THE GEOLOGY OF

THE CURLEW MOUNTAINS PERICLINE.

by

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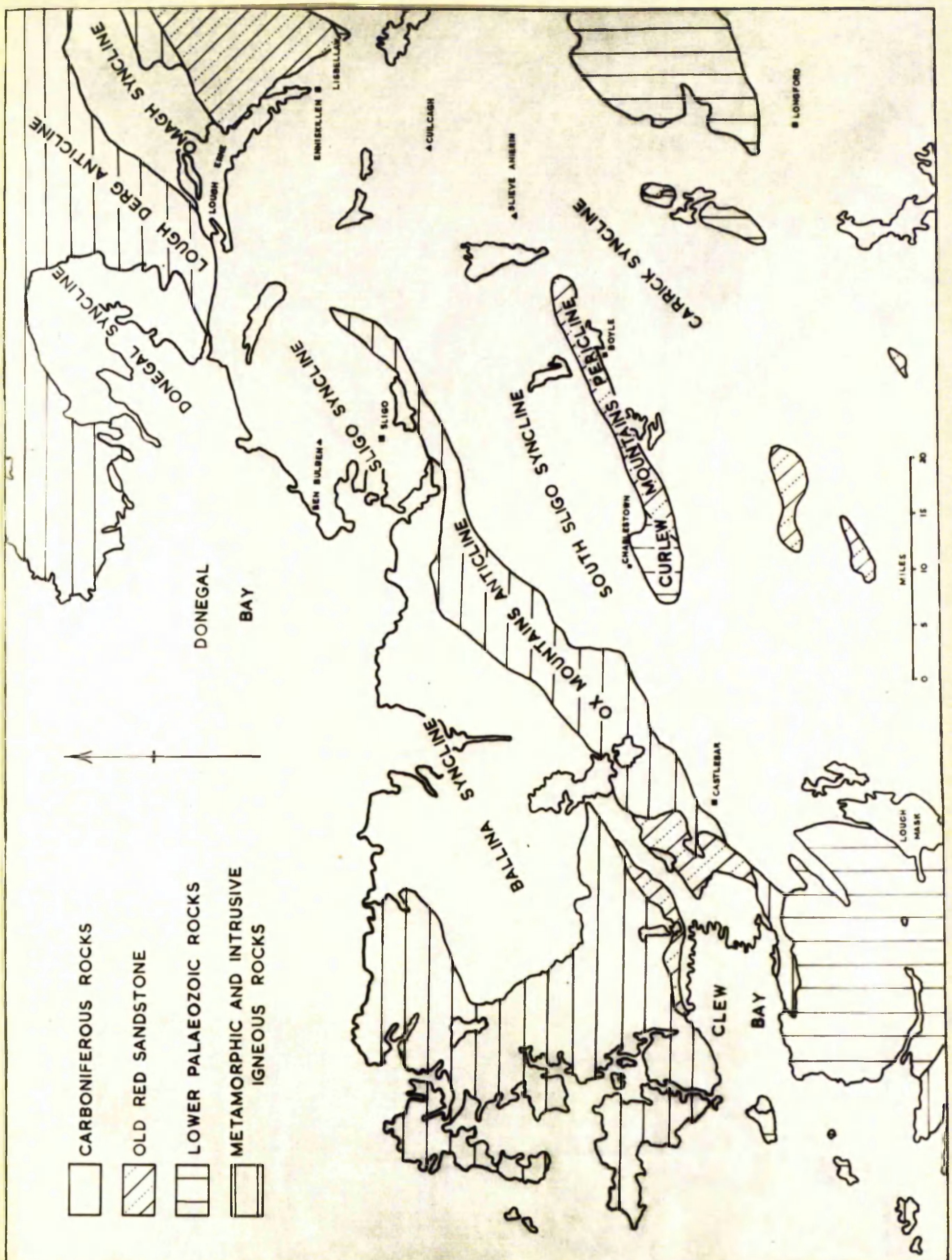

Fig. 1. A geological map showing the setting of the Curlew Mountains pericline.

I. INTRODUCTION

The area of about 150 square miles described in this paper lies in four Irish counties - Leitrim, Mayo, Roscommon and Sligo (Fig. 1). In it rocks of Ordovician, Silurian, Old Red Sandstone and Carboniferous age come to outcrop, the three older systems forming the core of the Curlew Mountains pericline, trending east-north-east, which is flanked by the Carboniferous.

The core of the pericline rises into a fairly well-marked chain of hills which ranges in height from 500 to 900 feet. Between Lough Gara and Lough Key it is known as the Curlew Mountains (Plate I). To the south the country has an average elevation of between 200 and 300 feet and is extremely flat, stretching into the Central Plain of Ireland. To the north a similar countryside, broken by the Bricklieve Mountains and one or two other hilly areas, lies between the pericline and the Ox Mountains (Fig. 1). This South Sligo syncline is formed entirely of Carboniferous rocks.

The pericline forms the watershed between the northward-flowing drainage (Owenmore and Unshin rivers), which reaches the sea within 30 miles, the Owengarry which flows westwards to join the Moy river, and the Lung, Feorish and Boyle rivers which flow eastwards into the

Shannon and ultimately into the sea nearly 200 miles away. The range of hills marking the core of the pericline is interrupted in two places by depressions occupied by Lough Gara and Loughs Key and Arrow (Plate I). Although these lakes are impounded by moraines and drumlins (Charlesworth, 1928, p. 14) - Hull (1891, p. 198) interpreted them as solution lakes - the larger depressions in which they lie may have resulted from a superimposed drainage. Thus the Lough Key-Arrow depression is 10 to 15 miles south-east of the breach in the Ox Mountains, made by the superimposed Ballysadare River a few miles south of Sligo town (Charlesworth, 1953, p. 188).

Throughout most of the area the ground is thickly covered with drift and bog. It is important therefore to emphasise that continuous exposures are extremely rare, and that some of the mapping and the results derived from it are regarded as only tentative.

II. ORDOVICIAN

Rocks of Ordovician age extend over an area of approximately 15 square miles between Charlestown, Kilkelly and Ballaghaderreen in the western parts of the Curlew Mountains pericline (Plate I); they give rise to Mullaghanoe (776) and the Kilgarrow Hills[(1)] (704).

(a) History of Research

On Griffith's map the Ordovician is shown as Yellow Sandstone (Carboniferous), and on Jukes' map of 1867 as metamorphic. The Sheet Memoirs 65 and 76 and 77 of the Geological Survey of Ireland, published in 1874 and 1881 respectively, delineate all the rocks now known as Ordovician and some of Silurian age under the term Wenlock. These consist of grits, "much altered and indurated" by intrusions of felstones, diorites, diabases, pyroxenites, melaphyres and quartziferous porphyries, which were earlier considered by Jukes & Foot (1866, p. 249) to be the "roots" of the Old Red Sandstone volcanic rocks outcropping further to the east. Kinahan (1879, p. 345) wrote on the findings of the Geological Survey as follows: "mapping some of these rocks as felstones is ... correct, ... the rocks so called being ...

(1) The convenient name Kilgarrow Hills appears on Griffith's map of 1838, but is not known locally today nor is it given on the current six-inch Ordnance Survey maps.

leptynites (metamorphic felstones), rocks which many petrologists include among the felstones; but mapping them as Upper Silurian must be incorrect as it is evident that these ... rocks were ruptured, upturned, metamorphosed and denuded prior to the ... Silurian rocks being deposited on them." The age of the rocks in his opinion was Cambrian or Cambro-Silurian.

McHenry & Watts (1895, p. 51) were the first to recognise the volcanic nature of these rocks when they wrote that, along with strata of "Wenlock" (now known to be Upper Llandovery) age there occurred "a series of volcanic rocks, including columnar and other felsites and their associated breccias and ashes, with associated masses of augitic granophyre." Kilroe (1897, p. 71) in endorsing this opinion, stated that the rocks afforded a close parallel with the succession in the country to the west of Lough Mask (Fig. 1), around Tourmakeady and Lough Nafooey, and that they also probably belonged to the Bala series. Further, that these rocks, "comprising what may prove to have been a distinct volcanic centre", contain fragments "of felsite, black and grey chert and other materials", and are "underlain and to some extent invaded by felsites which enclose lenticles and shreds of black and grey chert, as well as of black shale containing double graptolites."

In his review of the Ordovician and Silurian rocks of Ireland, Harper (1948, p. 54) wrote: "Ordovician cherts and black shales with graptolites are associated with felsites; there is a resemblance to the Ordovician rocks at Tourmakeady." Until 1954 these rocks had been variously assigned to the Pre-Cambrian, Cambrian, Cambro-Silurian, Ordovician, Bala, Wenlock and Lower Carboniferous. That at least part of the succession is Arenig in age has been established by Cummins (1954, p. 104). Cummins, investigating a small area in the Kilgarrow Hills, divided the rocks into a felsite group, which includes subsidiary tuffs and agglomerates and was compared with the Arenig felsites occurring west of Lough Mask, and a tuffaceous group, of which the chief rock type is a coarse, massive, green, felspathic tuff, with subsidiary agglomerates, lavas, fine-banded tuffs, interbedded cherty shales and massive tuffs.

(b) The Kilgarrow Hills

Ordovician rocks crop out in two fairly hilly areas east and west respectively of an expanse of bog devoid of exposures. The western area, the Kilgarrow Hills, shows very poor exposures except for a small area about Lurga, of four square miles, which lies from two to three miles south of Charlestown. The following description refers only to this area, since the other outcrops in the Kilgarrow Hills are sporadic and insignificant.

Succession Although exposures in the Lurga area are much better than in the rest of the Kilgarrow Hills, the ground is nevertheless extensively covered by drift and bog. The following broad succession, pieced together from partial successions in five more or less isolated outcrops, appears to be present in the northern half of the area:

		Thickness (in feet)
VI.	Massive, pale-green tuffaceous group.	800 +
V.	Fine-banded, bluish and green tuffaceous group.	1000-1300
IV.	Dark green agglomeratic group.	500-1000
III.	Pale green quartziferous tuff group.	600 +
II.	Porphyritic and columnar felsitic group.	600
I.	Bluish-green tuffaceous group.	500 +
		c. 4500

This succession, called the Tuffaceous Succession, as has already been emphasised, is partly conjectured, and the correlations proposed indicate considerable lateral changes in lithology such as are known to take place (p. 26); the succession corresponds to Cummins' tuffaceous group. The thicknesses, as elsewhere in the Ordovician, are based on width of outcrop and average dip and therefore are only approximations.

Group I. The rocks of this group are mainly massive, extremely hard, bluish-green tuffs. They are in general fairly basic in composition. The enclosed small fragments are of highly altered rock types and of crystal fragments, averaging about 1.0 mm. in diameter. The crystals are nearly all altered orthoclase and plagioclase (90%)[1], though there are some of a highly altered ferro-magnesian mineral, probably pyroxene, and a little magnetite (10%). The fine-grained groundmass is highly altered, containing much calcite, chlorite and magnetite. Numerous thin chlorite and quartz veins cut the rock and secondary quartz, which appears to have crystallised under stress, has collected in very small aggregates. Bent and sheared crystals provide other evidence of stress.

Group II. The rocks of this group, like those of Group I, are only found in Sub-area D (p. 27). They are mostly fine-grained, reddish-brown, porphyritic felsites in which columnar jointing is usually present, the columns being well-formed and from four to six inches across. The scattered phenocrysts, which average about 1.0 mm. in diameter and are regularly arranged throughout the groundmass, are of quartz (70%) and highly altered plagioclase (30%). The quartz phenocrysts have well-marked resorption rims of a colourless mineral whose refractive index is less than that of quartz (Fig. 2a). A large proportion of the groundmass is composed of this same material, the rounded crystals of which usually show a type of fibrous extinction, and quartz. The felsite, which has obviously undergone considerable late-stage alteration, was probably a fairly acid lava, to

(1) All percentages are modal.

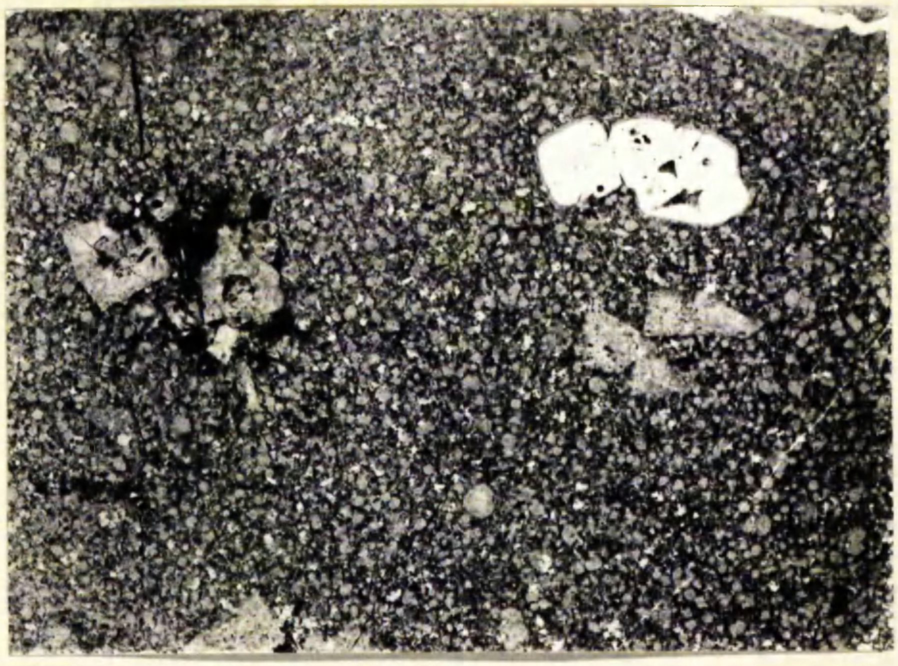

Fig. 2a. Porphyric felsite of Group II, showing a resorbed quartz phenocryst (p. 8). Ordinary light × 10.

Fig. 2b. Coarse-grained tuff of Group III, showing the contact between the matrix and an enclosed pebble of felsite (p. 10). Ordinary light × 10.

judge by the regular distribution of the phenocrysts and the columnar jointing.

Group III. The rocks of this group are usually fairly massive, extremely hard, coarse-grained tuffs. The predominant colour is light green though bluish-green varieties do occur, and rocks containing a large proportion of very small red fragments have a decided reddish tinge. The tuffs, which are very occasionally bedded, often enclose rounded blocks, up to one foot in diameter, of porphyritic felsite, reddish-brown to pale greenish-grey in colour (Fig. 2b) as well as numerous rounded quartz grains up to ¼ inch across, which stand out very clearly on weathered surfaces.

The felsite of the fragments is sparsely porphyritic, the crystals which are usually well-formed being of quartz (50%), orthoclase or plagioclase (50%). The homogeneous groundmass is mainly composed of altered felspar, and of quartz which sometimes shows evidence of resorption. The resemblance to the felsites of Group II suggests that the original rock was of igneous origin. Some of the small red fragments, up to ¼ inch across, which in places comprise a large proportion of the tuff, are made of this felsite, the others being felspar crystals. In hand specimen the contact between the pebbles and the tuffaceous matrix appears to be sharp, but in thin section this is seen not to be the case as if the tuff had been fairly hot when deposited. Occasional fragments of other volcanic rocks are found in the tuff; one fragment with well-formed plagioclase laths contains a number of very small zircons in the groundmass.

The tuff itself is less siliceous then the felsite of the pebbles, and is highly porphyritic with large rounded to subangular crystals. These are mostly plagioclase or orthoclase (80%) which are usually highly altered and occasionally full of inclusions, together with rounded grains of quartz (20%) which are occasionally highly resorbed and embayed. The quartzo-felspathic, very fine-grained groundmass of the tuff contains a large proportion of a chloritic mineral showing rather high birefringence, which probably accounts for the green colour of the tuff.

Quartz occurs in very small cavities where it appears to have crystallised under stress, and in numerous microscopic veins (Fig. 3a). Whenever a quartz or felspar crystal is seen to lie in the path of one of these, it is not cut by the vein. In the felspar crystals a zone lying along the line of the vein appears to have been heated up, causing the inclusions to vanish; quartz crystals appear to have been similarly heated. Associated with the quartz in these veins is an unidentifiable colourless mineral of high refractive index and rather low birefringence.

Group IV. The beds of this group are extremely variable in character, but are usually fairly massive and bluish or

Fig. 3a. The contact between the tuffaceous matrix of Group III and an enclosed pebble, showing a quartz vein affecting a felspar (top left) and a quartz (centre) crystal (p. 11). Ordinary light × 10.

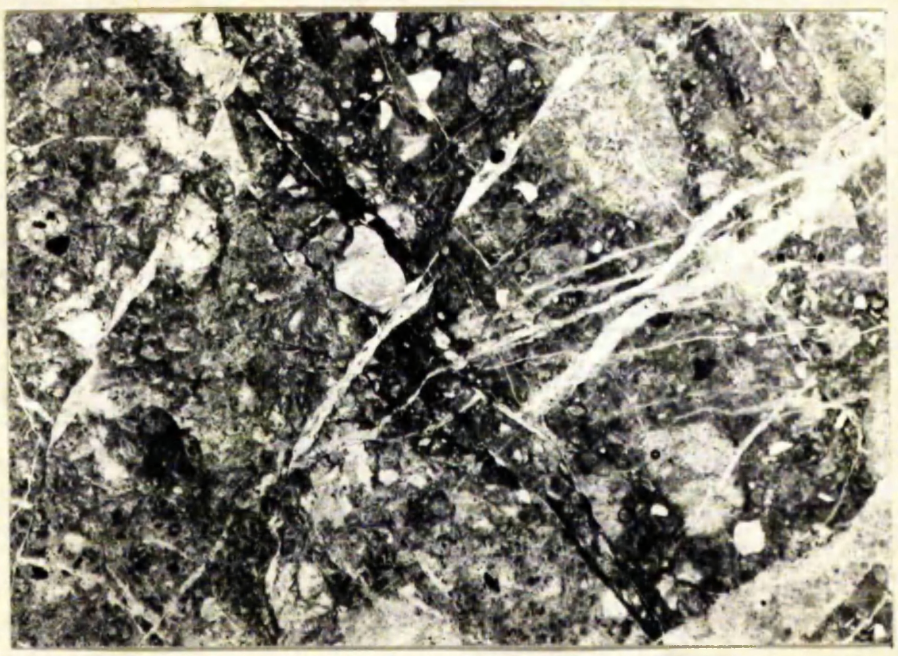

Fig. 3b. Quartz veins penetrating a tuff belonging to Group IV (p. 14). Ordinary light × 10.

greenish in colour. Though most often fine or medium-grained, they are occasionally agglomeratic and at one locality (p.26) enclose angular boulders, measuring up to ten feet across, of other fine-grained banded tuffs which are bent as if they had been fairly hot when ejected into the air. Banding is sometimes visible and crystal fragments are occasionally conspicuous in these rocks. In places finer grained types are encountered which sometimes contain numerous, extremely small, white particles that give the rock a speckled appearance. To the south, agglomerates with pebbles up to nine inches across become important.

