CHAPTER XXIV.

STAFFORDSHIRE.

By WHEELTON HIND, M.D., F.G.S.

INTRODUCTION.

THE three geographical divisions of the County of Stafford, North, Mid, and South Staffordshire, are due to the geological structure underlying each.

North Staffordshire is largely composed of Lower Carboniferous rocks, enclosing four coal basins, and is hilly and mountainous, deeply intersected by valleys and ravines, in which are the sources of the Trent and its important tributaries, the Hamps, Manifold, and Churnet. The hills reach a height of 1,500 to 1,700 ft. above O.D., the Millstone Grit hills of the Roaches and Axe Edge being higher than the limestones of the central axis. These Carboniferous rocks afford various types of scenery according to their composition. The limestone hills are all dome-shaped and almost treeless. The Pendleside shales form moors and uplands, often covered with peat and heather. The grits form edges which are often ragged and battlemented, undercut by sand-blast. On the west of the Pennine scarp are the Red rocks of the Cheshire plain which sweep round the southern end of the Pottery coalfield, and obscure it. Outliers of Trias here and there are found resting unconformably on various members of the Carboniferous series, but never above the 900 foot contour.

Mid-Staffordshire is an undulating plain drained by the Trent which has very little fall. This division of the county is occupied by various members of the Triassic rocks, and a small patch of Rhætic beds in the high ground of Needwood Forest. This is the pastoral and agricultural part of the county, which intervenes between the two thickly-populated Carboniferous areas. The highest point of Cannock Chase reaches about 900 feet above O.D. at Castle Hill in Beaudesert Old Park. It is probable that the Coal Measures are continuous from north to south below Mid-Staffordshire, but at present no details are to hand to calculate their depth below the Trias.

South Staffordshire is a gently undulating plain, 400 to 500 feet above O.D. A large part of this area is occupied by Coal Measures forming the South Staffordshire coalfield. Its margins pass beneath Triassic rocks. In this coalfield are several inliers of Silurian rocks. About the centre of the field are two, those of Sedgley and Dudley; and another is in the east at

Walsall, which rises to a height of 700-800 feet above O.D.—Sedgley Beacon is 760 feet, Dudley Castle Hill 730 feet, Wren's Nest, 730 feet, and Barr Beacon 800 feet.

By far the larger portion of the river drainage of the county belongs to the Trent basin, but in the north a few small streams join the Dane, which, forming a part of the northern boundary of the county, belongs to the Mersey system. Notable is the stream which drains the upper part of the Biddulph Valley, which must have once been one of the headwaters of the Trent, but has now cut its way back and flows north into the Dane. On the extreme west and south-west small streams join the Severn basin by way of the Tern, Meess, Werf, and Stour. In the Limestone district swallow-holes are numerous, and the Hamps and Manifold run an underground course for several miles.

The following table shows the various rocks found in the county:

TABLE OF STRATA.

River Gravels and Sands, Peat Beds and Alluvium.

Glacial. Boulder Clay, Sands and Gravels.

Pre-Glacial River Gravels.

Rhætic.

Keuper. { Keuper Marl.
 { Waterstones.
 { Upper Variegated Sandstones.

Bunter. { Pebble Beds.
 { Lower Variegated Sandstones.

Coal Measures : Maximum thickness about 7,000 ft.

Keele Group : Red Sandstones, Red Marls, thin Limestones with *Spirorbis*, and thin Coal Seams.

Newcastle-under-Lyme Group : Red Marls, Grey Sandstones, Marls with thin Coals and Limestones.

Etruria Marl Group : Red Marls, Green Grits, and thin Coals and Limestones.

Blackband Group : Grey Shales, Marls, Sandstones, thin Coal Seams, Blackband Ironstones, and thin Limestones. Zone of *Anthracomya phillipsi*.

Coal-bearing Measures : Sandstones, Clays, Fire Clays and Shales, Coal Seams and Clay Band Ironstones. Zones of *Anthracomya wardi*, *A. adamsi*, *A. williamsoni*, and *Carbonicola robusta*.

Lower Coal Measures : Coals, Grey Shale and fine Grits. Zones of *Gastrioceras listeri* and *G. carbonarius*.

Millstone Grit Series : Two to five beds of Grit separated by Shales and thin seams of Coal ; 1,200 to 300 ft. thick, rapidly thinning to the south.

Pendleside Series: Thickness 1,000 ft. to 1,200 ft. Shales, Crowstones, and Gannister Sandstones, with dark bands of limestone at the base, containing from below upwards the zones of *Posidonomya becheri*, *Glyphioceras reticulatum*, *G. spiralis*, *G. bilingue*.

Visean. Carboniferous Limestone (?) 1,700 ft. to 2,000 ft., the base not seen.

Cyathaxonia beds.

Upper *Dibunophyllum* beds,

Lower *Dibunophyllum* beds.

Silurian. Aymestry Limestone.

The Ludlow Shales and Wenlock Limestone and Shales.

Woolhope beds.

Mayhill Sandstone or Upper Llandoverly.

Intrusive Rocks of Rowley Regis, Pouk Hill and Clayton Edge.

Geologically the eastern limb of the broken anticlinal, which forms the west flank of the Pennines from Congleton Cloud southwards to Mow Cop, must be considered to come within the scope of this account of the geology of Staffordshire, although geographically it is included in Cheshire, and it will be found necessary on the east to trespass into Derbyshire to some extent; the general sequence in both counties being practically identical, with the exception that while 1,500 feet of limestone is seen in Derbyshire, probably little more than the upper 800 feet are visible in Staffordshire.

The geology of the north part of the County of Stafford is determined by the Pennine system of folding which took place in pre-Triassic times, and was not fully developed until the close of the Carboniferous period. Owing to the strain of the uplift, the upper beds were fractured and became tilted east and west, while in the centre the older or Lower Carboniferous rocks were thrust through the rent in the upper beds. Owing to differences in composition and stability of the various strata in the Carboniferous sequence, the uplift was not a simple one on the western flank, but several secondary buckles and folds took place, which were complicated by transverse fractures (Fig. 101). On the east, or Derbyshire side, the dip is more gentle and regular and the sequence less disturbed than on the west, or Staffordshire side, where the dip of the limestone is more sudden and the Pendleside shales have slipped and rucked up, so that only at Congleton Edge is there a normal sequence exposed. Denudation has also played a part in the exposure of the older rocks. Geographically the Pennine range extends into Staffordshire, and may be said to terminate along a line passing from the south of the Weaver Hills to the southern boundary of the Pottery coalfield. On either side of the Pennine uplift

Triassic rocks lie unconformably on all members of the series, but coalesce south of the Weaver Hills and form the series of undulating lowlands which occupy Mid-Staffordshire.

On the west the whole Carboniferous series is cut off by the Red rock fault which runs almost north and south for the greater part of its course, but towards its southern end has a south-westerly direction; it is connected with many other faults. The Red rock fault brings up beds of Bunter Sandstone and Red rocks of the Cheshire plain, against Pendleside series, Carboniferous Limestone, Millstone Grit, and Coal Measures, and as the Triassic side of the fault has moved it shows that this movement, though mainly pre-Triassic, was continued after Triassic times. It is along this line at the Astbury lime works that volcanic disturbance took place in Carboniferous times.

In the south of the county the Lower Carboniferous rocks are absent, except in the Cannock Chase district, where they rest unconformably on different members of the Silurian. The earth movements, therefore, which determined the geology of the south of the county are of much older date than

the Pennine uplift, and do not appear to have been much influenced by it. The diminution in thickness of the lower Carboniferous deposits as they pass south indicates that the sea in which they were laid down was bounded by a ridge of land which stretched across the country from Mid-Wales via the Wrekin to Charnwood, on the flanks of which only thin deposits of Lower Carboniferous rocks were ever laid down, but before Coal Measure time the land had sunk and permitted that overlap of Coal Measures which now forms the South Staffordshire coalfield.

