CHAPTER XXIII.

**THE LOWER CARBONIFEROUS ROCKS
OF DERBYSHIRE.**

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EXCURSIONS TO THE DISTRICT.

A GLANCE at the records of the three excursions which the Association has made in Derbyshire shows that the main object was to examine the lower Carboniferous Rocks of the County. Though the same places were visited during two or three of the excursions, the references to maps, books, and papers became more numerous on each visit, and now form a record of the advances made in the investigation of the geology of the County.

The first excursion of the Association to Derbyshire was in 1877. On July 22nd, and during the five following days, the members were led by the Rev. J. M. Mello and Mr. Rooke Pennington (*Proc. Geol. Assoc.*, vol. v, p. 186).

They visited the coalpits of the Clay Cross Company, the Creswell Caves, Miller's Dale, Buxton, and Kinder Scout.

The second excursion extended from August 2nd to the 9th, 1899 (*Proc. Geol. Assoc.*, vol. xvi, p. 221). A sketch of the geology of the lower Carboniferous Rocks of Derbyshire (which, as a separate publication, is now out of print) was written by the author of this article. The Directors were Mr. H. Arnold Bemrose, Dr. Wheelton Hind, and Messrs. J. Barnes and G. E. Coke. The number of members attending the excursion varied from fifty-two to sixty-nine, and the headquarters were at the Royal Hotel, Matlock, Bath.

Thirty-eight persons went down the Mill Close Lead Mine on August 2nd, 1899. On August 3rd Dr. Wheelton Hind conducted the party from Hayfield Station over Kinder Scout across the Edale Valley, through Mam Nick and the Winnats to Castleton. The next day the members visited Cave Dale and the Blue John Mine, examined the Vent at Goose Hill Hall, the Intrusive Sill at Peak Forest, and Barmoor Quarry in the Mountain Limestone with fish teeth.

On August 5th the lavas at Miller's Dale and the Intrusive Sill in the Faulted Inlier in Tideswell Dale were examined.

On August 7th the shales with limestones at Cromford Station, the Black Rocks, the Vents at Grange Mill, the bedded

tuff at Shothouse Spring, the quartz rock, quartzose limestone, and the agglomerate of Ember Lane Vent were visited.

On August 8th the members drove to Tissington to examine the new cuttings in the new London and North Western Railway, and on the return journey saw the Hopton agglomerate.

On August 9th the party went to Crich, and spent the day on the inlier of Mountain Limestone.

The third visit of the Association was made at Whitsuntide,

FIG. 94.—PLAN AND SECTION OF THE HARPER HILL QUARRIES.—
H. H. Hubbersty.

1904, and extended from May 21st to 25th. The Directors were Mr. H. Arnold Bemrose, assisted by Prof. Boyd Dawkins, and Messrs. H. H. Hubbersty and H. Lapworth. The headquarters were at the Crescent Hotel, Buxton (*Proc. Geol. Assoc.*, vol. xviii, p. 419).

On May 21st a visit was made to the Derwent Valley Waterworks. At the Howden Dam the trench had been excavated to a depth of about 80 ft. in the Limestone Shales, exposing a large fold or wrinkle which extended from the ground level to the bottom of the trench. The party proceeded to the

Bole Hill Quarries in the Rivelin Grit, from which the Water Board obtained gritstone for building the dams (Fig. 96).

On May 23rd the members walked to Staden Low, saw lava faulted against limestone, then proceeded to Harper Hill Quarry, in which the limestone beds "are thrown up and separated by vertical faults." The Fault Breccia was particularly interesting (Fig. 94).

On May 24th the members went to Crich and examined fine sections of Boulder Clay containing foreign erratics, and were shown calcrete and the striated limestone floor below the boulder clay.

INTRODUCTION.

The district described in this brief sketch includes the north and north-west portions of Derbyshire, and roughly coincides with the whole of the High Peak Division and the northern half of the West Division of the county. It consists of the hill country of Derbyshire, which forms the southern spur of the Pennine Chain, lies east of the watershed of the central part of England, and is drained by the Derwent and the Dove, which flow into the Trent.

A well-marked anticline passes through the district in a north-west direction. The beds dip steeply to the west, under the Coal Measures of Lancashire and North Staffordshire, and with a more gentle dip to the east, under those of Yorkshire and Derbyshire. In the north of the county a large dome-shaped mass of Mountain Limestone has been brought up. The severed strata on the west and east sides of the anticline, which were once continuous across the arch, have been removed by denudation which has not only laid bare the Mountain Limestone, but removed a small thickness of the upper beds.

A smaller anticline runs through Ashover, parallel to that of the Pennine Chain. At Matlock the limestone dips to the east beneath the Yoredales and Millstone Grit series, which form a small basin and soon dip west. This dip and the fall of the ground in the valley of the Amber expose the beds down to the Mountain Limestone at Ashover. Fig. 95 gives a rough section across the county from Buxton on the north-west to Stretton on the south-east.

The Mountain Limestone from Doveholes through Castleton and Bradwell to Eyam is bounded by a narrow belt of lower ground consisting of Yoredale Shales. Slopes which run nearly parallel to the limestone boundary rise from this depression. These slopes are the edges of several outliers of Shale Grit which once formed a large plateau extending from Chapel-en-le-Frith to Eyam, and include the moors in the extreme north of the

county. Edale, and the valley of the Derwent near Hope, Bamford and Hathersage, have divided this plateau into several outliers.

Near the centre of the Shale Grit plateau is an outlier of Kinder Scout grit, which is called the Peak. Though it is a flat table-land it reaches a height greater than any other part of Derbyshire, some portions of it being 2,000 ft. above the sea. The highest point in the limestone area reaches a height of only 1,800 ft. The Shale Grit dips under the Kinder Scout grit, which on the west forms a ridge from Chapel-en-le-Frith through Hayfield to Glossop, and on the north extends some distance east from Glossop into Yorkshire. On the west this grit forms the escarpments of Derwent and Bamford Edges. The Chatsworth or Rivelin grit forms the fine escarpments of Froggat, Curbar, and Baslow Edges, east of Stoney Middleton. The southern part of the limestone area is bounded by the Yoredale Shales, which in turn are covered unconformably by the Triassic rocks of the Midlands. On the west as far as Doveholes the limestone is bounded by the Yoredale rocks, though the boundary is often faulted. Near Hartington is an outlier of Millstone Grit on Sheen Hill in Staffordshire. About Earl Sterndale the boundary is much complicated by faults, and west of Buxton the limestone is faulted against the Yoredales and Shale Grit which dip under the Millstone Grit of Axe Edge

FIG. 95.—SKETCH-SECTION ACROSS DERBYSHIRE.

and the Goyt Basin. Between Buxton and Doveholes the limestone is bounded by the Yoredale rocks, which dip under the Millstone Grit of Combs Moss on the west.