When examined under the microscope these rocks are seen to be extremely badly altered. The rounded to sub-angular and occasionally fractured crystal fragments are usually of highly altered plagioclase with subordinate quartz; small fragments of other rock types also occur. The fine-grained groundmass is likewise badly altered, containing among other unidentifiable alteration minerals a normally and a highly birefrigent chloritic mineral, some carbonate, and some ilmenitic iron-ore. One outcrop is of a vesicular and amygdaloidal rock of basic composition, possibly a basaltic lava. The phenocrysts in this rock are of fresh pyroxene, some of them well-formed, and highly altered plagioclase; the fine-grained groundmass is made up of alteration material and the amygdales are probably of zeolitic composition. Secondary quartz is present in considerable quantity in the rocks of this group, both as thin veins along which displacement has sometimes taken place (Fig. 3b) and in cavities where the quartz appears to have crystallised under stress.

Group V. The rock-type commonest in the lower half of the group is a fine-grained, bluish-grey tuff which is usually laminated and very thinly bedded. The second main rock-type is a fairly massive, fine to medium-grained, porphyritic tuff which tends to be greenish towards the base and purplish towards the top. The fragments, which average about 1.5 mm. across, are mainly very badly altered plagioclase felspars which are sometimes zoned (60%), together with rounded quartz grains which are generally highly resorbed, embayed and cracked (Fig. 4a), and occasionally strained (35%). A small proportion of the fragments is of highly altered ferromagnesians and other volcanic rock-types (5%). The fine-grained groundmass consists of alteration material, including iron-ore which is usually magnetitic but sometimes ilmenitic, with chlorite and carbonate which occasionally becomes extremely abundant.

Among the finer grained tuffs are some cherts and

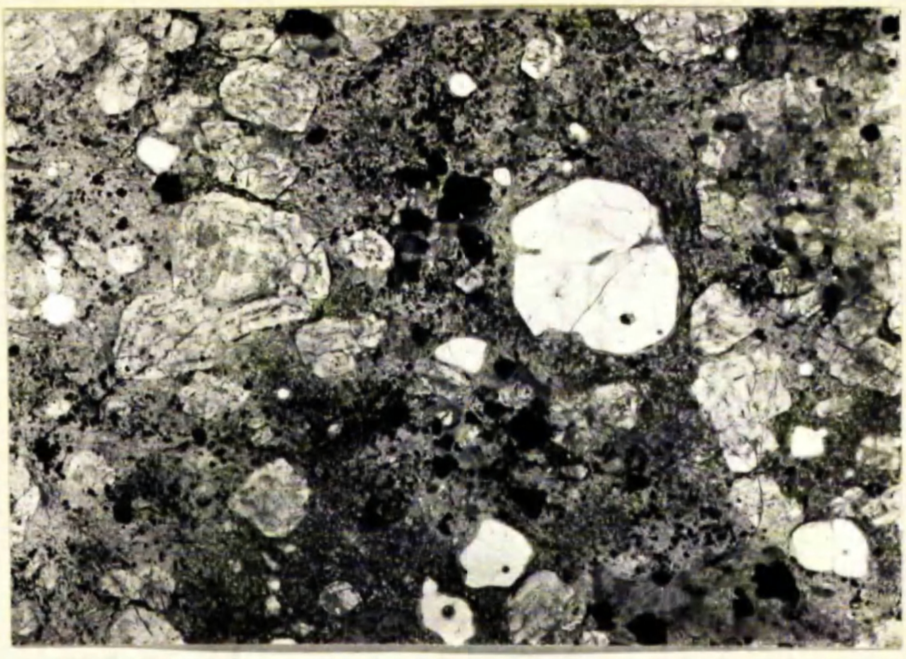

Fig. 4a. Tuff belonging to Group V, showing a resorbed and cracked quartz crystal (p. 14). Ordinary light × 10.

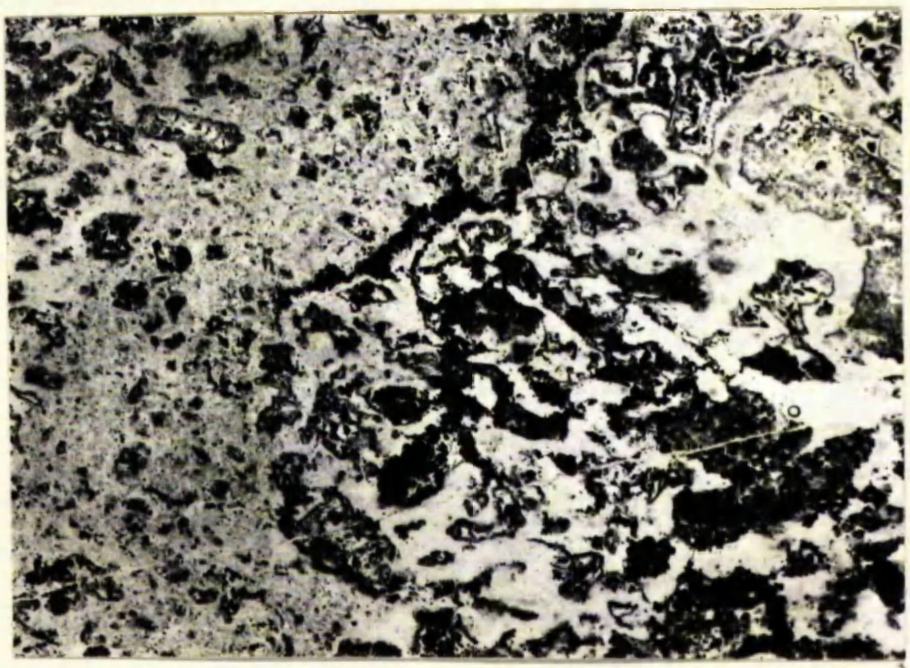

Fig. 4b. Recrystallised ferriferous chert from Group V (p. 16). Ordinary light × 10.

cherty shales, usually black in colour though occasionally grey or greenish. It was from these cherts that Cummins obtained the Arenig fauna. The tuffs, very fine-grained and highly altered, show a gradation from types which are composed entirely of tuffaceous material to types which are almost pure silica. The cherts are sometimes interbedded with thin bands of extremely friable, buff-coloured ashy sandstones which resemble a rock-type exposed only in Sub-area B (p.27). This is a thinly bedded, well-jointed, greenish-grey, ashy-looking siltstone with numerous very thin, rust-coloured laminae. Lenticles, irregular veins and thin bands of black, red and green chert, are common in the coarser grained rocks of this group; in one of these bands, just over an inch thick, several specimens of a brachiopod resembling Conotreta have been found. In Sub-area C there is a large outcrop of a rock made up entirely of recrystallised quartz (85%) and haematite (15%), with a trace of carbonate, which may be a recrystallised ferriferous chert (Fig. 4b). It is interesting to note that Gardiner & Reynolds (1912, p. 81) recorded the presence of "large veins or masses of red chert or of quartz", associated with the volcanic rocks of the Kilbride Peninsula, west of Lough Mask.

Group VI. The rocks of this group are fairly massive, pale green tuffs which are usually fairly coarse, sometimes agglomeratic, though finer grained types are met with. Quartz in any quantity is absent, a feature which distinguishes these rocks from those of Group III. The fragments in the tuffs include rounded to subangular crystals of highly altered orthoclase and plagioclase. Some quartz and fragments of other volcanic rock-types also occur. The very fine-grained groundmass, which is even more highly altered, contains chlorite and ilmenitic iron-ore.

To the south-east, in Sub-area B, there is a notably different succession called the Felsitic Succession, not readily correlated with that just described.

5. Finely porphyritic felsite group.
4. Spilitic group.
3. Dacite porphyry group.
2. Greenish agglomeratic group.
1. Red and green felsite group.

Although this succession, which forms Cummins' felsite group (p. 6), is not composite, its elucidation is not easy since the rock-types vary greatly along the strike, underlie a small area and are poorly exposed.

Group 1. The rocks belonging to this group are extremely variable in character. They are generally felsitic in appearance and most often reddish or greenish in colour. They commonly have a greater or less proportion of very small, angular to subangular phenocrysts, averaging from 1.0 to 1.5 mm. in diameter, 75% of which are plagioclase and 25% quartz; the plagioclase is sometimes antiperthitic. The fine-grained groundmass is composed of alteration material, including carbonate and ilmenite. Occasionally the rock is full of very small, pool-like aggregates of secondary quartz. At one locality there are numerous very small crystals of pyrites scattered through the rock.

Group 2. Rocks of this group are usually greenish agglomeratic tuffs, with small rounded pebbles up to six inches across of a fine-grained, brownish-red felsite. The felsite of these pebbles, which in thin section are seen to be sharply demarcated from the surrounding tuff, is composed of scattered rounded to angular quartz (40%) and altered plagioclase grains averaging about 1.0 mm. across, set in a fine-grained groundmass of alteration material including carbonate. The tuff itself is very fine-grained and siliceous, and encloses some rounded to subangular altered felspar (75%) and quartz (25%) crystals, which are usually less than 1.0 mm. in diameter. Both fragments and tuff are traversed by numerous thin quartz veins.

Group 3. The dacite porphyries of this group usually have a fine-grained purplish groundmass in which are embedded fairly numerous and large rounded to sub-angular crystals, varying in size from 2.0 to 3.0 mm. across, 60% of which are felspar and 40% quartz. The felspars, in spite of their pink colour, are all altered plagioclase, the colour being due in all probability to staining by iron from the groundmass. This is fine-grained and is made up of alteration material including chlorite and finely disseminated iron-ore. At a number of localities the groundmass is grey and the plagioclase crystals white, and sometimes the phenocrysts are fractured, the cracks being filled with an iron compound or invaded by groundmass.

Group 4. The rocks of this group include pyroclastic rocks and several basaltic lavas. The pyroclastics have an abundance of pink felspar crystals set in a fine-grained, bluish groundmass. The fresh felspar fragments, which are often fractured, are mostly plagioclase; occasional small fragments of other volcanic rock-types also occur. The groundmass is fine-grained and composed of alteration material. Small areas of the tuff are made up of very fine-grained basaltic material, which appears to have been injected into cracks and cavities in the unconsolidated tuff (Fig. 5a).

The laths of felspar, which make up much of the basic lavas, are arranged in typical spilitic fashion, though because of their highly altered state their albitic composition cannot be ascertained. The rest of the groundmass is composed of altered ferromagnesian crystals, probably pyroxene, a surprisingly large

Fig. 5a. Tuff belonging to Group 4 of the Felsitic Succession, invaded by basaltic magma (p. 19). Crossed nicols × 10.

Fig. 5b. Lava flow from Group i of the Old Red Sandstone succession (p. 42). Crossed nicols × 10.

proportion of magnetite, and chlorite. Some flows are porphyritic, with well-formed phenocrysts of highly altered felspar; occasional amygdales of carbonate were observed. The lavas reveal no pillow-structure.

Group 5. This group is made up of a fine-grained felsite which contains numerous small phenocrysts, usually less than 1.0 mm. in diameter, of quartz (30%) and felspar (70% - mostly orthoclase), the latter being well-formed. The fine-grained groundmass of alteration material, including carbonate, varies in colour from pink through brownish-red and light green to cream. Some fairly fine-grained, bluish-green tuffs, enclosing small reddish fragments, also occur.

The Granophyre. As already mentioned (p. 4), the Geological Survey's conception of the area was that of numerous intrusions, varying considerably in composition, surrounded by metamorphosed grits. More than twenty years later, McHenry & Watts (1895, p. 51) realised that most of these so-called intrusive rocks are in fact volcanic in origin, and that the only intrusions are those of an augitic granophyre.

This granophyre, as can be seen from the map (Fig. 6), crops out over a large area in the east. Projecting from the main outcrop are two sill-like extensions, one forming the boundary between Sub-areas B and C, the other between C and D (pp. 26-27). The junctions of the

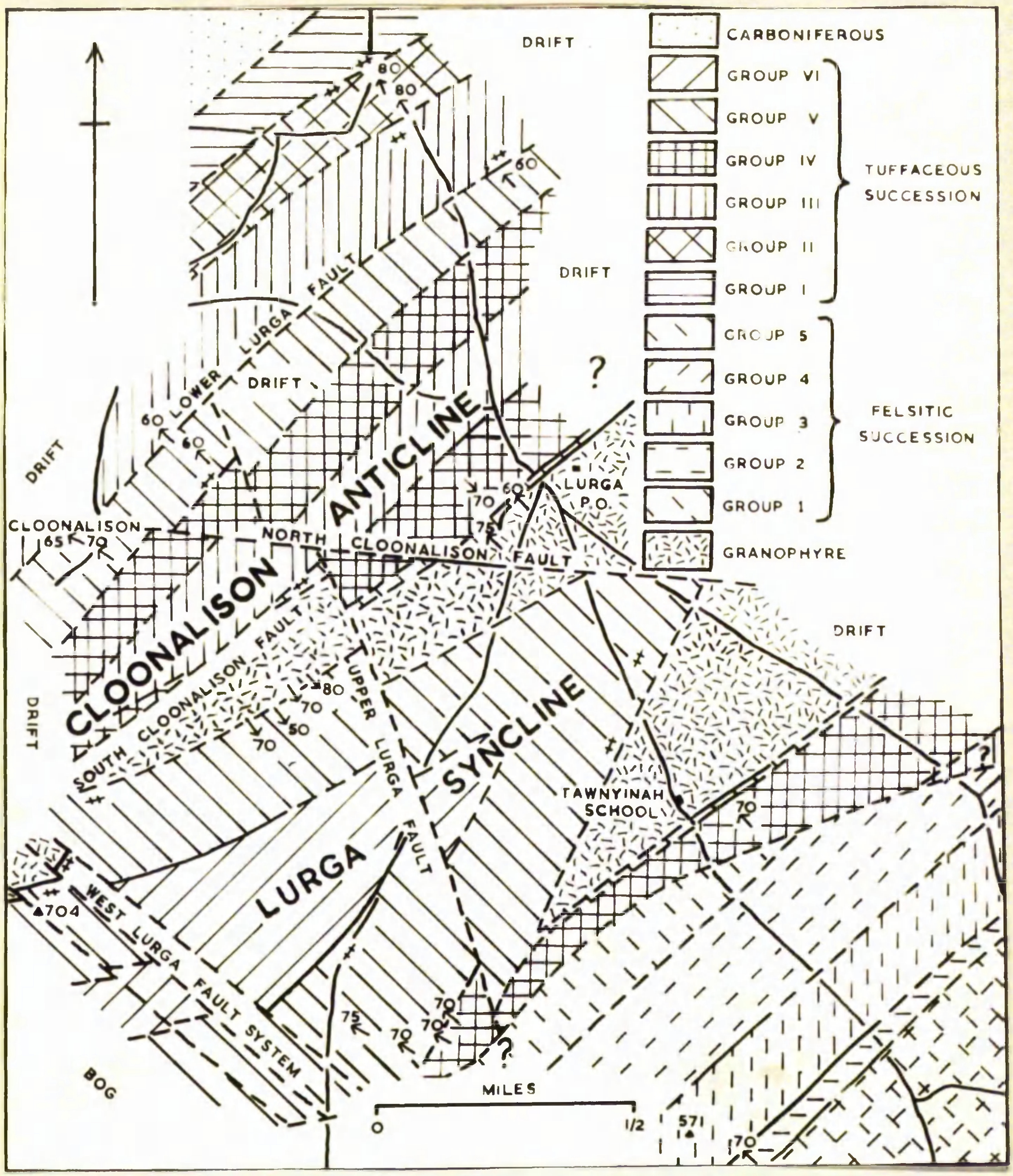

Fig. 6 . A geological map of the Lurga area.

south-eastern of these two extensions appear to be concordant, though the contact is seen only at one locality just east of Tawnyinah School in Sub-area E (Fig. 6). Here however the contact is far from simple, since the strike of the country rocks swings considerably near the granophyre, and the latter is either transgressive or the junction transcurrently faulted. The intrusion thins rapidly to the south-west, from about 1500 feet to zero in approximately 1200 yards. This thinning is probably not due to pinching out along a fault line, since the strata on either side of the granophyre are parallel to the inferred boundaries.

The north-western extension of the granophyre is the equivalent on the opposite flank of the Lurga syncline (p.100) of the south-eastern extension, and is intruded at the same horizon. It is however structurally much more complex. In Sub-area A, where the contact is well exposed, the granophyre has baked the country rock, which is a very fine-grained tuff, to a depth of about a foot. The granophyre itself is probably slightly transgressive, since the general trend of the contact does not correspond exactly to the strike of the adjacent tuffs. At the southern end of Sub-area A the contact is displaced to the west as the result either of a larger transgression or more probably of faulting (p. 102). A little to the south-west the granophyre again suffers a displacement of between 400 and 500 feet, also probably due to faulting (p. 102).

That these two displacements are due to faulting is confirmed by the fact that the intrusive horizon of the granophyre remains constant across the displacements - it is perhaps significant that the granophyre has been injected into the very well-bedded tuffs of Group V. Although the south-eastern boundary of this extension is never exposed, its inferred position always appears to be parallel to the strike of the adjacent country rocks. The non-appearance of the granophyre in the north-western limb of the Cloonalison anticline (p.100) may be explained by supposing that the granophyre transgresses to another horizon or thins rapidly to the north-west. The latter hypothesis appears at first to be somewhat unlikely, though a little to the south-east thinning takes place at the rate of two in five (see above). If this hypothesis is correct, the granophyre has decreased in thickness from 750 feet to zero within a distance of about 600 yards - at the same rate of thinning. The width of the granophyre outcrop appears to diminish south-westwards in the direction of pitch of the Cloonalison anticline, a fact which supports the thinning hypothesis. This reduction in width may however be due to pinching out along the South Cloonalison fault (p.103) or to lack of exposures, though the granophyre owing to its resistant nature usually outcrops when it is present.

The main mass of the granophyre, east of Lurga

Post Office (Fig. 6), may be concordant like the two extensions just described, or discordant. While the width of outcrop (over 1200 yards across the strike) suggests the latter alternative, two facts favour the former relationship and account for the great width. First, there is evidence that the granophyre is thickening rapidly north-eastwards across the Lurga area, until it is about 1500 feet thick in this region. Secondly, the centre of the outcrop coincides with the axis of the Lurga syncline. Thus it seems reasonable to assume that the granophyre intrusion is concordant and laccolithic in shape.

