THE GEOLOGY OF THE COUNTRY ROUND STIRLING.

By HORACE W. MONCKTON, F.G.S., with an Appendix by
J. G. GOODCHILD, F.G.S.

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THE area with which I propose to deal in the present paper is comprised in Sheets 31 and 39 of the Geological Survey Map (Scotland). An explanation of Sheet 31 has been published,* but there is no explanatory memoir of Sheet 39. Much information relating to the district will, however, be found in "The Scenery of Scotland," by Sir Archibald Geikie (2nd edition, 8vo, Edinburgh, 1887), and in a paper on "The Carboniferous Volcanic Rocks of the Basin of the Firth of Forth," by the same author.†

Sir A. Geikie divides Scotland into three belts of country: the Highlands, the Southern Uplands, and the Midland Valley. The district round Stirling he includes in the last of these divisions. It is divided from the Highlands by a great fault, that crosses Scotland from sea to sea and causes a displacement which is of unknown extent, but so great that in one place the beds of Old Red Sandstone are thrown on end for some two miles back from it.

On the Stirling side of this great fault we find a broad belt of Lower Old Red Sandstone, containing much conglomerate full of pebbles and fragments of older Highland rocks. I noticed a particularly good section in this conglomerate, by the roadside a little east of Aberfoyle. The remainder of the Lower Old Red Sandstone, so far as I have seen it, consists of sandstones, mostly of a red or purple colour and often full of vegetable remains, and of occasional beds of shale. The sandstone forms a fair building stone. One of the best quarries I have seen is at Stonehill, a mile east of Dunblane. I have not, however, explored the formation much. It was probably formed in a large lake, the bottom of which was slowly sinking.

The Lower Old Red Sandstone period was one of great volcanic activity, and the Ochil Hills are almost entirely formed of lavas and tuffs ejected during this volcanic period, of the duration of which some idea may be gathered from the fact that the erupted material is some 6,000 feet in thickness. The range of the Ochils forms a prominent feature in the landscape, as one looks across the plain of the Forth from the railway between Larbert and Stirling.

The Upper Old Red Sandstone rests uncomformably on the Lower division, and is usually treated as the base of the Carboniferous Series. It consists mainly of sandstones of a red and grey colour, and covers a large area round Loch Leven, but is not seen

* Memoirs of the Geol. Survey, 1879, price 2s. 3d.

† Trans. Roy. Soc. Edinburgh, vol. xxix, p. 437, 1880.

at the surface between the Ochil Hills and Stirling. A band of this formation runs from Gargunnoch to the Clyde ; and I believe there are quarries in it near Gargunnoch, but have not seen them myself. A long east and west fault runs from Kippen beneath the alluvium of the River Forth and along the base of the Ochil Hills, traversing the whole of Sheet 39 and bringing the various members of the Carboniferous Series into contact with the Lower Old Red Sandstone.

Resting on the Upper Old Red Sandstone there are, in Scotland, a series of rocks termed the Calciferous Sandstone Series, which are roughly equivalent to the Scar Limestone and Lower Limestone Shale of England. It is to this series that the celebrated Craigleith Sandstone belongs, as also does the Burdie House Limestone from which the late Dr. Hibbert collected a splendid series of Ganoid fishes. Both Craigleith and Burdie House are near Edinburgh, but in the Stirling district the Calciferous Sandstone Series is formed almost entirely of contemporaneous igneous rocks belonging to the second great volcanic period of the district. That the second volcanic period was separated from the first by a great interval of time, is sufficiently shown by the great unconformity between the Upper and Lower Old Red Sandstones. According to Sir Archibald Geikie, we may consider the Carboniferous volcanoes as diminished successors of the earlier series in the same region ; but, though diminished, their lavas and tuffs still cover large areas in Scotland. In our district they form the Gargunnoch Hills, the Campsie Fells, and the Kilpatrick Hills, reaching from Stirling to Dumbarton, and giving rise to the great escarpment which forms a very prominent feature in the landscape seen from the Highlands in the direction of Stirling. They are some thousand feet thick near Kilsyth, but thin out towards Stirling, and at Causewayhead, below the Wallace monument hill, have entirely disappeared. Near the base of this mass of lava there are intercalations of bedded rocks ; but in the upper part, which is seen near Stirling, such beds are wanting. The surface of the ground is for the most part moorland, and strictly preserved for grouse ; but many small sections may be seen in roadside quarries and along the course of the various streams. I may give as an example the sections along the burn which flows out of the northern end of Loch Coulter.