The district is noted for its fine scenery. The Mountain Limestone, with its outlines generally smooth, its well rounded grassy slopes, and deep, narrow dales and ravines, presents a marked contrast to the wild moorlands and escarpments of the Millstone Grit.

The chief points of geological interest in the Mountain Limestone, besides its fossil contents, are undoubtedly the igneous rocks, the lead mines, the caverns and underground watercourses. From a very early date lead, zinc, and other minerals have been obtained from the limestone. The rock is largely quarried for making lime, road metal, and for building purposes. It also provides chert, which is used largely in the Potteries, and sand and clay for fire-bricks. The intrusive dolerite in Tideswell Dale and at Bonsall is now being quarried for road metal.

DESCRIPTION OF STRATA.

THE MOUNTAIN LIMESTONE.

The Mountain Limestone, of which all but a small portion on the south-west is in Derbyshire, forms an irregularly shaped inlier, measuring about twenty miles from north to south, and ten miles from west to east. In addition to this there are four small inliers, viz., at Ashover and Crich on the east, at Kniveton on the south-west, and at Snelston, near Ashbourne. The large inlier is a pericline or dome, the longer axis ranging north-north-west. The beds dip away from the centre of the mass in every direction, and the dip on the west is generally greater than that on the east.

The Mountain Limestone varies in structure, composition, and colour. It is often an almost pure carbonate of lime, white or light grey or blue in colour, and breaks with an irregular and sometimes conchoidal fracture. The dark grey and black varieties often contain bituminous and argillaceous material. Some of the beds appear to have originated from reef-like accumulations, similar to those of existing coral reefs and shell beds, others are more or less fragmental and formed of broken corals, crinoid stems, and brachiopods and other shells which have been spread out on the sea floor. Sometimes all traces of fossils have been obliterated by dolomitization and silicification of the limestone and its contents. The fossils vary very much in the amount of detrition they have undergone. They are often very well preserved, so that the convolutions and spiral bases are clearly marked. In other cases they appear to have been much worn by water-action.

The upper beds of limestone are generally thin, and contain

numerous bands and lenticles of chert. In some places there is a second series of chert beds separated from the first by massive limestones, and chert nodules are often found still lower in the series.

The limestone is the lowest rock in Derbyshire. Its thickness is unknown, the basement beds not having been reached. The first systematic attempt to zone the Carboniferous Limestone of Derbyshire was made by Mr. Wedd in the Matlock district. He stated that the corals and brachiopods show that the bulk of the limestone of the district down to the second Toadstone (*i.e.*, lower lava of Matlock area) belongs to the upper *Dibunophyllum* Zone, D₂ of Dr. Vaughan's Classification.

Dr. T. F. Sibly during the years 1906 and 1907 investigated the faunal succession in Derbyshire and Staffordshire. His results were communicated in a paper to the Geological Society of London. The following is a brief summary of his work. The whole of the series exposed constitutes a greatly expanded development of the uppermost zone of the Typical Avonian succession of the South-Western Province, namely, the *Dibunophyllum* Zone. Three sub-zones were distinguished in descending order :

D₃—Sub-zone of *Cyathaxonia rushiana*.

D₂—Sub-zone of *Lonsdalia floriformis*.

D₁—Sub-zone of *Dibunophyllum*.

The section along the Midland Railway between Longstone and Buxton, more than eight miles in extent, showed a total thickness of 1,500 feet of Carboniferous Limestone, exclusive of the two lava-flows.

The sub-zones D₃ and D₂ included the beds of limestone down to the upper lava of Miller's Dale, and the D₁ sub-zone included all the beds exposed below the upper lava.

"It may be concluded that the Carboniferous Limestone of the Midland area (North Staffordshire and Derbyshire) and that of North Wales belong to one Province, distinct from the South-Western Province. The *Dibunophyllum* Zone of this Midland Province differs from that of the South-Western Province in the richness of its brachiopod fauna, and the Midland Province is further distinguished by the development of a *Cyathaxonia* sub-zone at the top of the *Dibunophyllum* Zone. This *Cyathaxonia* sub-zone has its typical development in Derbyshire and North Staffordshire, and is less clearly developed in North Wales."*

The Ashover Inlier.—About four miles north-east of Matlock is a small inlier of Mountain Limestone with an intercalated bed of volcanic tuff. An anticline passes through Ashover in a north-north-west direction. The River Amber has cut its way along this anticline through the Millstone Grit, Yoredale rocks and part

* T. F. Sibly, "The Faunal Succession in the Carboniferous Limestone of the Midland Area," *Quart. Journ. Geol. Soc.*, vol. lxiv, p. 67.

of the Mountain Limestone, into a bed of tuff which forms the bottom of the valley. The escarpments of grit are seen on both sides of the valley above the Limestone. In a direction northwards from Ashover the succession of rocks from the Limestone up to the Coal Measures is passed.

The Crich Inlier.—Crich Stand is a tower on the summit of a limestone hill, 940 ft. above sea level, about two miles north of Ambergate Station, and forms a conspicuous object for many miles. This mass of limestone is about a mile and a-half in length, and about twice as broad at its north-west end as at its south-east. It consists of an elongated dome, the main axis of which runs north-north-west and south-south-east. On the east the beds dip gently under the Yoredale shales, but on the south are more highly inclined and bounded by a fault.

Mr. Wedd has shown that the Ashover and Crich Inliers form part of a sigmoidal anticline which conforms closely in its curves to the outline of the anticlinal south-eastern spur of the main mass of Derbyshire Mountain Limestone, from which it is separated by a shallow syncline. He concludes that this long, curving anticline and its complementary syncline are the effect of the elevation of the limestone massif, which has wrinkled the neighbouring strata.