The granophyre itself is fairly coarse-grained and is usually dark green in colour, sometimes with a slight pinkish tinge. It is composed mainly of large orthoclase and sodic plagioclase crystals (60%) surrounded by later crystallising micropegmatite (30%). The felspars are highly zoned and badly altered, though the smaller crystals and the micropegmatite are less altered. The rest of the granophyre is composed of smaller crystals of rounded and resorbed pyroxenes, quartz, iron-ore, chlorite, epidote and other alteration material (10%). The rock is penetrated fairly frequently by late-stage replacement veins containing quartz, epidote and some chlorite.

The granophyre, since it is affected by the pre-Upper Llandovery earth movements (p.106), was probably intruded during the Ordovician. It is interesting to note that Thirlaway (1951, p. 17) recorded a negative anomaly of 20.9 mgls. at Station 1383, which is situated on the outcrop of the granophyre.

<u>Description of the Lurga Area.</u> The Lurga Area falls into five separate sub-areas which will be described separately.

Sub-area A, a small but well-exposed area lying just to the west of Lurga Post Office, is bounded on the south-east by the granophyre and elsewhere by drift. It reveals rocks belonging to Groups III-V. Though the strike is fairly constant, the dip varies considerably. It is usually to the south-east however, except along the contact with the granophyre where it is 60° to the north-west.

In Sub-area B, situated west of Sub-area A, the granophyre also forms the south-eastern boundary. Towards the south-west exposures are practically non-existent, but to the east and north-east of Cloonalison village (Fig. 6) rocks of Groups III-V are well exposed. Within Group IV a remarkable change in lithology takes place along the strike. East of Cloonalison the development is fairly typical, but when seen again about 400 yards to the south-west the upper part becomes coarsely agglomeratic, with angular boulders up to ten feet across which stand out clearly on weathered surfaces. So coarse are these rocks that they would not ordinarily have been correlated with those to the east of Cloonalison, had it not been for the presence in both cases of cherty mudstones belonging to Group V immediately to the north-west. These well-cleaved mudstones yielded no fossils, though a graptolite resembling **Climacograptus** was found in the ashy siltstone mentioned on p.16.

Sub-area C, which lies to the south of Sub-areas A and B, and is bounded on the north, north-west and north-east by the granophyre and elsewhere by bog, has a synclinal arrangement of rocks belonging to Groups IV-VI. The few outcrops of massive, fine-to medium-grained, greenish-blue tuffs and agglomerates to the south-east of the outcrop of Group V, are thought to belong to Group IV, especially since the agglomerates resemble very closely those in Sub-area E and those found along the south-westerly continuation of Group IV just outside Sub-area B.

The extremely few outcrops in Sub-area D, which occurs to the north of Sub-area A, are restricted to the small river valley which runs northward to Charlestown. Here about 500 feet of the rocks making up Group I are exposed before they pass underneath the unconformable Carboniferous sandstones (p. 86). In addition to the felsite of Group II and the tuffs of Group III, other rock-types not exposed may occur. Of the rock-types outcropping to the south-east of

Group III only two, which are in the extreme south-east, need be mentioned since they are quite unlike anything to be found in the Tuffaceous Succession. The first is an extremely well-compacted, pale mottled green tuff, with rounded to subangular grains of felspar (55% - very highly altered but probably orthoclase), rounded to angular crystals of quartz (45%), and a few dark-coloured crystals which are probably altered pyroxene (5%). The groundmass is very fine-grained and very siliceous; alteration minerals such as kaolinite, chlorite, calcite, ilmenite and rutile are common. The rock, which is traversed by a number of very thin quartz veins, shows evidence of shearing in places. The second rock-type is a reddish-brown felsite with very numerous large crystals of felspar (60%) and quartz (40%). Of the felspars, which are quite fresh, orthoclase is more abundant than sodic plagioclase, and the quartz grains usually show evidence of strong resorption. The matrix is made up of altered felspars, quartz, and magnetite, chlorite and epidote in close association.

Lying to the south-east of Sub-area C, in Sub-area E, of which the granophyre forms the north-western boundary and bog and drift the others, there occurs the whole of the Felsitic Succession as well as Groups IV and V of the Tuffaceous Succession. The beds, very well exposed just to the south-east of Tawnyinah School, resemble closely those of Group IV of Sub-area A, while the agglomerates, found further to the east, resemble those of the same group in Sub-area C. To the south-east of Group IV there are found, from north-west to south-east, the rocks of Groups 5-1 of the Felsitic Succession.

(c) The Mullaghanoe Region

This region, like the Kilgarrow Hills, from which it is separated by an expanse of bog devoid of exposures, is extremely badly exposed, so that it is only possible to give a fragmentary account of the main rock types found there. The exposures are practically confined to an area running from the top of Mullaghanoe (776) to a point about ¾ mile north of Carracastle. The southern part of the area is made up of rocks similar to those found in the Felsitic Succession of the Lurga area, and in the north the rock-types bear a resemblance to those of the Tuffaceous Succession. No details of the structure are to be made out.

The southern volcanics are usually fine-grained and vary in colour from pink and brown to white and green. They are often markedly porphyritic, the crystal fragments being mostly of albitic plagioclase (60%) and quartz (40%), though occasionally plagioclase is entirely absent. These fragments vary greatly in size from rock to rock and are up to 3.0 mm.

in diameter. In some rocks there is a sharp demarcation between groundmass and fragments, but in others no such abrupt break in grain size can be observed. The fine-grained material of the volcanics consists essentially of felspar, quartz, iron-ore, chlorite and other alteration minerals.

The volcanic rocks making up the rest of the area are variable in character. They are for the most part fine to medium-grained tuffs varying in colour from green to bluish and purplish. They often enclose fragments of a reddish volcanic rock and in places coarsen into agglomerates. Sometimes small cavities exist in the tuffs which are filled with chalcedony. Wherever the dip is to be observed it is to the north-west. At one locality nearly ½ mile north of Mullaghanoe there is a rock-type which, although highly altered, contains recognisable pyroxene and micropegmatite. This exposure may be at the north-eastern extremity of the granophyre, the main mass of which lies in the Lurga area, over two miles away to the west-south-west.

(d) General Considerations and Correlations

The most striking feature of the Ordovician succession in the Curlew Mountains pericline is the almost complete absence of sedimentary material. It is evident therefore that, at least for part of the

Ordovician period, the area was near a volcanic centre of considerable magnitude. The large amount of pyroclastic material in the succession bears witness to the explosive nature of much of the volcanic activity.

The age of the Tuffaceous Succession has been conclusively proved by Cummins to be Arenig. However the age of the Felsitic Succession and its relationship to the Tuffaceous Succession are not known, though the rocks of the Felsitic Succession may be post-Arenig in age (see below) and may rest unconformably on the rocks of the Tuffaceous Succession. The felsitic rocks outcropping in the south-east of Sub-area D (p. 28) may be the remnants of a volcanic neck penetrating, and therefore later than, the rocks of the Tuffaceous Succession.

The beds in the Tuffaceous Succession must be equivalent to the Arenig strata developed west of Lough Mask. In the Tourmakeady (Gardiner & Reynolds, 1909, p. 106) and Glensaul (Gardiner & Reynolds, 1910, p. 255) districts these strata, there named the Mount Partry Beds, consist of conglomerates, grits, cherts, shales and tuffs. In the Kilbride Peninsula (Gardiner & Reynolds, 1912, p. 77) and Lough Nafooey (Gardiner & Reynolds, 1914, p. 106) areas the Arenig rocks consist of agglomerates, tuffs, spilites, cherts, shales and grits. The beds of the Felsitic Succession may be the equivalents in the Tourmakeady district (Gardiner & Reynolds, 1909, p. 128) of the red felsites, which have been placed in the Lower Llandeilo.

III SILURIAN

(a) History of Research

Rocks of Silurian age, which outcrop over about seven square miles between the Ordovician to the west and the Old Red Sandstone to the east, do not appear on Griffith's map of 1838, though either he or his assistants collected fossils from the area which M'Coy described in his Synopsis of the Silurian Fossils of Ireland (1846). On Jukes' map of 1867 the Silurian beds are referred to under the term "metamorphic". The Geological Survey maps of the area, published in 1874 and 1878, variously represent the Silurian rocks as Wenlock in the west, Upper Llandovery in the east and Old Red Sandstone in the north. They incorporate in the Wenlock the beds to the north-west of the limestone (p.36), including all the Ordovician rocks already described. The rest of the Silurian succession is coloured in as Upper Llandovery except the rocks in the Carracastle stream section (p.33) which are shown as Old Red Sandstone.

Kinahan (1879, p. 345) took a step forward in differentiating between rocks of Ordovician and Silurian age, stating that the latter rests unconformably on and contains fragments of the former. One year later he and Baily (1880, p. 491) recognised the existence of two series of red sandstones, one, 1500 feet thick at the base of what is now known as Silurian, and a second, 5000 feet thick, comprising what is now known as Old Red Sandstone, and separated from the first by 4000 feet of green argillaceous rocks. They united the Silurian and the Old Red Sandstone into one system, the Silurian, contending that this was composed of a red arenaceous rock of shallow-water origin, and an argillaceous or green rock of marine and deep-water origin.

Kilroe (1897, p. 71) supported Kinahan's statement concerning the unconformable relationship of the Silurian to the Ordovician, and mentioned the resemblance of the Silurian succession to that of the "Upper Silurian" of the Lough Mask region. Cummins (1954, p. 102) has also written on the Silurian rocks of the area.

(b) Succession

The Silurian rocks have given rise to a featureless landscape largely covered by drift and bog. In the north exposures are practically confined to one stream section, and in the south to the poorly exposed ground about one square mile in area, lying to the south-east of Glen School (Plate I).

The stream section is to be found a short distance south-south-west of the village of Carracastle. The thicknesses in this imperfect succession given below are only approximate.

Upstream.	Thickness. (in feet)
25. Thinly and irregularly bedded, greenish, fairly fine-grained, fossiliferous sandstones.	150
Gap.	70
24. Thinly bedded, flaggy, greenish-grey, fine-grained, fossiliferous sandstones, which weather to a rusty colour.	6
Gap.	12
23. Fairly thinly bedded, bluish-grey, fine-grained, tough sandstones.	25
Gap.	5
22. Pebbly quartzose grit, with rounded pebbles of vein quartz up to one inch in diameter.	4
Gap.	2
21. Fine-grained, dark greenish-grey, pebbly sandstones, which sometimes have a purplish tinge.	10
Gap.	10
20. Thinly bedded, dark greenish-grey, fine-grained sandstones, which are slightly fossiliferous and occasionally banded.	12
Gap, fault A.	6
19. Very thinly bedded, yellowish-green, fairly fine-grained, friable sandstones, with occasional ribs of fine-grained, greyish, tough sandstones.	25
Gap.	5
18. Fairly thinly bedded and friable, greyish-green sandstones, which are sometimes purplish.	100
Gap.	5
17. Fairly thinly bedded and fine-grained, bluish-grey, hard sandstones, which are sometimes purplish or pebbly.	30

		Thickness (in feet)
16.	Fairly thinly bedded and friable, green sandstones.	12
15.	Dark grey, slightly purplish, hard sandstones.	20
14.	Light purplish-grey, fairly fine-grained and tough sandstones.	70
13.	Greyish-purple sandstones, which are sometimes friable and usually pebbly.	90
12.	Coarse purplish grit, with rounded to subangular pebbles up to six inches across.	6
11.	Light purplish-grey, fairly fine-grained sandstones, with occasional small pebbles and some very thin ferrugenous bands.	30
10.	Fairly coarse-grained, purplish sandstones, which are sometimes friable.	60
9.	Conglomeratic, purplish sandstones, which are sometimes friable.	5
8.	Thinly bedded, purple, fine-grained sandstones.	5
7.	Purplish conglomerate, with rounded pebbles up to nine inches across of vein quartz and quartzite.	15
	Fault B.	
6.	Purplish, fairly coarse-grained sandstones which are sometimes pebbly.	50
	Gap.	5
5.	Fairly thinly bedded, fine-grained and hard, purple sandstones.	70
	Gap.	5
4.	Thinly bedded, brownish, friable sandstones.	60
	Gap.	30

		Thickness (in feet)
3.	Fairly thinly bedded, and friable, greenish sandstones, which weathers to a reddish colour and has one pebbly horizon.	50
2.	Thinly bedded, greenish-grey sandstones, which are sometimes pebbly and occasionally current-bedded.	50
	Gap.	5
1.	Brownish-red, friable sandstones, which are sometimes laminated and current-bedded.	3
		1128

Downstream.

The strike-fault A is responsible for the inversion, the contortion and the variable strike where it crosses the stream. The strike-fault B has given rise to rapid variation in strike and dip, widespread slickensiding along several planes and the occurrence of sheared pebbles in the conglomerate. When seen in cross-section, the pebbles often have joints running at two directions at right angles to one another, the joints being similarly orientated in all the pebbles. The nature of the contact with the Ordovician rocks exposed further downstream is not known, but in all probability is an unconformity (p. 105).

In the area to the south-east of Glen School Cummins (1954, p. 102) read the succession to be, from top to bottom, grey sandstone, fine sandstone, limestone and purple sandstone, the total thickness being over 6000 feet. His subdivisions are employed here.

The basal group, about 1000 feet thick, is made up of fairly thinly bedded and coarse-grained sandstones, predominantly purple and red, though brown and pale yellow varieties also occur; some of these sandstones are very friable and occasionally colour-banded. At the base is a thin conglomerate (p. 105), and towards the top are some thinly bedded pale grey sandstones which pass into a thinly bedded impure fossiliferous limestone, less than 20 feet thick.

For about 1000 feet above the limestone the beds consist of hard, fine-grained sandstones, which are usually thinly and irregularly bedded and sometimes fossiliferous. They vary in colour from greyish, through a rusty green to yellowish and bluish, and are occasionally interbedded with bluish greywackes.

The remainder of the Silurian succession, in which no fossils were found, is about 5000 feet thick. Owing to the monotonous character of the sediments and the poor exposures, it was not found possible to make any further subdivisions. The lowest 500 feet is practically unexposed, the few outcrops being mostly of purplish-red sandy shales and thinly bedded purplish-red fine-grained sandstones. The remaining thickness is composed of various types of sandstone, usually thinly bedded and fine-grained, though thicker bedded and coarser types also occur. These sandstones are mainly greyish, though they are sometimes greenish and brownish; they are occasionally micaceous, and in places interbedded with reddish and greenish coarser grained sandstones, in which small, thin, green particles of shale are sometimes enclosed. These sandstones are occasionally friable and in places contain pebbles. An outcrop of a dark greenish greywacke, on the main road three miles south-east of Carracastle, probably belongs to this group.

The lower part of the succession resembles that exposed in the Carracastle stream section, where the beds upstream from the fault A, of which over 300 feet are exposed, correspond to the sandstones immediately above the limestone, and the beds on the downstream side, about 800 feet thick, to the sandstones beneath the limestone. The limestone does not appear in the stream section: it may have disappeared by thinning or have been cut out by the fault A.

The only fossiliferous horizon in the succession is the limestone and the immediately overlying sandstones. The limestone is exposed in a small stream just over ½ mile south-east of Glen School, where the specimens obtained are mainly of _Favosites_, _Halysites_ and streptelasmatids. The limestone was formerly much better exposed, the stream having been deepened for drainage purposes (incidently providing much dredged material, the mounds of which can still be seen) before the Geological Survey mapped the area in the 1860's. As a result their fossil list is of considerable length, though many of the names are suspect.

The sandstones overlying the limestone have yielded what Professor A. Williams identifies as an Upper Llandovery fauna, C_{3-4-5} in age. The following fossils have been obtained:

Atrypa sp. (long skirted)
cf. *Grammysia* sp.
Leptaena cf. *rhomboidalis* (Wahlenberg)
Mendacella sp.
Parmorthis sp.
Resserella sp.
Stegerhynchus cf. *llandoveriana* (Davidson)
Stricklandia lens ultima Williams
Stropheodonta compressa (J. de C. Sowerby)
cf. *Byssonchia* sp.
streptelasmatids
trilobite fragments
sponge fragments
Tentaculites sp.

(c) General Considerations and Correlations.

Since the beds immediately above the limestone are C_{3-4-5} in age, it is clear that the sea did not reach the area until a considerable part of Llandovery time had elapsed. This transgression, which correlates with the one observed by Gardiner & Reynolds to the west of Lough Mask, and may well be the Upper Llandovery transgression of the Welsh Borderlands, probably took place from the east. The sequence of deposits in the area has a slight resemblance to the succession developed west of Lough Mask, which is as follows (Gardiner & Reynolds, 1912 and 1914):

		Thickness. (in feet)
WENLOCK.	Doon Rock Grits.	2000
	Grey-green flags.	0-250
	Purple sandy shale.	75-80
UPPER LLANDOVERY.	Finny School Beds. (calcareous flags)	420-820
	Annelid-grits.	90-900
	Red sandstone.	200-700
	Basal conglomerate.	0-75
		c. 4400

A basal conglomerate is present in the Curlew Mountains pericline (p.105), but it is very thin. Red or purple sandstones occur at the base of the succession in both areas, though they are thinner in the region west of Lough Mask. The Annelid-grits appear to be unrepresented in the pericline, but the calcareous flags of the Finny School Beds, with their Upper Llandovery fossils, may be the equivalent of the limestone and the overlying fossiliferous sandstones. The remainder of the succession in the area is probably the equivalent of the Doon Rock Grits and the underlying purple and green beds, and therefore Wenlock in part.

IV. OLD RED SANDSTONE.

(a) History of Research.

Griffith, on his map of 1838, represented the Old Red Sandstone as extending from just north of Lough Gara to a point a few miles south-east of Drumshanbo. Surprisingly enough, however, he referred the Carboniferous of the Bricklieve Mountains (p.65) to the Old Red Sandstone, and the Old Red Sandstone west of Lough Gara to the Yellow Sandstone.[1]

The publication by the Geological Survey of the maps and memoirs dealing with the area (76 & 77, 66 &d 67), provided the most important contribution to the study of the Old Red Sandstone of the area. Other original contributions were made earlier by Kelly (1860) and Jukes & Foot (1860), and later by Kinahan & Baily (1880), McHenry & Watts (1895) and Geikie (1897), all members of the Geological Survey.

(b) Succession.

As has already been mentioned on p. 32 , Kinahan & Baily (1880, p. 491) combined the Silurian and Old Red

(1) The Yellow Sandstone Griffith originally placed in the Carboniferous, but two years later made a subdivision of the Upper Old Red Sandstone.

