-clear secondary feldspar and other substances at the expense of the original felspar.

"Lavas and tuffs occur in the neighbourhood of Plymouth and Tavistock, in Devon, and of St. Minver and other localities in East Cornwall. They are probably also represented in West Cornwall by many of the so-called hornblende slates, but the metamorphism in this region has been so intense that it is not safe to speak very confidently on this point. The intrusive rocks belong to the dolerite family of Mr. Allport, and from our point of view these are the most interesting. They have been less affected by surface agencies than the more porous lavas and tuffs, but they have been profoundly modified in certain localities by regional and contact metamorphism. The least altered rocks occur in the eastern portion of the district. The most common type appears to be an ophitic dolerite (diabase), with skeleton crystals of ilmenite. A certain amount of chlorite is usually present. Examples of this type occur at Yealmpton, Rock, Park House, near Dartington, Pollaphant, Catacleuse, near Padstow, south of Anstey's Cove, near Torquay, and at South Petherwin. Another type, containing deep brown 'basaltic' hornblende (original), and a rich brown biotite (not the pale brown biotite so frequently developed near the contact with granite), occurs at several localities in the Plymouth district.

"Dolerites of the above type have been profoundly modified by the granitic intrusions. The augite gives place to uraltite and actinolite, the feldspar breaks up into a mosaic or into an aggregate of irregular and often perfectly colourless grains; the ilmenite becomes replaced by leucoxene, and a pale brown mica is often developed in considerable quantity. Tourmaline, axinite, and garnets sometimes make their appearance.

"Where the rocks have been affected by pressure-metamorphism only, somewhat similar mineralogical changes occur. The

hornblende is, however, generally paler, and the contact minerals (the mica, tourmaline, garnet, and axinite) are not present. The most striking feature in these regions is, of course, the development of schistosity, in the manner described by Mr. Phillips. In the Land's End district the two kinds of metamorphism have been superposed, and the contact minerals occur in the foliated rocks. It must not, however, be supposed that the foliation was produced at the time of the intrusion of the granite. The relation of the granite veins (*e.g.*, those of Trewavas Head) to the sediments clearly proves that the latter were crumpled and cleaved before the veins were intruded.

"In studying the metamorphosis of the dolerites, the ophitic structure, when present, is of the greatest use. It is often preserved after the entire replacement of the augite by fibrous hornblende. Gümbel's term, epidiorite, becomes very useful if we limit it to dolerites in which the augite has been entirely replaced by hornblende. When the change has been accompanied without the obliteration of the ophitic structure, the rock may be termed an ophitic epidiorite. Now, the passage of ophitic dolerites into ophitic epidiorites, and, finally, into foliated hornblendic rocks, may be observed at many points in West Cornwall, as, for example, at St. Ives, near Penzance, and east of Marazion. The foliated rocks differ somewhat from the typical hornblende-schists."

Examples of the contemporaneous igneous rocks were seen at Brentor and in Dartington Park in 1884. Vesicular spilites and tuffs south of Saltash, and the tuff and schalsteins near South Brent were seen in 1907.

The Permian traps were seen in the Easter excursion, 1899, when the olivine trachyte in Pocombe Quarry and the quartz-basalt of West Town were visited. On that occasion the president (Dr. Teall) described the decomposition of the Exeter traps as largely of Permian age and of the lateritic type.

In the 1884 excursion the Yarnar Beacon dolerite (with labradorite, augite, and ilmenite) was visited. In the Easter excursion, 1900, ophitic dolerite was seen near Oddicombe beach (Babbacombe) and on Knowles Hill, Newton Abbot. In the Kingsbridge excursion, Easter, 1901, the igneous rocks of Torcross were visited. In the last Plymouth excursion, Easter, 1907, proterobases were seen near Forder, and mica diabase at Defiance Halt. The Clicker Tor "Serpentine" was the first rock inspected by the Association in the 1887 excursion to Cornwall. At Horswell House a Permian volcanic dyke in andesite, with quartz-porphry in the more deep-seated part, was seen in 1901, on the Kingsbridge excursion.

Of acid intrusions there are many examples in Devon and Cornwall, chiefly in the form of dykes injected after the solidification of the granite masses, and some, as the Cawsand and

Withnoe rocks, have an evident connection with the Permian eruptions; but others, such as the Bindown felsite, have undergone the stresses to which the enclosing Devonian rocks were subjected. An interesting series of acid intrusions occurs near Modbury, where the larger mass is a granophyre, and amongst the smaller dykes at a place called Shearlangston spherulitic rhyolite may be seen. The common types of the Cornish and Devon elvan dykes are fine-grained granite, quartz-porphry, and aplite. Of the latter a fine example was seen at Cann Quarry on the 1884 excursion.

Of minettes or lamprophyres there are examples in the Falmouth area, near North Hooe, at Ingsdon House, between Newton Abbot and Bickington, and at Rose Ash, North Devon.

"A comparatively unaltered sill of mica-trap seen on the coast at Mawnan is about four feet wide." It is mainly composed of fine crystals of biotite and felspar. (J. B. Hill, *Mem. Geol. Surv.*, Summary of Progress for 1898, p. 103.)

In North Devon and West Somerset some contemporaneous igneous rock or schalstein occurs at Adcombe, near the east margin of the Quantocks. Dr. Flett has proved the Hestecombe syenite to be a diorite. There is a greenstone at Fremington, and along the outcrop of the Morte slates there are several exposures of felsite, first described by Prof. Bonney at Bittadon.

The larger granite masses are more or less coarsely porphyritic, with large orthoclase crystals; but in many of them finer granites are present in the form of contemporaneous veins and more or less extensive masses which can be separated from the coarser material as in the Land's End, where a mass, six square miles in extent, is shown on the map, and in the Penryn granite, where two fine grained masses are shown. On the visit to Lee Moor, July 26th, 1884, some specimens of a very handsome black and white rock, picked up *en route*, have since turned out to be a variety of Luxullianite, with white instead of pink felspar; the first record of the occurrence of this rock in Devon. In the Bodmin Moor granite, the part nearest Bodmin, a rock closely resembling Luxullianite "has been found *in situ* in an adit to the old mine on the crest of the hill." (G. Barrow, *Mem. Geol. Surv.*, Summary of Progress for 1905, p. 32.) Schorl rock is common in veins ("peach") in the granite as at Carclaze, and as dykes and processes from it as in Roche Rock, St. Mewan Beacon, and near Buckfastleigh. A good example of greisen is to be seen in old pits near the Lee Moor china clay pits on Dartmoor.

The range of metamorphism varies with the subterranean slope of the granite, being sometimes little more than a quarter of a mile where the granite slopes steeply beneath the Killas, but where the slope is gentle the alteration may be traced to from half to three-quarters of a mile from the granites. The

most common type of alteration in the slates is spotting, and andalusite is often recognisable, and near the granite cordierite is present. On the 1884 excursion, Worth mentioned the strong development of andalusite in the altered slates of Cornwall. The dense rock met with on the borders of Dartmoor in places between Ivybridge and Wallaford Down, near Buckfastleigh, exhibits chialstolite alteration, as was seen in 1907, near South Brent. Schorlaceous alteration is very common in certain banded rocks on the borders of the St. Austell granite and sporadically in the contact zones.

One of the most interesting types of alteration is that afforded by calcareous rocks, such as fine-grained calcareous siltstones, dark calcareous slates, and igneous materials which contain lime. These have been converted into very hard porcellanized rocks or calc-flintas and diabase-hornfels. Thus we have Devonian rocks, Middle and Upper, presenting these characters on the south of Dartmoor, between Cornwall and Wallaford Down. On the west of Dartmoor, where they have been described by McMahon, and near Walkhampton, where scapolite was noticed in them by Dr. Teall. On the flanks of Bodmin Moor, on the south, at Camelford and elsewhere, I have also seen these types of alteration in the Upper and Middle Devonian. On the north and east of the St. Austell granite the calcareous bands in the Meadfoot group and igneous rocks, probably sills, locally associated with them, display these forms of alteration. Axinite and other products of pneumatolytic action are present in the calc-flintas and in veins and cracks in the diabase-hornfels of the St. Austell and Dartmoor granite contact zones. These types in the environs of the St. Austell and Bodmin Moor Granites have been specially referred to by Mr. Barrow in the *Summaries of Progress of the Geological Survey for the years 1905 and 1906*.

