

XXII.—*The Rock Series of Craigbeg and Ord Hill, Rhynie, Aberdeenshire.*¹ By WILLIAM MACKIE, M.A., M.D., D.P.H.
(With one plate.)

(Read 21st November 1913.)

IN the Geological Survey's Memoir in explanation of Sheet 76 (p. 21) occurs the statement—"Small intrusive masses of pinkish felsite and white felstone occur at Windyfield and on the slope of Ord Hill, near Rhynie." Early in 1910 two small specimens were collected by the author from an exposure of the former rock on the north side of the road leading from the village of the Muir of Rhynie in Aberdeenshire westward to Cabrach in Banffshire; at a point about half a mile from the former place. Both of these were at the time believed to be fairly typical specimens of the "intrusive felsite" above referred to. These specimens were not examined microscopically till sometime in the summer of 1911. Subsequently the examination of more typical specimens showed one of them to be a peculiar rock of a gritty character, much infiltrated with cherty material, and its vesicles to be due to the weathering out of some highly soluble original mineral—that it was, in fact, a highly specialised rock of sedimentary origin. The other specimen was found on section to be a fine grit of a buff colour containing numerous volcanic fragments in addition to composite fragments of both acid and basic plutonic rocks in a fine quartzo-felspathic matrix. Some of the included fragments of volcanic rocks showed numerous scattered felspar microlites, but usually without definite orientation as in a typical volcanic rock. Others contained porphyritic feldspars and quartz crystals of some size. These included fragments were almost uniformly of much larger size than the associated sedimentary fragments and the layers of the latter were at times seen to be bent down and around these igneous fragments in a way that suggested that they had fallen into these deposits at the time of their formation. Further, the longer axes of some of them were at times seen to lie at right angles to the bedding planes. These observations certainly pointed to the local occurrence of volcanic activity during or immediately preceding the period of deposition of these rocks and led one to believe that a detailed examination of the area would yield results of exceptional interest. Accordingly several visits were made to the area in 1911 along with W. R.

¹ A preliminary note on this subject was communicated to the Society by Dr Mackie on 20th March 1912. See also *Report of British Association, 1912*, p. 467.

Watt, M.A., B.Sc. ; and again in 1912 and 1913 several traverses were made. The results are embodied in the present paper.

My first impression that a large proportion of the rocks of the series was of volcanic origin has not been borne out by a detailed examination. Distinct lava flows do occur, but the rocks at first believed to be tuffs do not on closer examination bear out that conclusion. They consist in large part of a set of rocks of quite anomalous origin, which have been laid down under peculiar and exceptional conditions, along with sedimentary rocks or grits of quite normal character. As regards the intrusive rocks in association with these, several small patches of granite occur to the west of the area. Some of these are typical biotite microcline-bearing granites, while others present a distinctly pegmatitic facies. Their proximity and natural chemical consanguinity to the acid volcanic rock of the series raises the question of a genetic relationship between them. Another intrusive of a basic type is a broad lamprophyre dyke of vogesite character which follows the western border of this patch of rocks, but at some little distance from its margin in the diorite mass on which the rocks of the series lie.

GENERAL DESCRIPTION OF THE AREA.

The rocks in question occupy the somewhat hummocky farmland interrupted by irregular patches of rocky ground which it has been found impossible to bring under tillage to the north and south of the Easaiche Burn (Fig. 1), where it turns eastward into the long narrow valley occupied by the Old Red Sandstone of the Rhynie and Kildrummie area. They extend northwards from that stream to a line joining the farms of Longcroft and Windyfield, where, to judge from the contour of the ground, they appear to end abruptly, being probably cut off by a cross fault which would run in a more or less east and west direction between these farms, and practically at right angles to the boundary fault of the Old Red Sandstone area. Numerous points of outcropping rock occur in the fields on these farms on the north side, and on the farms of Upper and Nether Ord on the south side ; and from these the relations of the various members of the series have been pieced together. The chief outcrops, however, occur in the high bank that runs along the north side of the Cabrach road and which is known locally by the name of Craigbeg. Even here the exposures are very meagre and patchy. On the steep bank between the road and the valley of the Easaiche again, there are a few more exposures, but they really contribute very little toward a comprehensive view of the series.

On the south side the area occupied by these rocks extends

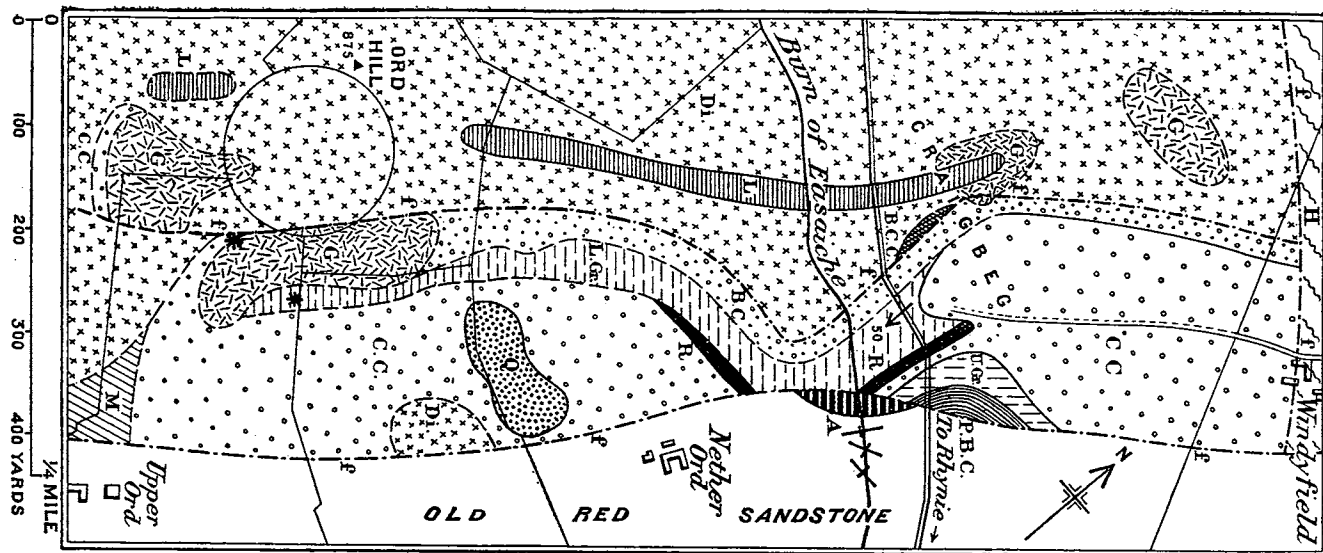


FIG. 1. Geological Map of the neighbourhood of Craigbeg and Ord Hill, Rhynie, Aberdeenshire.

P.B.C. Plant-bearing black chert; *U.Gr.* Upper grits; *L.Gr.* Lower grits; *C.C.* Cherty conglomerates; *Q.* Quartzite; *B.C.* Brecciated chert; *B.C.C.* Basal conglomerate chert; *R.* Rhyolite; *M.* Mudstone; *L.* Lamprophyre; *G.* Granite; *Di.* Diorite and gabbro; *A.* Andesite; *H.* Hornfelsed slates; *f.* Faults.

from the bed of the stream diagonally up the hillside and along the skyline of Ord Hill to just beyond the roundel of wood on its summit, where there are two small patches of granite. Thence the boundary runs diagonally down the hillside towards the farm of Upper Ord and cuts the boundary fault of the Old Red Sandstone some 200 yards south of that farm. This fault bounds the entire area on the east, and has cut off the outcrop of the series in a line which makes a very small angle with the general strike of its beds. The western boundary, save for the irregularity caused by the valley of the Easaiche, is roughly parallel to the same fault. The maximum breadth of the area from the fault westwards is about 200 yards, being roughly 150 along the line of the road and not much over 100 yards along the channel of the Easaiche, while its maximum length extends to about two-thirds of a mile.

GENERAL STRATIGRAPHICAL RELATIONSHIPS.