A little below the cottage Burnside there are good sections in the lava, which consists of a reddish-black, close-grained porphyry, with scattered crystals of felspar, usually termed Porphyrite in text-books. In one place two veins of barytes run through it. Such veins have been recorded from this formation in other places in Scotland, and Young's "Catalogue of Western Scottish Fossils" (Glasgow, 1876, p. 157) gives Corrieburn, near Kilsyth, as a locality. In the Carboniferous Limestone of Derbyshire they are common.

Somewhat lower down, the stream enters a wood, and a little to the south, in the bed of a tributary brook, the top of the lava-flow, which is ashy, and in places covered with tuff, may be studied. Still further down, at a waterfall, there is an excellent section in very hard porphyrite, a little beyond which that formation disappears under the beds of the Carboniferous Limestone Series. The porphyrite is of a somewhat variable character, and near Townhead Farm, to the north of the Bannockburn, it is externally like a basalt.

Overlying the porphyrite are the shales and ashy beds alluded to above, and then we come to the Hurler Limestone which marks the base of the Carboniferous Limestone Series. Above it there is in other districts a considerable thickness of strata, and then the Hurler Limestone forming the top of the lower division of the series. In this area, however, that part of the series is invaded and partly replaced by a great mass of igneous rocks, which are coloured pink on the geological map where they form a conspicuous feature. They represent the third period in the volcanic history of the district. These rocks are not of the same age as the strata in which they lie, and are consequently not interbedded with them as are the volcanic rocks of the Lower Old Red Sandstone and Carboniferous Sandstone of which I have been speaking; but they are of a somewhat more recent date, and are intruded into the Carboniferous strata, sometimes following the bedding and sometimes cutting through it. On the whole, however, they share in the general easterly dip of the bedded rocks, and consequently form a very prominent escarpment facing the west or north-west, and sloping down gradually towards the east. This escarpment is, however, broken by valleys into a series of separate blocks which are named the Abbey Craig (Wallace monument), Stirling Castle Rock, King's Park, Gillies Hill, and Sauchie Craig, and which bear a strong resemblance to the Salisbury Crags at Edinburgh.

The rock of which this intrusive igneous mass is formed consists of varieties of basalt passing into coarsely crystalline dolerite on the one hand, and into a greenish diabase on the other (Mem. Geol. Survey, Scotland, Sheet 31, p. 44).

There is an excellent section in Stirling at the north end of the Castle Rock, close to the railway. From that point the bottom of the basalt gradually rises in the hill, and close to Raploch a considerable thickness of shales, sandstones, and a thin limestone are to be seen beneath it. From a quarry at that place many fossils have, I am told, been obtained, but I have not myself collected there. On the western face of Castle Rock, the bottom of the basalt is at 180 ft. O.D., but at the King's Park it has fallen again and is hidden beneath the alluvium of the Carse, at 40 ft. O.D. At Cambusbarron there is a mine in a crinoidal limestone which is, I believe, worked for some distance under the basalt, the bottom of which is again rising.

The limestone, which is of a black colour and contains iron pyrites, is called the Murrayshall Limestone, and is equivalent to the Hurlet Limestone of other districts. It has been largely worked beneath the basalt on the western face of the Gillies Hill, and I have found fossils of Carboniferous species in the heaps of *débris*. There is a large quarry in the basalt of the Gillies Hill at Graystale Farm: the rock is dark-grey, rather close-grained, and with numerous small calcite veins.

At Wallstale, one of the long east and west faults breaks the continuity of the basalt, and the River Bannockburn, which has for some distance been flowing along the base of the escarpment, takes advantage of this break and turns through it to the east. Close to the river there is a small section showing basalt abutting against a white sandstone belonging to the Calciferous Sandstone Series. This is at the level of 234 feet O.D.

Following the edge of the basalt southwards, one meets with a series of very good sections in the Sauchie Craig. Along the road at the base of the crags, the fault of which I have spoken brings the basalt against the bedded porphyrite, so that it rises into the high crags on the south side, while the latter forms mounds on the north side of the road.

At the disused lime-kilns, between the Crags and the Bannockburn, the base of the basalt has risen to about 400 feet O.D., and is seen to rest very unconformably on sandstones and shales, of which some 60 or 70 feet are shown between the basalt and the river.