Sandstone systems, giving the following succession for that part of their Silurian system which is now called Old Red Sandstone:

	Thickness. (in feet)
Eurites, tuffs and limestones.	200
Purplish, red and greenish, conglomeratic sandstones and sandy shales.	5000
	5200

The Old Red Sandstone succession, in this revision, is divided as follows:

		Approximate thickness. (in feet)
vi	Red and green sandstone group.	400-500
v	Upper volcanic group.	50-100
iv	Red sandstone group.	600-1200
iii	Red pebbly sandstone group.	1650-3900
ii	Red and green pebbly sandstone group.	1000-1200
i	Lower volcanic group.	2000-2500
		c. 7500

i. <u>Lower volcanic group</u>. The volcanic rocks belonging to this group, which only crop out west of the Ballaghaderreen-Carracastle road (p. 51), appear to be all of igneous origin and andesitic composition. Although they resemble superficially the lavas of Group V, exposed in the country further to the east, they are more highly porphyritic, have some green pleochroic amphiboles among the phenocrysts and lack the flow structure which is so conspicuous in the lavas of Group v (Fig. 5b).

ii. <u>Red and green pebbly sandstone group.</u> The beds of this group are exposed only at Doon (p. 53), three miles south-west of Gorteen (Plate I), and in the area west of the Ballaghaderreen-Carracastle road. The rock-types met with at Doon include a thin conglomerate and a greenish-grey mudstone and shale near the base, and sandstones which are usually greenish but sometimes greyish or reddish. In the area west of the Ballaghaderreen-Carracastle road the following incomplete succession was measured (p. 52):

	Thickness. (in feet)
9. Fairly coarse-grained, purplish, felspathic sandstones, with pebbly and conglomeratic bands.	10
Gap.	3
8. Fairly fine-grained, red, felspathic sandstones.	12
Gap.	8
7. Greenish-grey sandstones, occasionally red or purple and usually fairly fine-grained but with coarser, pebbly and conglomeratic bands.	26
6. Fairly fine-grained, red, thinly bedded sandstones.	14
5. Fairly fine-grained, brownish-red, thinly bedded sandstones.	18
Gap.	12
4. Fine-grained, purplish-red sandstones.	4
Gap.	30

		Thickness. (in feet)
3.	Purplish-red, pebbly sandstones.	5
	Gap.	24
2.	Fine-grained, brownish-red sandstones.	10
	Gap.	100
1.	Fairly fine-grained, red sandstones, which are sometimes pebbly.	5
		281

The only other rock-type belonging to this group exposed in the area is a conglomerate to be found at the base.

iii. Red pebbly sandstone group. The conglomerates, which together with red and red pebbly sandstones make up this group, were first mentioned by Jukes & Foot (1866, p. 249). They are red in colour, with rounded to sub-angular boulders up to two feet across. These boulders are mainly white and pink vein-quartz and quartzite, with subordinate jasper, greenish-grey sandstone, micaceous and felspathic quartzite. The Geological Survey (Cruise, 1878, p. 11) recorded the presence of slate and schist boulders.

The pebbly sandstones are usually well-bedded and brownish-red to red in colour. The proportion of pebbly material varies considerably, there being all grades from sandstones with very few pebbles to fine-grained conglomerates. Current and graded-bedding are to be seen in these rocks, which like the conglomerates are extremely ill-sorted.

iv. Red sandstone group. The sandstones, which comprise this group and occur also in Group iii, are red, purple, brown or, very rarely in Group iv, green in colour. They vary considerably in coarseness; they are often slightly felspathic, sometimes being finely laminated, and frequently contain small, thin fragments of red shale. They are also well-bedded and occasionally have thin partings of red shale along the bedding planes.

v. Upper volcanic group. As Cole & Hallissy (1924, p. 20) recognised, the volcanic rocks of this group consist of both lavas and pyroclastic rocks. Although usually thickly bedded, the lavas occasionally become very thinly bedded. Invariably dull purple in colour, they often exhibit flow-banding (Fig. 7a); at one locality the flow-lines curve around a block of tuff about one foot in diameter. The rock is known locally as "copper rock", probably because of the occasional presence of malachite along the joint planes. Outcropping only in Area 2 (p.52), the lavas appear to be of two types, namely "normal" and "nodular".

The "normal" lavas are porphyritic, though the size and abundance of the phenocrysts vary considerably. The phenocrysts, which are occasionally glomeroporphyritically developed, consist of felspar and pyroxene; they are usually highly altered, though the intensity of alteration

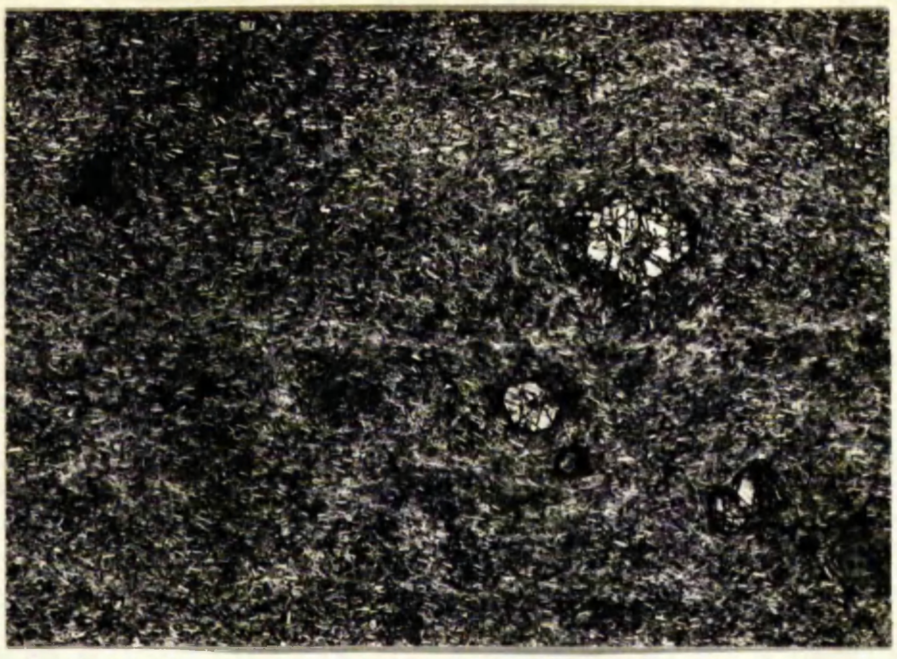

Fig.7 a. Lava flow belonging to Group v of the Old Red Sandstone succession, showing flow structure (p. 45). Ordinary light × 10.

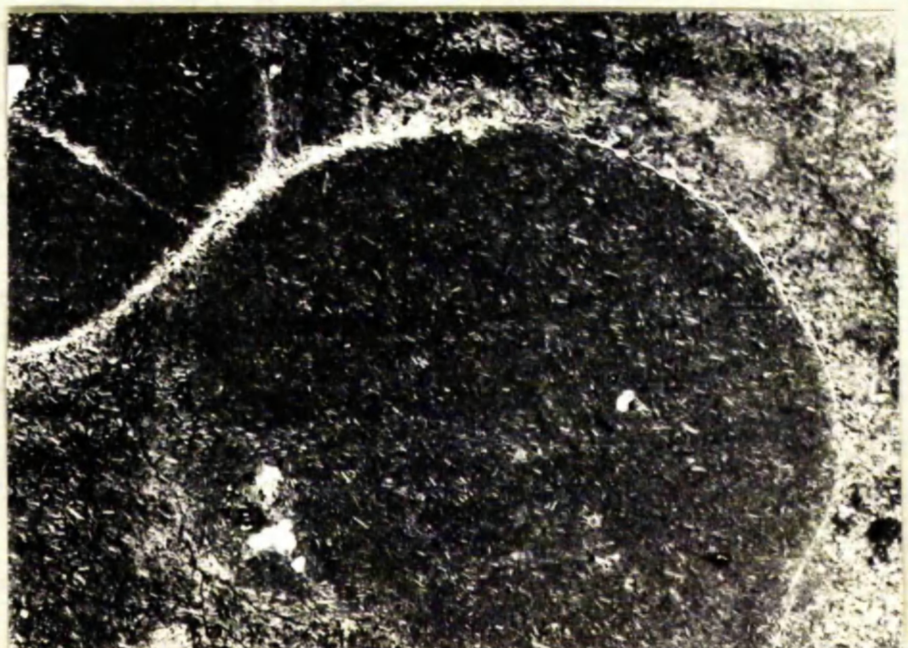

Fig.7 b. "Nodular" lava flow from Group v (p. 47). Ordinary light × 10.

varies from place to place. The groundmass consists mainly of highly altered felspar laths, which exhibit flow-structure. The alteration minerals include chlorite, carbonate and iron-ore, the latter sometimes associated with carbonate, sometimes with chlorite in patches. Secondary quartz, colloidal and crystalline, occurs to a limited extent in small cavities. Although the composition of the plagioclase cannot be determined, the texture of the rocks suggests that they are andesitic or trachytic in composition.

The "nodular" lavas, which appear to have the same composition as the "normal" lavas, are characterised by the presence of rounded amygdale-like nodules. These are usually from ¼ to one inch across, though occasionally rock-types with smaller, less well-developed nodules are met with. In the limited area over which the lavas are seen, the concentration of nodules at each horizon remains fairly constant, but varies considerably from bed to bed. The nodules, which are slightly elongated parallel to the bedding, are darker than the mass of the rock. They are usually bordered by a very thin rim of whitish, friable material, which allows them to become readily separated from the matrix.

Under the microscope the nodules are seen to be similar to the lava itself, the flow-lines, indicated by the laths of felspar, continuing uninterruptedly across them (Fig. 7b). Although the nodules must originally have been of the same composition as the rest of the rock, iron enrichment, probably connected with their development, appears to have followed the consolidation of the lavas. They not only contain more iron, both as small magnetite crystals and as finely disseminated particles, than the matrix, but, in marked contrast, the iron is more regularly distributed; they are surrounded by a narrow zone which is even more enriched in magnetite crystals. Usually they are separated from the matrix by fractures, along which weathering and leaching have given rise to the whitish friable material mentioned above, though occasionally the fractures do not quite coincide with the outer surfaces of the nodules. Sometimes the nodules, which have occasionally coalesced to form aggregates, are slightly irregular in shape. Phenocrysts are sometimes observed at the centres of the nodules, with small cracks occasionally radiating from them, and sometimes in less central positions.

The nodules may have developed in a number of different ways, possibly by growing around certain phenocrysts as a result of contemporaneous weathering during Old Red Sandstone times, since the "nodular" lavas tend to be more highly weathered than the "normal" lavas.

The pyroclastic rocks (Fig. 8), which are extremely compact and bear a superficial resemblance to the lavas, are usually dull purple in colour, though greenish varieties are occasionally met with. They vary

Fig. 8. Pyroclastic rock from Group v of the Old Red Sandstone succession (p. 48). Ordinary light × 10.

considerably in coarseness, from types in which the fragments are microscopic to agglomerates with pebbles up to six inches across, though usually the fragments are of the order of a few tenths of an inch in diameter. Wherever they were examined the fragments were found to be of volcanic origin; McHenry & Watts (1895, p. 46) however recorded the occurrence of slate, jasper and vein-quartz among the pebbles. The volcanic fragments include both igneous and pyroclastic rock-types; the former usually exhibit flow-structure and are much more abundant. Their rounded to subangular shape suggests that the original pyroclastic deposit was reworked by running water before being redeposited - a suggestion first put forward by Kinahan & Baily (1880, p. 491) and supported by McHenry & Watts (1895, p. 46). The surrounding fine-grained matrix encloses a few small crystal fragments of felspar and quartz which are sometimes cracked. In some cases the subangular quartz grains make up as much as 10% of the rock. Since they are usually strained, it is probable that they are derived from pre-existing rocks and deposited simultaneously with the resorted pyroclastic material. The original minerals of both fragments and matrix have been completely altered. In most cases secondary calcite occurring as large poikilitic crystals is surprisingly abundant; often it has crystallised selectively in the fragments, presumably because of the greater porosity. Magnetite and chlorite are also common.

vi. Red and green sandstone group. The sediments comprising this group vary considerably in their lithology. The predominant type is a fairly fine-grained, red or purple sandstone, sometimes containing small, thin particles of red shale; quite often these sandstones are interbedded with red or purple shaly mudstones or siltstones. Greyish-green sandstones are also abundant; they are usually very fine-grained and extremely hard, but occasionally much coarser grained and more friable types occur.

A single band of volcanic ash, a foot or so thick, is found among these sediments. This rock, which was mentioned by the Geological Survey (Cruise, 1878, p. 15) and Geikie (1897, p. 316), is greenish and well-compacted, enclosing angular fragments up to ½ inch across. The fragments are composed of volcanic material, some of which exhibits flow-structure. Individual subangular crystal fragments of quartz and felspar are also scattered through the groundmass; the quartz is usually strained and is probably of sedimentary origin. Like the fragments the groundmass is highly altered, consisting mostly of alteration minerals such as carbonate, chlorite and iron-ore.

(c) Description of the Old Red Sandstone Area

The outcrops of the Old Red Sandstone fall into four tracts:

1. West of the Ballaghaderreen-Carracastle road.

2. Between the Ballaghaderreen-Carracastle road and Lough Gara.

3. The Curlew Mountains.

4. East of Lough Key.

1. <u>West of the Ballaghaderreen-Carracastle road.</u>

Exposures are extremely few in this area owing to extensive drift and bog. The few outcrops that occur probably belong to Groups i and ii. The stream section in rocks of Group ii, tabulated on pp. 43-44, is to be found in the south-west of the area, about 300 yards north of Kilmovee School. The dip of the rocks in this section varies from 70° north-west to vertical, the strike swinging from N. 42°E. to N. 50°E. as the beds are traced north-westwards. Whether or not the strata are inverted cannot be determined owing to the lack of any visible current or graded-bedding. Apart from this section there are no exposures until a thin band of conglomerate is met with, about 450 yards farther north. By the aid of occasional outcrops and of immense boulders, locally derived, the band can be traced for some distance along its strike, which trends at N. 63°E.

The broad belt of country situated immediately to the north-west of this conglomerate, is underlain by massive and homogeneous volcanic rocks belonging to Group i, which have contributed abundantly to the spectacular accumulation of large boulders that bestrew the surface. This accumulation, together with the flatness of the terrain and the fewness and small size of the exposures, has made it impossible to determine either the dip or the strike of the rocks. Since however, as has just been seen, the sedimentary rocks to the south-east are dipping at high angles, and the breadth of the volcanic belt is nearly half a mile, the volcanic rocks must have a thickness of between 2000 and 2500 feet.

If the belt of volcanic rock is traced north-eastwards along the strike, both outcrops and boulders disappear. Instead there are two exposures, one of red conglomerate, the other of pebbly and conglomeratic red sandstone, striking at N. 60° E.; current-bedding in the latter indicates that the beds become older to the north-west. A fault, the Carrownlacka fault (p. 110), is postulated to explain these relations. Exposures are absent along the contact with the Silurian, but at the western end of the volcanic outcrop there are several very large slickensided boulders of volcanic rock, indicating that the junction might be faulted. East of the Carrownlacka fault the only exposures are in the south where a volcanic rock, probably a western continuation of Group v, is very occasionally exposed. The ground north of these outcrops is covered by an immense number of volcanic boulders, which have probably been deposited by northward-moving ice.

2. Between the Ballaghaderreen-Carracastle road and Lough Gara. In the west of this area, the best exposed of the four, the following succession can be made out on the

slopes of Bockagh Hill (749):

		Approximate <u>thickness.</u> (in feet)
v.	Upper volcanic group.	100 +
iv.	Red sandstone group.	600
iii.	Red pebbly sandstone group.	2800 +
		3500

The essential features of these groups have already been described. Group iii consists of, from bottom to top, red sandstones at least 500 feet thick, the Bockagh Hill Conglomerate about 300 feet thick, and red, pebbly sandstones 2000 feet thick.

In the eastern part of this area, in the hills culminating in Mullaghthee (647), exposures are good and reveal the following succession:

		Approximate <u>thickness.</u> (in feet)
v.	Upper volcanic group.	20
iv.	Red sandstone group.	600
iii.	Red pebbly sandstone group.	2250
		2870

Group iii is composed of, from bottom to top, the Moygara Conglomerate 50 feet thick, red, pebbly sandstones 1200 feet thick, the Mullaghthee Conglomerate 50-200 feet thick, and red, pebbly sandstones 850 feet thick. The sandstones separating the two conglomerates are poorly exposed, probably because of their softness. They are usually red, pebbly and slightly felspathic, but at one locality ½ mile north-east of Mullaghthee the sandstones are very thinly and irregularly bedded, very fine-grained and somewhat micaceous, varying in colour from dark red to greyish-green. At another locality ¾ mile west-south-west of Mullaghthee the sandstones are thinly bedded, fine-grained and reddish-purple, with mud-cracked shaly partings. Kinahan & Baily (1880, p. 491) observed just west of Lough Gara tracks, perhaps crustacean, very similar to those found at Valencia Lighthouse, Co. Kerry.

If the Bookagh Hill Conglomerate is the same as the Mullaghthee Conglomerate, the sediments must be much thicker at the western end than at the eastern end of the area, which is from six to seven miles long. However the two conglomerates may die out laterally and not occur at the same horizon, the Old Red Sandstone being similar in thickness at both ends. This is the more likely possibility since the Mullaghthee Conglomerate appears to thin westwards.

Less well-exposed is the central part of this area, where there appear to be from 5000 to 6000 feet of red and red pebbly sandstones without conglomerates, belonging to Groups iii and iv. At Doon these are possibly underlain by strata which probably belong to Group ii (p. 43) but may be Carboniferous in age. The rock-types include a thin conglomerate and greenish-grey shales and mudstones near the base, sandstones which are usually greenish but sometimes greyish or reddish, and a calcareous siltstone. These beds, which are bounded to the north by Carboniferous Limestone (p. 87), generally dip at high angles to the north-north-west, and since the outcrop is about ½ mile wide must be approximately 1200 feet thick. This thickness, which is far greater than that of the Carboniferous sandstones on the southern flank of the pericline (p. 62), together with the marked difference in lithology between the two successions, suggests that the beds are in fact Old Red Sandstone in age. The correlation is supported by the similarity in strike and dip between these beds and the undoubted Old Red Sandstone to the south, and by the occurrence in them of one rather obscure example of current-bedding suggesting inversion. It is possible however that the strata in the northern half of the outcrop, where the dip is less steep, are Carboniferous.

The volcanic rocks of Group v, which are restricted to four separate outliers (Plate I), are almost all lava flows in this area. However in some places up to 15 feet of agglomerate may be present at the base: in others the lavas rest directly on the sandstones of Group iv. The "nodular" lavas are restricted to the two easternmost outliers.