The rocks of the series are faulted against the diorite of the area. The fault plane hades to the east at an angle of about 50° , and at the northern end of the area may be traced from near the barren patch of ground on the crest of the hill to the north of the road right down to the valley of the Easaiche. The evidence of faulting is fairly clear. In an old quarry on the roadside the beds of the series are seen to rest against the diorite. Along the fault plane occurs a deposit of a reddish-purple clay due to local crushing of the diorite, which is here much decomposed and jointed—the main joints being roughly parallel to the fault plane. A spring occurs in this quarry near the line of the fault, and, at the bottom of the high bank leading down to the burn, slickensiding is observed in the particular member of the series which here abuts on the fault. Northwards from the roadside quarry the evidence is not so clear, but a small patch of granite on the slope of the hill has been divided into two owing to some slight lateral displacement along the fault plane. The same result has been produced on a larger scale at the southern end of the area, just opposite the clump of wood on Ord Hill, where an originally single mass of granite has been divided and separated into two masses by a similar displacement, so that a considerable isthmus of diorite extends in a lateral direction between them. There is some evidence that different members of the series come up to the fault line as it is traced from north to south. Thus at the northern end it is a cherty grit, followed to the south by a peculiar vesicular grit, known as the “slit” rock. In the old quarry above referred to it is a

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black conglomeratic chert. On the south side along the crest of Ord Hill, it is a cherty breccia, and still further south, as already indicated, it is a quartz-microcline aplite, passing into a biotite-microcline granite. The plane of the fault on the south side of the burn is inclined at a somewhat lower angle than on the north side, and the beds are evidently eroded down to the fault plane just to the south of the burn. A considerable mass of diorite appears at the surface within the area about 200 yards due south of the farm of Nether Ord, coming quite up to the Old Red boundary fault at this point. It owes its presence here to the fact that the beds of the series have been laid down on an uneven surface of diorite, though it may be that some trough faulting on a small scale may be the real cause of the appearance of the diorite here.

The Beds lie Unconformably on the Diorite.

When the low angle of the fault plane and the narrowness of the belt of rocks are considered, it will be seen that there is little room for observation in regard to the relations of the series to the underlying diorite. But there is little reason to doubt that they lie on an eroded surface of the diorite. This is borne out by the fact of the diorite coming to the surface in a considerable mass at the margin of the boundary fault, at the place already indicated. Numerous points of diorite have been observed at other places within the area, but they are so insignificant that they have in every instance been regarded as erratics brought from the diorite area to the west, though they may not all be of this character, but may in some cases actually represent the old diorite floor on which these rocks were laid down. An unexceptionable piece of evidence, however, in favour of the view just stated, lies in the fact that a small outlier of only 3 or 4 yards in superficial extent, and consisting of a rock which it has been found possible to correlate with one of the divisions in the main area, occurs at Upper Wheedlemont—a mile due south from the extreme southern end of the main area—where it lies on the edge of the serpentine mass of Cnoc Cailleaiche. As the serpentine is a member of the diorite and gabbro massive, this affords complete evidence that the rocks of the area rest unconformably on that group of rocks. Another observation of general significance as regards unconformity is the fact that fragments of diorite, ranging in exceptional instances up to 2 inches in diameter, are to be found in nearly every member of the series, at the bottom as well as at the top, showing that the diorite and gabbros were undergoing denudation during the period of deposition of these rocks.

Divisions of the Series.

For the purposes of detailed description of the individual beds, it will be best to divide the area into two parts, a northern or Craigbeg area, and a southern or Ord Hill area, the beds of the former being described under the name of the Craigbeg succession, of the latter under the name of the Ord Hill succession. From the quite local development and limited outcrop of some of the beds the succession is in a number of instances a matter of some uncertainty. Individual examples will be referred to as the different beds are described in detail. From above downwards, that is from the Old Red Sandstone boundary fault westward, the Craigbeg succession is as follows :—

CRAIGBEG SUCCESSION.

	Approximate Thickness.
Old Red Sandstone boundary fault—	
1. Black and gray cherts with plant and animal remains (provisional position) .	unknown
2. Upper micaceous grits	30 ft.
3. Cherty conglomerates	20 ft.
4. Fine flesh-coloured to dirty reddish-brown cherty band	1 to 2 ins.
5. Acid lava or rhyolite	40 ft.
6. Fine to coarse grey, yellow, and buff-coloured grits—lower grits	80 ft.
7. Band of coarse conglomerate passing northward into cherty grits	8 ft.
8. Fine to coarse grits with cherty matrix and numerous linear vesicles—known as the “ slit rock ”	30 ft.
9. Black cherty conglomerate	3 ft.
Fault between series and the diorite	—

ORD HILL SUCCESSION.

Old Red Sandstone boundary fault—	
1. Mudstones with cherty bands and thin brecciated lava flow	Indef.
2. Quartzite underlain by coarse grits	40 ft.
3. Coarse cherty conglomerates	30 ft.
4. Cherty band with scattered pebbles	several ins.
5. Acid lava or rhyolite	?
6. Micaceous passing up into coarse grits	30 ft.
7. Fine to coarse chert bréccia	30 ft.
Fault between series and diorite	—

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The rock of the *outlier* at Upper Wheedlemont corresponds to (1) of Ord Hill series.

Old Red Sandstone Succession as seen in the Easaiche burn from the boundary fault eastwards.

- | | |
|---|----------------------|
| 1. Andesite (hornblendic) | about 10 ft. exposed |
| 2. Calcareous shales } with traces of plant remains . . . | 10 ft. |
| 3. Fakey sandstones } and worm tracks | Indefinite |

DESCRIPTION OF THE INDIVIDUAL BEDS OF THE SERIES.

Craigbeg Succession from below upwards.

Black Cherty Conglomerate (9).

This bed has a very limited outcrop of only a few feet in linear extent, and from two to three feet in thickness, and is seen in the old quarry where it rests against the fault-plane. It is a very much broken, splintery rock in which it is difficult to get a fresh fracture, but a general mottled appearance in dark and light splashes can be made out with the naked eye. It is intersected by numerous secondary quartz veins. In section under the microscope, it is seen to contain scattered included fragments of a sedimentary character along with separate clastic grains embedded in a dark cherty matrix. A feature of many of these included grains and fragments is that they are found to be surrounded by zones of secondary quartz—a not uncommon phenomenon in the other conglomeratic beds of the series. The original matrix is dark brown to black and rather coarse in patches. In addition to the larger fragments and clastic grains which are of quartz, microcline, and less frequently orthoclase and plagioclase, there occur large irregular areas of a secondarily infiltrated fawn-coloured chert. In places where the grain of the black cherty matrix is coarser than usual, there appear darker patches, due to the infiltration of iron and manganese oxides around the constituent fine quartz grains. The outline of some of these masses and their regular cell-like structure suggest that they may represent some cellular organism, but this is probably illusory. Microcline in a very fresh state has been observed in one of the light-coloured cherty fragments. Derived diorite fragments have also been met with as inclusions in some of the sedimentary pebbles. Granite and diorite are certainly represented among these pebbles and some fragments of other fine grained igneous rocks also occur, but in the sections examined, it is doubtful whether any of the latter can without reservation be referred to a truly volcanic origin. Occasional small irregular vesicles, so far always found empty, are seen

throughout the rock and increase markedly in numbers as it grades into the next set of beds. In fact, near the junction they are quite numerous and in places are accompanied by a few of the peculiar slit-like vesicles that characterise that rock.

The "Slit Rock" (8).

This rock is of somewhat local development. It occupies the high bank on the north side of the road and is traceable for some distance northwards. An isolated point projects through the overlapping cherty conglomerates, just to the west of the summit over the road, where it shows its peculiar vesicular habit in an exaggerated degree. It has been located in the bed of the stream, but it is nowhere in evidence in the southern division. This rock presents a peculiar structure and habit characterised by the presence of numerous linear vesicles when viewed in section at right angles to the bedding planes. Hence for distinction it has been called the "Slit Rock." The series consists of fine to coarse grits with a cherty matrix, which is more or less evident throughout, but in places the rock runs into an almost pure dirty flesh-coloured chert, though the microscope always shows even in these cherty bands some coarser or finer constituents of clastic origin. Quartz and felspar, with muscovite and biotite, make up the bulk of the rock, but fragments of microlitic volcanic rocks are always present and in some sections have been found to be quite numerous. Rounded fragments of chert, dark as well as light coloured, are a constant feature. These chert fragments are usually larger than the clastic grains, and their rounded character is perhaps significant, though a doubt may exist as to the particular agency by which the rounding has taken place. The occurrence of the peculiar slits (Plate XXIII., Fig. 1) is the most interesting feature of this rock. At first sight they suggest a volcanic origin to the rock, but in face of its general constitution that cannot be maintained. Cut at right angles these vesicles appear as pure linear slits from $\frac{1}{16}$ to $\frac{1}{4}$ inch in length, but exceptionally they may reach quite $\frac{1}{2}$ inch. They lie more or less parallel to the bedding planes, though a proportion of them are seen to form considerable angles therewith, and locally they are almost at right angles. They are usually empty, though occasionally they have been found filled with secondary quartz. In a relatively compact specimen some of them were found filled with calcite. They are at times lined on both sides with secondary quartz, leaving a narrow linear slit along the centre. When two or more of these lie closely parallel the intervening space is seen to be filled in with fine cherty material without any of the coarser clastic debris. If

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the rock is broken parallel to the bedding planes so as to show their outline in that direction, they are found to exhibit rectilinear boundaries—triangular, quadrilateral, pentagonal, or occasionally even hexagonal. The surfaces exposed are smooth and present at times a polished appearance. There cannot be much doubt that they originally contained some highly soluble substance of a particular habit, which has now entirely disappeared. What this substance may have been is a very interesting question, but from experiments which I have made I am inclined to think that it was probably boracic acid. The crystals of this substance are of tabular habit, and boracic acid in a saturated solution has, on cooling, a tendency to form a thin crystalline pellicle on the surface of the solution, which on any movement of the liquid breaks up into angular fragments and goes to the bottom. The theory that they were filled with boracic acid would fit in very neatly with the particular view as to the origin of these sediments, which will be advanced later.