The China-clay worked on the southern edge of Dartmoor (Lee Moor) was visited in 1884, on the invitation of Mr. W. L. Martin.* The pit was then "a huge excavation, over 120 feet in depth, scarring the face of the hill for a considerable distance. Originally this pit was worked very shallow, and the water carrying the clay washed down from its sides to the depositing pits had to be pumped up. By driving an 'adit' level from a lower point in the face of the hill, a distance of about half a mile, the depth to which the pit can be worked by gravitation has been so increased that the Lee Moor works are now the most extensive in the country. This adit, although worked on continuously night and day by three gangs (locally 'cores') of men, took nine years to execute. Some of it was through exceedingly hard ground; some (and this gave the most trouble) through very loose ground. For a considerable distance it followed the line of a 'flookan' or cross-course which extends

* *Proc. Geol. Assoc.*, vol. viii (1884), p. 47c.

from end to end of the pit, and seems now as if it had reached a termination—if so, a very remarkable fact. In the course of driving the level several interesting minerals were found, including beautiful specimens of opal and jasper, an example of torbanite, and magnificent crystals and stones of tin, found at the intersections of some lodes and the cross-course. Although there are several lodes in the sett, the quantity of tin they contain is so small that Mr. Martin was perfectly astonished at the amount of work the old tanners must have done on that very spot, for what must have been very meagre results. The various lodes were clearly seen traversing the faces of the huge excavation, with the course of the flookan, and its effects in 'heaving' the lodes. One lode had been carried some distance along with the flookan before it started on its own course again. Mr. Martin also showed the position of the best runs of clay and their peculiar relation to the lodes and cross-course." In the St. Austell China-clay area, the oldest pit, Carclaze, was visited in 1887.* The decomposed granite is here traversed by "peach," or quartz schorl tin-bearing veins, and was originally worked as an open tin mine, or stockwork. Speaking of the kaolinization, the President, Mr. Rudler, remarked that "those who have given most attention to the subject are inclined to believe, as maintained by M. Daubrée, that hydrofluoric acid, or other fluorides, must have been the chief agent in attacking the felspar.† The presence of compounds containing fluorine, such as tourmaline, lepidolite, and fluor-spar, is very common in China-clay districts. Fine examples of fluor-spar, presenting a deep amethystine tint, were found by the party when examining the China-stone quarried at the West of England works."

The distribution of the China-clay in relation to fissures and greisen lines in a large part of the St. Austell Granite is described by Mr. MacAlister.‡ He believes with the writer that China-stone is not an intermediate stage in kaolinization, but the result of an allied type of alteration. Mr. J. H. Collins remarked: § "The China-clay rock seldom extends more than a few fathoms on either side of the schorlaceous veins in which kaolinization seems always to have originated, but may accompany them to a depth of 100 fathoms or more from the surface."

In Sir Warington Smyth's address|| on the Granite of St. Michael's Mount, he pointed out the paragenetic association of ores of tin, copper, arsenic, wolfram, etc., in tin lodes in accordance with Daubrée's theory of their pneumatolytic origin. This theory has in recent years been elaborated by Vogt in *Zeitschr. für Practische Geologie*.

* *Proc. Geol. Assoc.*, vol. x (1887), p. 108.

† See "Études synthétiques de Géologie expérimentale," par A. Daubrée. Paris, 1879, p. 29.

‡ *Mem. Geol. Surv., Summary of Progress for 1905*, p. 35.

§ *Journ. Min. Soc.*, vol. vii, p. 204.

|| *Proc. Geol. Assoc.*, vol. x, pp. 208-9.

In addition to the preliminary remarks by Mr. J. H. Collins on the lodes visited in the Camborne and Land's End districts in 1887, a paper "On the Mining District of Cornwall and West Devon,"* by the same author, may be consulted with advantage, as it gives many beautifully-engraved sections of the underground workings, some showing the relation of the Granite to the Killas, and sections through Carn Brea Hill, St. Agnes Beacon, and Carn Marth. Since the excursion Geological Survey Memoirs on the Falmouth District and on the Land's End have been published, in which the lodes have been described by Mr. MacAlister, who laid them down on the new Geological Survey Maps of these districts.

THE LIZARD.

This district was visited by the Association in August, 1887, under the guidance of Messrs. Howard Fox and E. A. Wunsch.

The following account of the geology of the Lizard has been kindly furnished by Dr. Flett at my request.

"The northern boundary of the Lizard area is a sinuous line which runs from Porthallow on the east coast to Mullion Cove on the west, and bends back on itself in a remarkable fashion near Bochym and Cury Cross Lanes. At its extremities, at any rate, where it is exposed in the coast sections, this boundary is a powerful fault. The central feature of the geology of the Lizard is the great, somewhat elliptical, mass of serpentine which measures eight miles from east to west and six miles from north to south. This is surrounded by a ring of schists (principally hornblende schists of various types, with some mica schist and granulite). In many places the schists have been denuded and the serpentine reaches the coast, as, for example, for most of the way from Mullion Cove to Pentreath Beach and from Church Cove to Coverack. A small boss of gabbro lies around St. Keverne and Coverack and sends innumerable dykes into the serpentine. About Kennack Bay, at Parn Voose (near Church Cove), and in many other places along the coast line, there is an extensive development of banded gneisses which have a very remarkable character and very perplexing relationships to the gabbro and serpentine. This has been called the 'granulitic series' by Professor Bonney, and its nature and history are among the most disputed of the many controversial points of Lizard geology. It consists of a dark hornblendic portion, sometimes resembling a diorite, at other times a hornblende schist, and a light-coloured granitic or gneissose portion. These are intimately mixed, banded and veined, but always in such a way that the granite seems later than the hornblendic rocks.

* *Inst. Mechan. Eng.*, July, 1873, p. 89.

"The nature of the Lizard rocks was recognised at an early period, and the best of the older accounts is that of De la Beche,* which is marked by singular judgment and caution, especially where he deals with questions regarding structure and succession. In 1877 Professor Bonney† published his first paper on the Lizard, and since then (with the late General McMahon) he has returned to this investigation more than once.‡ He has always maintained that the serpentine is a great igneous intrusion which penetrates the schists, and is as a whole much less metamorphic than they are. The 'granulitic series' he regarded at first as a sedimentary group, but subsequently recognised their igneous character; they are, in his opinion, older than the serpentine and gabbro. Dr. Teall and Mr. Howard Fox, in 1893,§ advanced an opposite hypothesis, holding that the 'granulitic series' was intrusive into both of these rocks. In this view they have been supported by Mr. Somervail,|| Mr. Lowe,¶ and Dr. Flett.** Another series of gneissose rocks occurs in the skerries off the Lizard Head (the Man o' War gneisses). They were first described by Mr. Fox and Dr. Teall†† in 1888.

"The Lizard district has now been re-mapped on the six-inch scale by the Geological Survey, and the following are the principal conclusions arrived at by Dr. Flett as the result of his work. The oldest rocks are the mica schists, quartzites, and granulites of the Old Lizard Head, Porthallow, etc.; they are accompanied by green schists, hornblende schists, epidotic hornblende schists which were probably intrusive dolerites, lavas and ash beds. Into these the Man o' War gneiss was intruded as a great boss which sends dykes into the surrounding country. The whole of this series is greatly crushed and folded, and was probably metamorphic before the serpentine was injected into them. The next episode appears to have been the intrusion of a group of coarse hornblende schists which occur in places at the margin of the serpentine (Predannack, etc.); it was followed by the great peridotite intrusion, of which the early parts are a fine, flinty-looking dunite serpentine, passing into the tremolitic serpentine (often schistose), while the latest portion is a coarse enstatite serpentine. After the peridotite consolidated the gabbro welled up, sending many dykes into the serpentine, but few or none into the schists. Then came a group of ophitic and porphyritic dolerites, which traverse all the rocks of the Lizard

* Sir H. T. De la Beche, "Report on the Geology of Cornwall, Devon, etc.," 1832 p. 96, *et seq.*

† T. G. Bonney, "On the Serpentine and Associated Rocks of the Lizard District," *Quart. Journ. Geol. Soc.*, vol. xxxiii (1877), p. 584.

‡ T. G. Bonney, *Quart. Journ. Geol. Soc.*, vol. xxxix (1883), p. 1. T. G. Bonney and Major-Gen. C. A. McMahon, *Ib.*, vol. xlvii (1891), p. 464.

§ *Quart. Journ. Geol. Soc.*, vol. xlix (1893), p. 199.

|| *Trans. R. Geol. Soc. Cornwall*, vol. xi (1895), p. 662.

¶ *Trans. R. Geol. Soc. Cornwall*, vol. xii (1901), p. 438.