3. <u>The Curlew Mountains.</u> Exposures are extremely poor in the Curlew Mountains: thick bog covers the northern and central areas, and thick drift the southern slopes. The rocks seen belong to Groups iii - vi. Although the sediments coarsen downwards, the change is gradual, so that the boundary between Groups iii and iv is difficult to draw. However the following table gives some idea of the thicknesses:

		Thickness. (in feet)
vi.	Red and green sandstone group.	50 +
v.	Upper volcanic group.	50-100
iv.	Red sandstone group.	1200
iii.	Red pebbly sandstone group.	2500
		c. 4000

The volcanic rocks in this area which, unlike those to the east of Lough Gara, are all of pyroclastic origin, form five separate outliers namely, from west to east, the Cornaglia, Cornamealta, West Garrow, East Garrow and Sheegorey Outliers.

At the top of the West Garrow Outlier, and overlying the volcanic rocks in the Sheegorey Outlier, are red sandstones of Group vi. The sandstones east of the Rock of Doon Dyke (p. 96) also probably belong to this group (p.107), and it was in these rocks that Kinahan

& Bailey (1880, p. 491) found tracks similar to those described on p. 55.

4. <u>East of Lough Key</u>. Eastwards from Lough Key, rocks of Old Red Sandstone age underlie a narrow, low-lying and drift-covered strip of country, which extends as far as the river Shannon. Beyond this river, the Old Red Sandstone sinks beneath the basal Carboniferous sandstones, although it rises to the surface again a few miles south of Drumshanbo. Since the structure of this eastern inlier is rather complex, due to faulting, this small Old Red Sandstone inlier should be studied in conjunction with the Carboniferous to the south, which has not been included in the present investigation.

All the sediments east of Lough Key probably belong to Group vi. The volcanic ash, which is interbedded with them and has already been described (p. 51), was placed in the Old Red Sandstone by Geikie (1897, p. 316), but in the Carboniferous by the Geological Survey (Cruise, 1878, pp. 15-16). It is now referred to the older formation for three reasons. First the ash wherever observed has a northerly dip, while the Carboniferous sandstones immediately to the south, and indeed everywhere along the southern flank of the pericline, dip to the south. Secondly, the associated beds are of Old Red Sandstone rather than of Carboniferous type. Thirdly, a volcanic episode of Lower Carboniferous age is not known from this part of the country, whereas vulcanicity was prevalent in the Old Red Sandstone period.

The relationship of the rocks in this area to those of the Curlew Mountains cannot be demonstrated. In all probability however, they belong to the upper part of the local Old Red Sandstone succession, that is above the volcanic rocks of Group v. This is suggested by the easterly pitch of the syncline in the Curlew Mountains (p. 106), and by the fact that some of the rock-types, including the ash and the greenish, very fine-grained sediments, are not met with elsewhere in the inlier. The thickness of Group vi in this area is difficult to determine, but is probably in the region of 500 feet.

(d) General Considerations and Correlations.

During Old Red Sandstone times the area of the Curlew Mountains Pericline lay within what Kinahan & Baily (1880, p. 488) called the Ulster-Connaught Basin, a basin of deposition which was probably continuous with the Caledonian cuvette of Scotland. The sediments comprising the succession, which were probably derived from the north and west, coarsen towards the base. Volcanic activity, represented by both pyroclastic and igneous rocks, took place towards the close of the period of deposition; further activity, which consisted entirely of the extrusion of lava flows, occurred at the beginning.

Similar volcanic activity took place in the large area of Old Red Sandstone in Tyrone and Fermanagh, west of the Omagh Syncline (Fig. 1), and in north-east Antrim (Wilson, 1953, pp. 295 and 306). The succession in the Curlew Mountains pericline differs from that in the Tyrone-Fermanagh area in the absence of shales and of volcanic boulders in the conglomerates. Since volcanic activity was restricted to the Lower Old Red Sandstone in the Caledonian cuvette, the succession in the Curlew Mountains pericline is thought to belong to that series.

V. CARBONIFEROUS

The Carboniferous rocks are best studied in the Bricklieve Mountains, which are situated immediately to the north of the Curlew Mountains (Plate I). Unfortunately neither the basal Carboniferous unconformity nor the junction with the overlying "Yoredale Series" is displayed in these mountains, but the stratigraphy is partially completed on the southern flanks of the pericline and the area east of Lough Arrow. The ground immediately to the north of the inlier, which unlike that to the south is strongly faulted, has also been examined.

(a) The Southern Flanks of the Pericline.

On the southern flanks of the pericline the Carboniferous rocks follow the Old Red Sandstone with gentle dips of 10^{o} or less, and the structural relationships are ones of simple unconformity. The contact between the two formations is to be seen at one locality only, towards the eastern end of the pericline. With the exception of the Kilkelly region, exposures are almost non-existent west of Lough Gara, but as is the case in the east, the junction between the Carboniferous and the underlying rocks is almost certainly an unconformity; this is indicated by the presence at infrequent intervals close to the junction of Carboniferous sandstones with low southerly dips. The thickness of these basal sandstones cannot be measured directly, but the width of outcrop and average dip give a figure of from 300 to 400 feet.

The Carboniferous sandstones, known locally as "freestones" to distinguish them from the Old Red Sandstone "whinstones", are generally fine or medium-grained, well-bedded, felspathic and pale. Coarser grained, reddish, orange and yellow varieties, which are slightly pebbly, probably with reworked material from the Old Red Sandstone, are met with towards the base. The sandstones vary greatly in grain size and are badly graded. The grains, of which as much as 25% are felspar (both plagioclase and microcline), are quite angular. Interstitial material is at a minimum exceptwhere the sandstones are calcareous; large flakes of mica are relatively common. In the finer grained types the sandstones are better graded, less felspathic and the grains less angular. Most of the quartz grains show evidence of strain, and were probably derived from the areas of metamorphic rocks to the north and west. The sandstones sometimes enclose small, thin particles of grey shale, and occasionally are very quartzose, having in the past been quarried for glass-making. In comparison the Old Red sandstones are less felspathic, the felspars being almost all microcline, and contain more iron and less mica. The Silurian sandstones contain no felspar and have much more angular grains which show more signs of strain; mica is quite common.

Towards the top of the Carboniferous sandstones in the Boyle area (Plate I), there occurs a thin bend of very dark, very fine-grained limestone and another of a soft, fireclay-like material. Plant remains are the only fossils. The topmost sandstones tend to be calcareous and iron-stained, and are overlain by fairly thinly bedded, dark-coloured crinoidal limestones in which chert is absent or extremely rare. The fossils of these limestones include:

Caninia spp.
Caninophyllum cf. *patulum* (Michelin)
Cyathoclisia tabernaculum Dingwall
zaphrentids
Michelinia sp.
athyrids
Chonetes cf. *papilionacea* Davidson
C. sp. (small)
Daviesiella destinezi (Vaughan)
Tylothyris laminosa (M'Coy)
Bellerophon sp.
Euomphalus sp.
cf. *Murchisonia* sp. (large)
Bryozoa

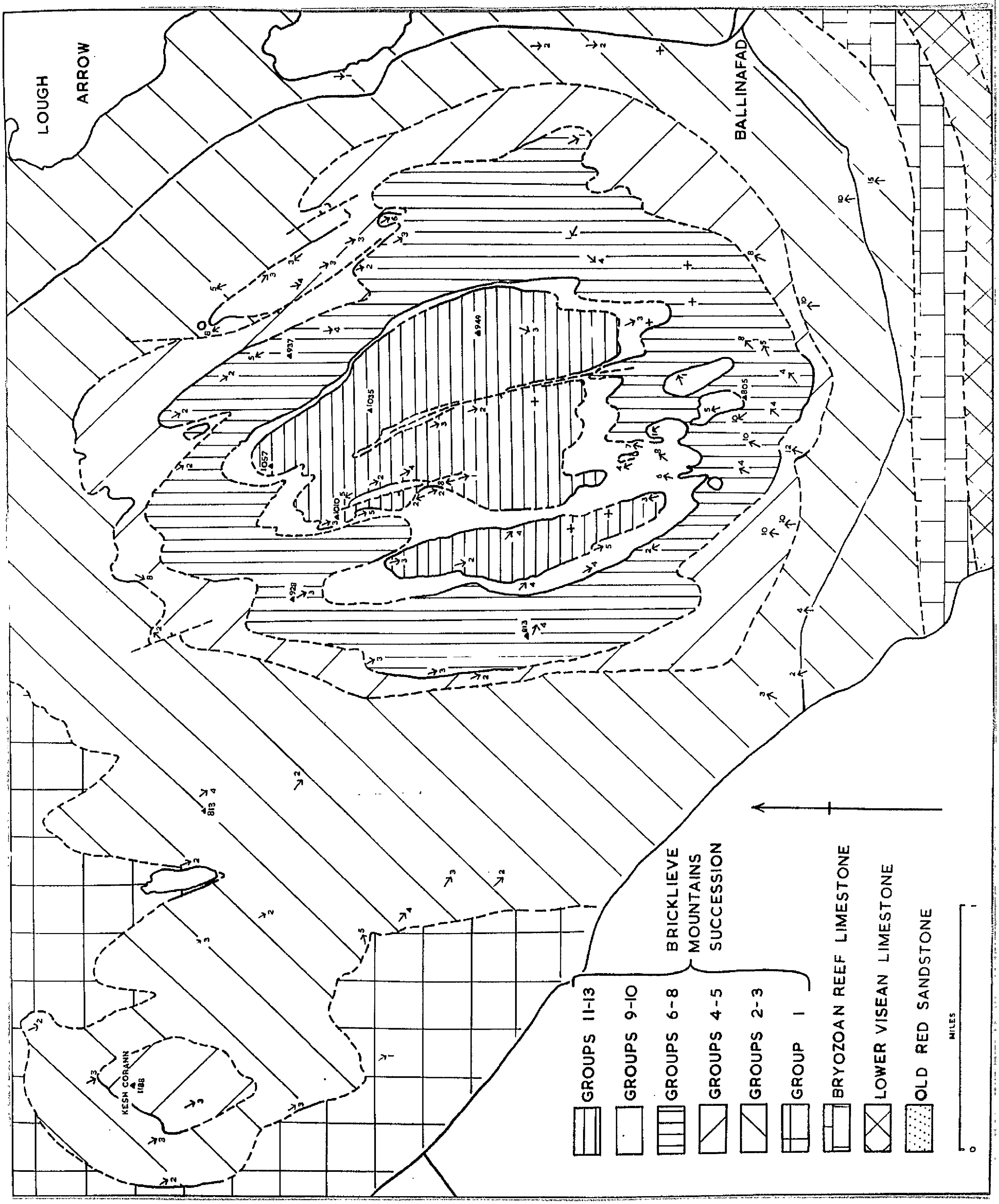

Fig. 9. A geological map of the Bricklieve Mountains.

(b) The Bricklieve Mountains and the Area East of Lough Arrow.

The Bricklieve Mountains, which are a distinct landmark when viewed from the north but are obscured by the Curlew Mountains on the south, average about 800 feet in height, and culminate in Kesh Corann[1] (1188). Exposures are usually excellent on the high, steep scarps, but are absent on the flatter slopes where thick peat has accumulated. The prominent north-north-west set of joints has considerably influenced the form of the outcrops (Fig. 9), and by its control of the drainage has given rise to several dry valleys (cf. Cruise, 1878, p. 7).

To the east of the Bricklieve Mountains, between Lough Arrow and the Arigna Plateau (ground which is underlain by rocks belonging to the "Yoredale Series" and the "Millstone Grit"), is an east-west, well-exposed strip of country, sandwiched between drumlin and bog-covered ground to the north and south. Some of this area, and part of the narrow strip of Carboniferous Limestone to the south of the "Yoredale Shales" (Plate I), as far east as Drumshanbo, has also been examined.

On Griffith's map of 1838, the Bricklieve Mountains are shown as being underlain by the Old Red Sandstone. The Geological Survey, when they mapped this area,

(1) An alternative spelling is Keshcorrin.

divided the Lower Carboniferous into Upper Limestone, Calp, Lower Limestone and Yellow Sandstone, though it is not possible to understand the basis on which this subdivision was made in this area. The succession in the Bricklieve Mountains has here been divided into the following groups:

		Thickness. (in feet)
13.	Fine-grained limestones.	50
12.	Cherty limestones.	50
11.	Upper *Lithostrotion junceum* band.	10
10.	Limestones.	40
9.	Middle *Lithostrotion junceum* band.	15
8.	Coral-rich limestones.	120
7.	Limestones with numerous coarse-grained crinoidal bands.	140
6.	Lower *Lithostrotion junceum* band.	3
5.	Limestones.	80
4.	*Lithostrotion martini* band.	40
3.	Limestones.	280
2.	The Kesh Corann *Lithostrotion* reef-limestone.	120
1.	Dark limestones.	150
		c.1100

1. Dark limestones. These limestones, which are only exposed on the north-western slopes of Kesh Corann, appear very white from a distance due to the growth of lichens; the escarpment to which they have given rise

contains the well-known Kesh Caves. The limestones are crinoidal and fairly thinly bedded, and contain black chert nodules. They become darker and more thinly bedded towards the base where there are some shaly partings. Fossils are extremely rare, though a few fragments of Caninia, athyrids, productids and Spirifer occur towards the base.

2. The Kesh Corann Lithostrotion reef-limestone. This remarkable band is packed throughout with clumps of Lithostrotion. The junction with the underlying limestones is sharp, but the upper limit cannot be mapped since the colonies of Lithostrotion die out gradually. The lithostrotiontids are commonly in the position of growth and, like the rest of the fossils in the reef, usually silicified. The reef, over its outcrop of three square miles, shows no diminution in thickness or in its richly fossiliferous nature. Phaceloid species of Lithostrotion are commonest, especially L. pauciradiale, though cerioid types are abundant, as are large caninias near the base. It is interesting to note that M'Coy's type specimen of L. pauciradiale came from Tobercurry, 10 miles to the west of Kesh Corann. The limestones comprising the reef are fairly fine-grained and crinoidal and enclose chert nodules. They contain the following fauna:

Caninia cf. caninoides (Silby)

C. cf. subibicina M'Coy

Caninia (Siphonophyllia) cf. cylindrica (Scouler)

Caninophyllum cf. archiachi (Edwards & Haime)

Carcinophyllum sp.

Clisiophyllum sp.

Diphyphyllum sp. (large)

Koninckophyllum sp.

Lithostrotion cf. affine (Fleming)

L. aranea (M'Coy)

L. cf. aranea (M'Coy)

L. cf. decipiens (M'Coy)

L. cf. flemingi (M'Coy)

L. pauciradiale (M'Coy)

L. cf. pauciradiale (M'Coy)

L. cf. portlocki (Bronn)

L. cf. scoticum Hill

L. cf. sociale (Phillips)

L. cf. verticale (J. Parkinson)

Emmonsia sp.

Syringopora sp.

Linoproductus sp. (large)

Rhipidomella michelini (L'Eveille)

Spirifer sp.

Bryozoa.

3. Limestones. The limestones of this group are fairly fine-grained and crinoidal, with numerous chert nodules. Towards the top are a well-marked, coarse-grained, pale crinoidal limestone band, and a band of calcilutite. The lower half of the group encloses fairly numerous, white, bun-shaped clumps of a cerioid lithostrotiontid. The fossils collected from the group are listed below.

Caninia sp.
Clisiophyllum sp.
Lithostrotion cf. *affine* (Fleming)
L. cf. *pauciradiale* (M'Coy)
L. sp. (cerioid)
zaphrentids
athyrids
Dictyoclostus sp.
Pustula (*Echinoconchus*) *elegans* (M'Coy)
P. cf. *pyxidiformis* (de Koninck)
P. spp.
productids
trilobite fragments
Bryozoa.

4. Lithostrotion martini band. This band repeats on a small scale the Kesh Corann reef, though the fauna is different. Its limestones are fairly fine-grained and crinoidal, with some chert, and it can be readily

traced for four miles. The *Lithostrotion* clumps, which are usually in place, tend to be silicified in the upper and unsilicified in the lower parts of the band. A distinctive feature of the fauna is the absence of any cerioid lithostrotiontids. The following fauna was collected:

Caninia cf. *juddi* (Thompson)
cf. *subibicina* M'Coy
C. cf. *subibicina* var. *densa* Hudson
C. spp.
Koninckophyllum sp.
Lithostrotion cf. *affine* (Flemingi)
L. martini Edwards & Haime
L. pauciradiale (M'Coy)
L. cf. *pauciradiale* (M'Coy)
L. cf. *scoticum* Hill
L. cf. *sociale* (Phillips)
Cladochonus crassus (M'Coy)
Syringopora sp.
productids
Bryozoa.

5. *Limestones*. The crinoidal limestones of this group are generally fine-grained, thinly and somewhat irregularly bedded, with considerable amounts of grey, nodular chert; occasionally they become slightly shaly towards the top. The beds of this group form the summit of Kesh Corann,

where Hinde (1887-1912, p. 101) reported the occurrence of sponge spicules in the cherts. The following succession was measured about ⅓ mile south-east of Doonaveeragh (937):

	Thickness. (in feet)
Lower *Lithostrotion junceum* band.	
(Lower *Lithostrotion junceum* band	12
Fairly fine-grained and irregularly bedded limestones, which become darker and slightly argillaceous towards the top; chert in small, thin, irregularly shaped nodules is abundant.	15
Fairly fine-grained and thinly bedded, crinoidal limestones with a little chert; some bands are packed with *Spiriferina* and other small brachiopods.	9
Fine-grained, irregularly bedded limestones with greyish chert; *Cladochonus*, bryozoa and zaphrentids are common.	14
Coarse-grained, pale crinoidal limestones.	5
Fine-grained, irregularly bedded, darkish coloured limestones with fairly numerous nodules of black chert; *Pustula* and other productids are common.	7
Gap.	18
	80
Lithostrotion martini band.	

The following fossils were collected from these limestones:

Caninia spp.

Dibunophyllum sp. (one specimen only)

Lithostrotion cf. *pauciradiale* (M'Coy)

Cladochonus crassus (M'Coy)

athyrids

productids

Pustula sp.

Reticularia sp.

Spiriferina sp. (small)

Parallelodon bistriatus Portlock

Bryozoa.

6. *Lower Lithostrotion junceum band.* This remarkably constant band, varying in thickness from one to five feet and marking the entry of *Lithostrotion junceum*, crops out over an area of about four square miles. Its fauna includes a cerioid and several phaceloid types of *Lithostrotion*. The band is best developed in the north-west; at the north-eastern end of its outcrop, the only lithostrotiontid present is the cerioid type. The following fossils were obtained:

Caninia juddi (Thomson)

C. sp.

Lithostrotion junceum (Fleming)

L. cf. *martini* Edwards & Haime

L. cf. *minus* (M'Coy)

L. pauciradiale (M'Coy)

zaphrentids

productids

Pustula (*Echinoconchus*) cf. *elegans* (M'Coy)

Bryozoa.