The Coarse Conglomerate (7).

The development of the coarse conglomerate appears to be very local—indeed, it crops out only in the little tunnel by the roadside and in the edge of the road itself in a position immediately above the last set of beds. It is made up for the most part of large fragments of chert of a dingy reddish brown tint. The most significant fact concerning it, however, is that a six-inch fragment of decomposing granite was obtained from it, which on section proved to be very rich in microcline. Its characters were such as left no doubt that it had been derived, if not from the adjoining Newseat mass, at least from one of the granite masses of similar character intruded in the diorite-gabbro massif, such, for instance, as occur at Gartnach Hill; Leithhall Home Farm; Auchmenzie, Clatt; Weets, Wardhouse; and also in addition at Newseat farm; in the serpentine of Scurdarg and at other places on the western side of the area.

Northern Cherty Grits (7).

The conglomerate evidently passes northwards into a narrow band of cherty grits, which may be traced from the eminence overlooking the road right up to the faulted boundary south of Longcroft farm. Along this line for some distance they lie next the western boundary fault. Their thickness cannot be more than a few feet. Several sections have been examined. Next the fault they are found to be composed of more or less rounded fragments of varying size of a dirty yellowish chert, with a few separate quartz grains along with a smaller number of rounded

feldspars. Fragments referable to a flaser or foliated granite and also to the diorite are met with from time to time. Other sections show some of the chert fragments with lighter or even white irregular nuclei, but without any visible fundamental difference in the constitution of the respective parts. This appearance is no doubt due to peripheral staining, and the irregular distribution of the fragments exhibiting this character suggests that the staining had taken place previous to their inclusion in these deposits. Higher in the bed the composition of the constituent particles is found to be more varied. Distinctly banded chert fragments appear along with fragments of the characters just enumerated, and notably fragments not unlike the mudstones which appear in the series in the southern area. Another section from immediately under the overlying fine cherty band was found to be uniformly composed of finely rounded fragments of chert, some of which showed secondary quartz veinings which did not pass beyond the margin of the grain, from which it is inferred that these quartz veins existed in them previous to deposition, that is to say, they must have been a feature of the rock from which they were derived.

Lower Grits (6).

These are in the main highly felspathic grits of fine to coarse texture and vary in colour from dirty grey through yellow to a fine buff colour. In some of them the feldspars are remarkably fresh, in others they are much decomposed. Orthoclase, microcline, and plagioclase are frequently all present. Some bands contain so much orthoclase that little doubt obtains that in these instances they have been largely derived from the waste of granite. Occasionally small fragments of granite are seen. In addition to unmistakable fragments of diorite, crystals of quartz have been observed with numerous included apatite crystals such as occur in the quartz of a quartz-diorite. Some of the sections have not been observed to contain any fragments of volcanic rocks, but in others they occur with a frequency that may be estimated as accounting for quite 20 per cent. of the entire rock. Nothing of the nature of true tuffs, however, has been observed among them. These volcanic fragments are usually much larger than the accompanying quartzo-felspathic debris. Several varieties of volcanic rocks are represented. The commonest is a somewhat coarsely microlitic rock like the matrix of an andesite. Others show ferromagnesian as well as felspathic microlites, but these occur far less frequently. Another noteworthy variety presents the characters of a porphyritic acid rock with phenocrysts of orthoclase and small quartz crystals

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in a microlitic base, and it is interesting to find that some of the detached quartz grains of the general rock may show central glass enclosures, indicating derivation from an acid volcanic. Garnet, zircon, and rutile represent the heavy minerals; but the first is by far the most plentiful. Small fragments referable to the clay-slate have been noted once or twice in these grits, but are relatively infrequent. Curiously enough neither in these grits nor in any division of the series have fragments referable to the hornfelsed margin of the clay-slate been observed; though garnet and cordierite-bearing pebbles, presumably from the hornfelsed margin of the clay-slate, have been found in the Old Red conglomerates of the adjoining area.

Contrary to what obtains generally in the much coarser cherty conglomerates and other finer-grained cherty beds of the series, the constituent particles are invariably angular. In addition to separate cherty fragments, which are fairly general, as an elemental part of most of these grits, cherty bands have been observed infiltrated along the fissures and divisional planes, but this is a distinctly local feature limited to the line of junction with the overlying fine cherty band and the cherty conglomerates. Secondary quartz veins occur to a varying extent throughout these grits, but they are decidedly more frequent when they come near to or in contact with the overlying rocks. A band of pebbles, some of them quite two inches in diameter, has been observed in one or two places along the division line between these and the cherty band. They include granite, diorite, and sedimentary fragments, but many pebbles of more or less pure chert also occur at this horizon. A two-inch pebble of diorite from just under the cherty band has been sectioned, and shows characters similar to the diorite in the roadside quarry, immediately beyond the fault plane. As in the local diorite there was evidence of crushing, if not of actual foliation, of the rock mass from which it had been derived.

The Acid Lava or Rhyolite (5).

Above the sedimentary rocks comes a vesicular igneous rock or lava flow, which must reach a thickness of about 40 feet, but its contact with the rocks above and below are nowhere seen. The exposures are bad and only some very rotten fragments were obtained from two old quarries overgrown with broom, and from the little runnel by the roadside. Only one passable micro-section could be got, though other very imperfect ones have been examined. They indicate a light fawn to reddish brown rock in the more decomposed specimens, showing a very vesicular structure. The amygdales consist of nests of quartz crystals,

or of these accompanied by aggregates of a radiating greenish mineral. In some specimens the amygdales are more or less rounded, in others they are very irregular, though there is a general extension of their outlines in the line of flow. Porphyritic orthoclases and a few quartz crystals appear in a somewhat coarsely microlitic base. Determination of the extinction angles of nine separate feldspars gave straight extinction in six and an average of about 7° in the three others. The presence of both orthoclase and albite may be therefore inferred. The microlites of the base usually show no particular orientation though in a much brecciated and secondary quartz- and chert-veined specimen from the south side of the burn, where a small exposure also appears, a definite orientation of the microlites does obtain. The base contains in addition to the feldspar microlites small crystals of iron ores, pyritized in part, and in part converted into anatase, thereby indicating their original titaniferous character. Small granules of epidote are scattered through the section and appear in most abundance round minute hexagonal holes in the section. What the significance of these holes and their association with the epidote may be has not been determined. No recognisable ferromagnesian constituents now appear in the rock, nor is there any evidence that any mineral of that character was ever present in it.

As already indicated much brecciation has occurred in some of the sections and all of them show abundant secondary quartz veins. Into the fissures produced by the brecciation (Plate XXIII., Fig. 3), the infiltration of beautifully rounded fine grains of cherty material has been observed in one instance. In the section from the southern area amygdales of limonite occur, and the fissures have been filled in partly with secondary quartz, in part with fine chert, but the cherty infiltration is seen to have invariably preceded the secondary quartz infiltration.

Fine Cherty Band (4).

A fine cherty band comes next in order, and overlaps all below it except the margin of the cherty grit of the northern, and the cherty breccia of the southern area. In a roadside section this band is seen crossing the basset edges of the grits which are inclined at a considerably higher angle. In fact, the section referred to gives the impression that a considerable amount of erosion of the grits had taken place before the cherty band was deposited on them. Several sections from this narrow band at different localities have been examined. In particular one from just over the cherty grits to the north of Craigbeg summit shows a uniformly fine material with small rounded cherty balls,

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which to all appearance have been formed in place, as their contours merge insensibly into the general matrix. They probably owe their origin to a gentle to and fro movement in the fine siliceous ooze as it was accumulating, or was at least as yet imperfectly consolidated. Towards the margin of the cherty grits—for both occur in the same section—there occur in large numbers what were originally, or at least at an intermediate period, crystals of magnetite, but are now in the form of limonite. Their presence at the very base of the cherty band suggests the sinking of the original iron ores by virtue of their weight to the base of this particular stratum. Another section from a locality near at hand presents much the same characters—fine cherty balls in a finer matrix, with at times long ovoid, at other times more or less irregular masses which appear to have been disrupted from an original continuous layer to be afterwards recemented by the deposition of finer siliceous ooze around them. A line of small pebbles or clastic grains occurs in a distinct band parallel to the fine lamination of the finer ooze. Some of these pebbles have been derived from the diorite—one fairly large fragment in particular showing felspar, quartz, iron ores, and some ferromagnesian elements.