SILURIAN ROCKS.

The oldest rocks found in Staffordshire occur as inliers in the Coal Measures at Walsall and, as shown by their fossil contents, belong to the May Hill Sandstone group of the Upper Llandovery series. They consist of variously-coloured sandstones. The series here consists of the following representatives about 1,000 feet thick:

At the base is the May Hill Sandstone, which contains *Stricklandinia lens*, *S. lirata*, and the trilobite *Encrinurus punctatus*. These beds are succeeded by the Barr Limestone characterised by *Illænus barriensis*, which is therefore the representative of the Woolhope beds, but much diminished in thickness. This bed is overlain by Wenlock shales and it, in turn, by the Wenlock Limestone, which here consists of two limestones, each 20-30 feet thick, separated by a bed of nodular limestone. Exposures are to be seen in railway cuttings and disused quarries, but opportunities of collecting fossils are now rare.

The Silurian inliers of Dudley Castle and the Wren's Nest are of Wenlock limestone overlain by Lower Ludlow shales. The limestones have yielded large numbers of typical fossils. As at Walsall, it consists of two limestones, separated by about 80 feet of calcareous shales. The limestones have been largely mined underground, to be used as a flux in the manufacture of iron. The shales yield well-preserved brachiopods and corals, but owing to the fact that the limestones are almost worked out few trilobites can be obtained now.

At the Sedgley inlier the Aymestry Limestone is present as a bed 25 feet thick lying on the Lower Ludlow shales. It has yielded the typical fossil *Pentamerus knighti*. Two other small inliers of Ludlow shales occur at Turner's Wood and The Lye; these shales enclose a thin limestone.

There is therefore reason to believe that the floor of the South Staffordshire coalfield consisted entirely of members of the Silurian series, but it is very probable that rocks of Cambrian and Pre-Cambrian age would be found below the Carboniferous rocks buried by the Trias of Mid-Staffordshire on a line between the Wrekin and Charnwood.

THE CARBONIFEROUS LIMESTONE SERIES.

Nowhere, either in Staffordshire or Derbyshire, is the base of the Carboniferous Limestone to be seen, and there are no local data whatever as to the absolute thickness of the series or as to what strata underlies them. If, however, the series is compared to that which obtains on the other side of the Cheshire plain at Minera in Denbighshire, about 37 miles west of the limestone inlier at Newbold-by-Astbury, the base of the limestone is seen lying unconformably on rocks of Bala age, and there are definite palæontological grounds for assuming that at Minera the base of the limestone is represented by 200 to 300 feet of beds of Upper *Seminula* age, a zone which is apparently not exposed in the Staffordshire-Derbyshire inlier.

Again in Leicestershire, 25 miles south-west of the most southerly outcrop of the limestone of Derbyshire, the Carboniferous Limestone is represented by only about 500 feet of the upper or *Dibunophyllum* zone, and its base rests unconformably on the pre-Cambrian rocks of Charnwood Forest.

In other directions the base of the Carboniferous rocks is not known nearer than North West Yorkshire, where, at the base of Ingleborough, rocks of Upper *Seminula* age rest on a pebbly conglomerate, which itself lies unconformably on the upturned edges of members of the Coniston series and other Ordovician or rather probably Cambrian rocks (Ingleton granite). In Belgium the Carboniferous Limestone is divided into two series, the Upper or Viséan, and the Lower or Tournaisien, and, as the Carboniferous sea deepened towards the east, it may be surmised that the base of the limestone in the Stafford-Derby inlier is from 300 to 500 feet below the lowest beds exposed—i.e., below the base of the Miller's Dale section—and that *Seminula* beds were laid down in the county, and that the pre-Carboniferous floor is probably of Silurian, Ordovician and Cambrian age.

The Carboniferous Limestone itself consists of both well-bedded limestones, and massive limestones whose bedding is extremely obscure, in practically one series from the top to the bottom. Here and there a thin shale-parting separates two beds. In the upper part of the series shale-partings occasionally are thicker and the limestone encloses strings and nodules of dark chert, a mineral distinctive of the upper part of the series. The colour of the limestone varies from light grey to blue and a dark, blackish colour. In places it is deeply stained with red hæmatite, and in others, e.g., the valley of the Manifold, at Swainsley, the upper end of Narrowdale, a good deal of dolomitisation has taken place. These two localities are in the neighbourhood of mineral veins. The great district of dolomitisation is across the border in Derbyshire, where a considerable area, Brassington rocks, and another patch along the Old High Peak Railway

from Long Cliffe Wharf to Wirksworth, are very much dolomitised.

In that part of the limestone inlier which comes within the borders of Staffordshire, the river drainage is from north to south; consequently the Manifold and Dove have cut out their valleys along the strike of the beds, and no extensive section is exposed by them other than the depth of the valley. The Hamps, which cuts across the strike, passes through an area where the same beds are repeated by a number of parallel folds, so that its channel is practically in the same beds for the whole of its course through the limestone country. Unfortunately, too, the passage of the limestone upwards into the Pendleside shale series is only to be seen at a few places, elsewhere the junction is either faulted or disturbed by the unequal movement of the rigid limestone below, and the more fragile shales above, during the Pennine upheaval.

The best sequence of limestones in Staffordshire is at Waterhouses, where a series of old and recent quarries expose some 500 ft. of beds, the dip of which gradually increases till the lowest beds seen are almost vertical.

The section of limestone commences in the river Hamps, where black shales of the Pendleside series are faulted against it. In a disused quarry on the west of the river are seen a series of limestones crammed with shells of large *Producti*, varietal forms of *P. giganteus*, often considerably rolled and mixed with well-rounded shell fragments. This bed does not represent the top of the series, for the *Cyathaxonia* beds are absent here, though higher up the hill in two quarries north-east and north-west of Field House these, the uppermost beds are exposed, and yield the typical fauna. A rolled shell bed is known at Castleton, on the northern margin of the inlier, and at Dibbles Bridge, near Grassington, Yorkshire, having about the same relation to *Cyathaxonia* beds. The rolled character of the fossils conclusively indicates that they were subjected to movements as they lay on the sea bottom by currents of water, probably due to other causes than mere advance and retreat of the tides. Beneath the rolled shale bed are some two or three hundred feet of well-bedded limestones, often fairly fossiliferous. Some beds are crinoidal, and have furnished in days gone by slabs for ornamental marble work. The fossils consist of large coral stools of *Cyathophyllum regium*, *Lithostrotion portlocki*, *L. irregulare*. *Campophyllum derbiense* and other single corals are not rare, but, curiously enough, the typical coral of the zone, *Lonsdalia floriformis*, has not been yet obtained on the Staffordshire side, though it is common enough on the eastern margin of the limestone anticlinal. With the corals are a very typical set of upper limestone brachiopods, and in some of the beds many teeth and spines of fish. *Fenestella* and other Bryozoa are not uncommon. The lowest beds in the sequence are almost vertical,

and are more thinly bedded than those above. These beds are almost unfossiliferous, and yield when burned a hydraulic lime. North of this quarry a series of much-contorted beds is to be seen along the light railway. These, I believe, are somewhat higher than those seen in the Waterhouses quarries, and therefore there must be a fault between them and the vertical bedded limestones.