** *Mem. Geol. Surv.*, Summary of Progress for 1906, p. 29.

†† *Quart. Journ. Geol. Soc.*, vol. xlv (1888), p. 309.

complex above mentioned. The granite followed, and in places found the dolerite still unconsolidated; banded and veined mixed rocks were the result—the 'granulitic series.' The last injections were felspathic red granites, which occur as dykes and small bosses.

"A special feature of Lizard geology is the manner in which rocks which have the facies of typical crystalline schists alternate with others of the same composition, but purely massive in structure. This has been remarked previously of the 'granulitic series,' but is equally well exemplified by the serpentinite, the gabbro and the doleritic or greenstone dykes. Dr. Teall has devoted special attention to these remarkable phenomena,* and has pointed out how sudden are the transitions between perfectly normal igneous rocks and completely metamorphic schists. He regards the changes as produced by pressures acting on rocks already consolidated. Professor Bonney, on the other hand, would explain them as due to fluxional movements in a partly crystalline magma. It is probable that both of these explanations are applicable in certain cases. One very important point is that it can be shown beyond dispute that the gneissose and foliated structures were there very shortly after the rock crystallised as they are frequently cut across by the later injections from the same magma, which are themselves perfectly massive or non-foliated."

START, BOLT, AND PRAWLE ROCKS.

As regards the Start, Prawle, and Bolt rocks seen during the Kingsbridge excursion in 1901, these consist, as then pointed out, of (1) an uppermost series of basic rocks, allied to the diabases in composition, and possibly in part of altered tuffs. This series, from its prevalent minerals, is called the Hornblende-epidote schists. (2) Mica schists and quartz schists of sedimentary origin, originally consisting of mud and fine silt, very similar in character and association to the prevalent sediments met with in the Devonian rocks on the north. (See Fig. 135.)

The rocks of the Mica schist group occupy the greater portion of the Start and Bolt districts. East of the Salcombe Estuary they are bounded on the north and south by two well-marked zones of the Hornblende-epidote schists, which gradually approach each other, coalescing near Malborough. The southern band forms the Prawle coast, the northern was seen in the Southpool, Kingsbridge, and Batson Creek sections. From Malborough to Hope the Hornblende-epidote schist band is bounded by Mica schists on the north as well as on the south.

The intensely contorted rocks in the junction section at Hope were seen, and the brown decomposed minerals, which so com-

* *Geol. Mag.* dec. 2, vol. iii (1886), p. 4^r 1.

monly occur at the junction between these rocks and the Devonian slates, were seen also in the Southpool Creek section. In the Survey Memoir, Kingsbridge and Salcombe District, 1904, the junction sections are specially described, and petrological notes by Dr. Teall are given. A non-committal attitude is taken regarding the age of the rocks.

ORDOVICIAN AND SILURIAN.

The Geological Survey Memoir dealing with the Geology of Mevagissey gives an admirable summary of Mr. J. B. Hill's work in establishing the age and sequence of the pre-Devonian rocks of West Cornwall, from which the following is extracted: In the year 1898 "Mr. Hill showed that the strata of Gerrans Bay, including the Lower Silurian fossiliferous quartzite of Carne that was coloured as Silurian on the old map, formed a natural sequence with the slates of the adjacent area to the westward coloured on the old map as Devonian. He further divided the Killas into four divisions, in descending order, as follows:

The Veryan series, comprising that part of the sequence coloured on the old map as Silurian.

The Portscatho series	} Coloured on the old map as Devonian.
The Variegated series	
The Mylor series	

"The variegated series was subsequently called by Mr. Hill the Falmouth series."

In 1899 Mr. Hill called attention to the existence of "wide-spread crush-breccias of a regional type." He correlated the conglomerate of Gerrans Bay with that south of the Helford river, and as both contain boulders of the quartzite he considered that this conglomerate (previously correlated with the Ladock beds by Mr. J. H. Collins) "represented an unconformity indicating a considerable break." He contributed a paper to the Royal Geological Society of Cornwall the same year, in which he showed "that the apparent thicknesses of the strata were exaggerated by repetition." He further showed that the four divisions of the sequence already alluded to spread practically over the whole of West Cornwall.

In 1901 Mr. Hill recorded at Gorran Haven for the first time the existence of pillow lavas similar to those of Mullion Island on a similar geological horizon. He pointed out their resemblance to the pillow lavas of Ballantrae, and suggested that they also might be of Arenig age. He pointed out also that fragments of the pillow lava were incorporated in the Nare Point Conglomerate. Later Mr. Hill indicated that the Grampound and Probus Conglomerate (recognised as the equivalent of the

Nare Point Conglomerate) might represent an unconformity between Silurian and Devonian rocks.

In 1906 he proved the unconformity of the Devonian to the Ordovician rocks, and the order of succession given above, the Mylor series being the oldest.

In 1904 Mr. Upfield Green recorded his discovery (*Geol. Mag.*, Dec. 5, vol. i, p. 289) in the crush-breccia cliffs of Porthluney of fossils which were identified by Messrs. Sherborn and Crick as Upper Silurian species. Peach had found fossils in the same material, but their exact position was not known through admixture with Ordovician fossils from the quartzite. Messrs. Upfield Green and Sherborn gave a list of the fossils found by them at Porthluney in the *Geological Magazine*, Dec. 5, vol. iii (1906), p. 33. They appear to be of Ludlow and Wenlock age. Mr. C. Reid thinks that the glossy phyllites of the Dodman are separated from the Veryan series by a considerable fault, and he leaves their age indefinite (Mevagissey Memoir, p. 33). A list of fossils from the Ordovician quartzite, drawn up by Mr. E. T. Newton, appeared in the Summary for 1904, p. 25, as follows: *Orthis porcata* (?) M'Coy.; *O. budleighensis*, Dav.; *O. vespertilio* (?), Sow.; *O. calligramma*, Dalm.; *Calymene* (perhaps *C. senaria*), *Trinucleus* (?).

The following fossils were obtained from the fine-grained quartzite of Perhaver Beach by Mrs. Reid, and identified by Mr. Philip Lake: *Cheirurus sedgwicki*, Salt.; *Calymene tristani*, Brongn.; *C. cambrensis*, Salt.; *Phacops nimus*, Salt.; *P. incertus* (?), Desl.; *Asaphus powisi* (?), Murch.

Mr. Lake adds that "the beds are apparently 'Landeilo'; but a good deal depends on the definition of 'Landeilo.' They evidently correspond either with the Angus slates or the *Grès de May* of Brittany and Normandy" (Mevagissey Memoir, p. 39).

DEVONIAN.

In the excursion to Plymouth in 1884 the local Director, R. N. Worth, gave an admirable description of the Plymouth limestone. He regarded the slate rocks on the north as older beds, and recognised three divisions in them, viz., slates associated with lodes and Elvans, slates with interbedded volcanic rocks, purple and green slates in places passing up into the limestone through calcareous shales. The rocks on the south, characterised by the presence of sandstones, he considered to be above the limestone, and regarded the Staddon and Maker (or Mount Edgcumbe) grits as probably equivalent to the Pickwell Down grits of North Devon.

The visit to Totnes under the directorship of Champernowne elicited an excellent detailed description of the geological structure of the Middle Devonian strata in and surrounding Dartington Park. The account was illustrated by a map and section,

FIG. 136.—GEOLOGICAL MAP OF PLYMOUTH DISTRICT.—W. A. E. Ussher.

the first really detailed map published, as far as I know, of part of the South Devon Devonian area, and constructed from his one-inch field maps before the six-inch maps were published. It affords a good example of Champernowne's conscientious field work.

In his address, Champernowne placed the slates of Berry Park over the limestone, and above them the purple and grey grits which border the Paignton New Red rocks, and form Westerland Beacon and Windmill Hill. These grits, generally called the Cockington grits, he correlated with those of Staddon and Mount Edgcumbe, regarding them as equivalent to the Pickwell Down grits and to the *Psammites de Condros* of Belgium.

The preliminary notice by the writer is in accord with the

FIG. 137.—PLYMOUTH DISTRICT. HOLL'S GROUPING, 1868.

above opinions, which had come down from the earlier observers through Holl. (See Fig. 137.)

The discovery of Upper Devonian fossils in the slate area west of Newton Abbot, between the Newton Abbot and Ashburton limestones, in placing slates considered below the limestones above them, reversed all previous ideas as to the succession, and the new reading was further established by the discovery of Lower Devonian fossils in the Cockington beds on the north and south of the Paignton New Red rocks.

This solution as regards the general structure and the relations of Upper, Middle, and Lower Devonian was tentatively applied to Cornwall in 1890, but the succession of the Lower Devonian subdivisions was not satisfactorily ascertained until 1902, when a direct comparison of the coast sections from Looe to Brixham was made.