The corresponding band in the Ord Hill area is of somewhat darker colour, and exhibits banding in places in lighter and darker colours, as well as finer and somewhat coarser material, though it is on the whole very fine. The coarser bands occasionally appear as if they had been forcibly projected into the finer. Here the cherty band lies on the edge of the brecciated cherts—indeed, it would appear that the latter have in part at least been derived from them. At this point, however, the fine cherty band is found to contain occasional pebbles up to $1\frac{1}{2}$ inches in diameter. Two of these have been sectioned. The first was a $1\frac{1}{2}$ -inch pebble of a fine sedimentary grit with angular quartz and occasional felspar grains embedded in a fine quartzo-felspathic matrix, and not unlike some of the grits that occur on the flank of the Hill of Noth, a mile and a half further north. The second was a fragment of black chert 2 inches in diameter with numerous secondary quartz veins and included fragments similar to the mudstones of the outlier, along with others evidently derived from the diorite. The latter pebble had all the characters of the black cherty conglomerate at the base of the series in the roadside section.

The Cherty Conglomerates of the Northern and Southern Areas (3).

In the northern area the cherty conglomerates, like the fine cherty band, overlap the edges of the underlying beds and with

the cherty band come quite up to the cherty grits that lie next the fault. In the southern area they probably occupy a similar position, but for more than one reason the relations there are not so evident. The main difficulty, however, is as to whether these conglomerates are really the highest beds of the series, originally overlapping the whole of the other beds, or whether, as is most likely, they should come in between the upper grits of the northern area, and between the quartzite of the southern area and the other rocks of the series in both divisions. The latter view is the one provisionally accepted, though there is little field evidence in its favour. Of more importance, however, is their lithological character, which, in my experience, is quite unique. Some twelve sections, well distributed over both areas have been examined. As regards their general characters, they present in a more or less fine siliceous cherty matrix numbers of isolated fragments of single minerals as well as composite rock fragments up to half an inch in diameter. From the smallest to the largest these fragments are generally well rounded, the smaller, however, more rounded than the larger. A few of cylindrical shape exhibit peculiar characters and are, as far as observed, exclusively of a cherty nature. The rounding of the grains and fragments, and another feature, their isolation in the matrix, that is to say, the fact that they rarely touch one another, being entirely surrounded, even the smallest, by a fine cherty matrix, are features which are present throughout. The individual fragments consist of quartz, orthoclase, microcline, and plagioclase, though the feldspars are relatively few, compared with the quartz particles. The composite fragments consist of granite, often of a flaser or foliated character, diorite of varying degrees of crystalline fineness, and often presenting quartz grains with the usual apatite crystals, grits of the character of those embraced in the northern group, micaceous schists, and in places numbers of fragments similar to the rocks of the Wheellemont outlier and the corresponding Upper Ord rocks. Others are exclusively of chert or of chert containing gritty particles of various degrees of fineness. Further, some of the fragments have been evidently derived from rocks of similar character to those in which they are now included as they show bands of chert running through them, the remaining parts of the fragments being made up of particles of very varying character. From time to time there appear fragments with coronas of cherty substance (Plate XXIII., Fig. 4) which is uniformly denser at the edge of the fragment, grading away insensibly at the periphery into the general cherty material of the matrix. These coronas are occasionally seen to be abruptly interrupted. They may occur on one side of a fragment and be completely absent from the other. Through the

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section many bands of fine chert may be traced for considerable distances. They are also liable to abrupt interruption where they come up against the side of a fragment, but may be seen to go on again beyond the fragment. Secondary quartz veins of varying breadth run through these rocks in all directions and occasionally the interspaces between the fragments may be seen to be filled with groups of radiating secondary quartz crystals. The secondary quartz veins give rise to some irregularities and occasionally to slight displacements in the fabric of the rock. But a significant feature is the fact that in a large number of instances the larger fragments are seen to contain secondary quartz veins which terminate abruptly with the fragment and are not continued into the surrounding matrix, thus showing that they have been derived from rocks in which this secondary quartz veining was already a prominent characteristic. Exceptionally fragments occur with concentric coronas of cherty material, the central nucleus containing a mineral particle or a composite fragment. In one instance the fragment shows as many as six concentric rings with an angular particle of a fine basic igneous rock forming one corner of the nucleus, the remaining part of which is composed of fine chert. Volcanic fragments are all but invariably absent from these conglomerates. They have, however, been seen in numbers in one specimen from the less flinty-looking conglomerate which occurs in place to the south of the quartzite on the front of Ord Hill. Here the volcanic fragments are of at least three kinds. One contained a large orthoclase and magnetite crystals in a microlitic base; another is dark red, almost opaque in section, with coarse felspar microlites, while others show coarse microlites in a light coloured base with much diffused epidote. In the same section also occurred a fragment of tuff containing at least three different kinds of volcanic rocks. These included the red volcanic with an amygdale of limonite, another with yellowish microlites and small hornblendes, and lastly a greenish rock containing what appeared a decomposing olivine along with an amygdale of a greenish radiating mineral.

One section from just within the lower margin of these beds and immediately over the fine cherty band in the northern area deserves description in detail, both on account of the variety of its enclosures and because it corresponds most closely of all the specimens examined to some fragments of these rocks found included in the granite of Ord Hill. To the naked eye it presents the characters of a dingy reddish brown chert. The section shows numerous diorite and granite fragments of some size, much biotite and some muscovites linearly arranged along the bedding planes. One or two microlitic volcanic fragments are present, also many fragments of chert, some of them with quartz veins

ending abruptly at the edges of the fragments, but the section generally is singularly free from secondary quartz veins. One relatively large chert fragment, in addition to a secondary quartz vein confined to itself, also shows what looks like a small fragment of plant tissue. There are also scattered through the section numerous quartz grains and some feldspar, both orthoclase and plagioclase. Another is a fragment of a brown acid volcanic with perlitic fissuring and several small porphyritic biotites. Others represent the schistose rocks. A proportion of the grains show a coating of ferric hydrate. This from its indeterminate distribution suggests some phase in the history of these particular grains before their actual inclusion in these deposits.

The Upper Grits (2).

These are exposed at one place only, in the corner of a field south of Windyfield farm, overlooking the Cabrach road, where it begins to ascend at Craigbeg. They are found to vary considerably in different specimens, but all of them are highly micaceous, both muscovite and biotite being present in large quantity. Generally they are of finer grain than the lower series of grits. Of the sections examined (7) some show large numbers of volcanic fragments—in one at least forming quite one-third of the entire rock—while in other specimens they are scarce or even absent. At least three different types of these volcanic fragments are present. Some are of acid type with feldspar phenocrysts along with both feldspathic and ferromagnesian microlites, others are more basic, and fragments have been observed with small augites in a microlitic base. In others of this type plagioclase feldspars of some size with included apatites have been seen and in one case a considerable crystal of sphene. In the section previously referred to, in addition to the volcanic fragments pure and simple, there occur quite a number of fragments made up of a fine radiating green mineral, often with a quartz bordering, and evidently derived from the amygdaloids of some volcanic rock. Green as well as brown palagonite has also been observed in this specimen. Cherty material of a greyish colour forms part of this section and through it is disseminated a small percentage of gritty material of the same character as the general rock mass. The deposition of the cherty material has no doubt been contemporaneous in this instance, but other cases occur where a black chert similar to that which occurs in the series of beds next above them has been infiltrated along the margin of the secondary quartz veins, but in other places the same material occurs in definite clots or patches in the general matrix without any relation whatever to quartz veins or bedding planes. Still another

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section shows parallel bands of grey chert; there is also much secondary quartz veining in this instance, but the cherty infiltration has always preceded the quartz infiltration. On the whole, I think that a proportion of the cherty material in these grits must be admitted to have been deposited contemporaneously with the beds.

Black and Grey Cherts with Plant¹ and Animal Remains (1).

These cherts occur in blocks, some of which are at least two feet in diameter, which appear to radiate from a small area just east of the outcrop of the Upper Grits. Some of them are embedded in the high bank on the roadside immediately south of that outcrop. Thence they spread eastward, and as quite a number of them have been found built into a garden wall in the Muir of Rhyne it is inferred that they originally occurred in the adjoining fields, on the east side of the Easaiche towards that village, though they have not been observed to occur there now. They may be seen in numbers in the rough stone dyke on the north side of the road from near the point indicated eastwards to a point in line with a small ditch that runs off at right angles to the road in a northerly direction. Along the edge of this ditch lie quite a number of fairly large blocks. They also occur in or on the broom-covered bank behind the dyke on the south side of the road. The furthest south they have been met with is in the channel or in the banks of the Easaiche—just south of the Upper Grit outcrop—where one or two large blocks have been observed above, *i.e.* to the west of the Old Red boundary fault. Northwards they do not extend to any great distance, being found only halfway across the field at its eastern end, while none of them occur in the dyke running east and west just to the south of Windyfield farm-house, though blocks of the cherty band and cherty conglomerate are exceedingly plentiful in it.