7. Limestones with numerous coarse-grained crinoidal bands. The most interesting feature of these limestones is the presence of a number of coarse-grained, crinoidal limestones, which are usually pale and always without chert. These bands, which are sometimes current-bedded and up to 10 feet thick, vary in thickness and grain-size over short distances; they were clearly deposited in shallow water. Dolomitic limestones, usually weathered brown, occur towards the top of the group. The following section was measured on the western slopes of Hill 813, at the south-western end of the Bricklieve Mountains, where the coarse-grained bands which typify the group are remarkably thin and few in number:

	Thickness. (in feet)
Coral-rich limestones.	
Gap.	5
Fine-grained dolomite and dolomitic limestones which weather brown and have elongated nodules and lenticular bands of black chert; a one foot band of dolomitic breccia contains chert fragments.	18
Fairly coarse-grained, pale limestones with *Cladochonus*.	6
Fairly fine-grained, thinly bedded, pale limestones, with nodules of grey chert increasing in number and size downwards.	15
Fine-grained limestones packed with very elongated, thin nodules of pale brown and sometimes reddish chert; an unsilicified *Lithostrotion* is common, and the bottom three feet are completely dolomitized, causing an overhang in the cliff.	15

	Thickness. (in feet)
Gap.	25
Fine-grained, thinly bedded limestones with thin, elongated nodules of dark grey chert.	2
Very coarse-grained, friable crinoidal limestones without chert.	3
Fairly fine-grained limestones, with large smooth nodules of blackish chert.	25
Gap.	30
Lower Lithostrotion junceum band.	144

The horizon with the extremely elongated chert nodules can be traced round most of the area, and is recognisable east of Lough Arrow where it is also slightly dolomitic and encloses the same species of Lithostrotion. In both areas the corallites, which are unsilicified and considerably crushed, lie parallel to the bedding planes. Although the coarse, crinoidal limestones are almost entirely made up of crinoid debris, they contain very few macrofossils. The following fauna was collected from the group as a whole:

Caninia spp.

Caroinophyllum sp.

Lithostrotion junceum (Fleming)

L. cf. pauciradiale (M'Coy)

L. cf. scoticum Hill

Cladochonus crassus (M'Coy)

Dictyoclostus sp.

productids

Pugnax pugnus (Martin)

Pustula punctata (Martin)

P. sp.

Spirifer sp.

Spiriferina sp.

Bryozoa.

8. *Coral-rich limestones.* These limestones, which are dolomitic towards the base, are characterised by a rich fauna of corals, mainly *Caninia*, *Dibunophyllum* and *Lithostrotion*; the fossils are usually silicified. The following section was measured on the slopes of Maelahoo (805):

	Thickness. (in feet)
Middle *Lithostrotion junceum* band.	
Fine-grained limestones, with irregularly shaped nodules of pale chert.	8
Fine-grained, fairly thinly bedded and dark limestones, with a few, thin, lenticular bands of black chert.	10
Gap.	5
Fairly fine-grained limestones, with some irregularly shaped nodules of pale chert; *Lithostrotion* is abundant in the lower six feet.	12
Fairly fine-grained, thickly bedded limestones, with some pale nodular chert; the lowest five feet are packed with *Lithostrotion* and *Caninia*.	15
Fine-grained, irregularly bedded, darkish limestones, with black chert nodules.	7

	Thickness. (in feet)
Fine-grained limestones with some chert, in which there is a two-foot band packed with athyrids and spiriferids (this band can be traced for over a mile).	8
Fine-grained limestones with some chert; the bottom foot is crowded with *Lithostrotion* and *Caninia*.	7
Pale limestones with a little chert and some large productids.	10
Fine-grained, fairly thinly bedded, crinoidal dolomite, which weathers brown and has a few somewhat elongate chert nodules.	12
Fine-grained limestones with nodules of greyish chert; solitary corals occur in the upper half and abundant *Caninia*, *Clisiophyllim*, *Dibunophyllum*, *Lithostrotion*, athyrids, *Dielasma* and productids in the lower half.	10
Fairly fine-grained limestones with large nodules of grey chert.	6
Fine-grained, fairly thinly bedded dolomite, which weathers brown, with some zaphrentids.	6
Fairly fine-grained limestones with some chert; athyrids, *Schizophoria*, productids, *Caninia* and *Lithostrotion* are common.	5
Limestones with numerous coarse-grained crinoidal bands.	
	121

The following fossils were collected from the limestones of the group.

Caninia spp. (large and small)

Dibunophyllum bipartitum bipartitum (M'Coy)

D. sp.

Lithostrotion junceum (Fleming)

L. martini Edwards & Haime

L. cf. *pauciradiale* (M'Coy)

L. cf. *septosum* (M'Coy)

Koninckophyllum sp.

Palaeosmilia murchisonia Edwards & Haime

Emmonsia sp.

Chaetetes sp.

zaphrentids

athyrids

Composita cf. *ambigua* (Sowerby)

Dielasma sp.

Rhipidomella michelini (L'Eveille)

productids

Pustula sp.

Spirifer spp.

Pecten sp.

Bryozoa.

9. Middle LithostCaninia sp. nd. This band,

pe 9. Middle Lith Carcinophyllum sp band. This band,

re perhaps the easiest horizon in the whole succession to

th recognise, is a pale crinoidal limestone, fine-grained, contains abundant *Lithostrotion junceum* and a large *Linoproductus*. Only about 6 of the 15 feet are richly fossiliferous, the fossils, which are usually silicified, occurring in three bands. The following fauna was obtained:

Caninia sp.

Carcinophyllum sp.

Dibunophyllum sp.

Koninckophyllum sp.

Lithostrotion junceum (Fleming)

L. cf. *decipiens* (M'Coy)

L. cf. *m'coyanum* Edwards & Haime

L. cf. *pauciradiale* (M'Coy)

Palaeosmilia murchisoni Edwards & Haime

Chaetetes cf. *depressa* (Fleming)

C. cf. *septosa* (Fleming)

Emmonsia sp.

athyrids

Linoproductus sp. (large)

Bryozoa.

East of Lough Arrow, for about 100 feet above the horizon mentioned on p. 74, the beds are extremely badly exposed. The next 50 feet, however, are rich in corals and are probably equivalent to the upper part of the coral-rich limestones and the middle *Lithostrotion junceum* band. The fossils collected are:

Caninia sp.

Lithostrotion junceum (Fleming)

L. cf. *pauciradiale* (M'Coy)

Carcinophyllum sp.

Clisiophyllum sp.

Dibunophyllum bipartitum bipartitum (M'Coy)

D. sp.

zaphrentids

Composita cf. *ambigua* (Sowerby)

productids

Spirifer sp. (very small)

Bryozoa.

The very small spiriferid found in these limestones is identical with one of the spiriferids found in Group 8 of the Bricklieve Succession.

10. *Limestones*. These limestones are usually pale, fine-grained and crinoidal. The following succession was measured about ½ mile north-north-east of Maelahoo (805):

	Thickness. (in feet)
Upper *Lithostrotion junceum* band.	
Fine-grained, thickly bedded, dark and slightly argillaceous limestones without chert; they are relatively soft and give rise to an overhang at the base of the cliff formed by the overlying limestones.	3
Gap.	10
Fine-grained, thickly bedded, pale limestones without chert.	12
Fine-grained, massive, pale limestones with irregularly shaped nodules of pale chert.	12
Fine-grained, thickly bedded, pale limestones with little or no chert.	10
Middle *Lithostrotion junceum* band.	
	47

The only fossils found in these limestones are *Chaetetes*, zaphrentids, productids and spirifers.

11. Upper *Lithostrotion junceum* band. This band is made up of fine-grained, very hard, massive, crinoidal limestones, about one foot of which is packed with silicified fossils such as *Caninia*, *Lithostrotion* and athyrids. This one-foot band is remarkably persistant, since nowhere in its one square mile of outcrop is it found to be absent. The following fossils were collected:

Caninia sp.
Dibunophyllum sp.
Koninckophyllum sp.
Lithostrotion junceum (Fleming)
L. cf. *pauciradiale* (M'Coy)
zaphrentids
Chaetetes cf. *septosa* (Fleming)
athyrids
Composita cf. *ambigua* (Fleming)
productids
Bryozoa.

12. Cherty limestones. The limestones of this group have at least 50% silica, disseminated as small angular fragments. The name Bricklieve is derived from the Gaelic *Breic-shliabh*, which means speckled mountain; in all probability therefore the Bricklieve Mountains get their name from the limestones of this group which have a speckled appearance. The following section was

measured about 2/3 mile north of Maelahoo (805):

	Thickness. (in feet)
Fine-grained limestones.	
Gap.	3
Fine-grained limestones without chert.	3
Fine-grained, very hard, massive limestones, usually pale but sometimes buff-coloured; fresh but weathers to an orange or purplish colour, occurring as small, irregularly shaped fragments or as large brecciated masses. They usually form a sheer escarpment, and have at their base a parting of shaly material.	36
Fine-grained, very hard, massive limestones with much chert.	12
Upper *Lithostrotion junceum* band.	
	54

The only fossils collected are a few small productids, spirifers, orthotetids, *Euomphalus* and bryozoa. East of Lough Arrow, for about 100 feet above the coral limestones mentioned on p. 78, the limestones become increasingly siliceous upwards until, in the upper part, they closely resemble those described above. Interbedded with the limestones is a two-foot band of reddish rottenstone. These cherty limestones can be traced eastwards as far as Lough Allen (Plate I). East of the lake, they were only examined in the bed of the Aghagra River, about 1½ miles east-north-east of Drumshanbo, where they have been almost completely decalcified and are in the form of rottenstones, which appear to extend as far east as Ballinamore.

13. Fine-grained limestones. The limestones, which form the top of the succession in the Bricklieve Mountains, are poorly exposed, since they crop out only over a small area on the flattish, bog-covered hilltops. The following succession was measured just to the south of Hill 949:

	Thickness. (in feet)
Tabular and much brecciated black chert.	2
Calcilutite and fine-grained limestones.	5
Very thinly bedded, darkish, crinoidal limestones which are friable and have yielded abundant productids and one specimen of *Rhipidomella*.	5
Fairly fine-grained limestones which are crinoidal, sometimes silicified and occasionally contain elongated chert nodules.	5
Gap.	10
Fine-grained, fairly dark limestones with much black chert in irregularly shaped nodules.	5
Calcilutites and fine-grained limestones with some black chert.	13
Gap.	5
Fine-grained, fairly dark limestones with black, tabular chert.	2
Cherty limestones.	
	52

Immediately to the east of Lough Arrow, the cherty limestones are overlain by some 25 feet of fine-grained limestones. These form a dip-slope, which falls gently south-eastwards to an abrupt fault-scarp, ¾ mile away. Just beneath this escarpment is a small exposure of "Yoredale Shale" with Posidonia. If this shale is in situ, the 50 feet of fine-grained limestones in the Bricklieve Mountains are represented east of Lough Arrow by only 25 feet of strata.

In the Aghagra River section (see above) the following succession occurs:

	Thickness. (in feet)
Black shales with abundant Leiorhynchus, Martinia and Sudeticeras (P_2).	20
Interbedded black shales and mudstones with Martinia.	40
Rottenstones and pipe-clays, white, grey and purple in colour, with interbedded black mudstones.	30
Black shales and mudstones, with ironstone nodules, Posidonia and Pterinopecten (P_1).	70
Interbedded black shales, black mudstones and calcilutites.	110
Fine-grained, yellowish-brown and green sandstones.	10
Interbedded black shales, black mudstones and calcilutites; the shales contain occasional ironstone nodules and wavellite is commonly developed along the bedding planes; one band of shale appears to be mud-cracked.	110
Small fault.	
Very thinly bedded, fine-grained, argillaceous limestones with thin chert bands.	10
Rottenstones.	15

	Thickness. (in feet)
Interbedded calcilutites, fine-grained thinly bedded darkish crinoidal limestones and brownish dolomitic limestones, with one band of coarse-grained, pale, crinoidal limestone; little chert is present.	60
Fairly fine-grained limestones with much nodular chert and some Lithostrotion cf. pauciradiale.	30
Rottenstones.	30
	535

The basal rottenstones are markedly similar to the cherty limestones, occurring at the top of Group 12 of the Bricklieve Mountains Succession. If they are their equivalents, at least 100 feet of strata separate the lowest shales from the cherty limestones in this district. It is presumed therefore that the exposure of "Yoredale Shale" mentioned on p. 83 is not in situ. If the 10 feet of sandstone is taken to be the base of the "Yoredale Series", the Carboniferous Limestone succession would be completed by at least 200 feet of strata occurring above the cherty limestones, and the Bricklieve Mountains Succession fails by more than 140 feet to reach the horizon of the base of the "Yoredale Series".

Discussion of the succession. At the top of the succession and only exposed in the Aghagra River section, the argillaceous and calcareous rocks are rhythmically developed, a type of sedimentation that continues apparently uninterruptedly into the "Yoredale Series". In the remainder of the succession arenaceous and argillaceous material is absent. This indicates that, throughout the period of its deposition, the Curlew Mountains area was the site of a shallow-water sea, which was sufficiently far removed from a land mass as to be free from terrigenous material, yet shallow enough to allow the deposition at one period of the coarse-grained crinoidal limestones of Group 7. That the sea was at times warm is suggested by the occurrence of coral reefs, especially the Kesh Corann reef. A striking feature of the succession is the great abundance of chert in the limestones which increases upwards until it constitutes over 50% of the rock. These extremely siliceous limestones have in places of poor drainage become decalcified to form rottenstones and pipe clays at the top of the succession. Various origins have been ascribed to the chert. Hull and Hardman (1878, p. 77) suggested that it was due to the replacement of the original limestone while still more or less plastic by inorganically precipitated silica. They also suggested that the sea became shallower in Upper Carboniferous Limestone times and had a higher proportion of dissolved silica. Sargent, in various papers, supported the inorganic origin but Hinde (1887, p. 437) claimed that the chert was organic and mostly derived from sponge spicules.

The Area immediately north of the Inlier.

On the northern flank of the Curlew Mountains pericline, immediately north of the inlier, there is a series of outcrops which, because of faulting, cannot be directly linked with the Bricklieve Mountains Succession. As can be seen from the map (Plate I), the Carboniferous sandstones are exposed at four localities. At the eastern end of the pericline the sandstones underlie a considerable area and are badly faulted. These beds are not discussed in this thesis, since they are best studied with the surrounding Carboniferous Limestone, which is similarly affected. At the western end of the pericline, about 1½ miles south-south-west of Charlestown, a greyish, felspathic sandstone rests unconformably on the Ordovician (p. 27), and north of Lough Key coarse-grained, felspathic sandstones, which are occasionally pebbly and vary in colour from orange-red, through yellow, to white, outcrop immediately to the north of the Old Red Sandstone. The sandstones exposed in the neighbourhood of Carracastle, and the northern part of the arenaceous succession at Doon (p. 55), are probably Carboniferous in age.

Along the eastern half of the pericline, between the main outcrop of the Carboniferous to the north and the Old Red Sandstone to the south, is a discontinuous series of limestone outcrops. The limestones are of two types: a normal, bedded limestone and a bryozoan reef-limestone. The latter appears to overlie the former, though they may be separated by a fault. The bedded, crinoidal limestones are fairly fine-grained and contain little chert. The fauna, which includes Chonetes, orthotetids, productids, Spirifer, athyrids and Euomphalus, and the almost complete absence of chert, suggest that the limestones are not far above the base of the Carboniferous succession, possibly immediately above the basal sandstones exposed in places just to the south. The irregularly bedded, fairly fine-grained, darkish, crinoidal limestones exposed at Doon, just to the north of the arenaceous succession described on p. 55, may lie at much the same horizon. These limestones, which have no chert, contain large caninias lying along the bedding planes, zaphrentids, small and large chonetids, orthotetids and spirifers. About one mile east of Ballinafad there is an outcrop of highly siliceous rottenstone, the exact relationship of which to the bryozoan reef-limestones cannot be determined.

The reef-limestones probably run uninterruptedly for about 15 miles, from 1½ miles west-south-west of Ballinafad to the extreme eastern end of the pericline, where they suddenly turn south-south-westwards. They are only occasionally bedded, and are lithologically very similar to typical reef-limestones. The fauna too is a typical reef fauna, with abundant athyrids, rhynochonellids, spiriferids, crinoids and bryozoa. The full fossil list is given below.

Amplexus coralloides Sowerby

Athyris globularis Phillips

A. (*Cleiothyridina*) *lamellosa* (L'Eveillé)

A. (*Actinoconchus*) *planosulcata* Phillips

A. spp.

Brachythyris cf. *integricosta* (Phillips)

B. cf. *ovalis* (Phillips)

Camarophoria (*Stenoscisma*) cf. *globulina* Phillips

Camarotoechia pleurodon (Phillips)

Dielasma cf. *hastata* (Sowerby)

Dictyoclostus spp.

Echinoconchus cf. *elegans* (M'Coy)

Leptaena cf. *analoga* (Phillips)

Martinia glabra (Martin)

Overtonia cf. *fimbriata* (Sowerby)

Phricodothyris sp.

Productus undatus Defrance

productids

Pugnax pugnus (Martin)

P. sp.

Pustula cf. *carringtonia* (Davidson)

P. cf. *spinulosa* (Sowerby)

P. spp.

Reticularia cf. *imbricata* (Sowerby)

R. spp.

Rhipidomella michelini (L'Eveillé)

Schizophoria cf. *resupinata* (Martin)

Spirifer cf. *bicarinata* (M'Coy)

S. cf. *bisulcatus* Sowerby

S. cf. *crassa* de Koninck

S. cf. *distans* Sowerby

S. cf. *trigonalis* Martin

S. *triradialis* Phillips

S. spp.

Capulus sp.

Naticopsis cf. *placida* de Koninck

Parallelodon cf. *bistriatus* Portlock

Pecten spp.

Conularia quadrisulcata Sowerby

Bryozoa

crinoid fragments

trilobite fragments.

Both *Camarotoechia pleurodon* and *Pugnax pugnus* occur very abundantly; surprisingly enough *Pugnax acuminatus* has not been found. The specimens of *P. pugnus* resemble the typical forms except that they have pronounced median septa. As is so often the case with bryozoan reefs, the fossils occur in "nests"; not only do the faunas of the individual "nests" differ significantly, but also differences in size and shape of fossils belonging to the same species can be observed. Many of the fossils, especially the spirifers, are deformed.