Kniveton Inlier.—Between the villages of Bradbourne, Kniveton, and Hognaston, and about four miles north-east of Ashbourne, is an inlier of Mountain Limestone, the boundary of which has not been accurately determined, as the ground is much covered by drift and the beds are contorted. The upper thin limestones are seen near Bradbourne, where they pass regularly beneath the Yoredale shales, and in an old quarry east of New House. In the quarry about 30 ft. of limestone with thin shale partings are seen resting on massive limestone which dips at an angle of 60 deg. in an easterly direction. Chert bands are found in an adjoining quarry, in Standlow Quarry, and east of Woodeaves Farm. Two faults were observed some years ago in Standlow Quarry, and are shown in a section given in the *Geological Survey Memoir*.^{*} The massive limestones occur in this quarry and on Wigber Low. Some of the limestone is dolomitized.

The Snelston Inlier.—About $3\frac{1}{2}$ miles south-west by south of Ashbourne in the Keuper Marl is an outcrop of Mountain Limestone roughly elliptical in shape. The inlier is a dome or pericline with its greatest extension in a north-north-easterly direction. Some of the limestone is dolomitized. In the rock are several quartzite dykes, consisting of quartz, felspar, and mica, often cemented by secondary silica. The minerals were probably

^{*} "Carboniferous Limestone, &c., of North Derbyshire," 2nd ed., p. 86.

deposited in the limestone joints and fissures during Triassic times, and afterwards cemented by secondary silica.

Metamorphic Limestones.—Contact metamorphism, due to the intrusion of igneous rock, is seen in some of the limestones in contact with the sills. The limestone above the sill at Peak Forest is rendered saccharoidal to a distance of 5 ft. from the junction, whilst that below the sill in Tideswell Dale has been altered to a distance of 12 ft., and a clay has been baked to a distance of 9 ft. from the junction. The saccharoidal or marmorised limestone is easily distinguished from the ordinary more or less crystalline variety of limestone with fossils, which is found in many localities. When completely marmorised, it is crystalline, hard and brittle, breaks with a powdery and saccharoidal fracture, and all traces of fossils are often obliterated.

Dolomitized limestone (locally known as Dunstone) is found in many parts of the district, but appears to be mainly confined to the southern portion. Some of the beds are almost pure dolomite, and in them the organic structure, if ever present, has entirely disappeared. This rock forms thick beds on Masson Hill, which are well exposed on the hill slopes and in the Cumberland Cavern at Matlock Bath. Near Hopton and Brassington, along the course of the High Peak Railway, it is apparently present as a bed in the Mountain Limestone. It weathers into castellated outlines, such as those at Harbro' Rocks and along the slopes of the valley leading from Longcliffe Wharfe to Bradbourne Mill, and presents a marked contrast to the white limestone of the district. It has a rough and often knotted weathering; the surface is frequently pitted with small holes, and some specimens contain hollow moulds of encrinite stems. It is also found north of Grange Mill; and in the neighbourhood of Winster crosses Gratton Dale, where it is interbedded with the limestone. Below the thick bed in this Dale, and separated from it by about 20 ft. of ordinary limestone, is another dolomitic limestone, the whole thickness of which is not visible.

The dolomitized limestone also occurs on a much smaller scale. Sometimes the dolomitisation has proceeded along joints in the limestone; at other times part of a bed is altered, and the remainder consists of ordinary limestone.

Quartz Rock or Silicified Limestone is found in blocks on the surface of the ground at Batham Gate, Brock Tor, and Oxlow Rake, near Tideswell, and in many other localities. At the head of Pindale, these blocks are large and numerous, and sometimes contain small quantities of chert. The rock occurs in irregularly shaped bosses on Masson Hill, near Matlock, and at Ashover. Its microscopical composition and its relation to the limestone beds show that it is a limestone which has been entirely converted into crystalline silica. It consists

of quartz crystals, often elongated and interpenetrating one another, forming an aggregate of quartz grains. It has originated by the crystallisation of the quartz in such a manner that adjacent grains have prevented their neighbours from assuming crystalline boundaries. It frequently contains fluor; associated with it is a quartzose limestone, i.e., a foraminiferal, and sometimes an oolitic limestone, containing a large proportion of quartz in individual crystals and bunches of crystals, like very minute portions of the quartz rock. Small veins of similar structure also traverse the quartzose limestone, and the latter is often found in small lumps inside the completely silicified rock. There is a gradual passage from the quartz rock through the quartzose limestone to an ordinary limestone, which contains few, if any, crystals of quartz. This mineral, therefore, is present in some parts of the limestone as numerous separate crystals, in groups of crystals, and on a larger scale as veins and bosses of quartz rock, and a common origin must be ascribed to the quartz in the quartzose limestone and in the quartz rock. The presence of chert in the quartz rock of Pindale and part of a foraminifer in the similar rock of Pounder Lane, and the frequent penetration of organisms by quartz crystals in the quartzose limestone appear to be sufficient evidence that the quartz rock is a replacement of limestone. In cases such as at Top Lift the whole of the limestone and quartzose limestone have been weathered away, leaving the quartz rock in bosses or loose blocks. In others, patches of the softer rocks are left which show the transition from an ordinary limestone to a completely silicified rock.

Caverns.—Many of the caverns of Derbyshire are old lead mines, but others are natural and connected with the underground drainage of those parts of the district in which they occur. Amongst others the following caverns are shown to visitors: the Peak Cavern, Speedwell and Blue John Mines at Castleton, Poole's Hole at Buxton, and the Cumberland, Jacob's, the Roman, the High Tor, and the New Key Caverns at Matlock Bath. These, however, only form a small proportion of the whole. Many parts of the limestone district are literally honey-combed with them. The hills south of Castleton, from near Mam Tor to Bradwell, and Masson Hill at Matlock are full of these underground passages.

The existence of unexplored caverns may be inferred by the lines of swallow-holes found in several parts of the limestone area. These holes in the limestone vary in depth and diameter, and have generally the shape of a wide cone with a blunted point at the bottom. The sloping sides are sometimes steep and generally covered with grass, with or without any sign of rock. The swallow-holes are formed by the action of surface water,

finding its way into joints, enlarging them by dissolving away the rock, and ultimately emerging at a lower level at some distance from the place of entry. As the volume of water increases, the subterranean course is enlarged by the solvent action of the water, and caverns are formed, the size of which is often augmented by the falling in of the roof, and the partial or complete removal of the resulting *débris*.