Champernowne discovered the volcanic area South of Totnes, which had formerly been confounded with the slates and grits. He compared the rocks to the Nassau schalsteins, and termed

the group the Ashprington Volcanic series. He also regarded the various limestone patches as belonging to one general group.

Pit Park Quarry, rendered classic by the researches of Champernowne, was visited by the Association.* The limestone is here much dolomitised. One four-foot bed is very rich in Stromatoporoids and other fossils, of which a list is given in the Report of the excursion.

The limestones of Chudleigh, Newton Abbot, and Torquay were seen in the Easter excursion, 1900, when it was pointed out that the limestone developments include, in their upper and more massive beds, strata which would be regarded as the lower, or *Rhynchonella (Wilsonia) cuboides*, zone of the Upper Devonian on the continent. These limestones have yielded an abundant fauna, described in the Rev. G. F. Whidborne's Monograph.† *Rhynchonella (Wilsonia) cuboides* has been found at Chudleigh, Lummaton, Wolborough, and Plymouth, but in none of these places can a boundary be drawn between Upper and Middle Devonian based on its occurrence. The celebrated pinkish Upper Devonian limestone of Ransley Quarry, which contains *Acervularia pentagona*, belongs to the same category. These limestones are necessarily included in the Middle Devonian chapters in the Geol. Survey Memoirs. *Stringocephalus burtini*, the characteristic Middle Devonian shell, has been found in the Lummaton and Wolborough limestones.

On Knowles Hill, Newton Abbot, the Upper Devonian slates were seen. Their correspondence with the German *Cypridinen Schiefer* was proved by the discovery of *Posidonomya venusta* and the Ostracods *Entomis serratostrata*, *E. gyrata*, etc., identified by Prof. Rupert Jones. The effect of this discovery has been already mentioned.

The Devonian rocks of the Kingsbridge area were seen on the Easter excursion, 1901, when the Lower Devonian became a prominent feature. The succession of the Lower Devonian rocks has been found much the most difficult problem in Devonian Geology. The absence of the Dartmouth Slates in the Torquay and Paignton anticlines primarily contributed to this. The absence of proof of the representation of the Looe beds in these anticlines, or even in Devon, led me to fall back upon the succession given by De la Beche in the Fowey Valley, which placed the Looe beds of Pencarrow Head beneath the Dartmouth slates. This led to the error in placing the Looe beds and Grampound grits below these slates in my map of 1890, in which, however, an alternative hypothesis as regards the anticlinal representation of the Dartmouth Slates is given at Watergate Bay. It is curious that the anticlinal structure of the Dartmouth Slates should first have been proposed for the spot where it was last established!

* *Proc. Geol. Assoc.*, vol. viii (1884), p. 471.

† *Pal. Soc.*, vol. i and ii (1889-95).

Fig. 135, which first appeared on page 121 of the Report of the Easter excursion in 1901,* only requires the obliteration of the numbers of the subdivisions south of the Dartmouth Slates, which denote a downward succession, leaving 3a to represent the Ringmore and 3 the Torcross and Tinsey Head beds. In the following year† the Looe Beds were identified in the Plymouth, Ringmore, Torcross, and Kingswear Promontory coast-sections, confirming the fossil evidence which had not long before been obtained in Torquay.

In the Plymouth excursion, 1907, something of the whole Devonian sequence was seen.

The diagrammatic section, Fig 138, is applicable to the succession of the Devonian of the Southern outcrop everywhere, with such local modifications as representation of limestone by slate or volcanic rocks, etc. All the addition necessary is to show the overlap of the Meadfoot Group on the pre-Devonian rocks, as I regard the Grampound Grits as a marginal phase of the lower beds of that group, and Mr. J. B. Hill has shown that the Grampound and Manaccan series correspond and rest unconformably on the different groups he has established in the Ordovician rocks.

In this excursion Upper Devonian rocks corresponding to those of Knowles Hill, Newton Abbot, were seen at Wivelscombe Quarry and in association with lower beds on the Ince Castle coast. The latter belong to the same series as the Büdesheim beds first discovered in England by J. E. Lee at Saltern Cove, near Paignton, and as the reddish shaly limestones with *Goniatites*, first described by Römer at Lower Dunscombe, near

FIG. 138.—SECTION OF THE DEVONIAN ROCKS OF THE PLYMOUTH DISTRICT.—W. A. E. Usher.

* *Proc. Geol. Assoc.*, vol. xvii, p. 119.
† "Summary of Progress for 1902."

Chudleigh, where they rest on the massive limestone of the *Rhynchonella cuboides* zone.

The vesicular spilites, or pillow lavas, which occur in the Upper Devonian, in the area between Plympton and Liskeard, and on a similar horizon, as shown by Messrs. Dewey and Reid, in North Cornwall, were seen on the Wearde Quay coast on the same excursion.

The latest discoveries in the Lower Devonian rocks of North Devon by Messrs. Upfield Green and J. G. Hamling favour the correlations set forth in my article on the Geology of Devon and accompanying maps in the Victoria History of Devon, viz., between the Staddon Grits, the Meadfoot Group, and Dartmouth Slates, and the Hangman Grits, Lynton Beds, and Foreland Grits respectively.

The types of the northern Devonian outcrop differ from the southern in the general absence of volcanic rocks, in the occurrence of intercalations and masses of grit in the Upper Devonian, of grit intercalations in the Middle Devonian, chiefly in the lower part, and in the greater proportion of grits to slate in the Lower Devonian.

The Pilton Beds and *Cucullæa* grits in the Baggy Beds are a sandy facies of the Upper Devonian corresponding to the *Psammites de Condroz* of Belgium, where the *Cucullæa* zone appears to be higher in the series.

The lower, or Frasnian, zones of the Southern outcrop are homotaxial with the nearly unfossiliferous Pickwell Down Grits, unless the upper part of the Morte Slates should eventually find a resting-place in this series. Mr. Hamling and I found *Spirifer verneuili* in the Oakhampton Slate Quarry in the Morte Slates, near Wiveliscombe, in 1906. We also discovered the *Natica* and *Myalina* bed, near Holford, at the extreme east of the outcrop of the Hangman Grits. It had previously only been known in the Hangman cliffs, at the extreme west of their outcrop.

In the preliminary notice* to the long excursion to West Somerset and North Devon in 1896 a list of fossils from the Upper Devonian by the late Mr. Whidborne is given. Mr. Valpy published a list of fossils he had obtained in the Middle Devonian rocks of Ilfracombe and Combe Martin.

The Middle Devonian limestone was seen at Adcombe on the east side of the Quantocks. The Trap Ash at Dibbles Quarry, near Quantock Lodge, was also visited. Here there appears to be 50 or 60 feet of contemporaneous volcanic rock. At Holford, by the stream, there is also a band of contemporaneous igneous rock, probably sheared tuff, denoting the northerly prolongation of the Trap Ash.

The Devonian beds inspected in Woodlands Quarry are in

the lower part of the Ilfracombe Group, and the exposure of the *Natica* and *Myalina* bed is by the lane between this quarry and Holford.

The Ilfracombe beds were seen at Combe Martin and in Haggington Quarry, and the Morte Slates in Shelfin and Mullacott Quarries, where *Lingula mortensis* was found. Woolacombe was also visited, and "the party proceeded to Barricane Beach, and began to hunt here and in the adjoining coves for fossils in the Morte Slates, but only a few imperfect specimens were found. It was at Woolacombe, near Barricane Beach, that Hicks first established the fossiliferous character of these slates. He here gave a short account of the controversy that had arisen over the Devonian rocks, when Jukes wrote his famous paper,* and of the subsequent history of the question up to and including his own announcement of the discovery of fossils in the Morte Slates, a discovery which, taken together with the stratigraphical evidence, in his judgment, proved them to be older than any of the Devonian rocks to the north and south of them, instead of being at the top of the series as Jukes suggested, or in the middle in regular sequence with the beds north and south as Mr. Etheridge and the officers of the Geological Survey would have us believe. He agreed with Jukes in thinking the Morte Slates were separated from the Pickwell Down Sandstones to the south by a great fault, but he went further and held that there was another great fault separating the Morte Beds from the Ilfracombe series to the north. He believed that the Morte Beds in this area were mainly of Upper Silurian (probably Wenlock) age, and that they had been thrust up in the middle of the Devonian sequence, throwing off the beds on each side."†

Between 1878 and the summer of 1880 the writer had the opportunity of constructing a General Geological Map of the Devonian rocks of North Devon and West Somerset, by coast observations and traverses across the strike at frequent intervals as far as North Devon is concerned, but in a more detailed manner in West Somerset. In the Survey referred to special attention was devoted to the irregularities of boundary produced by the plication of the junction beds of subdivisions. This is markedly displayed by the junction of the Pickwell Down Grits with the Baggy and Pilton Beds between Span Head, East Buckland, and North Molton, and still more in the junction of the Morte Slates and Pickwell Down beds around Brompton Regis, north of Dulverton, on Winsford Hill, and near Withypool. A coloured map showing these phenomena appeared in the *Proceedings of the Somerset Archaeological and Natural*

* *Quart. Journ. Geol. Soc.*, vol. xxii (1866), p. 320.