The large range of quarries at Cauldon Low afford fine sections. They are mostly in very unfossiliferous beds; but they contain a fauna peculiar to themselves which has not been obtained anywhere else in the area. The dominant fossil is *Productus humerosus*, and it is associated with *Chonetes* aff. *comoides* and *Orthis* aff. *crenistris*, *Bellerophon apertus*, *B. cornuarietis*, *B.* sp., a very large form of *Naticopsis*, *Syringopora*, and *Myalina*, sp. I have always considered that these beds were probably the lowest limestones exposed in Staffordshire, and I note that Dr. Sibly inclines to the view that the beds are low down in the series.* But *P. humerosus* occurs in Yorkshire, in the Swinden Moor quarries in beds of probably *Cyathaxonia* age, and certainly not below the Upper *Dibunophyllum*-zone. It is also said to have been obtained at Clitheroe, where the beds are high up in the *Dibunophyllum*-zone, and at Breedon Hill, Leicestershire; but from the last locality only one other fossil is stated to have been obtained—*Syringothyris cuspidata*, on the authority of Davidson. For the present, therefore, we have not sufficient palæontological evidence to say much as to the value of *P. humerosus* as a zone fossil; it is evidently at its maximum at the Cauldon Low horizon, and is accompanied by a curious variety, in which the mesial fold becomes occupied by a sharp ridge furnished with spines. I understand that *P. humerosus* occurs at the base of the Viséan in Belgium.

The great mass of the Weaver Hills, which lies to the south of Cauldon Low does not give many exposures; consequently that part of the district has never been examined from a palæontological point of view to the extent that has obtained elsewhere in North Staffordshire. I can only state that gigantic *Producti* occur in quarries near Wootton with a sparse brachiopod fauna characteristic of the Upper *Dibunophyllum*-zone. Probably the same beds occur everywhere, for the mass dips east, south, and west on each flank respectively, being the southern extremity of the periclinal mass of the Stafford-Derby limestone.

It may be stated as a fact that the upper beds are far more fossiliferous than the lower, and that the upper beds are always cherty. They are sometimes thinly-bedded and dark in colour, at others almost white, the bedding planes being difficult to make out, and they are crammed with fossils. These fossil beds are most interesting, and at the same time their exact

* *Quart. Journ. Geol. Soc.*, vol. lxiv (1908), p. 44.

horizons are obscure, and this is so whether they occur in the district under description or in similar conditions in Yorkshire and the Isle of Man. In the area under discussion such fossil shell beds occur at Thorpe Cloud, Narrowdale, Wetton, Park Hill, and Castleton. They consist of masses of brachiopods, with more or less intervening limestone mixed with lamellibranchs, gasteropods, cephalopods, bryozoans, and rarely single corals. The larger shells are filled with smaller ones, and there is much shelly débris. A large number of the brachiopods have the valves in contact, but lamellibranchs more frequently have them separated. The shells in most cases are beautifully preserved, and some possess their original colour bands and delicate shelly structures, so that they cannot have been rolled or brought far. On the other hand, the faunal list from any of these shell-beds contains forms which must have required different bathymetric conditions. The local condition of these shell-beds is very marked, and in no case is it easy to trace their exact position in the stratigraphical sequence or demonstrate their relationship to beds of well-bedded limestones obviously on the same horizon, if one may judge from the comparison of parallel sequences and the local fauna. At Thorpe Cloud the shell-beds seem to underlie the thin cherty limestones on which the village of Thorpe stands. These I take it represent the *Cyathaxonia* beds. At Narrowdale and Park Hill the shales of the Pendleside series are in each case seen dipping off the fossiliferous limestones, but the passage is either incomplete or faulted. It can, however, be stated with certainty that the shell-beds belong to the Upper *Dibunophyllum*-zone, a conclusion also arrived at by Dr. Sibly.* *Zaphrentis enniskilleni* has been obtained at Narrowdale.

The *Cyathaxonia* beds are much more strongly developed on the Staffordshire or western side of the limestone series than on the Derbyshire or eastern side. There is a fine series of quarries at Warslow, between the road to Hartington and the river Manifold in its gorge at Apes Tor.

These show a succession of about 300 ft. of thinly bedded limestones and shales, with strings and nodules of chert. The characteristic fossils of the zone are fairly common, and are best obtained in the joints where they weather out of hard limestones. A portion of the series are seen much contorted in the gorge of the Manifold at Apes Tor. Probably the uppermost bed of the series is to be seen in two places—one in a disused quarry in a field south of the Hartington Road, and again above the old lime kiln at the commencement of the gorge at Apes Tor. Here, immediately below in the bed of the river Manifold, black shales of the Pendleside series are to be seen, but

* *Op. supra cit.*, pp. 49-50.

there is no direct sequence between them. However, about one mile south of this spot near the house marked Pepper Inn on the 1-inch ordnance map, a fine series of *Cyathaxonia* beds, exposed in the gorge which runs down to Wetton Mill, is seen to pass up conformably into the black limestones and shales of the Pendleside series, with a typical fauna of *Posidonomya becheri*, *Posidoniella minor*, *P. lavis*, *Aviculopecten losseni*, *Glyphioceras striatum*, *Nomisomoceras rotiforme*, and *Orthoceras* sp.

An interesting series of the passage beds from the *Cyathaxonia*-zone to the Pendlesides is to be seen at Butterton Moor quarries. Here the top of the limestone seems to break up into alternating beds of limestones, sandstones, and shales. The limestones are crammed with brachiopod fragments and carbonaceous material. These beds are succeeded by the *Posidonomya* shales of the Pendleside series.

West of the main mass of limestone are the two small outliers of Butterton and Mixon, surrounded by the beds at the base of the Pendleside series. At Butterton some of the exposures have yielded a fairly rich brachiopod fauna typical of the Upper *Dibunophyllum* beds; but the Mixon series are much

FIG. 102.—SECTION THROUGH THE PERICLINE OF THE ASTBURY LIME WORKS.—W. Gibson and W. Hind.
(Reproduced by permission of the Council of the Geological Society)

altered by mineral veins and are cherty. No fossil lists have been published, but from their position relative to the *Posidonomya becheri* beds which succeed them they ought to belong to the *Cyathaxonia* horizon. A quarry just opened at Butterton shows black shales with *P. becheri*.

Eleven miles farther west is the interesting periclinal inlier of Newbould, near Astbury (Fig. 102), exposed in a large quarry, where the limestone is now reached by a long adit. The limestones here are dark blue in colour, and are thickly bedded, often stained by hæmatite. Fossils are somewhat scarce, but *Lithostrotion martini*, *Dibunophyllum*, sp., *Zaphrentis enniskilleni*, and other corals are obtained; *Productus pustulosus*, *P. punctatus*, *P. longispinus*, *Chonetes compressa*, Sibly, *Schizophoria resupinata*, *Spirifer bisulcata*. Some beds are largely crinoidal.