The Speedwell Cavern, near Castleton, may be cited as an instance of those caverns which are partly natural and partly artificial. The entrance is near the bottom of the Winnats. The Speedwell level is at a height of about 700 ft. above the sea and 600 ft. below the surface of the hills through which it was driven. The object in making it was to reach some of the 'rakes' which run through the hill. The total length of the level is about 1,350 yards. At a distance of 750 yards the level reached the "New Rake" which was found to have been hollowed out into a large swallow-hole or narrow cavern, extending a long distance upwards and about 80 ft. downwards to the "Bottomless Pit," which the author and other members of the Kyndwr Club explored several years ago.

The Blue John Mine is another instance of large underground cavities connected by artificial passages. It is supposed to have been discovered accidentally in some mining operations by the Romans. It is situated in Treak or Tray Cliff, near Windy Knoll and the top of the Winnats south of Castleton.

Blue John is a banded variety of coloured fluor-spar, and is largely worked into ornaments. It occurs in veins, nests, and fissures, and as nodules in the limestone. Barytes and calcite are associated with it.

The Peak Cavern at Castleton, the entrance to which is by far the finest part, is an example of a natural cavern connected with a system of underground drainage. This cavern drains the district immediately west and south-west of the village. The water enters the limestone along a line of swallow-holes from Perryfoot to Windy Knoll, near the boundary of the Mountain Limestone and Yoredale Shales, and finally discharges partly through the cavern, but largely by a spring near its mouth called Russet Well, and flows down the valley, joining the river Noe near Hope.

Some of the caverns at Matlock are well worth a visit; they are mostly combinations of old lead mines and watercourses and have been formed in a similar way to those at Castleton. We must, however, mention the so-called caverns on the High Tor. These roofless caverns consist of almost vertical fissures in the limestone. The fissure called the Fern Cavern runs north-north-west, and is nearly parallel to the precipice of the High Tor. It is about 600 ft. long, 150 ft. deep, and in places reaches a width of 2 ft. Apparently it once extended farther in the

direction towards Matlock Bridge, since the eastern wall of the fissure produced forms the face of the present cliff which bounds the valley. The Roman Cavern consists of a smaller fissure, which runs nearly parallel to the strike and to the boundary between the limestone of the High Tor and the Yoredales and grits of Riber Hill.

Lead and Lead Mining.—The discovery of pigs of lead with Latin inscriptions proves that lead ore was raised and smelted in Derbyshire during the Roman occupation. Curious customs and rights connected with the mining of lead have been in use from time immemorial, and these were confirmed to the miners by two Acts of Parliament passed in 1851 and 1852. The following short quotations from Mr. Stokes' exhaustive paper* on the early history of lead mining in Derbyshire will give some idea of these customs: "All subjects of the realm may dig or search for lead ore in or under any person's land (without even asking permission of the owner of the surface), and providing the miner finds ore and frees the mine by paying one dish to the Barmaster, he then claims and is entitled to sufficient surface or land for his hillock or spoil heap, a way for foot-passengers or carts from the highway lying most convenient to the mine, and also waterway to the nearest running stream of water. The owner or occupier of the land over which these things exist cannot claim any compensation." "The only compensation the landowner gets for all this annoyance and loss of surface is the right to sell and dispose of all and every other mineral raised by the miner except lead ore."

The lead ore which has been mostly worked is known as galena or sulphide of lead. It contains a small quantity of silver (two to four ounces per ton). Cerussite or carbonate of lead, called also white ore, is found in crystals lining cavities in galena, and is supposed to be an alteration or decomposition of the sulphide. Mimetite (brown lead ore), pyromorphite (green lead ore), and phosgenite (yellow lead ore) are also found in small quantities, but the two latter only as cabinet specimens.

The ore occurs in 'Rakes,' 'Pipes,' and 'Flats.' A 'Rake' vein is generally an almost vertical fissure or crack in the limestone. When the fissure is due to a fault the walls often have a slickenside surface and the beds on either side of it have suffered displacement. 'Scrins' are strings of ore which branch off from the 'rake' and form smaller veins. The ore occurs in ribs with layers of calcite, barytes, or fluor arranged more or less parallel to the walls of the 'rake.' Sometimes it is found in isolated cubes or assemblages of galena with calcite or barytes.

'Pipe' veins are irregularly shaped cavities or pockets in the limestone generally parallel to the bedding planes, and often

* *Trans. Chesterfield and Derbyshire Inst. Eng.*, vol. viii, p. 60.

connected with one another by a crack filled with clay or spar, called a leader. They vary considerably in size, and may be considered as the widening out of a 'rake' or 'scrin.' The ore in them is often found in lumps mixed with blocks of limestone, barytes, calc-spar, and clay. This mixture is apparently due to the falling in of the roof of a cavern lined with these minerals.

A 'Flat' is not so common as the 'rake' and 'pipe' veins. It is generally found along the junction of two beds, and consists of a low flat chamber with the roof and floor only a few feet apart, and seldom has any leaders connected with it.

LIMESTONE SHALES.

Yoredale Rocks.—The Yoredale Rocks of the Geological Survey include the sandstones, shales and limestones which lie between the lowest Millstone Grit and the Mountain Limestone. They were originally divided into the following three groups, and are mapped as such on the 1-inch Geological Map (old Series):

- UPPER YOREDALES. Yoredale or Shale Grit, with shale and thin sandstones above and below.
- MIDDLE YOREDALES. Yoredale sandstones, with beds of black shale.
- LOWER YOREDALES. Black shales, with thin beds and nodules of earthy limestone.

It was found that in Derbyshire there was a lithological difference between the Kinder Scout and Yoredale Grit, but that farther north these distinctions vanished. The classification was therefore modified, and the Yoredale Grit was transferred to the Millstone Grit group. At the same time the term Yoredale Grit was abandoned and Shale Grit was substituted for it. So that the Yoredale Rocks then consisted of two divisions, viz., the sandstones with shales and the shales with limestones. This classification was considered to be provisional.