A little further south, the base of the basalt seems to descend through the bedded rock, but soon rises again, and is about 600 feet O.D. at the Goat's Mouth—a place where a cart-track passes through an opening in the crag not marked on the map, but nearly opposite the name "North Third." At the Goat's Mouth is another good junction section, where the basalt rests on sandstone, below which is a bed of the indurated shale locally called Calm or Camstone.

A little further south there is a large, nearly perpendicular vein of calcite in the basalt; and, a little past it, great unconformity between that rock and the bedded rocks is very well seen, a mass of bedded rock being apparently enclosed in basalt, the bottom of which rises sharply across the stratification.

Further south, another break in the crags occurs, through which a path leads to Sir James Maitland's house, Sauchieburn (marked "Sauchie Ho." in the map). At this point the valley appears to me to cut through the basalt to a greater extent than is shown on the map, for Sir James Maitland showed me bedded rock 117 yards inside the boundary of the basalt as mapped, and it seemed to me that the boundary should have been carried some distance down the valley to the east.

South of this valley the bottom of the basalt rises in the

face of the crags to about 730 feet O.D., and its junction with the underlying shales and sandstone may be seen in several places. At the southern end of the Sauchie Craig it cuts down through the underlying strata; and, close to the point where a road crosses the River Bannockburn, sections in basalt are seen close to the 600 feet contour. From this point it again rises westwards with the dip of the bedded rocks, and in the picturesque valley through which the river flows, on Sir James Maitland's moor, there are many interesting sections. I give one at a waterfall some way up on the moor.

	1. Intrusive basalt from the top of the hill, 848 feet O.D. to about 800 feet O.D.	
	2. Sandstones and shales, many feet.	
CARBONIFEROUS LIMESTONE SERIES.	3. Limestone, with shells, crinoids, etc., over which the water falls.	ft. in. 4 0
	4. Blackish calcareous shale, full of fossils, mostly crushed.	5 6
	5. White shaley sandstone	4 6
CALCIFEROUS SANDSTONE SERIES.	6. Greenish sandstone, forming a lower fall	about 12 0
	7. Blackish shales, not well seen.	
	8. Ashy beds, some 12 feet shown.	
	9. Porphyrite, much decayed in the upper part.	

The intrusive basalt, as I have said, conforms to a certain extent to the dip of the bedded rocks, which is easterly, and consequently its top, which is 839 feet O.D. at Sauchie Craig, slopes gradually down to about 300 feet O.D. at Sauchie Gardens. Its eastern boundary is much obscured by drift, and is marked on the map by a broken line. Opportunities, during a series of years, of noting sections have led me to think that this line should be somewhat altered, and it may therefore be of interest to describe it in some detail.

The section close to the River Bannockburn at Wallstale, 234 feet O.D., has been already mentioned. From near that place a road runs to the Cultenhove Dam, and on its south side there is a narrow strip of wood, 900 yards from the sluice at the dam. In the wood there is an exposure of basalt at 900 feet O.D. and 67 yards outside the mapped boundary. To the south, in Sauchie Park, there are some small sections along the edge of the wood west of Sauchieburn House, and in one of them a bed of indurated shale or Calm is exposed, 300 yards inside the boundary of the basalt marked on the map. Basalt is seen in the bed of the stream which runs down the glen at the back of the house; and just below it there is an old pit, ten feet deep, in blue and grey fissile shale, which was re-opened for me by Sir James Maitland. In the shale from it Mr. Goodchild found a fossil fern. This pit is wrongly mapped as basalt, and is 115 yards inside the boundary. At the fence of the pleasure-ground round the house the map is correct, and the basalt is seen lying against the indurated shale at 340 feet O.D.

This evidence leads me to believe that the eastern boundary of the basalt should be carried a little further out between the "W" of "Wallstale" and the "C" of "Cultenhove," and should then be taken inside that marked on the map from near the "C" of "Cultenhove" to the "e" of "Sauchie Ho.," turning from there to a point in the stream about 120 yards higher up than is marked, and joining the mapped boundary close to the fence of the pleasure-ground of the house.

It may be suggested that, though the bedded rock occurs at the places I have mentioned, it is only a patch lying on the top of the basalt, and that the latter continues to follow the dip of the strata underground to the east. I have, however, come to the conclusion that this is not the case, and I have attempted to show what I believe to be the true condition of things in Fig. 1, though the exact course and thickness of the intrusive rock underground is to a great extent a matter of conjecture.

A well-section at Sauchieburn House seems to me to throw considerable light on this question, and I therefore give the details so far as I have been able to obtain them.

