33. *On the AGGLOMERATES and TUFFS in the CARBONIFEROUS LIMESTONE SERIES of CONGLETON EDGE.* By WALCOT GIBSON, Esq., F.G.S., and Dr. WHEELTON HIND, B.S., F.R.C.S., F.G.S. *With an APPENDIX on the PETROGRAPHY of the ROCKS by H. H. ARNOLD-BEMROSE, Esq., M.A., F.G.S.* (Read June 21st, 1899.)

1. Historical Summary.

CONTEMPORANEOUS igneous action during the deposition of the Carboniferous Limestone has long been known and described from several parts of England and Ireland. In the Annual Report of the North Staffordshire Field Club for 1898¹ and in the present volume of this Journal,² volcanic activity has been described as

Fig. 1.—Sketch-map of a portion of Congleton Edge.

a = Limestone.
b = Shales and thin limestones.
c = Agglomerate and tuff.
d = Shales, limestones, and tuffs.
e = Shales with coal.

f = Grit.
g = Shales and thin earthy limestones.
h = Shales and grit.
i = Third Grit.

¹ Wheelton Hind, 'Descr. of Section in Carb. Limest. Shales at Tissington, on Buxton & Ashbourne Ry.' Ann. Rep. & Trans. North Staffs. Field Club, vol. xxxii (1897-98) pp. 114-116.

² H. H. Arnold-Bemrose, 'Geology of the Ashbourne & Buxton Branch of the L. & N. W. Ry.: Ashbourne to Crake Low,' pp. 224-238.

occurring at Tissington towards the close of the deposition of the Carboniferous Limestone. The object of the present paper is to bring forward distinct evidence, hitherto unsuspected, of volcanic action of the same age on the western slopes of Congleton Edge, 20 miles west of Tissington.

This bed of igneous rock, though well exposed in an old quarry, seems hitherto to have escaped notice. It is omitted from the section in the Geological Survey memoir¹ and not mentioned in the text. The late Dr. Garner may possibly refer to it in his 'Natural History of the County of Stafford,' 1844, p. 212, where he says:—'On the western side of the coalfield, towards Mow Cop, there likewise occurs a rock which appears to owe its formation in part to igneous action. This is of a lively green colour, very hard, and enclosing many roundish pieces of bright red rock, which, however, are also seen in some of the grit of this spot.' But this description scarcely agrees with the coarse angular nature of the agglomerate at present exposed in the quarry at the foot of Congleton Edge. Again, in the appendix to the same work, p. 45, he says:—'The Astbury limestone at the west foot of Mow Cop is rather peculiar, being dark in colour, with blotches of red and green.' This may refer to some of the included fragments of tuff, or to the pockets of hæmatite and other minerals which occur in the heart of the limestone.

2. General Structure of the Area.

The area under discussion lies in the Geological Survey map, Sheet 81 S.W.

The ridge of Mow Cop, with its northern extension, Congleton Edge, forms the boundary between Staffordshire and Cheshire, and reaches an elevation of 1101 feet above Ordnance datum on Congleton Cloud. The ridge, whose scarp faces west, is capped by two beds of Millstone Grit, considered to represent the First and Third Grits, separated by a small amount of black shales. Below the Third Grit to the base of the hill a narrow dome of Carboniferous Limestone, lying in the midst of the so-called Yoredale Shales, is exposed in an old quarry. Immediately to the west, the Lower Carboniferous rocks end off against the Red Rock Fault, while the whole country is covered with a thick mantle of Glacial clays and sands. In order to bring out clearly the exact age and relationship of these igneous rocks to those of known age, a small tract—a little under one square mile—has been carefully examined and mapped on the 25-inch scale, and a reduction of this map is reproduced in fig. 1. The authors were so fortunate as to obtain, in the quarry-section of agglomerate, the help of Mr. Arnold-Bemrose, who also kindly furnishes some notes on the petrography of the igneous rocks.

¹ 'Geol. of Country round Stockport, Macclesfield, Congleton, & Leek,' Mem. Geol. Surv. 1866, pp. 9, 47, 72 & 73.