† *Proc. Geol. Assoc.*, vol. xiv (1896), p. 438.

History Society for 1879.* In the same year appeared "Notes on the Structure of the Palæozoic Districts of West Somerset," by Champernowne and the writer.† In 1889 a map was published giving the Devonian Geology between Oare and Nether Stowey in some detail, and showing the inosculation through plication of the Morte Slates and Pickwell Down beds West of Withiel Florey.‡

This stratigraphical evidence does not seem to have been sufficiently considered.

The following is from the paper by the late Dr. Hicks, read to the Geologists' Association in 1896§ :—

"The following is a list of the chief fossils hitherto discovered in these beds by the Rev. G. F. Whidborne, Mr. J. G. Hamling, and myself at Barricane, in Morte Bay, and Mullacott and Shelfin near Ilfracombe :

<i>Lingula mortensis</i> , Hicks.	<i>Orthis rustica</i> , Sowerby.
<i>Stricklandinia lirata</i> , Sowerby.	<i>Modiolopsis barricanensis</i> ,
<i>Rhynchonella lewisii</i> (?),	Hicks.
Davidson.	<i>Pterinea mortensis</i> , Hicks.
<i>Rhynchonella stricklandi</i> (?),	Also Encrinites and Graptolites.
Sowerby.	
<i>Spirifera hamlingii</i> , Hicks.	

"The fossils found in the beds usually classed with the Morte Slates in West Somerset are now being described, and belong to the following genera—*Orthis*, *Strophodonta*, *Leptæna*, *Rhynchonella*, *Avicula*, *Phacops*, *Cryphæus*, Encrinites, etc. These fossils show that the beds belong to higher horizons than those which have yielded fossils in the Morte Series in North Devon, and that they are, for the most part, of Lower Devonian age."

The Lower Devonian facies of the fossils subsequently described|| from Treborough in West Somerset (which included *Dalmanites*, sp.; *Homalonotus*, sp.; *Chonetes plebeia* and *Ch. sarcinulata*) induced the writer to revisit that part of the area in 1905 when on leave at Minehead. He then found the fossiliferous horizons to extend east to Leighland Chapel, beyond which they cross a deep valley where the strike rounds to a north-westerly direction from Woodadvent Farm to Roadwater and Goldsoncot.

Whilst the fauna is unusual for the limestones of the Ilfracombe series, and the fossiliferous slates of Leighland Chapel are lithologically similar to fossiliferous slates in the Meadfoot Group at Noss, near Dartmouth, etc., the stratigraphical

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

† *Quart. Journ. Geol. Soc.*, vol. xxxv, p. 532.

‡ *Proc. Somerset Arch. and Nat. Hist. Soc.*, vol. xlv.

§ *Proc. Geol. Assoc.*, vol. xiv, p. 350.

|| *Quart. Journ. Geol. Soc.*, vol. liii, p. 441.

evidence shown in diagram form by De la Beche* is very strongly in favour of the connection on the same strike of these horizons with the Middle Devonian limestone outcrops on either side of them. It is possible, however, that detailed mapping on the six-inch scale may vindicate Hicks's views regarding the Morte Slates, and the Association is to be congratulated for having had the privilege of seeing some of the evidence under his guidance.

The map accompanying Etheridge's paper† shows the sharp change in strike east of Treborough and the anticlinal structure of the Quantocks, but is otherwise diagrammatic. He regarded the Cannington Park limestone as Middle Devonian.

Both Etheridge and Townshend Hall‡ classed the Hangman Grits in the Middle Devonian, and prior to 1888 the writer did the same. The prevalence of grits in the lower part of the Ilfracombe series renders the line of junction between Middle and Lower Devonian somewhat vague and unsatisfactory.

CARBONIFEROUS.

The axis of Condroz, which forms the northern boundary of the Lower Devonian, according to Marcel Bertrand, runs from the Bristol Channel on the north of Dover by the Ardennes probably to the Black Sea. Somewhere about this great geotectonic feature important changes have taken place. In England, for example, the Marine Devonian of the Quantocks and Exmoor gives place on the north to the Old Red Sandstone of Hereford and the Bristol and Mendip areas, whilst the Carboniferous types of the South Wales, Bristol, and Somerset coal-fields on the north give place on the south to the Culm type which occupies the central trough of Devon.

To the north of the Bristol Channel the Axis of Condroz (if we may denote by that term the ridge of Ordovician, etc., rocks which extends from Wexford, through Central Wales, by Atherstone and Nuneaton eastward), although the estuarine or lacustrine Old Red is found within its limits, was not finally submerged until the deposition of the Coal Measures.

The question naturally suggested is :—What is the relation between the Lower Culm Measures and the Carboniferous limestone, as the plant-bearing Culm Shales and Grits have been shown by Mr. Newell Arber§ to be an unproductive phase of the Coal Measures, in which the *Goniatite* nodule beds of Instow, and elsewhere on the northern outcrop, were shown by Dr. Wheelton Hind to represent Lower Coal Measures.|| Mr.

* "Report," p. 55, Fig. 4.

† *Quart. Journ. Geol. Soc.*, vol. xxiii, p. 580.

‡ *Trans. Devon Assoc.* (1879), p. 189.

§ *Pal. Soc.*, 1904.

|| *Geol. Mag.*, dec. 5, vol. i (1904), p. 397.

Inkermann Rogers has done much to increase our knowledge of the occurrence of these beds.

Do these Lower Culm rocks represent the Carboniferous limestone, as is thought on the Continent, and as suggested by the writer for Devon, a suggestion later on propounded by Messrs. Fox and G. J. Hinde on palæontological evidence?

Do they represent the Yoredales, as suggested by Mr. H. B. Woodward in discussion on Hicks's paper in 1896?*. And are they, as maintained on palæontological grounds, by Dr. Wheelton Hind, the equivalent of the Pendleside series?

If Dr. Wheelton Hind's correlation of these beds with the Bishopston beds of Gower is admitted, as the latter overlie the *Dibunophyllum*-zone of the Carboniferous limestone, his point would be established.

There is, however, a *via media* based on the fact, which the writer ascertained by actual survey after the publication of Messrs. Fox and Hinde's Paper, that the *Posidonomya* beds invariably overlie the Chert beds, or their representatives. May not the Lower Culm represent the Pendleside and Carboniferous limestone facies? The *Posidonomya* beds are characterised by the presence of *Glyphioceras spirale*, a fossil which does not, as far as I know, occur below the Pendleside beds.

There are numerous specimens from Waddon Barton and from Bampton and Hele in the British Museum,† and also most of the Lower Coal Measure fossils from the Instow nodule bed horizon, the list given by Mr. Inkermann Rogers being as follows‡ :—

Calacanthus elegans (Newb.), *Elonichthys aitkeni* (Traq.), *Dimorphoceras gilbertsoni* (Phill.), *Gastrioceras carbonarium* (Von Buch.), *G. listeri* (Martin.), *Orthoceras morriscanum*, *Posidoniella lævis*, *Pterinopecten* (*Aviculopecten*) *papyraceus* (Sow.), *Calamites* (sp.), *C. suckowi*, *Cordiaites*, *Lepidodendron* (sp.).

Along the southern outcrop, from Ugbrooke Park westward, the Lower Coal Measure representatives seem to be absent, but in the neighbourhood of Exeter it is quite possible that they may occur. The dark mudstone underlying the thin grits and splintery shales of the Exeter type in Perridge Tunnel contains *Glyphioceras*, which Mr. Wedd considers to be *G. bilingue* and not *G. crenistria*, as I supposed. (See Exeter Memoir, p. 15.)

There is, in fact, a considerable unconformity between the Plant-bearing Culm Shales and Grits and the Lower Culm in the southern outcrop. This was pointed out in the St. Mellion Outlier on the visit of 1907, when we saw the Plant-bearing Culm rocks resting in places directly on Upper Devonian, from which

* *Quart. Journ. Geol. Soc.*, vol. lii, p. 272.