These are succeeded by earthy limestones and shales about 40ft. thick, in the midst of which is intercalated a bed of tufaceous ash, which has baked the shales with which it is in contact above and below. This set of limestones and shales form a series of passage beds into the Pendleside series, and contain small corals—*Cyathaxonia* and *Amplexi-zaphrentis*, *Loxonema*, also Trilobites and *Prolecanites compressus*. At the north end of the old quarry is a mass of igneous rock which has the character of an agglomerate. In it are imbedded masses of marmorised limestone-corals, such as *Campophyllum derbiense*, as well as brachiopods and gasteropods. The mass suggests a neck.* A brook section 250 yds. north of this mass gives the following descending section:

	ft.	in.
Tufaceous limestone	4	0
Gap, a few feet.		
Small coal	0	5
Hard calcareous nodular rock	0	3
Gap	2	6
Flaggy calcareous sandstones, passing into shale	5	0
Limestone with producti and crinoids	1	2
Black shales with nodular concretionary limestone	3	0
Encrinital limestone	1	3
Tufaceous limestone	8	0
Tufaceous limestone	1	9
Tuff, much decomposed	120	0
Gap	130	0
Coarse tuff, with fragments of limestone	100	0
Tufaceous limestone with fossils	2	0
Well-bedded calcareous tuff	6	0
Massive limestone	3	0
Hard tuff	8	0
Tufaceous limestone	0	8
Well-bedded calcareous tuff	1	11
Thin, hard tufaceous limestone	0	2

* W. Gibson and W. Hind. *Quart. Journ. Geol. Soc.*, vol. lv, p. 548.

	ft.	in.
Tuff	1	0
Hard limestone	3	0
Gap	12	0
Tulaceous limestone	2	0
Tuff, coarsely laminated	5	0
Limestone passing into calcareous tuff	2	6
Yellowish-brown tuff	6	0

Igneous conditions therefore lasted for some time, and more or less interfered with animal life; but at times the conditions enabled it to flourish, and many of the beds were laid down mingled with volcanic material. It is most important to note the presence here of *Prolecanites compressus*, which is typical of the upper part of the *Cyathaxonia* beds and the lower Pendlesides, in other parts of the Midlands, Yorkshire, and the Isle of Man. It is probable that the poverty of the fauna and the absence of the *Posidonomya* beds at this locality are due to the prevalence of volcanic disturbances.

In one other locality, recently described by Mr. G. M. Cockin,* traces of the upper beds of the Carboniferous Limestone have been found, namely, in a sinking and boring at Fair Oak, No. 1 pit of the Cannock Chase Colliery. This sinking was made in 1875, and after an interval of almost 30 years fossils which must have come from the base of the sinking were brought to Mr. Cockin, who showed them to the writer. Small corals referable to *Amplexi-zaphrentis* and *Cyathaxonia* were abundant, and they were associated with a number of brachiopods of Upper *Dibunophyllum* facies. So it may be definitely stated that these fossils demonstrate the horizon of the *Cyathaxonia* beds. Previous to this discovery no Lower Carboniferous rocks had been known to exist below the Coal Measures of South Staffordshire, which certainly in the greater part of its extent lies unconformably on Silurian rocks of varying age.

It is known that the Carboniferous Limestone is represented at Lilleshall by less than 150 ft. and at Wellington by 50 ft. of strata. These localities are some 22 miles west of the Fair Oak sinking, so that in this latitude there was a rapid diminution of the Limestone at the expense of its lower members.

The whole of the Carboniferous Limestone of Staffordshire belongs to the Upper or Viséan Division. It is probable that nowhere in England south of Ingleborough, except in the Bristol district, the Mendips, and South Wales, are there any representatives of the Tournaisian beds of Belgium. The lowest carboniferous beds of the North are to be found in Ravenstonedale and round Arncliffe and Kendal. They are referable to the *Seminula* Beds and some of the beds in Pinskey Gill, Ravenstonedale, are probably Tournaisian.†

* *Quart. Journ. Geol. Soc.*, vol. lxii, p. 523.

† See *post*, chap. xxvii, p. 648, and chap. xxviii, p. 683.

THE PENDLESIDE SERIES.

The Pendleside series is remarkably well developed in North Staffordshire, being exposed in the valleys of the Hamps, the Upper Manifold, and the Dane, and in many small streams which flow into these rivers. The series consists of black limestones with shales at the base, a shale group in the middle, and sandy shales, crowstones, and grits at the top, clearly a transition series between massive limestone and grits. The whole series reaches a thickness of about 1,000 ft. in North Staffordshire, and occupies the elevated moorlands of the north of the county. The upper limit of the series is taken at the base of Farey's Grit. The passage from the Limestone up into Pendleside is, as has been stated above, rarely seen, but the locality of Pepper Inn has been mentioned (p. 573), and also the old quarry near Astbury (p. 574), and a third exposure has recently been made opposite the school at Butterton. Palæontologically the series is interesting on account of the life zones which can be recognised in it. While in Staffordshire there are about 1,000 ft. of beds included in the series, in Leicestershire, only 25 miles south-west, the beds have thinned to 150 ft., and to practically nothing in the coalfields of Cannock Chase and Coalbrookdale. Immediately the series comes on, a group of lamellibranchs and cephalopods make their appearance, many of them for the first time; but other forms which are rare below reach their maximum, and a very large percentage of organisms which flourished previously are not met with again. The lamellibranchs which are of special importance are *Pterinopecten papyraceus*,* *Posidonomya membranacea*, *P. becheri*, *Posidoniella lævis*,* and the cephalopods are *Prolecanites compressus*, *Glyphioceras striatum*, *Nomismoce as rotiforme*, *Orthoceras konincki*. All these forms, with the exception of those marked * are confined to the base of series, and the plant *Andiantites antiquus* is associated with them. The Black shale series which succeeds these limestones is characterised by *Glyphioceras reticulatum*, *G. phillipsi*, *Orthoceras steinhaueri*. Still higher beds are characterised by *Glyphioceras spirale* and *G. diadema*, and the upper part of the series by *Glyphioceras bilingue*.

The fish fauna, which is found in the limestone ceases and a new one comes in with the change in the molluscs—*Elonichthys aitkeni*, *Acrolepis wilsoni*, and other forms, a list of which are given by Dr. Welburn.†

At a quarry near Mixon (Plate XVII, Fig. 2, p. 498) there are fine sections of the lower Pendleside beds, with abundance of *Pterinopecten papyraceus*, and a plant new to the series, *Bythotreptis gracilis*, Hall, kindly determined for me by Mr. Kidston. Small producti were also obtained. In the brook at Mixon Hey,

†*Proc. Yorks. Geol. and Polytech. Soc.*, New Series, vol. xiv, part iii, p. 465.

beds slightly lower in the series are seen full of *Posidonomya becheri*.

The Hamps runs through a country of the Pendleside series till it reaches Waterhouses, and many sections are to be seen. At the village of Ford is a small waterfall, where *Posidoniella lavis* and *Actinopteria persulcata* are common, and lower down, near Onecote Grange, sections yield *Posidonomya membranacea*, *Pterinopecten papyraceus*, *Posidoniella lavis*, *Orthoceras*, and *Prolecanites compressus*, a fauna which points to the base of the series.

Near Butterson a stream at the Bolland Farm shows a fine series of black limestones and shales, which have yielded *Posidonomya becheri*, *Posidoniella lavis*, *Pterinopecten papyraceus*, *Pugnax* sp. cf., *P. papyraceus*, Roemer sp., and the fern *Adiantites antiquus*, kindly determined by Mr. Kidston.

An interesting series of shales is seen in the river Dove between Hartington and Glutton Bridge. Near the latter the following species have been obtained: *Glyphioceras bilingue*, *G. diadema*, *Posidoniella minor*, *P. lavis*, *Chænocardiola footi*, and *Orthoceras* sp.

These shales abut on the limestones of Glutton Dale, and the presence of *Glyphioceras bilingue* shows that the fault is of some considerable throw, as this is the fossil which characterises the upper part of the series immediately below Farey's Grit, which crops out in the hill above on the Longnor, or Staffordshire, side, forming a marked feature. I estimate that from 500 to 700 ft. of Pendleside shales are cut out by a fault which runs along the upper Dove Valley, between the river which runs in the shales and the limestones of Chrome Hill, Park Hill, and Glutton Dale.