SECTION AT A WELL, SAUCHIEBURN HOUSE, 1891.

	ft.	in.
1. Sandstone, with vegetable remains	17	0
2. Sandstone, of the hardness of Craigleith stone	2	6
3. Limestone—hard	3	0
4. Calm, very good quality (a whitish shale)	3	3
5. Various strata	7	3
6. Calm	5	6
7. Sandstone	3	9
8. Limestone	2	5
9. Sandstone	4	2
10. Limestone	0	8
	<hr/>	
	49	6

It will be observed that there are in this well two beds of Calm, or altered and indurated shale, and this seems to show the presence of the igneous rocks below ground. On the other hand there can, I think, be little doubt that the limestones belong to the Hurlet seams which have been so largely worked below the basalt on the west face of the crags; and if so, it follows that the basalt does not continue towards the east on the horizon at which it is found in the crags, and it seems to me probable that it descends through the strata in the manner shown in Fig. 1.

The character of the small sections at the edge of the wood north-west of the house favours this view, for the shale appears to be in contact with the top of the igneous mass, and not underlying it as was the case at the crags. In several places in these small sections, patches of shale or calm are seen, partially enclosed in, or resting on the top of, the basalt, the junction being well shown in hand specimens. On removing the turf to show this

to Mr. Goodchild, the surface of the shale or calm was seen to be beautifully striated by glacial markings.

The bottom of the basalt rises rapidly from Sauchieburn House to the south, and at a stream 300 yards distant the following section is seen:—

SECTION IN THE GREY MARE'S TAIL BURN, SAUCHIE
WOOD.

1. Intrusive Basalt, forming a cliff over which the burn falls, extending from about 550 to 430 ft. O.D., *i.e.*, to a little below the mapped boundary about 120 ft.
2. Carboniferous Limestone Series.
 - a.* Sandstone at 400 ft. O.D.
 - b.* Shales and sandstones.
 - c.* Fissile blackish shale at 320 ft. O.D.
 - d.* White Calm at 300 ft. O.D.

I failed to find the limestone here, and have little doubt that the basalt has risen through the stratified beds. A limestone was formerly worked near Old Sauchie House, and it clearly belongs to the higher seam locally known as the Hosies Limestone. It is a dark grey crinoidal limestone, with much iron pyrites, of much the same character as the Hurlet Limestone.

At the lodge north-west of Old Sauchie, there is a good exposure of sandstone in the road, 50 yards inside the mapped boundary of the basalt, which should, therefore, be carried further back here. The old lime workings are seen in the wood below the lodge.

Close to Old Sauchie House there is an excellent section in a burn: the Hosies Limestone is seen, and below it there is a bed of coal three inches thick. Somewhat higher up the same burn, towards Sauchie Farm, there is a splendid example of ice-worn and striated rock, overlaid by 15 feet of Boulder Clay. The ice-markings on the basalt are wonderfully fresh, though they cross the bed of the stream, down which a strong current constantly flows. The basalt continues to be seen, from time to time, in the burn, up to the watering-place at Sauchie Farm; but on the moor, some 570 yards north-west of the farm, Sir James Maitland found bedded rock—shale, with Carboniferous fossils—at 600 feet O.D., in the midst of the patch mapped basalt. I visited the locality, and think there is probably a patch of bedded rock on top of the basalt; but further investigation is required, as it is possible that the shale was part of a large boulder in the Boulder Clay. If it is *in situ* it is interesting, as bedded rock on the top of the basalt is very rare, it having been almost entirely denuded away. No doubt, however, the basalt was originally covered by a great thickness of stratified deposits.

At Millholm (marked "mill" on the map, near Craigquarter), just below the large hatching house of the Howietown Fishery, there is an excellent section in the burn:—

1. Intrusive Basalt, over which there is a water-fall.
2. Indurated whitish shale (Calm), forming the bed of the stream.

Some distance further down this burn, which is the same as that mentioned in an early part of this paper as flowing out of Loch Coulter, there is a section at the point where it flows under the main road from Kilsyth to Stirling :—

1. Basalt, well shown, 10 feet at 280 feet O.D.
2. Calm, with *Productus* and *Chonetes*.
3. Shales.

This section is more than 300 yards from the nearest mapped basalt; and as the section is, I believe, not old, there was, probably, no sign of igneous rocks there when the country was surveyed. I am inclined to think it belongs to a small patch of basalt, distinct from the main mass. There is a similar instance of a small separate patch on the Bannockburn, shown on the 6-inch map, and marked, but not coloured, on the copies of the 1-inch map which I possess.