† "Catalogue of Fossil Cephalopoda," by A. H. Foord and G. C. Crick, pt. iii, p. 211.

‡ *Trans. Devon Assoc.* for 1907, p. 398.

they were in places separated by patches of Lower Culm Chert beds, whilst in the Haltonquay section by the Tamar the *Posidonomya becheri* beds are present, as well as the Chert beds. In the Newton Abbot and Ugbrooke Park districts the Culm Sandstones contain conglomerates usually rather small, with rolled fragments of Lower Culm Chert.

Although no signs of unconformity have been detected in the northern outcrop, it does not seem probable that so marked a change in the character of the sediments could have been produced consecutively, and without considerable lapse of time.

That the fine-grained *Posidonomya* beds and radiolarian cherts of the Lower Culm indicate deeper water, as advocated by Messrs. Fox and Hinde*, seems proved by the relative distribution of these types and of the Carboniferous limestone. The Carboniferous limestone extends over areas where the Old Red Sandstone or shallower water Devonian sediments prevail; but as the latter become finer and indicative of deeper water the Lower Culm types dominate.

The Carboniferous limestone extended at least as far south as Cannington Park, probably farther.

The Lower Culm rocks come on about sixteen miles to the south, overlying on their northern outcrop the shallow water Upper Devonian type of the Pilton and Baggy beds allied to the *Psammites de Condroz*.

In Belgium the *Tournaisian* or lower zones of the Carboniferous limestone overlie the *Psammites de Condroz*, and in Westphalia the Upper Devonian underlying the Carboniferous limestone is a more or less sandy type (*Flinz*). The Upper Devonian over which the Lower Culm type prevails seems to be of the *Cypridinen Schiefer*, or slate type.

In the Devon basin Lower Culm rocks of the same or similar character overlie Upper Devonian rocks of different bathymetric types on the north from those on the south. This is suggestive of an unconformity or lapse in time to permit of the adjustment of bathymetrical conditions to suit the deposition of the fine Lower Culm rocks all over the area.

The Culm type seems a misnomer, as the name is really applicable to those beds of unproductive Coal Measures which, near Bideford, contain Anthracite bands, and now it is applied indifferently to the arenaceous or shallow water lower Carboniferous and the deeper water chert beds or *Kieselschiefer* as well.

As far as our Devon and Cornish area is concerned, the limestone developments of West Leigh, on the northern outcrop, await careful palæontological research, and their relations to the Devonian are not clear at the place where both pass eastward under the newer Permian and Trias rocks.

On the southern outcrop there is much to be learned by a

* *Quart. Journ. Geol. Soc.* (1895), p. 662.

special study of the Exeter type and underlying Lower Culm beds, and detailed stratigraphical work will no doubt throw much light on the unconformity so manifest in the St. Mellion and Beer Alston districts.

NEW RED ROCKS.

On the Easter excursion, 1899, the fine coast-section of the New Red rocks was explored, from the outcrop of the Keuper Marls from beneath the Rhætic Beds, near Axmouth, to the faulted outcrop of the Breccias at Exmouth; and the Permian traps of Dunchideock, Westown, and Pocombe were seen. The lowest beds, the Watcombe Clays and overlying breccio-conglomerates of Watcombe and Petitor Crags were seen in 1900.

No proofs of discordance were detected in the junction of the various subdivisions of the series traced by the writer from the Bristol to the English Channel between 1870 and 1880. On the contrary, apart from the physical break between the (Bunter) Pebble Bed and Conglomerate and the Permian Marls, there is a certain amount of reciprocity in their relations at or near the junctions, and this is more especially the case between the Permian subdivisions.

The Budleigh Salterton Pebble Bed contains numerous large ellipsoidal quartzite pebbles, in which W. Vicary, in 1863, discovered Ordovician and Devonian fossils identified by J. W. Salter.

These foreign pebbles decrease in size, become sparse, and finally disappear as the bed is followed northward to Burlescombe.

Between Straight Point and Exmouth the section consists of Marls with alternating beds and masses of Sandstone, apparently representing a thickness of from 300 to 400 feet. This series passes, no doubt, downward into sandstone and breccia; but there is reason to think that it also passes westward into, or is replaced by, sandstones and breccias horizontally. At Straight Point, where the first considerable mass of sandstone is seen, breccia of the Exmouth and Dawlish type is present in it. It is quite possible that the section between Straight Point and Exmouth may be the outward extension of, and represent, the section between Exmouth and Holcombe Tunnel, on the line between Dawlish and Teignmouth.

In a recent Paper "On the Origin and Mode of Formation of the Breccias of the S. Devon Coast," Mr. Bernard Hobson* alludes to the occurrence of fragments of felspathic trap in the Watcombe, etc., conglomerate below the horizon assumed by the writer to correspond to that of the Exeter traps, viz., above the Watcombe and Petitor Conglomerate, and below the Teign-

* *Geol. Mag.*, dec. 5, vol. iii (1906), p. 313.

mouth and Labrador Inn boulder breccias. He readily admits that he may be mistaken in this. At any rate, the largest boulders and masses of igneous rock occur in the Teignmouth breccias.

On the other hand it is by no means certain that the Exeter, Poltimore, Killerton, Crediton, and Tiverton traps are on the same horizon. The local clusters in which they occur renders it probable that they came from different vents, and that these were not in eruption at the same time, so that there is sufficient antecedent probability for supposing eruptions to have taken place in the southern part of the area just after the deposition of the Watcombe clay beds.

The following passage is extracted from the account of the excursion of April, 1899* :—

“The President (Dr. Teall) thought that the red colour of the formation was mainly due to the subaërial decomposition of rocks containing ferriferous compounds, under conditions similar to those prevailing at the present day in India, the Southern States of eastern North America, Brazil, and parts of Africa, in short, to what might be termed the lateritic type of decomposition. Under this mode of decomposition the iron becomes oxidized, and deposited as a coating on the grains of quartz and other undecomposed minerals. The red material thus produced would mantle the slopes, fill up the hollows, or be spread out as flat fans over the low ground by torrential action. It would also be deposited in lakes, lagoons, or seas. In the presence of decomposing organic matter the ferric oxide would be reduced, the red colour would disappear, and the iron would take the form of a sulphide or carbonate. Thus the change in the colour seen near Axmouth at the junction of the Rhætic and Keuper was directly connected with the absence of fossils from the latter and their abundance in the former deposit.”

The following quotations from the Memoir on the Geology of the Quantocks are from Notes by Mr. H. H. Thomas on samples of the New Red Sands submitted to him :—

“The grains composing the sandstones below the pebble-bed are all well-rounded, the finer material of the breccias angular, of the pebble-bed sub-rounded, and of the Upper Sandstones and marls sub-rounded to angular according to dimensions. It is generally in the Lower Sandstone division that the rounding of the grains is most complete.”

“As in other districts garnets are more abundant in the upper beds. In Somersetshire, however, garnets occur together with blue tourmaline all through the various divisions of the New Red, whereas to the south their vertical distribution is more restricted.

“Ilmenite and its dependent tabular anatase is more abundant in the upper beds.

* *Proc. Geol. Assoc.*, vol. xvi, p. 141.

"Stauroilite continues as a constant and plentiful constituent of the pebble-bed from the south coast as far north as this horizon is exposed, and as in the southern district is more abundant in the lower divisions of the series.

"It is worth mentioning that this mineral is extremely common in the pebble-bed of the Midlands, occurring with the same associates and presenting identical characters. It appears likely that these two areas were connected (probably east of the Mendips) and that part of the material in each case was derived from the same source."

The most recent contribution to the geology of the New Red rocks of our district (*Geol. Mag.*, dec. 5, vol. v, 1908, pp. 150-157) gives the results obtained by Mr. E. C. Martin from a careful examination of the Lower New Red (Permian) Gravels of the Tiverton, Butterleigh, Silverton, Bradninch, and Thorverton districts. His researches prove conclusively that these gravels have been largely derived from Upper Devonian rocks of the fossiliferous types met with south of Wiveliscombe, and at Stawley in the northern outcrop. This is strongly suggestive of torrential drift from the north and north-east, whilst the apparent failure of the fossiliferous stones west of Thorverton, where igneous rocks are so abundant in the breccia, is attributed to torrential action from the west.

RHÆTIC AND LIAS.

These beds, though extending into Devonshire, are more conveniently described with the adjoining deposits of Dorset, and to the article on that county the reader is referred. (See Chapter XVII, *ante*, p. 382.)

CRETACEOUS.