Dr. Wheelton Hind considers that the Yoredale rocks of Wensleydale are the equivalent of the upper part of the Carboniferous Limestone, and that the Yoredale beds of Derbyshire are a different series and occupy a position above the Carboniferous Limestone. He would restrict the term Yoredale series to the district of Wensleydale, and suggests that the name Pendleside series should include the shales and limestones which rest on the Mountain Limestone.

The Geological Survey has discarded "the term Yoredale for the shales above the limestone in the Midlands and adopted Dr. Hind's term 'Pendleside series' for these beds" in Staffordshire, but in Derbyshire they propose to use "the term 'Lime-

stone Shales ' for the shale series intervening between the limestone *massif* and the Shale Grit of the Millstone Grit series."*

The Limestone Shales contain the usual marine fauna of the Pendleside series, and vary in character and thickness in different parts of the county. In Edale they consist of shales with nodules of limestone containing *Goniatites*. At Cromford the limestone forms short lenticular beds in the shale. In other places the limestone is in thin beds intercalated amongst the shales, and the proportion of limestone to shale varies greatly.

FIG. 96.—CONTORTED BEDS IN THE DERWENT VALLEY.—H. Lapworth.

- A.—Is a distinctive bed of carbonaceous black shales.
 B. and C.—Are two separate sandstone beds, each about 4 ft. thick.

The Derwent Valley Water Works, which are now in progress for the supply of water to the towns of Leicester, Derby, Nottingham, and Sheffield, were visited by the Association in May, 1904. The excavations for the Derwent Dam are in shales which appear

* "Mem. Geol. Survey," Explanation of Sheet No. 125, p. 8.

to conform to that of the typical "Pendleside" strata of Messrs. Hind and Howe. The upper or Howden Dam rests upon the foundation shown in the sketch by Dr. H. Lapworth (Fig. 96).

MILLSTONE GRIT.

The Millstone Grit series of Derbyshire consists of five thick sandstones parted by shales with which thinner sandstones are interbedded. These grits vary in character from a fine-grained sandstone to a conglomerate, and consist mainly of quartz, orthoclase-felspar and mica (muscovite).

The Fifth, or Shale Grit, consists of thick massive sandstones, hard and close-grained, passing often into a conglomerate. It attains a thickness of 500 or 600 ft. around the Peak, thinning away to the south and being absent in some places. South of the Peak the Shale Grit caps the ridge between Lose Hill and Mam Tor. The beds dip north, and farther south, at Castleton, we come to the Mountain Limestone.

The Fourth, or Kinder Scout Grit, consists of two thick beds of sandstone separated by shale. The lower one—a coarse grit and conglomerate—dies away on Bamford Edge, and is not found farther south. The upper one varies from a coarse grit to a fine grained sandstone. The Kinder Scout grit generally forms bold craggy cliffs surmounted with piles of rock weathered into fantastic shapes. Robin Hood's Stride and the Rowtor rocks, near Rowsley, are formed of this grit. The Black Rocks is the name given to an escarpment of the Fourth grit near Cromford, along the base of which the High Peak Railway runs.

The Third, or Chatsworth Grit, varies greatly in character. In the centre of the district it is a coarse conglomerate, and becomes a fine-grained sandstone as it is traced north and south. It is often called the Escarpment Grit. The broken edge of its outcrop forms long escarpments, which often run for miles along the country and make a distinctive feature.

The beds between the Third and First Grits are very changeable, being made up of shales with sandstones which vary in thickness and horizontal extent, beds of gannister, and thin coals.

The First or Topmost Grit is known as the Rough Rock, and is the most constant of the series in thickness and character. It is described as a massive coarse grit with a large proportion of felspar, the decomposition of which makes the rock loose and crumbly. Its average thickness is 100 ft.

The terraces or escarpments formed by the various grits are seen along the line of Horizontal Section, No. 69, of the

Geological Survey. The entire series is crossed from the Lower Coal Measures on Ughill Moors to Derwent Chapel.

SANDS AND FIRE CLAYS IN THE MOUNTAIN LIMESTONE.

Deposits of coloured sand and clay, with quartzite pebbles, occur in pockets or irregular hollows in the limestone in the neighbourhood of Newhaven and Brassington. They are situated on a line running in a direction from north-west to south-east for a distance of about seven miles from near Hartington, on the north-west, to Brassington, on the south-east. In addition to smaller pits, larger ones have been worked at Newhaven, Minninglow, Longcliffe, Harbro', and Brassington. The clay from the latter place was worked previous to 1789, and sent to Derby Porcelain Works. These hollows in the limestone, which may represent swallow-holes, reach as much as 100 yards across. The deposits consist of a very fine clay and clean sand, the lines of division between them often being nearly vertical. The sand is sometimes bedded in the form of a basin, that in the centre of the pit being nearly horizontal, and that near the edges dipping steeply away from the limestone which forms the sides. At Newhaven and Longcliffe, the removal of the sand and clay has brought to view the weathered upper surface of the limestone, which forms part of the walls of the pit. The clay and sand are sometimes white, and at others coloured red and yellow. The sand contains many quartzite pebbles, which are generally white, but sometimes red.

Various explanations of the origin of these deposits have been given. The presence of quartz pebbles was considered by the Geological Survey officers to denote that a portion at least was derived from the Kinder Scout Grit, and it was supposed by them that a large part of the material was due to the decomposition of chert and sandy or argillaceous limestone, and that the hollows, as in the case of the similar Welsh deposits, were filled in pre-Glacial times. The origin of the sands and pebbles has also been attributed to the Bunter Beds. However much opinions may differ about the origin of the deposits, there is no doubt that they are pre-Glacial. Mr. Deeley and the author have found undoubted proof of this in the case of one of the pits.

An examination of the sand shows that it consists of small, well-rounded grains of quartz, unlike the angular grains found in the Kinder Scout Grit. If, therefore, it has been formed from that rock, it must have been subjected to such an amount of trituration as would convert the angular into rounded grains. The author found, in one of the hollows near Brassington, a piece of reddish-coloured grit, with quartz pebbles embedded in it.

GLACIAL DRIFT.