The rocks themselves embrace several types. Farthest west the blocks are composed of a grey more or less irregularly banded variety, in which plant remains are observable though they do not appear to be at all plentiful, nor to be very well preserved where they do occur. Some of these blocks in addition to containing cherty bands have a large proportion of gritty or sandy material intermixed. Another variety is distinctly banded in lighter and darker bands, and in the sections cut from them—and they were first to be observed and sectioned—no plant remains were found. This type is not plentiful as only the specimens from which the sections were cut have up to the present been obtained. The most characteristic type is a dark massive rock generally much intersected with secondary quartz veins,

¹ Dr R. Kidston is engaged on an investigation of the fossil plants.

and often showing the plant remains in dark round spots, or less often in dark bands or streaks—according as transverse or longitudinal sections are exposed—in a lighter coloured matrix. Other specimens are uniformly black and the plant remains in them are not revealed till they are cut in thin section. Some of the specimens are highly vesicular, the vesicles being usually empty and of very irregular shape. But they have occasionally been found filled with zeolites of which mesolite is one. Others are filled with chalcedony and very frequently in section the interspaces between the plant remains are found to be filled in whole or in part with fine spherical groups of this substance. Calcite and in one instance barytes have also been seen filling some of the larger cavities.

A section of a typical specimen (Plate XXIII., Figs. 5 and 6) of the chert shows the plant remains in large numbers. What was original plant structure may occupy quite three-fourths of the surface of a micro-section, the interspaces being filled in with a lighter coloured brown chert, or with chalcedonic aggregates, occasionally and locally with fine gritty material among which flakes of muscovite by reason of their relative size are distinctly conspicuous. The chalcedonic aggregates are particularly fine. Their beautiful concentric arrangement is evident in almost every slide and they are often seen to have formed round a small stem as nucleus, occasionally even round a spore, while they have also been seen to have formed in the interior of a stem, occupying there irregular areas, probably original cavities caused by local decay in the plants before their actual entombment in the chert. Sometimes even a single cell will show internally a fine concentric chalcedonic deposit.

The animal remains represent very minute organisms, which show characters that suggest their being crustacea. Their distribution is somewhat local: while they are entirely absent from many sections, they occur in numbers in others.

Up to the date of my last visit to the Rhynie area, which was on the 13th October 1912, these cherts had not been found anywhere *in situ*, and my general conclusion from a study of the distribution of the blocks was that they radiated from a small area just east of the outcrop of the Upper Grits in the corner of the grass field in the angle between the main road and the service road to Windyfield farm, and probably extending from the point indicated some little distance southwards across the road towards the Easaiche burn. As regards their possible relations to the Old Red Sandstone and the older formation, in the absence of field evidence, I was led mainly on the presumptive ground of their cherty character, which is more in conformity with the general lithological characters of the older formation—which, as

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we have seen, is in large part of a cherty character—to the conclusion that they belonged rather to that formation than the Old Red Sandstone. That was the provisional position I assigned them. Of their coming quite up to the Upper Grits of the older series at the point indicated I had, and still have, no doubt. My main difficulty was as to which side of the boundary line they should be placed on. Since the date indicated Mr Tait—fossil collector to the Geological Survey—has visited the area and has made several excavations on the ground with the view of definitely deciding once for all the exact stratigraphical position of these rocks. Through the kindness of Dr Flett I have been favoured with a copy of Mr Tait's report, which forms a valuable contribution towards the elucidation of this important point. From this report I quote the following :—

“Three trenches were dug in the lower field between Easaiche Bridge and Windyfield farm-house—the field in which corn was grown last year.

“The first trench was situated 53 yards north-east of the public road—measured parallel with the ditch which separates the two fields and alongside of which lie numerous blocks of chert—and 4 yards south-east of the ditch. It was 8 yards long and its greatest depth a little over 4 feet. As the dips observed on both sides of the field indicated an east and west strike, the trench was made in a north and south direction to obtain the best section possible. The section exposed was as follows (beginning at the top of the section and north end of the trench) :—

	ft.	in.
1. Yellowish clay with small stones (? much weathered sandy shale <i>in situ</i> . This occupied about 3 yards of the trench)	0	0
2. Loose sharp-edged fragments of chert (nearly <i>in situ</i>)	0	0
3. Cherty sandstone, micaceous, hard (<i>in situ</i> , dip 45° to north)	0	4
4. Chert bed (a few inches below surface)	0	10
5. Cherty sandstone in 1-inch beds	0	6
6. Thin bands of gritty chert 2-3 inches thick	0	6
7. Solid bed of chert, with vertical joints and with plant remains	1	0
8. Cherty sandstone	0	9
9. Solid bed of chert, with vertical joints and with plant remains	0	10
10. Cherty sandstone	0	3
	<hr/>	<hr/>
	5	6

"11. Loose and sharp-edged fragments of chert with a little solid chert occupied the southern end of the trench. This part attained a depth between 4 and 5 feet without solid rock being reached."

Two other trenches were dug substantially parallel to the first, the second "70 yards north-east from the road and 28 yards south-east of the ditch," the third "83 yards from the road and 49 yards from the ditch."

"Cherty sandstone similar to those seen in No. 1 trench was exposed in the bottom of the second trench at its southern end. The beds were lying flat or nearly so and many angular fragments of chert were embedded in the clay above it."

The results from the third trench, *i.e.* the most easterly, were on the whole negative. These trenches, even the first, which was the most westerly of the three, it will be observed, were made quite 200 yards within the area mapped as Old Red Sandstone on the six-inch maps of the Geological Survey, and the same or perhaps a slightly greater distance from the most westerly point at which these blocks are seen. As the march of the ice certainly did not carry them westwards, it is to be inferred that a chert band or bands must run from the point or from near the point I have already indicated in a south-east direction into the Old Red Sandstone area. This seems conclusive evidence that they belong to that formation. But the question is really of such importance that even the barest evidence pointing to a different view should be distinctly stated. At one period in this investigation I was decidedly of opinion, in consequence of my observing numerous points of outcropping diorite in the road from just west of Eassaiche Bridge onwards to just the beginning of the rise at Craigbeg, that the diorite was actually in place below—a view which is supported by the undoubted occurrence in place of a similar ridge of diorite in a corresponding position in the Ord Hill division of the area. But latterly I found it impossible to maintain that view in consequence of the belief that these points of outcropping diorite were in all probability carried blocks. A considerable doubt, however, remains as to their being entirely of this character. The view might be advanced that there exists here a ridge of diorite running out more or less at right angles from the main mass and that it has been let down by a trough fault or at least a fault parallel to the Old Red boundary fault, or that there is here an acute bend or branch of the boundary fault itself.¹ The marked bending round of the strike of the Old Red Sandstone beds (which I have remarked on in another part of this paper), from being parallel to the line of the fault to an almost east and west direction when traced eastwards

¹ *As bearing on this point I may state that last April (1914) I observed a line of springs, parallel to, and immediately to the south of the road.*

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from the position of the fault on the Easaiche Burn, and the vertical position of the Old Red beds would be very easily explained by the existence of such a diorite ridge as has been indicated. The cherty beds might then be supposed to lie more or less directly on the surface of this diorite ridge and to have a more or less east and west strike with a high dip to the north (45° in the first trench, according to Mr Tait). The absence of the cherts in the most easterly trench might be held to be due to their being cut out by the northern extension of the boundary fault on the eastern side of the hypothetical block of faulted diorite.

That such a change as occurs on the Easaiche Burn in the strike of the Old Red Sandstone beds as they come up to the boundary fault is not unique, is seen in the farmyard at the farm steading of Lower Wheedlemont, where the strike a few yards from the line of the fault was found to be at right angles thereto. Here, as may be the case on the Easaiche, there is a rather acute bend in the direction of the fault line.

Mr Tait looked for the chert bed at other likely places in the Old Red Sandstone area to the north and east of Windyfield. He did not find it *in situ*, but he found fragments of chert in different places, and notably at Castlehill about a mile and a half to the north-east of Windyfield, in numbers that suggested the existence of the plant chert bed at no great distance. These had "plant remains in them." I may say that in one of my later traverses of the area I found a somewhat rounded 3-in. pebble of black chert on the road near Castlehill, but on breaking it up I referred it at once to the black basal chert of Craigbeg. What is of much more interest, is that I have a distinct recollection of finding—it must be more than thirty-five years ago—in a field south-west of Craighall House and about $2\frac{1}{2}$ miles from Windyfield—an angular 2-inch fragment of dark flinty looking substance with cylindrical structures in it which I could not then understand. In the light of recent discoveries it has become much more intelligible to me, and I have little doubt it was a fragment of the Windyfield plant-bearing chert.