The shales exposed in the Dane Valley belong to the *Glyphioceras reticulatum*-zone. *Pterinopecten papyraceus*, *Posidoniella lavis*, *Stroboceras bisulcatus*, *Dimorphoceras gilbertsoni*, and *Orthoceras* species, with fish remains belonging to *Acrolepis hopkinsi*, *Elonichthys aitkeni*, and *Marsdenius* sp., also occur.

Locally, the most interesting sequence in the Pendleside series is to be seen in the various streams, quarries, and exposures west of the Millstone Grit ridge (Congleton Edge), which continues the escarpment of Mow Cop to Congleton Cloud. The lowest part of the series, as I have mentioned above, succeeds the *Cyathaxonia* beds of the Astbury limestone with *Prolecanites compressus*. A small gap succeeds this horizon, but a little higher in the sequence is a small coal 1 ft. 6 in. thick overlain by greyish-black shales about 50 ft. thick. These pass up into lavender-red shales and red grits succeeded by about 70 ft. of a hard, close-grained grit with red spots, resembling in lithological characters the grits of the Millstone Grit series. Above these is a succession of about 1,000 ft. of mudstones, shales,

sandy shales, and grits. Then comes the exposure at the Silica Works, a quarry opened to work a hard, siliceous gannister, which is used for lining steel furnaces. The gannister beds contain obscure plant remains and thin coals, with *Stigmara*, and are about 38 ft. thick. Above them are 20½ ft. of calcareous mudstones and strings of calcareous nodules, many of which are highly fossiliferous. The quarry shows the following section:

	ft.	in.
Dull grey and yellow clay with blocks of grit (drift)	5	0
Rotten limestone, crammed with <i>Schizophoria resupinata</i>	5	0
Grit	1	0
Shales, grey	3	0
Shales, with thin, slightly calcareous nodules	0	9
Hard, fine grey sandy shales	0	4
Shales, with eleven bands of calcareous nodules, containing a rich marine fauna	5	7
Shales, rather darker, with two lines of calcareous nodules	3	0
Shales, with <i>Goniatis</i> , <i>G. diadema</i>	0	8
Darker carbonaceous shale, coarsely laminated with <i>Glyphioceras spirale</i> and <i>Posidoniella laevis</i>	1	0
Shales, with calcareous nodules and marine fossils	1	0
Gannister grits with strings of coal	0	0½
Gannister like grit	20	0

About 500 ft. higher than the top beds of this section the lowest bed of Millstone Grit crops out, but no details of the intervening beds are shown (see Fig. 103).

FIG. 103.—SECTION THROUGH THE ASTBURY LIME WORKS IN AN EAST AND WEST DIRECTION.—*W. Gibson and W. Hind.*

(Reproduced by permission of the Council of the Geological Society.)

The fauna of this quarry is large and interesting:

CORALS.	<i>Orbiculoidea nitida</i>
<i>Amplexi-zaphrentis</i> , rare	<i>Lingula mytiloides</i>
	„ <i>scotica</i>
	<i>Schizophoria resupinata</i>
	„ <i>micelini</i>
BRACHIOPODA.	<i>Productus cora</i> , var.
<i>Seminula ambigua</i>	„ <i>hemisphericus</i> , var.
<i>Chonetes</i> cf. <i>laguessiana</i>	„ <i>longispinus</i>
<i>Dielasma hastata</i>	

Productus scabriculus
 „ *semireticulatus*
Spirifer (Martinia) glabra
 „ *bisulcata*
 „ *trigonalis*
Derbya, sp.

LAMELLIBRANCHIATA.

Aviculopecten gentilis
 „ *carboniferus*
Actinopteria persulcata
Allorisma sulcata
Ctenoöonta levirostris
Edmondia sulcata
 „ *senilis*
 „ *maccoyi*
Leiopteria squamosa
Modiola transversa
Myalina peralata
Mytilomorpha rhombea
Nucula gibbosa
 „ *æqualis*
Nucularia attenuata
Grammatodon obtusus
 „ *bistriatus*
Posidoniella lævis
 „ *semisulcata*
Pteronites angustatus
Palæosolen parallela
Protoschizodus orbicularis
Sanguinolites v-scriptus
Scaldia benedeniana

Schizodus axiniformis
Sedgwickia ovata

GASTEROPODA

(about a dozen species).

Dentalium, sp.
Loxonema, sp. 2
Pleurotomaria, sp.
Macrocheilina, sp.
Raphistoma junior
Euphemus urei
Bellerophon, sp.

PTEROPODA.

Conularia quadrisulcata

BRYOZOA.

Millepora interporosa

CEPHALOPODA.

Temnocheilus coronatus
Ephippioceras bilobatum
Stroboceras bisulcatum
Cælonautilus cariniferus
Glyphioceras diadema
 „ *spirale*
Orthoceras steinhaueri
 „ *teres*

CRUSTACEA.

Ceratiocaris oretonensis
Dithyriocaris testudineus

It is important to note the much more gannister-like and quartzose nature of the beds on the west of the Pennine anticlinal than that which obtains on the east, and it is curious that this fossiliferous horizon is not known anywhere else in the district, unless it is represented by some beds containing *Schizophoria resupinata* in a pit at Dingle Brook, described by Mr. Wedd.*

In the district round Leek the Pendleside series are chiefly represented by black shales with *Glyphioceras reticulatum*; but the old quarries at Leek Waste are in a coarse sandstone full of plant remains. In Hollywood Dingle, a little north of Endon, Mr. D. Tait, of the Geological Survey, collected the following plants, with remains of insects.

* "Geology of the Country around Macclesfield," etc., *Mem. Geol. Survey*, Sheet 110, p. 15.

<i>Adiantites tenuifolius</i>	<i>Neuropteris antecedens</i>
<i>Archæopteris tschermaki</i>	<i>Rhabdocarpus</i> , n. sp.
<i>Dactylothea aspersa</i>	<i>Rhodea</i> , n. sp.
<i>Lepidodendron</i> (branchlets)	<i>Sphenopteris quercifolia</i>
<i>Lepidophyllum</i> near to <i>L.</i> <i>lanceolatum</i>	<i>Stigmaria ficoides</i> ,
<i>Lepidostrobus</i>	

The flora of the Pendleside series is interesting, for it belongs to the Lower Carboniferous flora; but the fauna, on the other hand, is an Upper Carboniferous one, so that the new fauna came in before the older flora died out. Apparently the new flora came in about the base of the Millstone Grit, and persisted through Coal Measure times, *i.e.*, in terms of thickness about 1,200 ft. higher than the first occurrence of the upper fauna, which may be said to be characterised throughout by *Pterinopecten papyraceus*. This species comes in the Midland province immediately above the *Cyathaxonia* beds, and recurs again and again as high as the Gin Mine coal and its equivalents.

THE MILLSTONE GRIT SERIES.

It is very difficult to give a short and succinct account of the Millstone Grit of North Staffordshire, for the series, though it enters the county at Axe Edge about 1,200 ft. thick, in the course of some 20 miles thins out to about 400 ft. at Stockton Brook. In Leicestershire the Grits are represented by 200 to 300 feet of strata.* In the north of Staffordshire five beds of Grit are recognised, separated by black shales, which as a rule contain a marine fauna. There is often a coal above the First Grit or Rough Rock and the Third or Roaches Grit.

A sixth bed, the Shale or Farey's Grit, may be considered as the base of the series, and near Longnor this is a well-marked horizon, and its outcrop forms a fine feature along the Upper Dove Valley. The rock is a fine-grained grit, but farther west and south does not seem to have been laid down. Where most fully developed the general section of the grits south-west of Buxton is as follows:

- Feather-edge* coal.
- Rough rock, or First Grit.
- Shales.
- Haslingden flags, or Second Grit, which coalesces with the First Grit owing to the thinning out of the shales.
- Shales.
- Coal.
- Third, or Roaches Grit.