South of Millholm, a great east and west fault cuts through both the igneous rocks and the stratified beds, which on its south side are carried forward to the east. It is interesting to observe that, as the River Bannockburn takes advantage of the fault between the Gillies Hill and Sauchie to make its way through the line of the intrusive basalt, so the burn from Loch Coulter takes advantage of this fault and passes through the basalt in a deep and picturesque glen. Near the line of this fault the basalt has been much altered, and contains much calcite and serpentinous matter. There is a large quarry, called the Jews' Quarry, in which that rock has been worked for road metal, a little north of the fault. I showed some specimens from it to Dr. Hatch, and he described the rock as a diabase, consisting of a crystalline aggregate of felspar in lath-shaped needles showing twin striation (plagioclase), serpentine, titaniferous iron ore, quartz and apatite. He added that the serpentinous matter had doubtless resulted from the alteration of the augite, which had completely disappeared. The quartz occurs in isolated clear grains, and is probably secondary. The brown ground-mass, which everywhere fills in the interspaces, consists of a finely fibrous micropegmatite, representing, probably, the final product of consolidation.

South of the fault, near Craigend House, the basalt rises into a high cliff, and is worked in two quarries, where it is seen to be a grey dolerite.

It will have been observed that there can be no doubt as to the intrusive character of the basalt; for it is found resting sometimes on shale and sometimes on sandstone, while the beds on which it rests are hardened and altered; moreover in places it cuts through the stratified rocks, and occasionally has caught up and surrounded portions of them. It may, however, very possibly

not be more recent than the Carboniferous period, for all faults cut the basalt as well as the Carboniferous rocks.

The Hosies Limestone, the occurrence of which at Old Sauchie I have already mentioned, is regarded as the top of the lower group of the Carboniferous Limestone Series. A little above it, a sandstone occurs which is quarried as a building-stone at Park Mill, close to the River Bannockburn. From that quarry Sir James Maitland has obtained a number of large pieces of *Stigmaria*, and other roots or branches of trees. A very similar stone, also full of *Stigmaria*, was found on about the same horizon when the ponds for the Howietown Fishery were excavated, and there it was overlaid by a black shale.

A little higher up in the series are some thin coals, and somewhat above them the Knott Coal and the Bannockburn Main Coal, both of which have been a good deal worked in shallow pits. Just above the latter of these coals another sandstone has been largely worked for building purposes in the Cat Craig Quarry, near Bannockburn. At Kilsyth, to the south-west of the district of which I am speaking, this middle group of the Carboniferous Limestone Series is rich in coals and black-band ironstone. The base of the Upper Group is marked by the Index Limestone. It contains thin coals and limestones, and fair building stone. It extends upwards to the Castlecary Limestone which marks the top of the Carboniferous Limestone Series.

We next come to the Millstone Grit or Moorstone Rock, consisting of sandstones and shales, with a little coal. On it the fine old house of Carnock stands. To a great extent it is buried under the alluvium of the River Forth. The Coal Measures near Stirling are also largely buried under alluvium, but on the east they emerge and form the Clackmannan Basin, and on the south-east there is a small area near Carron and Larbert which is practically part of the Falkirk Coalfield.

The Coal Measures end off with an upper red sandstone, which, so far as stratified deposits are concerned, completes the solid geology of this part of Scotland ; and I have found it by no means easy to explain to persons who have studied geology only in Scotland what a vast lapse of time there was between the Carboniferous Period and the Great Ice Age, to which the Boulder Clay or Till belongs.

But though there are no sedimentary deposits to represent the Secondary or Tertiary Periods, we find in the long east and west dykes of basalt, which run across the map, the evidence of a fourth outburst of volcanic activity in the Stirling district, which is supposed to have occurred in Tertiary times. These dykes consist of a dark blue, greenish, or black crystalline basalt, and are quarried for road-metal. I saw a good section in one of them in a quarry a little north of the Wallace Stones on Sheriff Muir.

SECTION THROUGH SAUCHIE CRAIG, NEAR STIRLING.—*H. W. Monckton.*

EXPLANATION.

Carboniferous Limestone Series.

- 1. Bannockburn Main Coal.
- 2. Knott Coal.

- 3. Thin Coals.
- 4. Horizon of Park Mill Sandstone.

- 5. Hosies Limestone.
- 6. The Hurlet Limestone.

Calcififerous Sandstone Series.

- 7. Shale and Tuff.
- 8. Porphyrite interbedded.