I attach relatively little importance to the occurrence of chert fragments at points distant from the main area. There can be no doubt that the march of the ice in the Rhynie area was mainly out of the side valleys on the west, then down the central valley towards the western flank of the Hill of Knockandy to the north of the railway, with a sweep westwards of at least part of the ice mass towards Gartly. This is precisely the direction that would make for the distribution of chert fragments to the places where they have been observed. And not only the planty cherts but fragments from undoubted members of the older

series have been scattered over the valley to the north and east. Thus fragments of the cherty conglomerate and the fine flesh-coloured chert from near Windyfield farm-house have been observed in numbers to the north of Longcroft, and in several of the small streams that run off the Hill of Noth through the farm land to the north-west of Milton of Noth, and even as far as Craigton on the opposite side of the valley, half a mile north of Craighall, within two or three hundred yards of the railway, where a block a foot in diameter of the reddish yellow chert seen *in situ* near Windyfield farm-house was observed by Dr Flett and myself last April.

In my opinion if the point at issue is to be definitely and absolutely settled on stratigraphical evidence, a trench or trenches should be dug immediately to the east of the outcrop of the Upper Grits, but the conditions are not at present favourable from the farmer's point of view, the field being under grass. Not till then, I think, unless in the interval the palæontological evidence comes to our aid, will an absolutely final conclusion be arrived at.

THE ORD HILL SUCCESSION.

The Chert Breccia.

The members of the Ord Hill Series will now be described in so far as they have not been included in the description of the corresponding beds of the Craigbeg succession.

The cherty breccia lies next the fault along the top of Ord Hill. It is composed of sharply angular fragments of dirty yellowish to reddish brown chert, the fragments ranging up to half an inch in diameter, in a matrix of finer debris of the same character. Towards the fine cherty band which lies above it and which is seen to contain scattered foreign pebbles up to $1\frac{1}{2}$ inches in diameter, the fragments of chert get larger and may be as much as 2 inches in diameter. Here they are of the same character as the cherty band of a dark reddish brown colour, and give the impression that the breccia has at this point been in whole or in part derived from the cherty band. As in the cherty band proper, foreign pebbles have been found in the cherty breccia at some distance from the former. One of these, a half-inch pebble, was found to be a fine sedimentary grit with a cherty matrix, in all respects resembling a fine specimen of the "Slit Rock" save in the absence of the characteristic slits. Like that rock it contained some fragments of microlitic volcanics as well as some fragments of chert.

The Quartzite.

The outcrops of quartzite run down the hillside in a direction at right angles to the western fault about 100 yards to the south of Nether Ord. The place of this rock in the succession is a matter of some doubt, but it is held to be the equivalent of the Upper Grits in the Craigbeg succession. It is seen to be underlain by a very hard coarse grit. The rock itself is a typical white quartzite of saccharoid texture, and is highly shot with secondary quartz veins, which, though characteristic of the whole group, here reach their maximum development. Indeed, it is difficult to obtain a specimen sufficiently free from large quartz veins for slicing. The joints and fissures are stained with oxide of iron, leading to the impression that the Old Red Sandstone once overlay this rock. A section shows the rock to be made up in large part of clear angular quartz grains in a matrix of diffused cherty material. There are certainly no secondary quartz-rims around their constituent particles. Garnet and zircon are conspicuous as heavy minerals. A few ragged biotites are present. Light-coloured cherts, as well as a few fragments referable to the clay-slate, have also been observed.

Mudstones of Upper Ord and Wheedlemont Outlier.

The rocks at these two places, though they lie a mile apart, are so like one another that they may be conveniently described together. The outlier as already stated lies on the serpentine of Cnoc Caillaiche; the rocks at Upper Ord, so far as exposed, lie on the diorite, and a question arises as to what position they really occupy in the series. Are they the actual basal beds of the entire group? or are they the uppermost, overlapping all the others and extending over them on to the diorite and the other rocks of that massive?

From the number of fragments similar to the rocks exposed at both these places, which are included as pebbles in the other beds of the series, the presumption is that the former view is the correct one, but no stratigraphical evidence has been found in support of that conclusion and the question may for the present be left an open one. Unlike the other members of the group these rocks are of a greyish green to dark olive green colour and present some characters that have not been observed in the other members of the series. One conspicuous feature which is frequently seen, particularly at Wheedlemont, is fluidal banding, or what appears very like it, the fine paste of the matrix looking as if it had actually flowed round the included quartz, felspar and composite rock fragments, which thus look like the "eyes" in a

highly sheared rock (Plate XXIII., Fig. 4), and yet the general mass of the rock, though locally showing considerable brecciation, affords no evidence of shearing. Another noteworthy feature is the fact that the mineral and rock fragments embedded in the basal paste very frequently have narrow veins of secondary quartz intervening between them and the matrix, being in this respect similar to the fragments in the black basal cherty conglomerate of the Craigbeg succession and the cherty conglomerates of the formation generally. The matrix is frequently a structureless green and brown mottled paste of the nature of a mud or clay and includes widely scattered fine to coarse fragments of quartz, which largely predominates, felspar, and composite rock fragments—the last occasionally reaching a quarter of an inch or more in diameter. There is frequently a considerable amount of brecciation, much fine secondary quartz veining, and locally a good deal of secondary calcite, particularly at Upper Ord. Cherty bands also appear from time to time, but so far as observed they always contain some gritty particles. Among the rock fragments diorite in both coarse and fine varieties is conspicuous. Magnetite in rounded grains appear in some of the beds and in larger irregular masses which are extensively pyritised. Basic igneous rock fragments of finer grain than the usual diorite fragments are present and some of these have been observed to be partly serpentinised. In one of the sections from Upper Ord radiating clumps of muscovite with finer interleaved biotites were met with.

A very thin brecciated lava flow has been observed at Upper Ord interbedded with the other rocks there. To the naked eye it is so similar to the general facies of the associated rocks, though it is slightly darker in colour, and so limited in vertical extent that it could not be located on a subsequent visit. Sections of it show it to be a somewhat basic rock with a hazy opalised appearance in which scattered much-altered feldspars, some of them of very irregular shape, corroded, and in large part calcified, are conspicuous. In places scattered felspar microlites show faintly through the general haze. The average extinction angle of the felspar phenocrysts (6) was found to be about 16° . They are, therefore, in all probability andesine. There exist much secondary green decomposition products, but no distinct ferromagnesian minerals are present. There are also diffused irregular patches of iron ores mostly in a pyritised condition. Perlitic structure is well marked in places, but is rather patchy in its distribution. Irregular amygdales filled with chalcedony and a greenish radiating mineral have also been observed. From this description it will be seen that this is quite a different type of rock from the included acid flow in the Craigbeg succession.

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THE OLD RED SANDSTONE BEDS ON THE EASACHIE BURN.

The position of the Old Red boundary fault can be fixed more or less definitely as it runs along the eastern margin of the area, though it is nowhere actually seen. Even in the Easachie Burn it is not seen, but its position can be located within a few feet. The rock lying next it on the Old Red Sandstone side is a greenish grey andesite, weathering with a yellowish crust. It was discovered by Mr Macconnachie of the Geological Survey. The outcrop in the burn—and it is the only one as yet discovered—extends to about 10 ft., though there is a possibility of its thickness being as much as 30 ft. It occurs at a point in the burn to which the acid flow in the older series could without much straining of the contour lines be easily joined up, but the wholly different characters of that rock are absolutely against any such idea. All the beds of the Craigbeg succession above a rather coarse grit, which may be correlated with some of the grits considerably below the top of the lower grit beds, are manifestly cut out by the boundary fault, though some of the higher beds, and notably the acid volcanic, can be identified as they swing round to the south side of the burn.

The Andesite

Sections of this lava flow show it to be a typical hornblende andesite. The felspar phenocrysts are largely calcified, and such areas as have escaped exhibit radiating aggregates of fine kaolin crystals in a hazy matrix of amorphous kaolin. Apart from the felspars some areas of the general rock mass are also highly calcified. The ferromagnesian element is a green hornblende, partly chloritised—in rather ragged crystals, though a few show idiomorphic outlines. A green radiating mineral of a zeolitic character occurs in small patches. The amygdales proper are for the most part rounded or ovoid and of variable size. They are made up of nuclei of a green chloritic mineral from which radiate fine colourless needles. One large ovoid amygdale which was extracted from the matrix was found to be largely composed of pyrites. Some minute magnetites are scattered through the rock and larger masses of pyrites may be detected with a lens. The felspars and hornblendes occasionally occur in glomero-porphyritic aggregates and at other times small hornblendes are seen included in the felspars. In addition to the felspar microlites, which in the sections examined (3) show no particular orientation, there are seen in places numbers of fine needles, which may be apatite, but they are much too fine for absolute determination.