Gault Clay was observed by Mr. De Rance at Pinhay; by Mr. Jukes-Browne in 1895 on the shore in front of Humble Green, below Whitlands Cliff, in a slipped mass; also to the west of Culverhole Point, where Conybeare in 1840 noted its possible occurrence; by the writer in 1874 in the railway-cutting at the eastern mouth of the tunnel east of Honiton.*

To account for this localisation of the Gault Prof. Clayden suggests its deposition in submerged valleys of the old land surface not wholly effaced by the planing action of the Cretaceous sea.†

West of Seaton the *Upper Greensand* is in faulted contact with the Keuper Marls. From the fault westward all the component beds of the Upper Greensand are successively brought down to the shore by the westerly dip in Whitecliff.

* *Mem. Geol. Surv.*, "Sidmouth and Lyme Regis," pp. 45 and 50.

† "History of Devonshire Scenery," p. 125.

The basement bed, consisting of about 20 feet of dark greenish argillaceous sand, was regarded as Gault by Meyer, who observed a bed of minute subangular pebbles of the underlying rocks near its base.* Above this the Upper Greensand is about 136 feet thick. The details in descending order are as follows:—

	ft.
Nodular, calcareous sandstone	8
Grey and yellow glauconitic calcareous sands and sandstones with nodules and masses of chert	60
Calcareous sandstone with many fossils	2½
Soft grey and green-grey sand with layers of calcareous sandstone (Foxmould)	50
Dark greenish sand with flattish masses of calcareous sandstone (Cowstones)	15

The Rev. W. Downes† divided the Upper Greensand of the Haldons and the Blackdowns into 15 zones.

The three upper beds (viz., *Orbitolina* chert 6 feet, schorlaceous sand 8 feet, shell beds in sand about 2 feet) he considered peculiar to Haldon, above the Blackdown beds.

The next three beds (viz., sand with cherty sandstone layers with *Pecten quadricostatus*—35 feet on Haldon, 25 feet and passing up into chert in the Blackdowns; sand with impersistent, broken, worn shell bands—18 feet; and fossiliferous sandstone layers with sand partings—about 3 feet) are common to Haldon and the Blackdowns.

The next eight beds belong to the Punchey Down Whetstone beds of Blackdown, consisting of concretions in layers and beds in, or alternating with, sand, taken together—about 20 feet. The lowest bed is whitey-brown unfossiliferous sand about 30 feet thick.

Prof. Clayden‡ tells us that among the cherts and harder sandstones sponge spicules are to be seen in immense numbers, and that the glauconitic grains which colour some of the sand beds under the microscope are recognised as internal casts of the shells of foraminifera, formed, as off the coasts of Georgia and South Carolina at the present day, by the deposition of the green mineral inside minute calcareous skeletons and in the interstices of shells.

Mr. Jukes-Browne considers the schorlaceous sand the highest bed of the Haldon Greensand, and takes it as evidence of the exposure of the eastern and northern borders of the Dartmoor Granite on the shores of the Selbornian Sea.§

As regards the *Chalk*, Dr. A. Rowe and Mr. C. Davies Sherborn|| single out "the fine inland Cliff of Pinhay," which

* *Quart. Journ. Geol. Soc.*, vol. xxx, p. 370.

† *Quart. Journ. Geol. Soc.*, vol. xxxviii, p. 75.

‡ "History of Devonshire Scenery," p. 128.

§ "The Cretaceous Rocks of Britain," vol. i, p. 405, *Mem. Geol. Sur.*

|| "The Zones of the White Chalk of the English Coast, Part iii, Devon," by Dr. Arthur Rowe. Cliff Sections by C. Davies Sherborn. *Proc. Geol. Assoc.* vol. xviii, p. i.

attains 400 feet above sea level, and "stands back 220 yards from the coast," as affording "the solitary accessible junction on this coast between the zones of *Terebratulina gracilis* and *Holaster planus*, and between *Holaster planus* and *Micraster cor-testudinarium*. The evidence of the removal of higher beds by denudation is furnished by flint casts of fossils typical of the *Micraster cor-anguinum*-zone, and by the discovery by Mr. F. G. Collins, of Exeter, of a flint cast of a well-preserved *Marsupites* plate."

It would be waste of time and labour to try to summarise the contents of that splendid paper. Plates I and II show the position of the zones in Pinhay Cliff and Chapel Rock. Plates III and IV, the coast on either side of Seaton. In Plate IV, the Greensand faulted down at Seaton is shown with the overlying succession of Cenomanian limestone, *R. cuvieri*-zone, *T. gracilis*-zone, in part overlain by beds belonging to the *H. planus*-zone. Plate V gives the section at Connetts Hole, S.W. of White Cliff, and shows the positions of marked bands dividing the zones of *R. cuvieri*, *Terebratulina gracilis*, and *Holaster planus*, and of two marly flintless bands in the *T. gracilis*-zone, which is here about 70 ft. thick. The same bands are shown in Plates VI and VII, of Beer Harbour, East Ebb, and North side. In the cliffs on the north side the *M. cor-testudinarium*-zone is seen. In Beer Harbour, Plate VIII, the Greensand is shown at the base of the cliff. In Plate IX all the zones and their divisional lines, from the *M. cor-testudinarium*-zone at the top to the Cenomanian limestone at the base, are shown in Beer Head viewed from the west (the Hooken). The zones of *R. cuvieri* and *T. gracilis* in Hooken Cliff are shown in Plates X, XI, and XII.

The Beer stone is described (p. 28) as a freestone about 11 feet thick, forming the basal bed of the *Rhynchonella cuvieri*-zone. It is not "represented properly at Beer Harbour, and though it is better shown in the Hooken, where the adit for working it still exists, it has nothing like the thickness of that at the quarries." In a general section, Plate XIII, the relative positions of the localities photographed are shown. A synopsis of Zonal Measurements is given, p. 46.

This paper is not referred to in the article on Devon in the Victoria County History, as it was not published when that article was begun.

The Lower (Cenomanian) and Middle Chalk have been let down by a fault between Widworthy and Offwell, east of Honiton. The former consists of hard glauconitic and quartziferous limestone about 2 feet thick, upon 6 feet of rough yellowish fossiliferous calcareous sandstone. There is a freestone bed, about 5 feet thick, in the lower part of the Middle Chalk in the quarries near Widworthy, which probably represents Beer Stone. Lower and Middle Chalk also occur at Mem-

bury and near Chardstock. In the Membury outlier, Mr. Jukes-Browne estimated the thickness of the Lower Chalk at from 50 to 60 feet.*

TERTIARY.

In April, 1899, the gravels on Great Haldon were seen in a pit 766 feet above sea level. These were claimed as Eocene by Mr. C. Reid in 1898.† The writer had suggested a Tertiary age for a gravel, "near Staple Hill," on the summit of the Blackdowns (Burnworthy Farm) in 1878.‡ Mr. H. B. Woodward described a patch of sand and gravel ("Summary of Progress," 1901, pp. 53-59) on the Cretaceous plane about 500 ft. above the sea at Combe Pyne, near Lyme Regis.

The chief pits in the Bovey clays and lignites were visited in 1900. To these beds Heer had assigned a Miocene age,§ and Starkie Gardner had referred them to the Middle Bagshot,|| but Mr. Reid has not yet had the opportunity of forming an opinion by botanical investigation.

On the same occasions the excursionists saw the bordering gravels of Staple Hill and Woolborough, which dip from heights of 80 to 120 feet above the surface level of the basin at angles of 35° and more, under the clays and lignites.

These and the Milber Down gravels, which rise to 400 feet above the basin, and the gravels which extend for some distance up the slopes from Kingsteignton northward rest on New Red, Culm, and Devonian rocks, so that the Cretaceous rocks had been denuded away prior to their deposition, whilst the Haldon gravels rest on about 80 feet or so of Greensand. The correlation of the Haldon with the Bovey Basin gravels is therefore extremely problematical. It is, moreover, necessary to account for the discrepancy in level between the bottom of the basin, which in a sinking of 520 feet was not reached, and the top of Haldon. This discrepancy Prof. Clayden,¶ after allowance for dissolution of chalk, estimates at about 1,500 feet.

Prof. Clayden** regards the plateau gravels of Haldon as "primarily marine created in the first instance as shore and shallow water deposits due to the retreating sea, and considers that they have been rearranged, sorted, and distributed eastward by the various streams." "As the upheaval progressed, the beach line would retreat eastward." "If, now, we suppose that when the land began to rise and the Haldon gravels were the beach line, the general eastward slope was about five degrees steeper than it is now, we bring the two to a common level."

* *Mem. Geol. Surv.* "Sidmouth and Lyme Regis," pp. 57-60.