Besides the sandstones and basal limestones described above, various other outcrops of limestone, whose exact position in the Carboniferous Limestone succession cannot be determined, are to be found at infrequent intervals along the northern flank of the pericline. In the extreme west limestones are exposed at two localities. Four miles west of Kilkelly, where they lie just above the basal sandstones, the limestones contain large caninias and productids. Five miles north of Kilkelly the limestones, which are also presumably close to the junction, are in part shaly and contain caninias including Caninia cf. cylindrica, Syringopora, and abundant productids including Pustula cf. pilosa and P. cf. punctata. The limestones in both places are almost without chert. One mile east of Gorteen there are a few outcrops of limestone, which is also without chert and often shaly. The following fossils occur:

zaphrentids

Chonetes sp. (small)

Phricodothyris sp. (small)

Pustula cf. spinulosa (Sowerby)

Rhipidomella michelini (L'Eveillé)

Tylothyris laminosa (M'Coy)

Beyrichoceras sp.

Bryozoa.

The occurrence of Beyrichoceras probably denotes an

S_2 age. It is possible that the outcrop of these beds swings round so that they immediately underlie those of Group 1 of the Bricklieve Mountains Succession, at the foot of the western slopes of Kesh Corann. Thus the basal limestones of that group are argillaceous, and the ground just beneath these beds, though steep, is completely without exposures, suggesting that it is underlain by relatively soft strata.

Immediately to the west and south of Drumshanbo (Plate I), a small area underlain by shales and argillaceous limestones is bounded to the north by bryozoan reef-limestones, and to the south by basal Carboniferous sandstones. The beds, originally placed by the Geological Survey in the Silurian, probably lie at the base of the Carboniferous Limestone succession, possibly just above the sandstones. The shale is no longer exposed, but the following fossils were obtained from the tip-heap beside the old canal, about ½ mile south-west of Drumshanbo.

<u>Caninia</u> sp.

<u>Fasciculophyllum</u> cf. <u>omaliusi</u> (Edwards & Haime)

zaphrentids

<u>Athyris</u> sp.

<u>A.</u> (<u>Actinoconchus</u>) sp.

<u>A.</u> (<u>Cleiothyridina</u>) sp.

<u>Chonetes</u> sp. (small)

productids

Rhipidomella michelini (L'Eveille)

Spirifer spp.

Michelinia sp.

Bryozoa.

(d) General Considerations and Correlations.

It is apparent that the Lower Carboniferous sea over the area of the Curlew Mountains pericline was both shallow and clear, and, except during its initial transgression, was sufficiently removed from the land mass to the north and west, for no terrigenous material to be deposited. The sea probably reached the area in Lower Visean times - the basal limestones are taken to be C_2S_1 in age since Mr. G. Caldwell (personal communication) has found a diphyphylloid *Lithostrotion* about 50 feet above the base of the limestone succession. Conditions probably did not favour the growth of *Lithostrotion* previously. The Carboniferous transgression therefore reached the Curlew Mountains area at roughly the same time as it did in the north and west, though the basal beds in the Omagh syncline are thought to be C_1 in age (Simpson, 1955), and much later than in the Dublin area and co. Clare.

The bryozoan reef-limestones, which are developed only along the northern flank of the pericline, appear to be very close to the base of the limestone succession, and are probably C_2S_1 in age. They may occur at the same horizon as some calcilutites, which are 50-100 feet above the sandstones on the southern flank of the pericline. The reefs may however be Upper Visean (p.113), and the direct equivalents of those to the north (see below). The nearest reefs are those of D_1 age to the east of Ben Bulben (Fig. 1), and those of C_1 age in co. Clare. It seems probable that the Curlew Mountains axis exerted a considerable influence over the growth of the reefs, and that the conditions for their development only obtained along the northern, faulted flank of the pericline, just as the Ox Mountains anticline probably contributed to the establishment of reef-forming conditions in Upper Visean times (George, 1953, p. 72).

The next oldest beds exposed in the pericline are the shaly limestones east of Gorteen (p. 90), which are probably upper S_2 in age and lie immediately beneath the Bricklieve Mountains Succession; there is thus a gap, representing an unknown thickness of the upper C_2S_1 and lower S_2 zones. The shaly limestones may be the equivalent of the Upper Calp Shale, exposed in the country to the north-west of the Ox Mountains. If this be so, the local equivalents of the upper part of the Lower Limestones (C_2S_1), the Lower Calp Shale (C_2S_1)

and the Calp Sandstone (S_2) are not exposed, though the small outcrop of shale and shaly limestone near Drumshanbo (p. 91) may represent the Lower Calp Shale. The succession in the Bricklieve Mountains and the area east of Lough Arrow is probably the equivalent of the Calp and Upper Limestones (D), in the country to the north-west of the Ox Mountains. The Upper Visean bryozoan reefs of the country to the north appear to be unrepresented in the Curlew Mountains pericline. The Kesh Corann Lithostrotion reef-limestone, a striking feature of the Bricklieve Mountains Succession, appears to have no representative in the country to the north or south, though Douglas (1909, p. 554) recorded that Lithostrotion becomes "enormously abundant" towards the top of S_2 in co. Clare.

The abundance of chert in the limestones of the Bricklieve Mountains Succession, especially in those towards the top, has its parallel in the country to the north-west of the Ox Mountains and elsewhere in Ireland. The rottenstones and pipe-clays are also to be found in the Upper Visean of many parts of the British Isles, e.g. in Gower and the Dublin area. The horizon of the S-D boundary is not known with any certainty in the Bricklieve Mountains. The Lower Lithostrotion junceum band provides a suitable horizon, though the large amounts of chert in the underlying limestones suggests that they should be correlated with the lower half of the Upper Limestones (D_1) in the country to the north, and in co. Clare

L. <u>junceum</u> does not make its appearance until upper D_1 times.

At the top of the succession, there appears to be a complete transition from the Carboniferous Limestone into the "Yoredale Series". This contrasts strongly with the situation in the country to the north-west of the Ox Mountains, where an unconformity separates the limestone from the "Yoredale Sandstone". In the Aghagra River section, the shales immediately above the sandstones are probably P_1 in age, though no evidence of the existence of D_2 limestones beneath this horizon has been found. The "Yoredale Sandstone", which forms a convenient base to the "Yoredale Series" in this area, is remarkably thin; it thickens northwards until it is from 200 to 300 feet thick in the country to the north-west of the Ox Mountains.

VI. TERTIARY DYKES

The five dykes which are exposed in the pericline have been examined. From east to west, with their approximate directions and thicknesses, they are as follows:

Name	Direction	Thickness. (in feet)
Kilbryan Dyke	N. 10° E. (average)	100
Rock of Doon Dyke.	N. 10° W.	100
Fintagh Dyke.	N. 5° W.	20
Sheegorey Dyke.	N. 5° E.	50
Moygara Dyke	N. 25° W.	10

The dykes are doleritic in composition, being made up of zoned felspar laths, almost all labradorite, with rounded crystals pyroxene; olivine appears to be absent though McHenry & Watts (1895, p. 51) named the dykes ophitic olivine dolerites. The texture varies from ophitic, through sub-ophitic to intersertal. A little primary quartz in the Rock of Doon Dyke suggests that the dolerites are tholeiitic. The dykes have been considerably altered, the felspars being sericitized and the pyroxenes chloritized and in some cases completely decomposed. Skeletal ilmenite and carbonate form a high proportion of the dolerite. Fine-grained chilled margins are exhibited by most of the dykes; along its contact, the Kilbryan

Dyke encloses quartz xenocrysts derived from the adjacent sandstones.

The Kilbryan Dyke, north of Lough Key, can be traced for 1/3 mile and is somewhat complex in structure. The main body trends N. 10° E., but changes direction twice so that the extremities are out of alignment. It may be connected with another dyke, also trending N. 10° E., about 1/3 mile to the north-north-west. The Rock of Doon Dyke, which has given rise to the prominent Rock of Doon situated above the western shore of Lough Key, is straight for one mile. The Fintagh and Sheegorey dykes are exposed over very small areas, about 1¼ miles north-east and ½ mile north-north-west of Hill 770 at the western end of the Curlew Mountains. The Sheegorey Dyke is highly and irregularly jointed in a longitudinal direction. The Moygara Dyke is only exposed over a few square yards west of Lough Gara, where it cuts the Moygara Conglomerate. Its margins are highly jointed longitudinally, fine-grained and deeply weathered; the central part of fresher, more massive dolerite, contains numerous, dark, rounded amygdales up to ¼ inch across, which are chloritic in composition. The dyke encloses a screen of country rock, which has been altered from red to dark grey.

McHenry & Watts (1895, p. 51) assigned a post-Carboniferous or Tertiary date to the dykes. In the pericline they cut the Old Red Sandstone only, though a few miles east of Drumshanbo a similar dyke penetrates the Carboniferous. Their composition and direction together suggest a Tertiary date, though the dyke-trend 20-30 miles to the north swings into an east-west direction (Walker and Leedal, 1954, fig. 10).

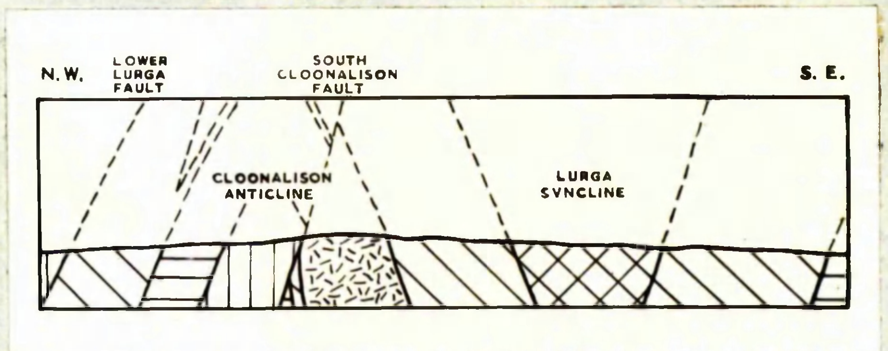

Fig. 10. A section across the Ordovician rocks of the Lurga area. Natural scale: 3 inches to 1 mile. Key as in fig. 6.

Fig. 11. A section across the Old Red Sandstone rocks at Mullaghthee, in the eastern half of Area 2. Natural scale: 3 inches to 1 mile.

VII. STRUCTURE

The structures in each of the four systems comprising the Curlew Mountains pericline differ so fundamentally that they probably arose during separate periods of earth-movement.

(a) Ordovician Movements

The Arenig volcanic series, structurally more complex than the Silurian rocks appears to have been affected by an orogeny which took place between the Arenig and the Upper Llandovery. The actual relationship between these two series is obscure, but in all probability it is, as Kinahan (1879, p. 345) suggested, one of unconformity. At one locality about 1/2 mile north-east of Glen School, a small trend was dug across the contact. At the base of the Silurian sandstones and immediately overlying the Ordovician tuffs, which are highly stained with iron and much broken up, a conglomerate, about one foot thick and made up of rounded quartzite pebbles, was uncovered. West of Lough Mask the basal Silurian conglomerate, which also rests on the Ordovician, is similarly composed mainly of quartzite pebbles (Gardiner and Reynolds, 1912 and 1914). In the Glen School area the Ordovician tuffs are dipping at 40° to the north-west, and the Silurian sandstones at about 50° to the south-east, giving an angular discordance of approximately 90°.

The Ordovician beds have been considerably faulted and folded in a north-east south-west direction (Fig. 10). The small Lurga area (p. 6) is the only part of the ground where these rocks are sufficiently well-exposed to enable the succession and structure to be worked out, and it alone will be described.

None of the previous work in this area made any notable reference to the structure of the Arenig, though Cummins (1954, p. 102) mentioned the steep dips and the north-east south-west strike of the beds. Like the succession, the structure is difficult to elucidate, but two main structural elements appear to be present - the Cloonalison anticline and the Lurga syncline.

In Sub-areas A and B (p. 26), the rocks of Group III form the crest of the Cloonalison anticline, which is slightly displaced by the North Cloonalison fault (p. 102). The dips in the north-western limb, which is seen in Sub-area B, average 65° north-west, and those in the south-eastern limb, seen in Sub-area A, about 70° south-east - most of this limb in Sub-area B is cut out by the South Cloonalison fault (p.103). The anticline is probably pitching south-westwards, since the two limbs converge, and the granophyre thins (p. 24) in this direction. Rocks belonging to Group III, seemingly continuous with those in Sub-area D, appear immediately to the north-west of the outcrop of Group V in Sub-area D, and in both areas are dipping steeply to the north-west. This relationship clearly implies a fracture, called the Lower Lurga fault, between Groups III and V. If the rocks of Group III are the right way up, those of Group IV should appear to the north-west. In Sub-area D however rocks belonging to Group II occupy this position. Therefore unless another structural break separates the outcrops of Groups II and III, the beds of Group III must be inverted, and the Lower Lurga fault be either a thrust or a reversed fault. The hypothesis of inversion is supported by the occurrence in the agglomeratic tuffs of Group III of pebbles very similar to the felsites of Group II.

The Lurga syncline, lying immediately to the south-east of the Cloonalison anticline, is seen in Sub-area C, where rocks of Group VI lie in the trough of the syncline, surrounded by strata of Group V, which dip inwards at angles averaging about 70°. The difference in strike between the two limbs, and the triangular shape of the outcrop of Group VI, suggest that the syncline like the Cloonalison anticline pitches south-westwards. As mentioned on p. 25, the syncline is probably responsible for the great width of the granophyre outcrop east of Lurga Post Office.

The North Cloonalison fault runs through Sub-area B and is responsible for the displacement of the granophyre to the south of Sub-area A (p. 23). In the former case it explains a 5^{o}-10^{o} difference in strike across the fault, and the slight displacement of the groups to the north and south. In Sub-area A it is probably responsible for the considerable amount of veining and slickensiding in the granophyre. Finally at the northern end of Sub-area C, it appears to truncate the outcrop of Group V, and must have a large effective downthrow to the south. In Sub-area B however it is either downthrowing to the north or is a dextral tear fault. At the southern end of Sub-area A its nature is difficult to determine owing to the oscillatory nature of the dips, but it is probably either downthrowing to the south or is a dextral tear fault. Hence it may be a dextral tear fault with a downthrow component to the south.

The Upper Lurga fault, which also displaces the granophyre (p. 23), is possibly responsible for the slight displacement of the boundary between Groups IV and V, somewhere in the almost exposureless ground between Sub-areas C and E. Since the movement at both localities is right-handed, the fault is assumed to be a dextral tear fault, with a strike-slip of between 400 and 500 feet. The relationship between this fault and the North Cloonalison fault cannot be determined, which however it does not appear to displace.

There is no direct evidence for the South Cloonalison fault (p. 101). Its presence is postulated to explain the absence of rocks belonging to Group III in south-eastern limb of the Cloonalison anticline. It may also account for the slickensiding, dipping at 45^0 to the north-west, in the granophyre immediately to the south-east. Since its course on the map is essentially straight, the fault is assumed to be a reversed fault or a high-angle thrust, rather than a low-angle thrust. There is no evidence for the fault on the other side of the Upper Lurga and North Cloonalison faults, but it may run through Sub-area A, giving rise to the anomalous dips close to the granophyre (p. 26). The small effect of the fault here suggests that it may accommodate to the Upper Lurga or North Cloonalison faults.

Towards the south-west of Sub-area C is a series of faults, called the West Lurga fault system, which probably trends in a north-west south-east direction. Its presence is betrayed by slickensiding, by excessive jointing, brecciation, shearing and distortion of bedding, by rapid changes in strike direction and by displacement of the group boundaries. To judge from the latter and from changes in strike, the faults probably downthrow to the north-east, with a considerable lateral component in a sinistral direction. The increase in the width of the granophyre outcrop across the faults accords with a downthrow to the north-east (p. 24).

In the area underlain by the rocks of the Felsitic Succession, it was not found possible to elucidate any structural details. It has to be assumed, in the absence of any contrary evidence, that the strata are dipping uniformly to the north-west, since the one dip reading observed is in this direction and there does not appear to be any repetition of the groups. The beds are probably the right way up since the pebbles found in the agglomeratic tuffs of Group 2 resemble some of the rock-types making up Group 1. By joining up outcrops of similar rock-types belonging to Groups 4 and 5, a third to half a mile apart, strike directions of N. 50° E. and N. 53° E. respectively are obtained. At the one locality where bedding is visible, the strike is about N. 45° E. It is impossible to find out the relationship between the Felsitic and the Tuffaceous Successions, or the nature of the transcurrent break separating them. This could be a fault or a thrust - even an unconformity, though this is extremely unlikely since it necessitates the removal of the whole of Groups I-III, as well as any strata occurring between Groups I and 5.

(b) Caledonian Movements

Since the Silurian is everywhere steeply inclined, but the overlying Old Red Sandstone is not, the structures in the Silurian are probably to be attributed to a movement, equivalent to the main phase of the Caledonian orogeny which took place in Upper Ludlow or lowermost Old Red Sandstone times.

The Silurian rocks wherever examindd appear to dip uniformly to the south-east, the dips varying from 40° to 90° and the strike remaining fairly constant. The ground is doubtless crossed by numerous faults, but the only evidence of these is met with in the Carracastle stream section. To judge by current-bedding throughout the succession, the strata also become younger south-eastwards, so that the succession is not inverted as the Geological Survey (Wilkinson and Cruise, p. 22) erroneously concluded. The Survey were misled because the limestone, containing apparently typical Wenlock fossils, lay beneath sandstones with Upper Llandovery forms. The fossils, however, such as <u>Halysites catenularis</u>, which were then thought to be restricted to the Wenlock, are in fact facies fossils and occur in Upper Llandovery rocks to which the limestone in fact belongs.

(c) Old Red Sandstone Movements

The structures in the Old Red Sandstone are much more complex than that in the Carboniferous. Since the Old Red Sandstone is unconformably overlain by the Carboniferous the movements which affected the former must be pre-Carboniferous in age. They may belong to Stilles Svalbardic orogenic phase which took place during the Middle Old Red Sandstone.

The Old Red Sandstone in the southern part of the inlier is gently undulating. The structure is essentially synclinal, though the dips are irregular in both magnitude and direction. The pressures which have severely affected the strata over the rest of the inlier have, in this region, caused the beds to buckle in places, as, for example, about 1 1/4 miles south-east of Bockagh Hill (749), where a very small inlier of sandstone emerges abruptly through the overlying volcanic rocks. The volcanic rocks of the Curlew Mountains and Area 2 are situated in the trough of this synclinal region. Notwithstanding the slight easterly pitch of the suncline in this area, the outliers are all at roughly the same height. It is concluded therefore, as is shown on the map, that the rocks of the various outliers are brought up by at least two transcurrent faults, with apparent downthrows to the west of about 50 feet. Analogy with Area 2 (p. 108) suggests that these faults are tear faults with subsidiary vertical movements.