This andesite presents characters which are markedly different from those of all the other andesites of the Old Red Sandstone area, and on the whole it looks decidedly more ancient than any of them. These rocks differ chiefly in the character of their ferromagnesian constituent, though hornblende as well as augite and an occasional hypersthene appears in the Contlach rock. Augite is the characteristic ferromagnesian constituent of the Boghead, Culdrain, and Gartly rocks. The Contlach flow contains xenolithic quartz, but so do the Boghead and Culdrain rocks, though probably not so frequently. Xenolithic orthoclase fragments have also been observed at Culdrain, but the Easaiche andesite, so far as examined, does not show either of these.

Sediments.

A band of light blue calcareous shales, about 10 ft. in thickness, succeeds the andesite. These shales are seen standing on edge under the right bank of the burn. They show worm tracks on the bedding surfaces, and some evidence of plant remains in an indeterminable condition. They have their strike parallel to the line of fault, but farther down the burn yellowish fakey sandstones, also on edge and showing indefinite plant remains, have a strike which is almost if not quite at right angles thereto. Some packing of the Old Red beds against the fault is therefore evident.

INTRUSIVE MASSES.

Granites.

Several granite masses fall to be described in immediate association with the rocks of the Craigbeg and Ord Hill series—two on Ord Hill and four in the Craigbeg end of the area. The Ord Hill masses have originally been one, which at an intermediate date has been divided into two by the fault that lets down the whole series on the east. The faulted portion of this mass lies wholly within the area occupied by these rocks and there exists unmistakable evidence that it is really intrusive in the Ord Hill series. Contact phenomena are apparent at two points marked by asterisks in the accompanying map (Fig. 1). About 50 yards to the south-east of the roundel of wood, rocks referable to the series—in this case fine grits—were found in a fragmentary condition mixed and cemented together with granitic material, and exhibiting large irregular drusy cavities lined with secondary quartz. Embedded in the granite were also found highly altered fragments, often presenting a green glassy appearance, along with others of a dark colour in which the original clastic grains could be observed with a lens. On

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section one of the latter is seen to contain large numbers of ragged flakes of greenish mica, along with angular quartz and felspar particles, and some fragments and veins of yellowish chert. Several quartz veins in the fragments end abruptly at their edges, that is to say they are not continued into the surrounding granite. A fine grained narrow yellowish margin comes next to the granite. In another specimen, contrary to the habit of the granite generally, some muscovite appears in the granite at the edge of the fragment. At the other point of contact, a highly siliceous whitish rock very much baked, with large irregular drusy cavities is seen, but the actual junction is not exposed in this case. Along the edge of the unfaulted portion of the granite mass, on its southern margin, numerous angular blocks of baked siliceous rock, some of them conglomeratic, are observed in the field and suggest that here also the rocks of the series have been altered by the intrusive mass, but no actual junction has been seen.

The granite of Ord Hill is mainly composed of quartz and microcline, with quite a minimum of biotite. In parts it is a pure quartz-microcline aplite, the quartz appearing in beautiful graphic intergrowth with the microcline. Its graphic character in some specimens is quite evident to the naked eye, while to judge from the sections examined it quite as frequently occurs on a microscopic scale. Indeed, the whole mass appears to consist of an almost pure eutectic mixture of quartz and microcline. A mass of similar rock is seen breaking through the serpentine towards the west end of the hill of Tombhreach. Occasional nests of black tourmaline have been observed in the Ord Hill mass near the little wood. Tourmaline, it may be remarked in passing, is a frequent mineral in the pegmatites of the adjoining area, and its frequency of occurrence locally is suggestive, when taken in consideration with the theory of boracic acid as accounting for the particular feature of the "Slit Rock."

At the Craigbeg end of the area, two small masses of granite lie, one of them just to the west of the summit and another and smaller just inside the fault line to the south of the summit. Here the same contact phenomena have been observed as at Ord Hill—baking and the formation of drusy cavities in a siliceous rock, the original characters of which are not very evident, but it lies on the line of the "Slit Rock" outcrop. If it is this rock, the characteristic cavities have been obliterated. The two masses here differ considerably in character. The smaller intruded mass is very like the granite quarried at Newseat some 200 yards to the west, and, like it, is rich in microcline, with some biotite and plentiful orthoclase. The sections obtained

owing to surface decomposition are far from satisfactory. The other and larger mass is of a different character — much finer grained and of a much darker red colour. Microscopically it is also different, though there is still a large amount of microcline. It contains relatively much more biotite which is of a greenish colour. The orthoclase is generally fairly fresh, but there are present a large number of much decomposed smaller feldspars which are probably albite. But the chief distinguishing feature is that its quartz exhibits a marked flaser structure, contrary to the general character of the granite masses intruded in the diorite. Fragments of a similar granite have been seen in a rock slice from the lamprophyre dyke, which has in all probability invaded this granite mass, but the actual contact of the two rocks is not observed. These observations would go to show that this particular mass is probably the oldest of the local granite masses intruded in the diorite.

The Newseat granite which is exposed in a quarry to the north of the road, about 200 yds. west of the fault, presents characters very similar to several of the other granites intruded in the diorite-gabbro massive, such as at Gartnach Hill; at Weets, and to the west of the railway station Wardhouse; at Leithhall Home Farm; also south-east of the farm of Auchmenzie, Clatt; at the mill dam of Newseat Farm, and also intrusive in the serpentine of Scurdarg. Like all these it is rich in microcline with a minimum of biotite, usually slightly decomposed. In the quarry at Newseat the granite is seen to be in contact with a mass of decomposed diorite and some irregular pillars of diorite stand up through the granite mass. Spheroidal weathering is a feature of the decomposing diorite, the centre of the spheroids remaining quite fresh. The other granite mass to the north-east may be considered as an extension of the Newseat mass. The contour of the ground suggests a bridge of diorite between them, but there is no field evidence on the point.

It is noteworthy that all the red granites intruded into the diorite or gabbro mass hitherto examined are found to be rich in microcline, contrary to what obtains in the larger masses of Benachie and Ben Rinnes. The inference is that they represent a later phase of the differentiation of the original magma, and for that reason that they are possibly of slightly later date than the masses of granite just referred to. The flaser structure of the quartz in the small Craigbeg mass has been observed in other masses belonging to the diorite massive, notably in one some 15 miles farther east at Loanends of Durno, where the mica is largely muscovite but with slight interleavings of biotite. A crystal of corundum has been identified in a section from this rock.

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The Lamprophyre.

A lamprophyre dyke about 60 ft. broad has been traced along the crest of Ord Hill and its occurrence here has given rise to this natural feature. It may be seen in the gorge of the Easaiche in the cliff on the right bank, and again in the most westerly of the old quarries on the roadside at Craigbeg. Numerous fragments of this rock also occur on the summit in the field north of the road. On Ord Hill it is intersected by many fine granite veins, and larger veins up to 6 inches in width are seen where it crops out in the gorge of the Easaiche.

Petrologically the rock is of the vogesite type, consisting of small irregular hornblendes with occasional larger ones along with fine biotites, which are more plentiful in some places than in others, but the dominant ferromagnesian element is hornblende. The matrix is made up of water-clear plagioclase feldspars. There is a sprinkling of iron ores and some colourless sphenes which are also more abundant in some places than in others. An occasional quartz grain has also been observed, invariably containing fine rutile needles, and probably of the nature of a xenolith.

CONDITIONS OF DEPOSIT.