3. Succession of Limestone and Igneous Rocks.

(a) Quarry-section, Astbury Limeworks.—The quarry is about 1 mile north-east of Mow Cop Station and is represented on the Geological Survey map by a small patch of dark blue, ending off to the west against the Red Rock Fault, and lying between this fault and another to the east, in the midst of beds mapped by the officers of the Geological Survey as Yoredale Shales.

The limestone was worked for a long time in an open quarry; but of late years these workings have been abandoned, and the limestone is now obtained by an adit commencing on the west in Triassic rocks. The limestone is massive and thickly bedded, containing corals and encrinurites and the fossils usually found in the Carboniferous Limestone, among them *Chonetes papilionacea*. A detrital bed, containing rolled shells, occurs in the upper portion. The massive limestone is shown in the old quarry to be overlain by calcareous shales with thin bands of impure limestone, a series of passage-beds which is generally found to succeed the Mountain Limestone mass in North Staffordshire, Derbyshire, and South-west Yorkshire.

Fig. 2.—Section along CD (see map, fig. 1, p. 548) on the scale of 25 inches to the mile.

At the present day the quarry is much overgrown by grass, especially on the west side. The igneous rock, however, is well exposed in the north-eastern corner in a face about 25 feet high and 160 feet long, while recent land-slipping has brought to light other sections on the eastern and south-eastern sides.

The mass in the cliff-section is an agglomerate—consisting of angular fragments of green tuff—often vesicular, embedded in a greenish calcareous matrix. Fragments of marmorized limestone are not infrequent, and in some places there are corals and other fossils roughly occupying certain layers in the mass. The rock does not disintegrate rapidly, but weathers on the outside to an ochreous colour. It is much harder in the cliff than in any of the other exposures. The agglomerate is underlain by thin limestones and calcareous shales; the dip is into the hill, or eastward. The top of the mass is not seen, being covered by grass and débris.

South of the cliff occurs a gap of 150 feet in which no rock is visible, while south-west of the gap thin limestones and

calcareous shales are exposed on the same strike with the agglomerate. This suggests a neck, the gap representing the actual site of the vent. No further evidence is obtainable at the surface, and unfortunately the underground workings cease 58 yards before the critical point is reached. There are some slight appearances at the surface of a fault, but no absolute proof. The limestones and shales can be followed for the next 150 feet, then all exposures are lost beneath a slipped mass of stiff chocolate-coloured Boulder Clay. The dip is seen to be changing from east to south-east. South-west of the slipped mass of clay the thin limestones and shales are exposed, and above them lies a thin band of calcareous tuff, overlain by 10 feet of agglomerate with encrinites. This agglomerate is much decomposed and of a deep ochreous colour, but the evidence is not sufficient to settle whether this is the same band as that seen in the north-eastern corner of the quarry. Above the band of agglomerate lies a hard dark shale, and 15 feet above this a coal 1 foot 6 inches thick is seen, the intervening beds being hidden beneath rubbish.

The dip is here nearly due south. The agglomerate ends off against a small fault with a northerly downthrow, but thin limestones and shales are again seen in the extreme south of the quarry.

(b) Brook-section 250 yards north of the Quarry.—No signs of igneous rocks are met with south of the quarry, the dip bringing in higher beds, but about 250 yards north of it a small stream shows the following apparent descending sequence :—