Owing to the fewness of exposures, the structures of the four western outliers cannot be determined. The Sheegorey Outlier is however better exposed, though even there exposures are usually lacking in critical areas, so that the structures are difficult to elucidate. The sandstones at A, B and C (Plate I) probably overlie the volcanic rocks and form the base of Group vi. To the north-west of B, the sandstones are brought against the volcanic rocks by a normal fault. The contact, dipping at 50° south-eastwards and associated with a certain amount of brecciation and considerable slickensiding, can be seen in a small quarry about 400 yards south-east of Hill 770. The fault, which can be traced for a short distance by the feature it produces, has a throw of between 50 and 100 feet in the north-east, but appears to die out south-westwards. The sandstones at C overlie the volcanic rocks to the south, but are faulted both to the north-west and east; the line of the eastern fault may have been followed in Tertiary times by the Rock of Doon Dyke (p. 96), or the fault may trend in a more north-westerly direction. As stated on p. 57 the sediments to the east of this fault probably belong to Group vi, in which case the fault has an apparent downthrow to the east. All the Old Red Sandstone rocks east of Lough Arrow lie in the region of gentle dips. In the eastern half of the area there is a very shallow east-west syncline, which is probably cut off from the western half by a fault, since the dips there appear to be consistently to the south.

Over the rest of the inlier the dips increase rapidly immediately to the north of the synclinal region (Fig. 11), becoming vertical within a distance of from 50 yards, as at Brislagh (867) in the Curlew Mountains, to 400 yards, just to the west of the Srove Fault (p.109) in Area 2. Still further north, the strata dip to the north-west at angles varying between 90° (in the south) and 45° (in the north). Current and graded bedding indicate that the base of the succession lies to the north-west, in both this and the zone of vertical beds. The strike of the steeply dipping strata varies from N. 50° E. in the extreme west, through N. 60° E. and N. 55° E. in Area 2, to an average of about N. 70° E. in the Curlew Mountains.

A series of tear faults, trending in a north-west direction, is seen to traverse Area 2. The faults, which have sometimes given rise to small gullies running across the hills, e.g. the Srove and Moygara Faults (see below), are recognisable by slight though sharp changes in strike, e.g. 8° in the case of the Drumacoo Fault, by displacement of structures and lithology, e.g. the Srove Fault, and by veining and local contortions in the case of the Bockagh Hill and Srove Faults. The structures on either side of the faults are often seen not to correspond. Thus in the case of the Drumacoo Fault, the boundary between Groups iii and iv dips at 55° on one side, and at 80° on the other. This change in structure across the faults makes it likely that the faulting and the folding were more or less contemporaneous. The faults, with their probable strike-slips and directions, are listed below from west to east.

Fault	Direction	Strike-slip (in feet)
Bockagh Hill	N. 15° W.	500
Cloonmeen	N. 20° W.	600
Fallsolles	N. 35° W.	350
Drumacoo	N. 20° W.	500
Srove	N. 45° W.	900
Moygara	N. 45° W.	50-100

Horizontal slickensiding or other positive evidence of lateral movement has not been observed. Nevertheless the faults are assumed to be tear faults since lateral, rather than vertical, movement accounts more easily for the lateral displacements of more or less vertical strata. Moreover, since the displacements are consistently right-handed the faults, if normal or reversed, would require to have a total throw which would be immense. This is highly improbable since the relatively flat-lying volcanic rocks to the south are not appreciably affected by the faults.

In Area 1, notwithstanding the north-westerly dips, the succession probably becomes older in that direction. This agrees with the single case of current-bedding which has been noted. Thus the inversion zone, which is so well seen to the east, is probably continued into this area. As already stated on p. 53, the junction with the Silurian is probably faulted, a probability which is supported by the 18° difference in strike between the Old Red Sandstone and Silurian strata. The stratigraphical position of the volcanic rocks of Group i presents a difficult problem. They may either be lower than any Old Red Sandstone beds exposed elsewhere in the inlier or at the same horizon as the volcanic rocks of Group v. The former solution is the more likely, because of the discrepancy in thickness and lithology between the two groups, and because the Group i volcanics are apparently overlain by sediments quite unlike those of Group vi. The Carrownlacka fault (p. 53,) is thus probably a sinistral tear fault with a strike-slip of about 4000 feet. It is possible however that this large slip, which is necessary to bring these rocks into their present position, may be shared by one or more unexposed faults in the wide gap between the Bockagh Hill and Carrownlacka Faults.

A large reversed fault or high-angle thrust may lie to the north of the zone of inverted Old Red Sandstone strata. This would bring Lower Palaeozoic rocks to the north against Old Red Sandstone to the south, and would explain the steep dips in the latter. This fracture, which may be the one separating the present outcrops of the two systems, probably runs for some of its length along the post-Carboniferous Curlew Mountains fault (p. 112), which moved in the opposite direction. It is interesting to note that Thirlaway (1951, fig. 7), using gravimetric observations, concluded that no Old Red Sandstone exists north of the Curlew Mountains fault. This would make it appear likely that the area to the north of the Curlew Mountains pericline was uplifted in pre-Carboniferous times, allowing the Old Red Sandstone to be eroded.

(d) Hercynian Movements

The movements affecting the Carboniferous are in all probability Hercynian though direct evidence is lacking. The main post-Carboniferous structural feature is the Curlew Mountains pericline itself. This extends for a distance of over 40 miles in a west-south-west direction, though at its western end there appears to be a separate, smaller pericline, trending N. 50° E. (Plate I). The Carboniferous strata on the southern flank of the main pericline dip off the older rocks at angles of 10° or less, but the northern flank is faulted for most of its length, and the dips are more in the region of 20° - 30°, close to the contact with the Old Red Sandstone, where unfortunately exposures are very poor. The Curlew Mountains fault runs parallel with the pericline, though its course is slightly sinuous. Its downthrow is everywhere to the north and, though field evidence is lacking, it is probably a normal fault. In the east the fault appears to bifurcate, since bryozoan reef-limestones are thrown against Old Red Sandstone to the south and Upper Visean limestones to the north. It throws limestones belonging to Group 3 of the Bricklieve Mountains succession (p. 66) against the reef-limestones to the west of Ballinafad, and continues west of Lough Gara, where beds of S_2 age are brought up against Old Red Sandstone. It almost certainly runs in the neighbourhood of the basal limestones at Doon (p. 81), but cannot be traced to the west (cf. p. 117). Should the bryozoan reef-limestones be Upper and not Lower Visean, they would have to lie in an improbably long, narrow graben about 100 yards wide and at least 15 miles long. The throw of the Curlew Mountain fault is difficult to determine, since the total thickness of the Carboniferous succession is unknown, but it must be at least 2000 feet. Thirlaway's gravimetric observations (1951, p. 16) gave a figure of approximately 2500 feet in the Ballinafad area. Hull (1891, p. 189) stated that the direction of the Curlew Mountains fault "is very similar to that of the post-Miocene faults of Antrim," and that the fault itself is "very nearly continuous with a great line of displacement which ranges by Swanlinbar, and which, after crossing the Lough Erne valley by Knockninny, ranges by Slieve Beagh towards Lough Neagh by Coal-Island. The actual fracture may not be continuous throughout, but the separate fractures . . . probably belong to the same system of disturbances."

As already mentioned the Carboniferous strata at the eastern end of the pericline are considerably faulted. The Bricklieve Mountains are traversed only by a number of minor faults, trending north-north-west (the same direction as the main set of joints), with downthrows to the west of 50 feet or less; each fault can be seen to die out within short distances. East of Lough Arrow four faults, trending north-west south-east, are to be found within a distance of 1 1/2 miles. The three eastern faults, which have given rise to pronounced scarps, have each a downthrow to the west of the order of 50 feet. The western fault, on the other hand, has a downthrow to the east of about 100 feet. The third fault from the west dies out to the north within approximately one mile. This is readily seen since, at the southern end, the fault is bounded by two scarps, composed of the same limestone and separated by a vertical interval of about 50 feet; as the southern end is approached, the two scarps gradually reach the same elevation and merge into one.

Apart from the area in the neighbourhood of the Curlew Mountains fault, the Carboniferous strata to the north of the inlier everywhere dip at angles of less than 10°. Over most of the Bricklieve Mountains the dips are very gentle; they are generally to the south-east, though there are occasional "rolls" as at the northern end of Doonaveeragh (937). In the extreme south of the Bricklieve Mountains however, in the neighbourhood of Maelahoo (805), the strata undulate considerably, due probably to the Curlew Mountains Fault a short distance to the south. On the whole the dips are northerly in this area, so the axis of the South Sligo syncline (Fig. 1) is here very close to the axis of the Curlew Mountains pericline. East of Lough Arrow, the strata fall away gently to the south-east, except near the Curlew Mountains fault, where the dips are northerly.

(e) Final structural pattern

The pattern resulting from these four periods of movement is somewhat complex. The Hercynian structures are the easiest to recognise, since they govern the shape and direction of the pericline itself. They were probably influenced to a certain extent by the underlying Old Red Sandstone structural trend. It is interesting to note that the post-Carboniferous Curlew Mountains fault probably coincides for much of its length, with the pre-Carboniferous fault that is postulated to explain the structures in the Old Red Sandstone (p. 111), though the direction of movement is reversed.

As already mentioned the pericline is 40 miles long, trends approximately N.50°E., and is faulted both along most of its northern flank, and at its eastern extremity. The main feature of the Old Red Sandstone structural pattern is the reversed fault, and the upended and overturned beds lying along its southern border. The strata also yielded along tear faults, which are usually dextral and at about 30° to the strike of the beds. The Silurian strata appear to dip consistently to the south-east at high angles, but the Ordovician structures are much more complex. In the area examined they are steeply folded, and the beds are crossed by an extensive fault pattern.

VIII. PALAEONTOLOGICAL SECTION

Caninophyllum cf. patulum (Michelin). Plate IIa. One specimen of this coral was obtained from the basal limestones on the southern flank of the pericline, in an old disused quarry ¼ mile south-west of Cleen cross-roads, 5 miles north-east of Boyle. It is very similar to a coral of this name described by Lewis (1927, p. 380) as coming from Cleen, co. Roscommon, though it is somewhat larger, having a diameter of about 45 mm. and about 70 major septa. Lewis had this to say about his specimen: "It agrees most closely with the tortuosa type in the γ beds of Barry I., South Wales." M'Coy (1844, p. 267) recorded Turbinolia fungites and Favosites tenuisepta from Cleen, near Boyle. Michelinia tenuisepta has been found at this locality, and M'Coy's T. fungites could well be C. cf. patulum (Edwards & Haime, 1850, p. 171), so it is highly probable that Lewis' locality and that given above are one and the same. C. patulum has hitherto been recorded only from Z_2 and γ, and C. aff. patulum from C_1 and C_2.

Cyathoclisia tabernaculum Dingwall. Plates IIb & IIc. One specimen of this coral was collected from the basal limestones on the southern bank of the Boyle River, ¾ mile west-south-west of Boyle. The coral is simple, cornute, and at a length of 40 mm. has a diameter of   mm. and 57 major septa. The epitheca is fairly smooth but with some horizontal ridges; the calyx is not preserved. The major septa curve in an anti-clockwise direction round the central column, to which they extend. The minor septa are from 1/3 to 1/2 the length of the major septa. Both sets reach the outer wall and are dilated in the outer parts of the tabularium in the cardinal quadrants. The well-marked cardinal fossula expands inwards to the central column; the cardinal septum is long but extremely attenuate, especially at its inner end. The dissepimentarium is from 2-5 mm. wide with from 3-6 rows of dissepiments. The central column is composed of a thickened median plate, 3.5 mm. long, numerous somewhat indistinct septal lamellae and equally numerous steeply inclined tabellae; the tabulae, which are sharply demarcated from the tabellae, are only moderately inclined. The coral resembles the Howth type of C. tabernaculum (Dingwall, 1926, p. 8), and has hitherto only been found in γ and C_1.

Dibunophyllum bipartitum bipartitum (M'Coy). Plate IId. Many specimens which have been referred to this species have been found in Group 8 of the Bricklieve Mountains Succession. The corals usually have a diameter of between 35 and 30 mm. The central column, which is approximately 1/3 diameter of the corallum, consists of a long median plate with about 6 slightly sinuous septal lamellae on either side. The calyx is very deep with a long domed, oval boss. The major septa, which extend to the central column and vary in number from 40 to 60, are usually dilated in the tabularium and somewhat thin and sinuous in the wide dissepimentarium; the minor septa are very short. A cardinal fossula is present due to the shortening of the cardinal septum. The medium plate reaches the periphery at the cardinal end but falls short at the counter end.

Finally I should like to express my sincere thanks to Professor T. Neville George for all the help and encouragement he has given me during the course of this research. I am also pleased to acknowledge the help given by many people, in particular Professor A. Williams of the Queen's University of Belfast, and Dr. M. G. Bandy and Mr. R. Johnston of the University of St. Andrews.

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Plate I.

The geology of the Curlew Mountains pericline.

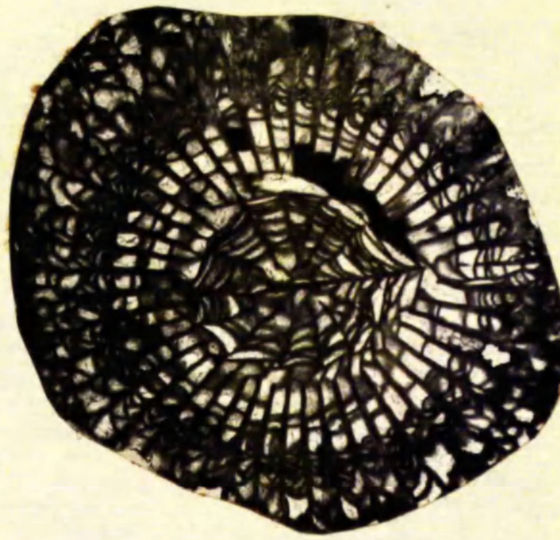
Plate II.

a. *Caninophyllum cf. patulum* (Michelin). Horizontal section x 1.8.

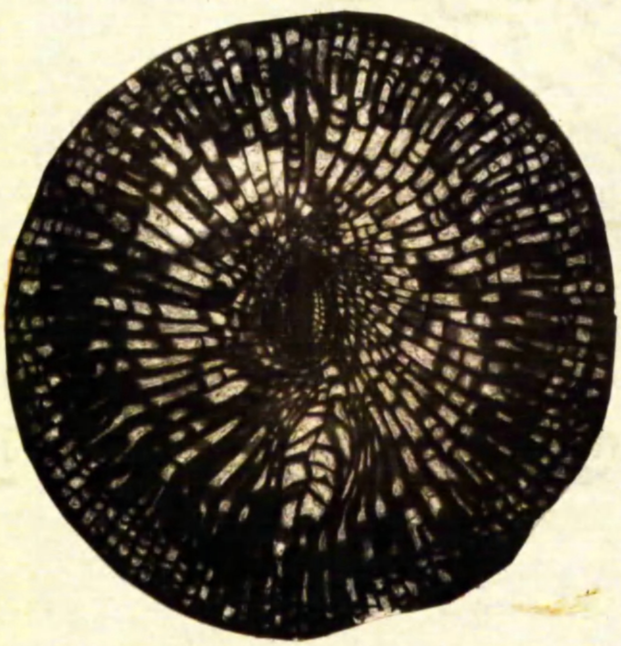
b. & c. *Cyathoclisia tabernaculum* Dingwall. Horizontal and vertical sections x 1.8.

d. *Dibunophyllum bipartitum bipartitum* (M'Coy). Horizontal section x 1.8.

(a)

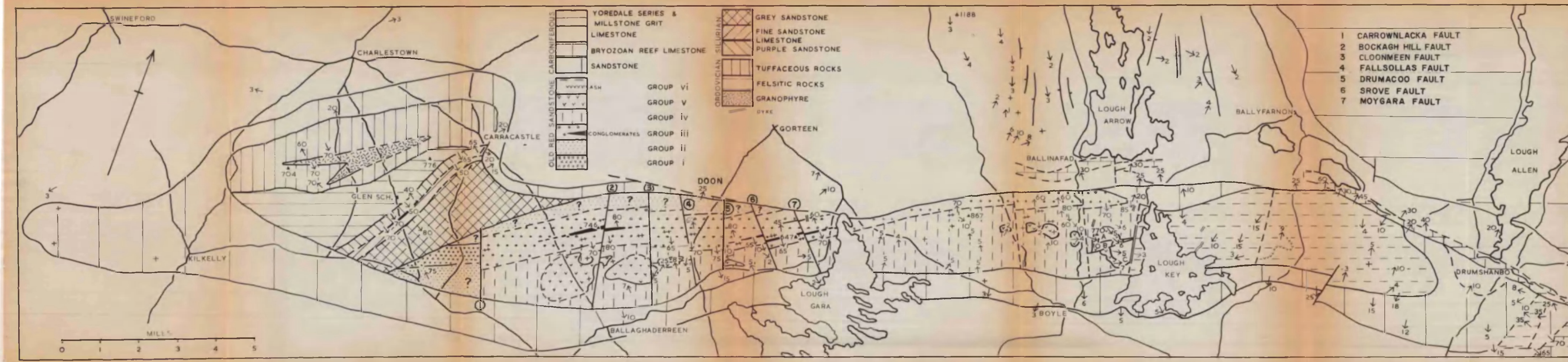


(d)



(b)

(c)


SWINEFORD
CHARLESTOWN
CARRACASTLE
GLEN SCH.
KILKELLY
BALLAGHADERREEN
GORTEEN
DOON
LOUGH GARA
BOYLE
BALLINAFAD
LOUGH ARROW
LOUGH KEY
BALLYFARNON
LOUGH ALLEN
DRUMSHANBO
MILES
0 1 2 3 4 5
CARBONIFEROUS
YOREDALE SERIES & MILLSTONE GRIT
LIMESTONE
BRYOZOAN REEF LIMESTONE
SANDSTONE
OLD RED SANDSTONE
ASH
GROUP vi
GROUP v
GROUP iv
CONGLOMERATES
GROUP iii
GROUP ii
GROUP i
SILURIAN
GREY SANDSTONE
FINE SANDSTONE
LIMESTONE
PURPLE SANDSTONE
ORDOVICIAN
TUFFACEOUS ROCKS
FELSITIC ROCKS
GRANOPHYRE
DYKE
1 CARROWNLACKA FAULT
2 BOCKAGH HILL FAULT
3 CLOONMEEN FAULT
4 FALLSOLLAS FAULT
5 DRUMACOO FAULT
6 SROVE FAULT
7 MOYGARA FAULT