The drift deposits of the lowlands of Derbyshire have been fully worked out by Mr. R. M. Deeley, but very little has been done at those in the hill district included in this Sketch. Deposits of clay containing striated limestone boulders, large pebbles of grit, and a few boulders of foreign rocks are found in the valley of the Wye, at Monsal Dale, Longstone, Baslow, Haddon Hall, and Youlgreave, and on the flanks of the Derwent Valley near Matlock and Crich. Thick deposits of Boulder Clay were found in the five cuttings in the London and North Western Railway between Ashbourne and Tissington. The clay contained numerous boulders of well-striated Mountain Limestone, of grit, sandstone, shales, chert, and igneous rocks foreign to the county. At Spital Hill, a short distance south of Ashbourne, a well boring passed through 50 ft. of clay with large limestone boulders, and 20 ft. of running sand.

The presence of a large mass of Boulder Clay near the village of Crich has long been known. Some years ago Mr. Deeley and the writer found that the limestone floor which had been recently exposed by removal of the Boulder Clay in quarrying operations was finely striated, polished, and grooved. The striæ ran 20 degrees west of north, indicating an ice flow roughly coinciding in direction with the neighbouring Derwent Valley. Deposits of Calcrete resting on the limestone have been found in Hill's Quarry at Crich.

PLIOCENE AND PLEISTOCENE MAMMALIA.

Many Pleistocene Mammalia have been discovered in caverns and fissures in the Mountain Limestone. Elephant remains were found at Balleye, near Wirksworth, and in a fissure at Doveholes, and a rhinoceros tooth was found at the entrance of Peak Cavern. In a cave near Matlock, rhinoceros, cave hyæna, bear, reindeer, fox, red deer, and bison were discovered, and in Hartle Dale remains of rhinoceros, bison, and mammoth. At Windy Knoll, near Castleton, bones of bison and reindeer, with grizzly bear, wolf, fox, hare, rabbit, and water vole, were obtained by Mr. Rooke Pennington from a swallow-hole in the Mountain Limestone. A cavern in Cave Dale contained bones of recent fauna, as well as relics of human occupation.

In 1875 from the Creswell Caves in the magnesian limestone of the lower Permian, some thousands of bones of Mammalia and implements made by man were obtained by the Rev. J. M. Mello and Prof. Boyd Dawkins.

In 1903 an ossiferous cavern of Pliocene age at Doveholes, Buxton, was worked out by Prof. Boyd Dawkins.* Teeth of

* *Quart. Journ. Geol. Soc.*, vol. lix, p. 105.

Machairodus crenatidens, and of *Mastodon arvernensis* were found.

In 1905 an ossiferous Cavern of Pleistocene age was discovered at Longcliffe, near Brassington.* Mr. E. T. Newton and the author obtained over 8,000 specimens of bones of Mammalia. The presence of bones of fallow-deer closely associated with those of Pleistocene Mammalia, proved that the fallow-deer, or a form which could not be distinguished from it, existed in Pleistocene times in Britain.

The chronological order of the Derbyshire Cave Deposits, according to Prof. Boyd Dawkins, is as follows: (1) Doveholes, (2) Longcliffe and the older deposits of Creswell Crags (Kirkdale Cave age), (3) Upper deposits of Creswell Crags, and (4) Windy Knoll (see discussion on last-cited paper).

CALCAREOUS TUFFA, STALACTITIC DEPOSITS, AND WARM SPRINGS.

These deposits are due to the solvent action of water charged with carbonic acid on the limestone. As the water evaporates, the carbonate of lime which has been dissolved is redeposited as beds of tufa, and in a cavern the drippings from the roof form stalactites and stalagmite. The tufa consists of amorphous carbonate of lime, which has often been deposited around twigs, leaves, moss, shells, and bones of animals. Large deposits of this rock have been formed by the warm springs at Matlock. Above the right bank of the Derwent it reaches a thickness of 30 ft., and is at the present time well exposed near the New Bath Hotel, which is built upon it.

Owing to the readiness with which the surface waters make their way down into the limestone it is not surprising to find that many parts of the area covered by this rock are destitute of water. Were it not for the beds of toadstone and the clay partings which are impermeable to water there would be no springs on the limestone hills at any height. Many of the springs issue from the top of a toadstone bed, the upper surface of which may often be traced at points along the line of its outcrop. Several springs flow from the top of the bedded tuff near Grange Mill. Dunsley spring, which runs down into the Via Gellia, Five Wells, and other springs near Taddington flow from the upper surface of toadstone beds.

Many of the springs are warm, or at least tepid. The most noted are at Buxton, Matlock, and Bakewell. Those at Buxton are supposed to have been used by the Romans. The temperature of St. Ann's Well is 81 deg. F. The water is remarkable for the amount of free nitrogen dissolved in it.

The temperature of the warm springs at Matlock Bath is 68 deg. F. They supply the Fountain swimming bath, and smaller baths at the New Bath and Royal Hotels.

* *Quart. Journ. Geol. Soc.*, vol. lxi, p. 43.

IGNEOUS ROCKS.

The igneous rocks of Derbyshire are locally known as Toad-stones. The word is derived either from the supposed resemblance of the amygdaloidal varieties to the back of a toad or it is a corruption of the German Todstein (Deadstone), so called because the rock was considered to be unproductive of ore. It is also known as dunstone, channel, blackstone, and cat dirt.

The igneous rocks of the county have been mapped by the author, and his maps appear in a paper read before the Geological Society in 1907.* There are three main areas of volcanic activity, viz. : the north-west or Miller's Dale area, the south-east or Matlock area, and the south-west or Tissington area. Lava flows, bedded tuffs, and volcanic vents are found in the three areas, and in addition several intrusive sills occur in the Miller's Dale and Matlock areas. In the first two areas the igneous rocks (except the Hopton Vent) are in the Mountain Limestone, but in the Tissington area the thick band of volcanic tuff is in the beds mapped as Yoredale by the Geological Survey. Dr. Sibly has recently shown that this tuff is succeeded by a splendid development of passage beds which lie below the true Pendleside shales.

The northern and most extensive of the three is the Miller's Dale area, which covers a superficies of 72 square miles. The two main lava flows are separated by about 150 ft. of limestone. The upper lava is 520 ft. down in the Mountain Limestone series. A good section of this lava with some feet of tuff below it is seen in the quarry near Miller's Dale Station, and can be traced as far as Litton Mills, where it is cut off by a fault with a downthrow to the east of about 200 ft.; the result being that the massive white limestones have been brought down to the level of the railway at Litton Tunnel, and the lowest beds of the cherty-limestone series, which, in their normal sequence, are above the massive limestones, have been brought in juxtaposition with the lower part of the upper lava flow. The lower lava is seen at the bottom of the Valley of the Wye east of Miller's Dale Station and can be traced as far as Raven's Tor.