† *Quart. Journ. Geol. Soc.*, vol. liv, p. 235; see also *ibid.*, vol. lii, p. 490.

‡ *Quart. Journ. Geol. Soc.*, vol. xxxiv, p. 452.

§ *Phil. Trans.* (1862).

|| *Quart. Journ. Geol. Soc.*, vol. xxxv, p. 227.

¶ *Hist. of Devonshire Scenery*, p. 165.

** *Op. cit.*, pp. 153, 154.

Prof. Clayden gives reasons for the lessening of the slope through a more rapid upheaval in the east than the west, whereby a river depression in the position of the Bovey Valley would, through the raising of the barrier of Permian breccias, be converted into a lake, along the borders of which the gravels might mark the embouchures of streams that drained the neighbouring districts.

The Petrockstow clays must be included in the same category with those of the Bovey Basin, provisionally at least. Taken in connection with the traces of gravels with Cretaceous materials at Orleigh Court and near Rivaton Farm, all these phenomena seem to justify the attitude taken regarding them in the Victoria Counties History, viz., that they represent stages in Tertiary denudation of which the gravels on the Cretaceous plane, whether they be marine or fluviatile, of Bagshot age or earlier, are the oldest.

The clay with flints, as stated in the Victoria Counties History, is confined to the plateaux. "The upheaval and denudation of the Cretaceous sea bed, the deposition of argillaceous and loamy Tertiary materials, whether Woolwich and Reading beds or London Clay, and the subsequent solvent action of percolating water corroding the Chalk remnants or calcareous Selbornian beds and substituting clay or loam derived by filtration from the overlying materials, explain the local variations of the accumulation." The effect of Glacial conditions in aiding the distribution of the materials was suggested by the writer in 1878.*

PLIOCENE.

With reference to the Pliocene beds of St. Erth and St. Agnes, in the Geological Survey Memoir on The Geology of the Land's End District, by Mr. C. Reid and Dr. J. S. Flett, we read (p. 73): "The fossiliferous strata occur at 100 ft. above present sea-level. The land rises rapidly to the south-east." Littoral shells, and those which inhabit sheltered creeks, are absent from the clays, the character of which points to deposition in fairly still water; the partial exposure of the area to the Atlantic swell would hardly favour such deposition at a less depth than 50 fathoms. The total depression of the area is estimated at about 400 feet, making Cornwall an Archipelago, in which the high land close to St. Erth would be a submerged shoal.

Mr. Reid has expressed a similar opinion in *Nature*, August 12th, 1886, which was combated by Mr. Bell (*Rep. Brit. Assoc.*, 1887, pp. 718-719), who considered that the majority of the shells indicated a laminarian zone not exceeding 15 fathoms.

* *Quart. Journ. Geol. Soc.*, vol. xxxiv, pp. 449, 453; see *Ibid.*, vol. lxii, pp. 160, 161

Thanks to the Royal Geological Society of Cornwall, the Members of the Association who visited St. Erth in August, 1887, were afforded exceptional opportunities for studying the Pliocene beds. (See *Proc. Geol. Assoc.*, vol. x., pp. 206-207.) Although fossils have not been found in the clays of St. Agnes, they have been referred to the same period. The Pliocene shelf, without contemporary deposits, has been detected in other parts of Cornwall at 400 feet or thereabouts above ordnance datum.

PLEISTOCENE AND RECENT.

Of the earlier deposits of the Pleistocene period we only possess such traces of fluviatile deposition as from their height above the valley bottoms can be confidently attributed to a period anterior to the raised beaches. Such gravels are met with forming remnants of old terraces at Exeter, near Holne Bridge, at about 50 feet above the Dart*, and in many other places; but they are at best fragmentary, and have yielded no organic remains. The Gravels of the Axe, with worked flints, belong to a long subsequent stage, when the valleys had been eroded to their present depths.

Kent's Cavern was visited twice—in 1884 under the guidance of Pengelly, and in 1900, under Mr. A. R. Hunt. R. N. Worth described the caves of the Plymouth District on July 21st, 1884, and the Hoe Raised beach. The Hopes Nose Raised beach and Torbay submerged forest were seen under Pengelly's direction a few days later.

Good sections of Head were seen on the Prawle coast in the Easter excursion, 1901, and at Bovisand on the Easter excursion, 1907.

Mr. R. H. Tiddeman's discovery of the subordination of the raised beaches to Glacial deposits on the South Wales coast in 1900,† supplemented and confirmed by the observations of Messrs. Muff and Wright in 1904 on the South Coast of Ireland,‡ have marked a new departure in the Pleistocene Geology of our district.

The existence of Glacial deposits in the Scilly Isles, which had been surmised by Nicholas Whitley in 1881,§ was proved by Mr. Barrow's discovery of striated erratics, announced in the Summary of Progress for 1903.|| Mr. Reid, in company with Prof. Nathorst, traced the striated fragments of grit to 140 feet or more above ordnance datum on St. Martin's Head.¶

Maw, in 1864,** described the clay of Roundswell, north of

* *Trans. Devon. Assoc.* (1876), vol. viii, p. 231.

† *Rep. Brit. Assoc.*, for 1900, p. 760, and see *ante*, p. 851.

‡ *Sci. Proc. Roy. Dublin Soc.*, vol. x, pp. 250-324.

§ *Trans. Roy. Geol. Soc. Corn.*, vol. x, p. 134.

|| At page 31; and see *Mem. Geol. Surv.* "Geology of Scilly."

¶ *Geol. Mag.*, Dec. 5, vol. v (1908), p. 188.

** *Quart. Journ. Geol. Soc.*, vol. xx, p. 447.

Tawstock Park, as a boulder clay, and from the stones found in it by Mr. Inkermann Rogers it would appear that his description is justified.

Nicholas Whitley, from the granite boulder in the Saunton raised beach and the gravels at and south of Fremington, had referred the raised beaches to the Drift or Glacial Period in 1852, and he seems to have been inclined to include the Head and stream tin in the same category.*

In the writer's classifications in 1878† and 1879‡ the stream tin deposits were classed with the Head as coeval with Prof. James Geikies' Second Glacial Period, the forest growth being regarded as Post-glacial and the raised beaches as Inter-glacial.

Mr. Codrington§ disputed the priority of the raised beaches to the stream tin gravels with which he correlated certain stony-clay bottom deposits in the submerged rock valleys of the Plymouth estuaries. These Mr. R. H. Worth|| also regarded as boulder clay.

Mr. A. R. Hunt in 1888¶ cited certain shells in the Thatcher Rock raised beach as evidence of a rather colder climate.

There can hardly be any doubt that during the raised beach period bergs capable of transporting large boulders, such as that of Saunton, stranded on our coasts, and this at a time anterior to the boulder clay of the south coast of Ireland and the glacial deposits of the South Wales coast. The Roundswell Clay and the Scilly Island's erratics may be due to continued subsidence in these localities, for the Head could only have been accumulated during a period of elevation, and the chiselling out of the rock valleys demands a similar explanation. The stream tin gravels may, in fact must, be of different ages, owing to their occurrence at the base of the assumed Pliocene deposits of St. Agnes beacon, but those found in the rock valleys evidently belong to the same period, and this was succeeded by forest growth during the ensuing subsidence, which culminated in oscillations between fluvial and estuarine conditions, and permitted for a time the readvance of the wood-growth on the foreshore.

The correlation of the Cave deposits with these events is quite problematical.

* *Trans. Roy. Geol. Soc. Corn.*, vol. vii, p. 236-238.

† *Quart. Journ. Geol. Soc.* vol. xxxiv, p. 457.

‡ *Geol. Mag.*, dec. 2, vol. vi (1879), p. 262, and "Cornish Post-Tertiary Geology" 1879), p. 50.

§ *Quart. Journ. Geol. Soc.* vol. liv, 265-268.

|| *Trans. Devon Assoc.* vol. xxx (1898), pp. 378-390.

¶ *Ibid.*, vol. xx (1888), pp. 225-252.

GEOLOGICAL MAP
of
CORNWALL
by
W.A.E. USSHER.

INDEX.

Upper Devonian	UD UD
Middle Devonian	MD MD
Staddon Grits	S S
Lower Devonian { Meadfoot Group	m m
Grampound Grit	g g
Dartmouth Slates	d d
Ordovician { Veryan Beds	v v v
Portscatho Beds	P P
Falmouth Beds	F F
Mylor Beds	M M
Dodman Phyllites	D D
Hornblende & Schists	[Hatched Box]
Basic Igneous Rocks	[Solid Black Box]
Serpentine	Σ Σ