* See "The Country between Burton-on-Trent, etc., and Loughborough." *Mem. Geol. Survey*, Sheet 141, p. 20.

Shales.

Fourth Grit.

Shales.

Fifth Grit.

Farey's, or the Shale Grit of Derbyshire.

At The Roaches, 4 miles north of Leek, the whole series can be made out fairly well, each member, owing to denudation of the softer shales, rising up and forming its own separate escarpment or feature.

The outcrop of the Fifth Grit forms the rocks of Ramshaw, that of the Fourth Grit is known as Hencloud, while The Roaches themselves are formed of the Third Grit. It is as a rule much more pebbly than any of the others.

The First and Second Grits have coalesced and are succeeded by the Coal Measures of Goldsitch Moss.

Farey's Grit is seen as a feature on the east of Ramshaw rocks, and is thinning out rapidly, for it cannot be identified farther south.

There are not many exposures of the shales between the Grits, and no fossils have been noted from them, probably on this account, for in the Lancashire and Yorkshire Grit areas the intervening shales contain a rich Goniatite fauna.

In the neighbourhood of Ipstones and round the Cheadle coalfield two grits are found, with an intervening black shale yielding, near Ipstones, *Gastrioceras listeri*, *G. carbonarius*, and *Dimorphoceras gilbertsoni*, *Pterinopecten papyraceus*, and *Posidoniella laevis*, and *Orthoceras* sp. The occurrence of the genus *Gastrioceras* at this horizon is important. It seems in Staffordshire to come in somewhere in the Millstone Grit series for the first time, and reaches its maximum in the lower Coal Measures, of which horizon the species *G. listeri* and *G. carbonarium* may be considered as zone fossils.

To the west, and forming the eastern, northern, and western margins of the Biddulph coal basin, is the Grit synclinal, which outcrops in Cloud End to the north and Congleton Edge and Mow Cop to the west, and Biddulph Moor to the east. At Congleton Cloud there are three Grits, but the lowest soon disappears, so that at Biddulph and Congleton Edge only two, the 1st and 3rd Grits, are present. These Grits are separated by a rapidly-thinning band of shales and a coal, which has been worked along its outcrop. There are many quarries in the Grits, along the outcrops. In one place on each side of the syncline there are quarries which show the First Grit decomposed, its cementing material, felspar, has broken down, and the grains of grit are worked for a fine sand.

The Third Grit contains a good deal of barium sulphate in its joints, and at Congleton Edge has a bed of clay intercalated in it. It contains many quartz pebbles and fragments of felspar,

showing that the material was derived from the erosion of a granite country. The Wickenstone at Wetley Moor, the Old Man of Mow, and the summit of Mow Cop show fine examples of the weathering of Millstone Grit rocks.

The small isolated coalfield of Wetley or Shaffalong is surrounded by two beds of grit, the lower of which forms the weathered escarpment of Wetley rocks, the upper forming here and there a not very conspicuous feature.

In the River Dane, near the salmon ladders, the lowest Grit seen lies in a small syncline. It is supposed to be the attenuated representative of the Fourth Grit, and is somewhat fine in grain; it rests on black shales.

Near Stockton Brook the Pottery Waterworks Company sank a shaft, from which they drove a level through the Grits, showing the following section:

First Grit, 70 ft.
Black shale, 120 ft.
Coal, 1 ft. 6 in.
Third Grit, 190 ft.

In the black shale I obtained some years ago the following plants, kindly determined for me by Mr. Kidston: *Lepidophloios* sp., *Lepidodendron sternbergi*, *Lepidodendron* sp., *Lepidostrobus* sp., *Calamocladus* sp., *Alethopteris lonchitica*. Fish scales were also present, but I saw no trace of mollusca, which is somewhat surprising. These grits crop out a short distance north of the sinking, and are quarried for building stone.

THE COALFIELDS OF STAFFORDSHIRE.

There are five coalfields in the county of Stafford, of which four are in the north and the remaining one is the South Staffordshire coalfield.

The four northern are known as the Pottery, the Cheadle, the Shaffalong, and the Goldsitch Moss coalfields. Each of them reposes in a Millstone Grit basin, but in the case of the Pottery and Cheadle fields in the southern portion of the margin, the grits are either absent, having thinned out, or are obscured by Triassic deposits.

The Goldsitch and Shaffalong basins are small, and contain only the lowest coals of the series, and no coal is being obtained from them at the present time. These coals represent the mountain mine of Lancashire or the hard bed of Halifax and the *Crabtree* of the Cheadle and Pottery coalfields, and the lowest coals are characterised by the presence of a marine roof with *Gastrioceras listeri* and *Pterinopecten papyraceus*. The following section of the Goldsitch Moss field, situated about five miles north of Leek, was given by J. Ward.*

* J. Ward, "Geology, North Staffordshire Coalfields." *Trans. N. Staff. Nat. M. and M. Engineers*, vol. x, p. 64.

	ft.	in.	ft.	in.
Coarse red grit rock	—	—	—	—
Shale	—	—	—	—
Coal (<i>silver seam</i>)	1	4	to	1 6
Measures	130	0		
Coal (<i>thin seam</i>)	1	4	"	1 6
Measures	45	0		
Coal (<i>thick seam</i>)	2	0	"	2 3
Measures	60	0	"	72 0
Coal (<i>cannel seam</i>)	0	6	"	2 0
Shales and marine band	9	0	"	12 0
Coal (<i>Bassey</i>)	5	0	"	6 0
Sandstone	57	0		
Black shales, ironstone and flags	267	0		
Coal (<i>Feather Edge</i>)	4	0	"	6 0

Marine fossils have been obtained from the beds lying over the cannel and thick seams.

The Shalfalong coalfield is very small. It contains two seams of coal, each of which has marine fossils in its roof,* and there can be no doubt whatever that they correspond to the two lowest coals of the Cheadle and Pottery coalfields.

The Cheadle coalfield is much more important, and contains valuable seams of coal, classified by Mr. Barrow, of the Geological Survey, as follows:

	ft.	in.
Coal and gravel	2	6
Measures	42	0
<i>Two yards coal</i>	5	6
Measures	61	0
<i>Yard coal</i>	3	6
Measures	51	0
<i>Litley coal</i>	2	9
Measures	33	0
<i>Four foot coal</i>	3	6
Measures with marine band 71 ft. below 4 ft. coal	120	0
Coal, variable	2	0
Measures	60	0
<i>Dilthorne coal</i>	6	0
Measures	190	0
<i>Stinking or Alecs coal</i>	3	9
Measures	55	0
<i>Foxfield coal</i>	1	8
Measures	64	0
Coal	1	5
Measures	130	0
<i>Cobble coal</i>	3	9
Measures	55	0
Coal	1	1
Measures	95	0
<i>Rider coal</i>	1	6
Measures	125	0
<i>Woodhead coal</i>	2	9
Measures	500	0
<i>Stinking or Crabtree coal</i>	2	0
Measures	120	0
1 in. Grit.		

* J. Ward, *op. cit.*, p. 61.