From the number of fragments of volcanic rocks present in the various beds of both the Craigbeg and Ord Hill series—for though admittedly rare in the cherty conglomerates they have been found in all the divisions with the exception of the black basal cherty conglomerate, which has probably been insufficiently exploited in this connection—it is evident that volcanic action, at some little distance no doubt from the immediate area, was a feature of the period just antecedent to the deposition of these rocks. That there was a recrudescence of volcanic action at a later period towards the close of the interval represented by these rocks is shown by the presence in the series of a distinct acid lava flow. That there was some volcanic activity at some little distance in the interval between these dates is shown by the number of volcanic fragments in some of the purely sedimentary beds or grits, for the conditions under which they occur, and the fact that in many cases they are much larger than the associated sedimentary debris, appear to indicate direct projection from a volcanic vent. The theory which suggests itself as a competent explanation of the cherty developments, which are such a prominent characteristic of this series of rocks, is that during the decadent phases of local volcanic action, geysers

or hot springs were the efficient cause that gave rise to the particular features presented by this suite of rocks. The essentially local development of many of these beds, and their essentially cherty character, point to their deposition in small basins filled with hot silicated water. A high temperature appears to be indicated by an observation which has been made time and again, particularly on the basal cherty conglomerate, in the Upper Ord and Wheedlemont rocks and less frequently in the cherty conglomerate, that is the existence of peripheral secondary quartz veins around the included fragments, particularly the larger ones. It is natural to suppose that the contraction of these fragments in passing from a comparatively high to a low temperature would cause zones of lessened cohesion around the fragments which would naturally afford a nidus for the deposition of secondary silica from the supersilicated waters of the medium. Water saturated with silica at a high temperature would naturally deposit its excess of silica on cooling, and to this cause may be attributed the bands of pure chert, the finer wavy bands of the cherty conglomerates, and the infiltration of fissures and cavities in the beds previously deposited with cherty material. At a later stage, when cooling had taken place, the silica would be deposited more slowly and naturally in more or less perfect crystals. This may be taken as having been the cause of the formation of the secondary quartz veins which are such a prominent feature throughout the whole series of rocks. The features exhibited by the cherty conglomerates in particular indicate an alternation of quiet and disturbed conditions. The fine cherty bands might be taken as representing the quiet intervals between the explosions of a geyser, while the irregular conglomeratic bands would represent the explosive stages, following which the sinking of the rougher debris projected from the geyser would disturb the bands of fine siliceous ooze that had accumulated in the interval, as is strongly suggested by the general arrangement of these deposits, as seen in numerous microsections. The rounding of the finer debris and to a less extent of the larger fragments is to be ascribed to repeated trituration in the vent of the geyser. That some of the fragments had been used over and over again with intervals of accretion during which they rested in the deposits at the bottom of the pool surrounding the geyser orifice is borne out by the evidence of repeated accretions exhibited by a proportion of the fragments occurring in the conglomerates (Plate XXIII., Fig. 4), while the fact that some of them had already formed an integral part of similar deposits is indicated by their cherty character in whole or in part, and the fact that they had already been shot with secondary quartz veins in the beds from which they were derived.

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... The peculiar features exhibited by the Wheedlemont and Upper Ord beds—that is to say, the secondary quartz veins around the pebbles, their fluidal banding and “eye” structure, their cherty bands and brecciated volcanics—suggest the eruption of hot mud along with siliceous ooze and a minimal representation of actual volcanics such as at times is found to characterise the decadent phase of volcanic activity. Recrudescence of volcanic action occurred at a later period, and was followed by a similar sequence of events. At last a stage was reached when the temperature of the water, which was still highly silicated, was such as to allow of the growth of land plants around the geyser pools and the existence of living creatures in their waters. These were later entombed and preserved in the precipitated silica, as is shown by the occurrence of the black plant and animal-bearing cherts.

THE AGE OF THESE ROCKS.

Not the least interesting question regarding these rocks—and it is one that for the present is incapable of settlement within wide limits—is, what is their age? To what period of geological time do they belong? The palæontological evidence so far does not appear to help us. But there is evidence that ties down the age of these rocks to a particular interval of time. They are manifestly older than the local Old Red Sandstone, and though a doubt may exist as to whether or not they may possibly belong to an older division of the Old Red Sandstone than has hitherto been considered to be present in the north of Scotland, the general facies of the beds is in favour of referring them to still earlier times. They are at least younger than the intrusion of the diorites and are contemporaneous with the period of intrusion of some of the local granites. But all the evidence goes to show that the period of granitic intrusion extended over a considerable interval of time, and it is possible to show that this series of beds preceded the intrusion of some of these masses and followed the intrusion of others. Two if not three classes of red granites found intruded in the diorite exist, exclusive of the hornblendic granites which form a class apart. The first, and presumably the earliest, is represented by those showing flaser structure of their quartz grains; the second class are normal quartz-orthoclase-microcline granites, and the third consists of quartz and microcline almost pure and simple. One of the intrusive masses in the series belongs to the second class, the other to the last. Of the second class of granites representative fragments of considerable size have been found as pebbles in these beds; and the first class is possibly also represented by some of the flaser

quartz grains observed among their constituent particles—time and again, as individual grains, and frequently also as composite particles, along with felspar. So that the general inference would be that these beds are contemporaneous with the later phases of the granitic intrusion, but were clearly earlier in time than some of these masses, and later than others. The period of intrusion of the younger granites of the north of Scotland is generally referred to Old Red Sandstone times. The evidence is confined to the south of the Grampians, but the presumption is that these intrusions in the diorite, to judge from their composition and particularly their richness in microcline, were a late feature in the general scheme of intrusion of the younger granites.

Again, these beds are younger than the clay-slates. That is self-evident. The clay-slates have been hornfelsed by the intrusion of the diorite, and the diorite itself is older than these beds. Broadly, then, they belong to a period intervening between the Old Red Sandstone period and the period of the clay-slates.

The evidence again goes to show that these beds at Craigbeg and Ord Hill are only a local manifestation of a much larger formation both in vertical and superficial extent. As regards the former greater vertical extension of these beds, the occurrence of grit fragments in the black basal conglomerate may be taken as proof, while as regards their greater superficial extension, it has to be noted that grits occur at intervals around the valley occupied by the Old Red Sandstone of the Gartly and Kildrummie area.

EXPLANATION OF PLATE XXIII.

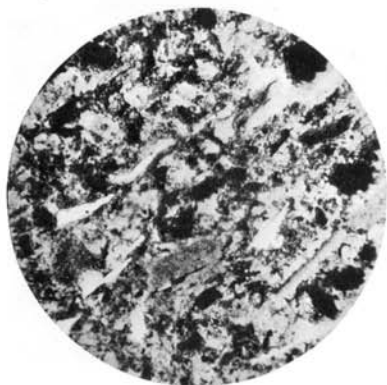
Photomicrographs.

- FIG. 1. The "*Slit Rock*," from roadside, Craigbeg, magnified 20 diameters.
- FIG. 2. *Mudstone* from Wheedlemont, magnified 18 diameters. It shows fluidal banding and "eyes" of quartz, felspar, and composite rock fragments.
- FIG. 3. *Rhyolite* from roadside, Craigbeg, magnified 18 diameters. Note the marked development of secondary chert and quartz, the result of silicification subsequent to consolidation of the rock.
- FIG. 4. *Cherty conglomerate* from the Ord Hill area, magnified 21 diameters. The large fragment consists partly of chert, partly of an igneous rock, and is surrounded by concentric bands of chert.
- FIG. 5. *Plant-bearing chert* from boulder collected in field south of Windyfield, magnified 18 diameters.
- FIG. 6. *Plant-bearing chert* from boulder collected in field south of Windyfield, magnified 20 diameters.

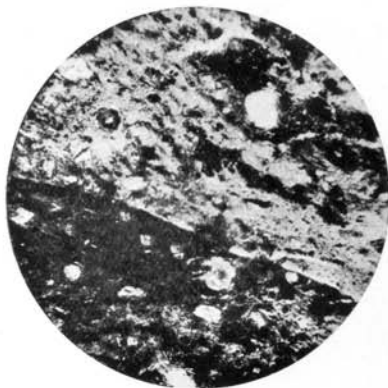
I gratefully acknowledge a grant from the Carnegie Trustees in aid of the printing and illustration of this paper.

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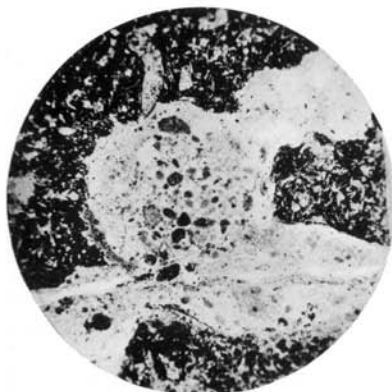
Vol. X., Plate XXIII.



1.



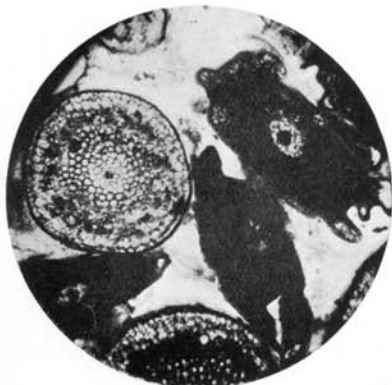
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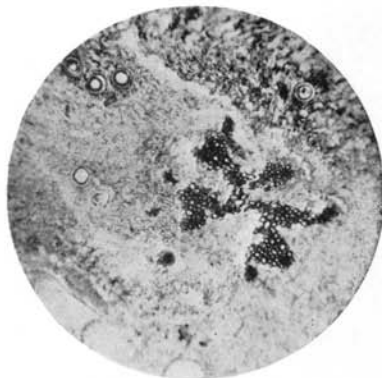
3.



4.



5.



6.

W. Mackie Photo.