		[The letters and numbers refer to specimens examined by Mr. H. H. Arnold-Bemrose: see pp. 557-558.]		Feet	Ins.
N	1060.	Tufaceous limestone	4	0	
		Gap, a few feet.			
		Small coal ..	0	5	
		Hard calcareous nodular rock	0	3	
		Gap	2	6	
F	1065.	Flaggy calcareous sandstones, passing into shale	5	0	
		<i>Productus</i> - and encrinite-limestone	1	2	
		Black shales, with nodular concretionary limestone ...	3	0	
Y		Encrinite-limestone	1	3	
	1068.	Tufaceous limestone	8	0	
X	1061.	Tufaceous limestone	1	9	
M	1062.	Tuff, much decomposed; no fossils.			
		Exposure obscured towards bottom	120	0	
		Gap	130	0	
O	1063.	Coarse tuff, with fragments of limestone	100	0	
C	1011.	Tufaceous limestone, with fossils	2	0	
V	1056.	Well-bedded calcareous tuff	6	0	
E		Massive limestone	3	0	
		Hard tuff	8	0	
T	1057.	Tufaceous limestone	0	8	
A	1009.	Well-bedded calcareous tuff	1	11	
R	1058.	Thin hard tufaceous limestone	0	2	
D	1012.	Tuff	1	0	
		Hard limestone	3	0	
		Gap	12	0	
B	1010.	Tufaceous limestone	2	0	
P	1059.	Tuff, coarsely laminated	5	0	
		Limestone passing into calcareous tuff	2	6	
		Yellowish-brown tuff	6+

The stream thus shows a much more complete section than that of the quarry, but it is believed that this is in part deceptive: thus the apparently thick beds of tuff seen in the stream are regarded as the same bed on the east and west sides of the dome, and the greater width of outcrop is probably due to the stream following the same bed for some distance along the strike.

Towards the lower part of the section the strata are thrown into gentle folds. This is diagrammatically represented in fig. 4 (p. 553). There seems, however, to be a greater number of beds of tuff exposed in the lower part of the stream than are seen either in the quarry or towards the summit of the section. The stream-section places beyond doubt the age of the volcanic outburst at the close of the Carboniferous Limestone episode.

4. Succession between Top of Limestone and Third Grit.

(a) Brook-section in Limekiln Wood.—In the brook-section north of the quarry it has been seen that the tuff-beds and thin encrinital limestones are succeeded by a few feet of shaly sandstones and then by a thin coal. By means of the sections on the mountain-road leading from Limekiln Farm on to the moor, and the streams flowing down the northern margin of Limekiln Wood, an almost continuous section between the limestone and the Third Grit can be obtained.

Near the southern edge of the limestone-quarry, in the roadside leading from Limekiln Farm, a coal 1 foot 6 inches thick, passing under greyish-black shales, is exposed. The dip is not very high, showing that the summit of the dome is

close at hand. The shales that succeed have a fairly high dip, and are about 50 feet thick. These pass up into lavender-red shales, and red grits, succeeded by about 70 feet of a hard close-grained grit, with red spots and resembling in lithological characters the grits

Fig. 4.—Section along line AB (see map, fig. 1, p. 548) on the scale of 25 inches to the mile.

of the Millstone Grit Series. The road-section shows more shales, and then a hard calcareous mudstone. The succession above this is best shown in the stream running alongside Limekiln Wood :—

	Feet	Ins.
Hardened mudstone	7	0
Dark shales	200	0
Grey shales, hardened in places	6	0
Dark sandy shales, with numerous thin ferruginous bands ...	50	0
Sandy shales	40	0
Hard grit	1	0
" "	2	0
Sandy shales	16	0
Hard sandstone	1	6
Sandy shales	45	0
Thin flaggy sandstone	50	0

The section in the main stream at this spot is hidden, but it is continued in a tributary stream to the south, where deep narrow gorges have been excavated :—

	Feet.
Flags, as in the above section	50
Gap	150
Grit	12
Shales	30
Grit	8
Shales	80
Grit	9
Gap	30
Grit	5
Shales	8
Grit	9
Gap	120
Shales	30
Grit	8
Shales	35
Grit with red spots	20

The dip is often as high as 65° , and is seldom lower than 55° . The north-easterly strike remains constant.