At the base of the Coal Measures in the neighbourhood of Froghall a valuable seam of hæmatite has been mined; but this does not persist over other parts of the field, and seems to be a local representative of the *Feather-edge* coal. Although the names of the seams differ entirely from those of the Pottery coalfield, yet there is no doubt that the seams of each are represented by definite coal in the other, a fact brought out by the excellent palæontological work of the late Mr. J. Ward and Mr. Stobbs.* The *Littley* coal I should consider to be the equivalent of the *Holly Lane* seam; the marine band below the *Four-foot*, the equivalent of the *Seven-foot Banbury*; and the *Dilhorne* coal equals the *Cockshead* seam of the Pottery coalfield, so that the Cheadle coalfield represents only the lower and middle portions of the Pottery coalfield. The marine band below the *Four-foot* coal is very rich in species, much richer than the fauna gathered from the *Seven-foot Banbury*.

The Pottery Coalfield.—This coalfield is the principal one in North Staffordshire, and owing to the numerous open workings for clays which occur between the coals, and to railway and road cuttings, practically the whole of it, excepting the measures below the *Winfenny Coal*, is exposed in section. The measures which succeed the Millstone Grit are about 7,000 ft. thick, but the upper 2,000 ft. do not contain coal of sufficient thickness for practical mining. The palæontology of this coalfield has been more thoroughly studied than that of any other, possibly because of the richness of its organic remains. It has been found possible to map out certain life-zones in the lower 5,000 ft. of strata which are represented in the following table, the various species of fresh-water shells have a definitely restricted vertical distribution, and these life-zones seem to obtain broadly in other coalfields.

Alternating with these fresh-water zones are marine bands, of which ten have been described,† and the definite relation of each of these to the coal-seam, the roof of which contains a Fresh-water zone, enables mining engineers to make use of palæontological data as an accurate guide in sinking and other methods of mining coals.

The Keele Group is identified by Mr. Kidston, from the examination of the flora, as the equivalent of the Radstock series. He also recognises that the Blackband Group is characterised by a set of plants containing "an admixture of Upper and Middle Coal Measure species." He proposes the name *Staffordian Series* for the Newcastle, Etruria Marl and Black Band Groups as an equivalent for the term *Transition Series* which he had originally given them. He recognises

* *Trans. N. Staff. Field Club*, vol. xl, pp. 87 and 102.

† J. T. Stobbs and W. Hind. *Quart. Journ. Geol. Soc.*, vol. lxi, p. 495.

FIG. 104.—SECTION OF NORTH STAFFORDSHIRE COALFIELD.

Scale 800 ft. to one inch.

also two lower floras, a middle and lower Coal Measure group, to which he gives the names *Westphalian* and *Lanarkian*, and he would draw his lines at the *Ash* coal, the *Bassey Mine* coal, and the top of the Newcastle-under-Lyme Group.

The Pottery coalfield is rich in ironstones, which exist in the form of clay bands and black bands; in the latter there is enough carbonaceous matter to calcine the stone. Many of the ironstones are rich in fish remains. The black bands are in the upper part of the productive Coal Measures, and form a sub-division characterised by the presence of *Anthracomya phillipsi*. The clay-bands occur lower down, but the lower part of the Measures are much less rich in ironstones than the middle portion. Some limestones occur, containing *Spirorbis* and fish remains. Some thin bands are in the Keele Group. One important band exists a few feet above the Bassey Mine ironstone, one other below the *Great Row* coal, and another over the *Bowling Alley* coal.

The South Staffordshire Coalfield.—This coalfield rests unconformably on Silurian rocks, except in the extreme north of Cannock Chase (*vide ante* p. 575), and the lower Carboniferous rocks are absent. On palæontological grounds the Coal Measures seem to possess no representative of the lower Coal Measures or *Gastrioceras listeri*-zone, and the lowest beds of the series are probably well up and correspond to the middle part of the North Staffordshire coalfield. The important sinking at Hampstead Colliery, on which a paper was published by Mr. Kidston,* yielded a large series of plants which showed that some 450 yards of marls, red sandstone, and shales contained a flora characteristic of the Upper Coal Measures. The top of the *Thick* coal was reached at 615 yds., and the *Heathen* coal at 631 yds. At 341 yds. 1 ft. *Spirorbis* limestones were met 8 in. thick.

Prof. Lapworth subdivides the series into an upper or Hales-owen Group, which he considers the equivalent of the Newcastle-under-Lyme Group, and a middle division or Espley Group of marls and grits, the equivalents of the Etruria marls.

A very interesting fauna and flora is obtained from a series of small nodules in the clays above the *Thick* coal in South Staffordshire. Several specimens of fossil spiders and crustaceans, wings of insects, with fruits and ferns, and one mollusc, *Naia-dites* sp., are not uncommon. *Anthracomartus*, *Eophrinus*, *Anthracosiro*, *Ettoblattina*, *Leptoblattina*, *Euphoberia*, *Pygocephalus*, *Prestwichia*, and *Bellinurus* are represented.

The Grains Ironstone below the thick coal contains *Anthracomya modiolaris* and other molluscs; the Gubbin, still lower, contains *Carbonicola turgida*. The only important coal-seam below the *Thick* coal is the *Heathen* coal. Only a few marine

* *Trans. Roy. Soc. Edinburgh*, vol. xxxv, p. 317; and vol. xxxvi, p. 63.

lands have as yet been tabulated. Mr. Kidston mentions one in the Hampstead sinking 60 yds. above the *Thick* coal.

Jukes mentioned the marine bands in the Whitestone and Pennystone Beds, and at least three others exist, but their exact horizon has not yet been determined.

Molyneux ("History of Burton-on-Trent") mentions a marine fossil from the *Cannel* coal of Cannock Chase.

I would suggest that the Pennystone is the equivalent of the *Gin Mine* of North Staffordshire.

The beds of coal of the northern or Cannock Chase portion of the field differ considerably from those in the south, the difference being due to the fact that some fourteen seams which are distinct in the north coalesce by the thinning out of the intermediate deposits, to form the *Thick* Coal of the south, some 30 ft. thick. Above this coal, in the south, are some three coals, the *Sulphur*, the *Two-foot*, and the *Brooch*, of which the latter is most important. Its roof contains many specimens of *Carbolicola aquilina*.

Below the horizon of the *Thick* Coal the following seams are worked in the Cannock Chase district—*Yard*, *Bass*, *Cinder*, *Shallow*, and *Deep* Coals. The latter is probably the equivalent of the *Cockshead* Coal of the Pottery Coalfield.

In the Cannock Chase district there are some interesting intrusive igneous rocks, and the *Cinder* Coal has been destroyed or carbonised in places by contact with them.

THE TRIASSIC ROCKS.

The Triassic rocks enwrap the Pennine uplift on the east, west, and south, and are rarely if ever seen above the 900 ft. contour line in North Staffordshire. They lie unconformably on all the members of the Carboniferous succession, and small outliers at Leek, Endon, Hugbridge, and Cheddleton, represent portions of tongues of deposit which have crept up small fiords excavated in the older rocks, and been cut off from the main mass by subsequent denudation.

The country occupied by the Bunter sandstone is weathered into numerous low rounded hills, and is well seen near Leek, Trentham, Normacot, Maerheath, and Cannock Chase.

The Bunter beds are the most important water-holding rocks of the county, and furnish much of its water supply.

At the base of the Bunter a conglomerate or breccia is occasionally seen; for example, it occurs in Spring Valley, Trentham Park.

The Bunter pebble beds are, from the question of origin, perhaps the most interesting part of the Trias. The quantity of pebbles varies locally, but it may be said that in the north part of

the county the lower beds have more pebbles than the upper. The whole of the Bunter is remarkably false-bedded, and its pebbles exhibit a peculiar pitting or erosion where they have come in contact with each other. The pebbles themselves are from various sources, and are well-rounded but generally oval in shape. They comprise quartzites of various colours, milky quartz sandstones, grits, cherts, and decomposed agates. Some of the stones contain derived fossils of Carboniferous and Silurian age, but the most interesting are a set of quartzites containing fossils which belong to the Ordovician, and which have been thought to resemble the quartzites of the Lickey Hills south-west of Birmingham. It is suggested that the Bunter beds were deposited under desert conditions, with intermittent torrential rains, which would account for so much false bedding.