Three Volcanic Vents, viz., Speedwell Vent near Castleton, Monk's Dale Vent, and Calton Hill Vent, the largest one in the county, occur in the northern area. The Calton Vent, which forms a well-marked feature, consists mainly of Olivine Basalt; all the other vents in Derbyshire consist of fragmental rock or agglomerate. Bedded tuffs contemporaneous with the limestone are found at Doveholes, in Brook Bottom, Cressbrook Dale, and at Litton. The two beds of tuff in Cressbrook Dale are above the upper lava.

The south-eastern or Matlock area covers a superficies of about 56 square miles. In it there are two main lava flows separated by about 80 to 100 ft. of limestone. A good section

* *Quart. Journ. Geol. Soc.*, vol. lxiii, p. 241.

of the upper lava is seen in the railway cutting near the mouth of the tunnel north of Matlock Bath Station. It is about 150 ft. down in the Mountain Limestone series.

The lower lava is much more extensive than the upper and may be traced from Matlock Bath as far as Gratton Dale. Near Tearsall Farm is a good section showing several feet of bedded tuff above the lava. There are at least five vents in this area, viz.: Cracknowl near Bakewell, Grange Mill, Ember Lane, Moor Lane and Hopton. Bedded tuffs occur at Shothouse, Low Farm and Ashover.

In the Tissington area are four or five vents, two small outcrops of lava, and a bed of Volcanic Tuff, which attains a thickness of 140 ft.

There are nine occurrences of intrusive rock or sills, viz.: at Peak Forest, Potluck, Waterswallows, Tideswell Dale, New Bridge, Ible, Bonsall, High Peak Tavern, and Low Farm. Generally speaking, the rock passes from a coarse-grained dolerite through an ophitic dolerite in the centre to a fine-grained dolerite at the margins.

The following description of some of the vents, tuffs and sills visited by the Association must conclude this short account of the igneous rocks.

Speedwell Vent.—About a quarter of a mile south-east of the entrance to the Speedwell Mine, and between the 800 and 900 ft. contour lines, is a small vent, elliptical in outline. It pierces the limestones near the base of the northern slope of Cow Low, and is the most northerly vent in the county. The limestones may be seen dipping about 20 deg. north, on the north, south, and west of the agglomerate, and within a short distance of it, so that the igneous rock undoubtedly cuts across the beds, which, from their position, are very near the top of the Mountain Limestone. The agglomerate is not well exposed, but a portion of it forms a low ridge covered with grass and about 80 ft. in length. It is composed of a mass of small lapilli containing crystals and is seldom vesicular. Scattered through this softer and more decomposed rock are blocks of a doleritic type, with minute feldspars and an isotropic ground-mass.

Ember Lane Vent.—Immediately east of Bonsall, and about two miles north-west of Cromford, a coarse agglomerate is exposed in the banks of Ember Lane and in the field above. It extends over 1,000 ft. in a north-west direction, and at its broadest part measures nearly 400 ft. It is remarkable for the large admixture of calcareous material with the volcanic detritus. The rock may be described as a calcareo-igneous breccia, and consists of an intimate mixture, in varying proportions, of limestone fragments, some angular and others more or less rounded, containing fossils, and of volcanic lapilli, which are often of

a dirty green colour. A short distance higher up the lane it consists of a more comminuted volcanic detritus containing a few limestone pebbles as large as one's fist firmly embedded in it. The position and extent of this agglomerate and its relations to the surrounding rocks, as far as they have at present been ascertained, are indicated in *Proc. Geol. Assoc.*, vol. xvi, Pl. III, facing p. 186. Unfortunately there are no exposures showing the dip of the beds of limestone contiguous to it. The only rocks seen near it consist of quartz or silicified limestone, from which all trace of bedding has been obliterated. The composition and

FIG. 97.—PLAN OF NECKS AND BEDDED TUFF AT GRANGE MILL, FIVE MILES WEST OF MATLOCK BATH.—*Sir A. Geikie.*

appearance of the agglomerate, and the fact that it cuts across the strike of the unaltered limestones 500 ft. north of it, seem sufficient to justify us in considering it to be a vent.

On the south-east it abuts against a much decomposed vesicular toadstone, which is the lower lava of the Matlock area.

Grange Mill Vents.—The most interesting group of vents is found at Grange Mill, about five miles west of Matlock Bath. Two dome-shaped hills, with grassy slopes and well-marked contours, rise from the valley to a height of 100 and 200 ft. respectively. Their summits are more than 900 ft. above the sea. The larger vent covers an area measuring 2,400 by 1,300 ft., and the smaller one an area of 1,300 by 900 ft. Good views

of these hills are seen on the roads from the village of Aldwark and from Longcliffe Wharf to Grange Mill. The smooth and steep grassy slopes consist almost entirely of a grey rock with green lapilli and a few limestone pebbles. It weathers into spheroids, some of which are well exposed opposite a cottage on the southern vent close to Grange Mill, on the road to Winstar.

The rocks in the immediate neighbourhood of the vents form the northern part of a dome, the longer axis of which ranges north-north-west. The two vents lie on this anticline. In several places the limestone is seen within a few feet of the agglomerate. South-west of the northern and smaller vent, it dips north or north-west at an angle of 10 to 15 deg. South of the western vent, the beds are much disturbed, and at one point they may be

FIG. 98.—SECTION ACROSS THE SMALLER VOLCANIC NECK AND THE STRATIFIED TUFF IN CARBONIFEROUS LIMESTONE, GRANGE. MILL.—*Sir A. Geikie.*

1. Limestone. 2. Stratified tuff intercalated among the Limestones.
3. Agglomerate.

(Figs. 97 and 98 are reprinted, by permission, from "The Ancient Volcanoes of Great Britain.")

seen striking at the agglomerate. There is, therefore, no doubt that the igneous rock traverses the limestone beds.