(b) Quarry below the Third Grit, near roadside leading from Gillow Heath to Congleton.—Many of the grit-bands can be traced to the north-east for several hundred yards. In this direction, about a mile distant from Limekiln Wood, a quarry mentioned in the Geological Survey memoir¹ has of recent years yielded a varied marine fauna.² A measured section shows, in descending order, the following strata:—

	Feet	In.
Dull grey and yellow clay, with blocks of grit, 0-5 feet.	5	2
Rotten limestone, made up of <i>Orthis resupinata</i>	1	0
Grit	3	0
Shales, grey	0	9
Shales with thin slightly calcareous nodules	0	4
Hard, fine, grey sandy shales	5	7
Shales, with eleven bands of calcareous nodules, containing a rich marine fauna	3	0
Rather dark shales, with two lines of calcareous nodules.....	0	8
Shales with <i>Goniatites</i>	1	0
Darker calcareous shales coarsely laminated, with <i>Glyphioceras spirale</i> , <i>Posidoniella levis</i> , etc.	4	0
Shales, with calcareous nodules; marine fossils	0	0½
Coal, about ½ inch, twisted into joints of grit	5	8
Gannister-like grit	33	7
Gannister grits and shales, with plant-remains		

The dip is 45° to the south-east, giving with the rise in ground and distance from the Third Grit a thickness of about 500 feet of strata, chiefly shales, between the *Orthis resupinata*-limestone and this grit. The shales between the bands of grit are much crushed, showing that they have been subjected to considerable pressure.

The strata between the limestone-massif and the Third Grit are thus seen to consist of two portions—an upper series of thin grits and shales with a marine band in the middle, and a lower series of shales and thin, hardened, slightly calcareous mudstones, apparently unfossiliferous and having a massive grit 70 feet in thickness near their base. The hardened calcareous mudstones possibly represent the thin limestones mapped in Staffordshire and Derbyshire by the officers of the Geological Survey as occurring some few hundred feet above the main mass of Carboniferous Limestone, and are representatives of the Pendleside Limestone of Lancashire and Yorkshire.

The twisted nature of the Astbury Carboniferous Limestone-inlier with its compressed structure, the crushing of the shales between the bands of grit seen in the quarry below Congleton Edge, and the evident folding and crumpling of the shales in the brook-section north of the limestone-quarry, make it possible that the beds between the Third Grit and the limestone may owe part of their thickness to reduplication by overfolding; but we think that the stream-sections in Limekiln Wood, with their distinct divisions

¹ 'Geol. of Country round Stockport, Macclesfield, Congleton, & Leek,' Mem. Geol. Surv. 1866, p. 92.

² Wheelton Hind, Geol. Mag. 1897, p. 208, and 'Brit. Carb. Lamellibr.' Monogr. Pal. Soc. pt. ii (1897) p. 93.

into a grit-and-shale series above and a shale series below, and with no demonstrable reduplication of any one bed, render this unlikely.

Beyond indications of the strata having been considerably squeezed we find no evidence for the complicated system of faulting, represented on the Geological Survey map as surrounding the limestone-inlier. The fault on the Survey map represented as cutting off the limestone series to the east does not exist, and was probably introduced to

Fig. 5.—Section along GH (see map, fig. 1, p. 548) on the scale of 4 inches to the mile.

account for the absence of the great thickness of strata assumed to exist elsewhere between the limestone and the Third Grit. Towards the north-western portion of the inlier, as already stated (p. 552), minor folds exist in proximity to the Red Rock Fault, and in the stream a little farther north the shales are much disturbed, but in some cases this is due to the different resistance offered to tangential pressure by the more massive beds, whether limestone or grit, and the thin fissile shales.

So far as the evidence goes, there seems no reason for placing the strata between the limestone and the Third Grit in the Yoredale division, while, on the contrary, the fauna of the marine band and the presence of numerous grits of Millstone Grit type, containing plant-remains, point to their connexion with the Grit Series of the Carboniferous system.

5. Summary and Conclusion.

The occurrence of contemporaneous volcanic action towards the extreme summit of the Carboniferous Limestone exposed in the small inlier on Congleton Edge is interesting, as it brings the rocks into close relationship with the similar rocks in Derbyshire. Whatever opinion is held regarding the position of the vent, or the age of the beds lying between the Third Grit and the main limestone, there is no doubt that the volcanic tuff fell into the Carboniferous sea at the time when the main oscillatory movements which characterized the later Carboniferous period began.