- 9. *Intrusive Diabase*, forming the upper part of Sauchie Craig.

- a. Sauchieburn House.
- b. Sauchie Craig.
- c. River Bannockburn.

It will be seen, on looking at the map, that the country is cut up by a vast number of faults. As a rule, these faults make no sign at the surface of the ground ; but there are marked exceptions, for where a fault brings igneous rocks against soft strata the former frequently stand out as a hill or ridge. For example, there is a long east and west fault, which forms the northern boundary of the Clackmannan coal-field, on the north side of which the contemporaneous igneous rocks of the Old Red Sandstone rise up steeply, forming the Ochil Hills, whilst on the south the Coal Measures form a flat plain. At Craigend House also, four miles south of Stirling, the intrusive basalt rises up steeply on one side of a fault, whilst the soft strata of the Carboniferous Limestone Series form a stretch of undulating ground on the other.

The Drift formation in this area is of very great interest, but I do not propose to deal with it on this occasion. I have therefore completed my survey of the country round Stirling, and will only add that anyone travelling through that place will have little difficulty in making out, from the train, the general succession of the strata which I have described.

APPENDIX.

NOTE ON THE SPECIMENS OF CALM, OR CAMSTONE, AND BASALT COLLECTED AT SAUCHIE BY SIR JAMES MAITLAND.

By J. G. GOODCHILD, F.G.S.

The chief points of interest connected with these specimens are three :—(1) their variation in structure ; (2) their relations to the rocks with which they are associated ; and (3) the changes that have operated upon them since their consolidation.

(1) The basalts consist of a very compact, semivitreous, ground-mass of basic composition, in which are included a few small lath-shaped crystals of a plagioclase felspar, which seems to be labradorite. Apparently there is no augite, nor even magnetite. Throughout the whole of the ground-mass, there is more or less evidence of a spherulitic structure ; but whether this is due to early devitrification, or to the subsequent filling of numerous steam-cavities by radiating spheroids composed of zeolites, does not seem to be clear. Lines of these pseudo-spherulites range parallel to the junction of the basalt with the overlying camstone ; but that they are not connected with fluxion-structure is rendered sufficiently evident by the diverse orientation of the larger crystals enclosed in the ground-mass.

The shale welded on to the upper surface of the basalt does not present any special feature to distinguish it, under the microscope, from other examples of the same kind. The rock is considerably indurated, and is converted into an impure lydian-stone. Under a quarter-inch objective the camstone appears to be full of minute specks, which appear semi-translucent under ordinary light, but which remain dark through a complete rotation under crossed nicols. These may, therefore, be garnets. Irregularly scattered throughout the camstone are little nests of material, darker than the matrix, which remind one of the appearance presented by spotted schist.

Notwithstanding that the eruptive rock under notice is so compact as to suggest that it was formerly a tachylyte (now quite devitrified), it graduates, in the field, into a holocrystalline, and, sometimes, coarse-grained rock which is typical dolerite. As this is by no means an unusual occurrence, one is led to inquire whether it is really advisable to employ three names for the chief structural varieties of the pyroxene-plagioclase rocks. We very much need a good generic name which will embrace, under one term, the granitic, the ophitic, the hemicrystalline, and the vitreous, structural varieties of these basic eruptive rocks.

(2) The Sauchie rock is intruded amongst Lower Carboniferous rocks of Yoredale age; but there is nothing to show whether it represents a late manifestation of the volcanic action to which the Stirling lavas and tuffs are due; or, whether, like the Whin Sill of Teesdale, it may not be, as that certainly is, of later date than some of the faults affecting the Carboniferous rocks. The Whin Sill is newer than the chief disturbances affecting the Carboniferous rocks, but it seems to be older than the Magnesian Limestone.

(3) The Sauchie specimens illustrate the phenomena connected with jointing in a very interesting manner. The basalt itself is divided up into irregular polygons—(in most cases these are irregularly hexagonal)—and the joints, which are remarkably fine and regular, cut down perpendicularly to the plane of junction with the overlying shale. Owing to the fact that the shale is welded on to the basalt, the joints pass uninterruptedly from the basalt into the shale or camstone, and divide this up into as neatly-cut polygons as the eruptive rock beneath. This is well shown, even in hand specimens.

A further point of interest connected with the Sauchie rock is afforded by the glacial striæ, which are seen in the quarry over a surface of several square feet. These striæ must date from the very climax of the Glacial period, just before the movement of the ice came to an end, and its included stones and mud began to be deposited as the Boulder Clay.