East of the vents is a small valley with its eastern slopes running up to a well-marked escarpment of limestone higher in the series. This escarpment reaches a height of 1,000 ft. above the sea, and may be traced from near Whitelow Farm, where the beds dip south-east and east, to Shothouse Spring, where they dip nearly north.

West of the vents is a smaller and less marked escarpment of limestone, which may be traced, with the exception of a few breaks, from near Aldwark Grange road to Shothouse Spring, where it joins the eastern escarpment. A bed of laminated tuff underlies the escarpments on both sides of the valley. It is about 90 ft. thick and made up of alternations of finely and coarsely laminated bands of lapilli in a calcite cement. It is exposed at Shothouse Spring and near Whitelow Farm on the east, being continuous between these two places, as indicated by fragments in the grassy slope. It can also be traced on the western side of the valley from Shothouse Spring to within a short distance of the Aldwark Grange road.

The limestone resting on the tuff is nodular and concretionary

in character, and similar to that found above the tuff bed at Litton, near Tideswell. Numerous minute lapilli are distributed irregularly through the limestone up to a height of at least 18 ft. above the tuff at Shothouse Spring. The general arrangement of the rocks is shown in Fig. 97, and a section through the smaller vent from east to west in Fig. 98, which are from blocks lent by Sir A. Geikie. The tuff has since been traced farther to the south-west, and beyond the boundary of the plan (Fig. 97), and the southern vent a short distance farther to the north-west. Two small dykes of dolerite traverse the southern vent, but are only seen for a short distance. The northern one is at least several feet in width. The southern, which is much smaller, penetrates the agglomerate to a height of several feet near the roadside, and either dies out or changes its direction and turns inwards into the hill. They run in a direction east and west.

Litton Tuff.—At the village of Litton, near Tideswell, is a well-banded tuff intercalated with the limestone. It consists of alternations of fine and coarse laminæ of a green and yellow colour, with pebbles of coralline limestone and blocks of dolerite or basalt up to 18 inches in length. The matrix is formed of very vesicular lapilli cemented by calcite.

Cressbrook Dale Tuff.—In Cressbrook Dale some portions are very fine grained, and slabs are found about a foot in length which can readily be split into thin laminæ. Below this tuff, and separated from it by 15 to 20 ft. of limestone, is a lava-flow 10 to 20 ft. thick seen in Cressbrook Dale. The limestones above the Litton tuff contain a few lapilli up to a height of at least 18 or 20 ft.

Peak Forest Hill.—In Dam Dale, south of the village of Peak Forest, is an intrusive sill of ophitic dolerite. Its base is not seen, and its thickness is unknown. The portion exposed in this small valley does not cut across the beds, but its upper surface dips regularly beneath the limestones in a north-east direction. The limestones immediately above it are marmorised for a distance of about 5 ft. A few feet higher up they contain chert nodules, and are partly dolomitised. The metamorphism may be traced about 800 ft. horizontally on the north-east of the outcrop, and for about half that distance in the limestones on the north-west on the opposite side of the valley, south of Damside Farm. The marmorised limestone is saccharoidal, and composed of crystalline calcite, showing the characteristic twinnings under the microscope. Two yards above the junction the limestone contains traces of organisms and patches of either crystalline calcite or dolomite. The intrusive igneous rock is generally a coarse crystalline ophitic olivine dolerite, but near the junction it loses its ophitic structure and becomes more fine grained.

Tideswell Dale Sill.—Another interesting sill occurs in Tides-

well Dale, half a mile south of Tideswell village. The only visible portion is contained in a faulted inlier of Mountain Limestone. North of the inlier is a small lava-flow, and south of it are two small lava-flows.

Intercalated with the limestones is a bed or stratum of red clay very much like a volcanic mud, which varies in thickness, and is sometimes absent in this part of the Dale. This appears to have been followed by a flow or several flows of lava. At a later period the intrusive rock made its way into the lava and spread along planes of weakness. It is found to occupy different horizons in the lava, sometimes resting on the limestone, at others on the clay, and at others on the vesicular lava.

Below the sill the clay has been indurated and rendered columnar to a depth of 9 ft., and the limestone has been altered to a hard saccharoidal marble to a greater distance from the junction than the alteration has extended in the limestones above the Peak Forest Sill. That this metamorphism is due to the compact dolerite or sill, and not to the vesicular lava below it, is shown by the fact that the bases of the compact dolerite and the marmorised limestone are approximately parallel. Where the non-vesicular and compact dolerite rests on the clay or on the limestone the clay is rendered columnar, and the limestone is marmorised sometimes to a depth of 10 or 12 ft. Where some feet of the vesicular or slaggy toadstone separates the dolerite from the clay or the limestone beneath it the latter is unaltered. The sill is not found to transgress the upper portions of the vesicular lava, consequently it has not been sufficiently near to the limestones above the lava to alter them.

The sill is about 70 ft. thick, and may be traced for nearly half a mile from north to south. It is well exposed in the old Marble quarry. It varies in structure, being coarsely crystalline in the centre and fine-grained near its upper and lower surfaces. The rock in the quarry is traversed by numerous veins of chrysotile or fibrous serpentine. The metamorphosed limestone is a hard coralline marble, and at one time was largely quarried.

The dolerite is now being used for road metal by the Derbyshire County Council.

The Geological Map (*Proc. Geol. Assoc.*, vol. xvi, Pl. VI, p. 210), and sections Figs. 99 and 100, will explain the position of the sill and its relation to the rocks of the neighbourhood.

FIG. 99.—SECTION ACROSS TIDESWELL DALE.—*H. H. Arnold Bemrose.*

Scale, 6 inches to 1 mile.

FIG. 100.—DIAGRAMMATIC SECTION ALONG THE MIDDLE ROAD FROM MILLER'S DALE TO TIDESWELL, OPPOSITE THE OLD MARBLE QUARRY, ILLUSTRATING THE METAMORPHIC EFFECT OF THE INTRUSIVE DOLERITE.—*H. H. Arnold Bemrose.*

Horizontal Scale, 96 feet; Vertical Scale, 32 feet to an inch.

(Figs. 99 and 100 are reproduced by permission of the Council of the Geological Society.)

The datum-line AM is a thin bed of finely-laminated limestone. The boundary between the metamorphosed and the unaltered limestone is almost parallel to the lower surface of the intrusive rock.