It will be noticed that on the west side of the Pennines no rocks representing the Permian deposits on the east are found between the Keele Group and the base of the Bunter. In bygone days the Keele and Newcastle Groups were mapped as Permian by the Geological Survey. The question as to what was going on west of the Pennines while the Permians of the east were being laid down, at once presents itself. It has been shown at the Thurgarton boring that the basal bed of the Magnesian Limestone series, the Permian of Nottinghamshire, consists of a coarse breccia, which rests on rocks of the Keele Group. At Gedling, seven miles away, this breccia rests on rocks of the Etruria Marl Group. If the reading of these sections is correct, then it follows that the Staffordshire area west of the Pennines did not become submerged in Permian times, and that denudation had taken place on the east before the deposition of any Permian strata, of which on the south-west flank of the Pennines there is no equivalent, for it is improbable that Permian rocks were laid down and so completely denuded that no trace whatever is to be found. In the neighbourhood of Stockport, however, there is a well-developed series of Permian beds.

The Keuper Series.—There are no sections showing the passage of Bunter beds into the waterstones; but the latter probably are a transition from the pebble-beds into the marls. The waterstones in places give excellent building stone, as at Beech, Chapel Chorlton, Hollington, and Stanton. They are subject to current bedding, and occasionally contain footprints of animals. The skull of the Labyrinthodont genus *Dasyceps* has been found at Stanton, and the abdominal ribs of *Hyperodapedon* at Hollington. Near Stone the rock is so soft that it is quarried for sand. The Keuper marls extend largely over Mid-Staffordshire, and contain beds of rock-salt and gypsum. The latter is extensively quarried at Fauld, near Sudbury. Good sections are to be seen at Meir Station, Totmanslow, and in various brick-pits. These

marls were evidently deposited in an inland sea, where evaporation was in excess of the fresh water flowing into it, so that precipitation of the salts occurred. Borings for brine occur at Stafford, and there is always a risk that water may be too salt for domestic use if wells are sunk in this series.

The Keuper marls are almost unfossiliferous, but *Estheria minuta*, var. *brodieana* was obtained by Mr. de Rance at Fulford, and I obtained some vegetable stalks at Totmanslow railway cutting.

THE RHÆTIC ROCKS.

A very small patch of Mesozoic rocks exists at the high ground of Needwood Forest. These were referred to the Lias by Jukes, but later Molyneux showed that they contained *Avicula contorta*, and *Pecten valoniensis*, and therefore should more correctly be referred to the Rhætic beds. The series is about 160 ft. thick, and there were exposures at Buttermilk Hill, Marchinton Hill, and on the roadside between Hoarcross and Christchurch. Remains of several fish were also obtained, leading to the conclusion that the bone-bed of the South West of England is represented here.

PLEISTOCENE AND RECENT.

Three large glaciers brought erratic blocks to the county of Stafford. The Arenig glacier, so-called because it had its origin in the Arenig Hills of North Wales, passed through the Vale of Llangollen and distributed its morainic matter over Shropshire; it there met the large glacier which, coming down the West of Scotland, filled the Irish Sea, and was by it deflected south, so that it distributed its erratics of Welsh origin around Wolverhampton. The Irish Sea glacier was more important. It brought granites from the West of Scotland and the western part of the Lake District in enormous numbers, and strewed them over North Staffordshire as far as a line joining Buxton and Wolverhampton. This glacier was deflected south when it met the western scarp of the Pennines, and there is little drift to be found over the Grit, Pendleside and Limestone hills to the east. But tongues of ice worked over into the Biddulph Valley and so down the Trent, where they have left beds of sand, clay, and many boulders. In the glacial sands are found fragments of marine shells, which were torn up from the floor of the Irish Sea by the advancing ice and carried up to a height of 1,200 ft. near the Setter Dog Inn, on the Macclesfield-Buxton-road. Chalk flints are found in the glacial gravels, rarely in the neighbourhood of Stoke, but more commonly farther west at Little Madeley. Good sections of glacial-beds are seen in the sandpits near Alsager, at Biddulph, Bucknall, and also at the top of the marl-holes at Fenton Low. An interesting section exposed in the sewers and foundations for a pottery at Stoke-road, Shelton, showed a pre-

glacial river-bed hollowed out in Coal Measure sandstone, whose gravels were overlain by Boulder clay. This must have been the pre-glacial Trent, whose course is now about half-a-mile farther east. At times these drift-beds are as much as 100 ft. thick, and they spread over all the lower ground of the northern half of the county.

Yet a third glacier contributed its quota of erratics to Staffordshire, the North Sea glacier, which must have been of very large extent, for it brought rocks from Scandinavia, and crossing the North Sea, tore up Jurassic and newer rocks as it passed across the north-east of England, and left fragments of Lias fossils and Chalk flints at the extreme east of the county. Of course, the local hills had their own glaciers, which added fragments of Carboniferous limestone, chert and Millstone Grit to the erratics. A fine example of the remains left by the glacier of the Weaver Hills is to be seen a little north of Ellaston. A result of the distribution of glacial débris has been to alter the system of river drainage to some extent. One notable example was the alteration of the course of the Trent near Stoke, which previously ran down the now almost waterless valley used by the railway and canal. Enough glacial matter was deposited at Sideway to block the stream, and it was dammed back and formed a large lake at Stoke, stretching up the Foulea and Trent Valleys till it overflowed into the valley of the Lyme Brook, and has since that time cut its narrow gorge at Hanford Bridge in the soft Etruria marls.

Caves and River Drift.—Cave hunting has not been carried out thoroughly in Staffordshire, but bones have been found in several caves. Thor's cave in the Manifold Valley yielded ornaments and pottery of the Romano-British period. The mammoth has been found in a fissure at Bank End Quarry, near Waterhouses; *Bos primigenius* and *Bos longifrons* and other mammalian remains have been obtained at Etruria and Stone.

Weapons of Neolithic man are not uncommon in the shape of polished celts and hammers.

VOLCANIC ROCKS.

An account has been given (p. 574) of the Intrusive agglomerates and sills at Newbold Quarry, Astbury, and it may be mentioned that at exactly the same horizon similar beds are found at Tissington railway cutting, a little way across the Derbyshire border.

In South Staffordshire, Basalts or Trap rocks are found intrusive into the Coal Measures at Rowley Regis, Barrow Hill, Pouk Hill, and near Wednesfield. They occur as sills, and have

baked the shales and burned the coal seams with which they come in contact. The date of these Basalts is problematical, but they are probably of Tertiary age.

In North Staffordshire a dyke which sometimes splits into two beds extends from near Keele to Chebsey. There are quarries in this rock in Butterson and Swinnerton Parks. The dyke is intrusive in rocks of Coal Measure and Triassic age, and is possibly of the same age as the Rowley rag.

MINERALS.

Lead, zinc, and copper have been worked in the Carboniferous limestone chiefly at Mixon and Ecton, where a century ago copper was worked extensively. Thin seams of lead (galena) are not uncommon in veins in several places in the limestone. It has also been rarely found in faults in the Coal Measures. Hæmatite occurs in small quantities in a calcite vein at Cauldon Low, and sparingly at Astbury Old Quarry.

Ironstones and Marls (so-called) are largely worked in the coalfields.