THE GEOLOGY

OF

THE CASTLEBAR SYNCLINE,

CO. MAYO.

BY

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Geological Map of the Castlebar Syncline, Co. Mayo. Scale: 1 inch to 1 mile; and Sections across the Castlebar Syncline.....Inside back cover

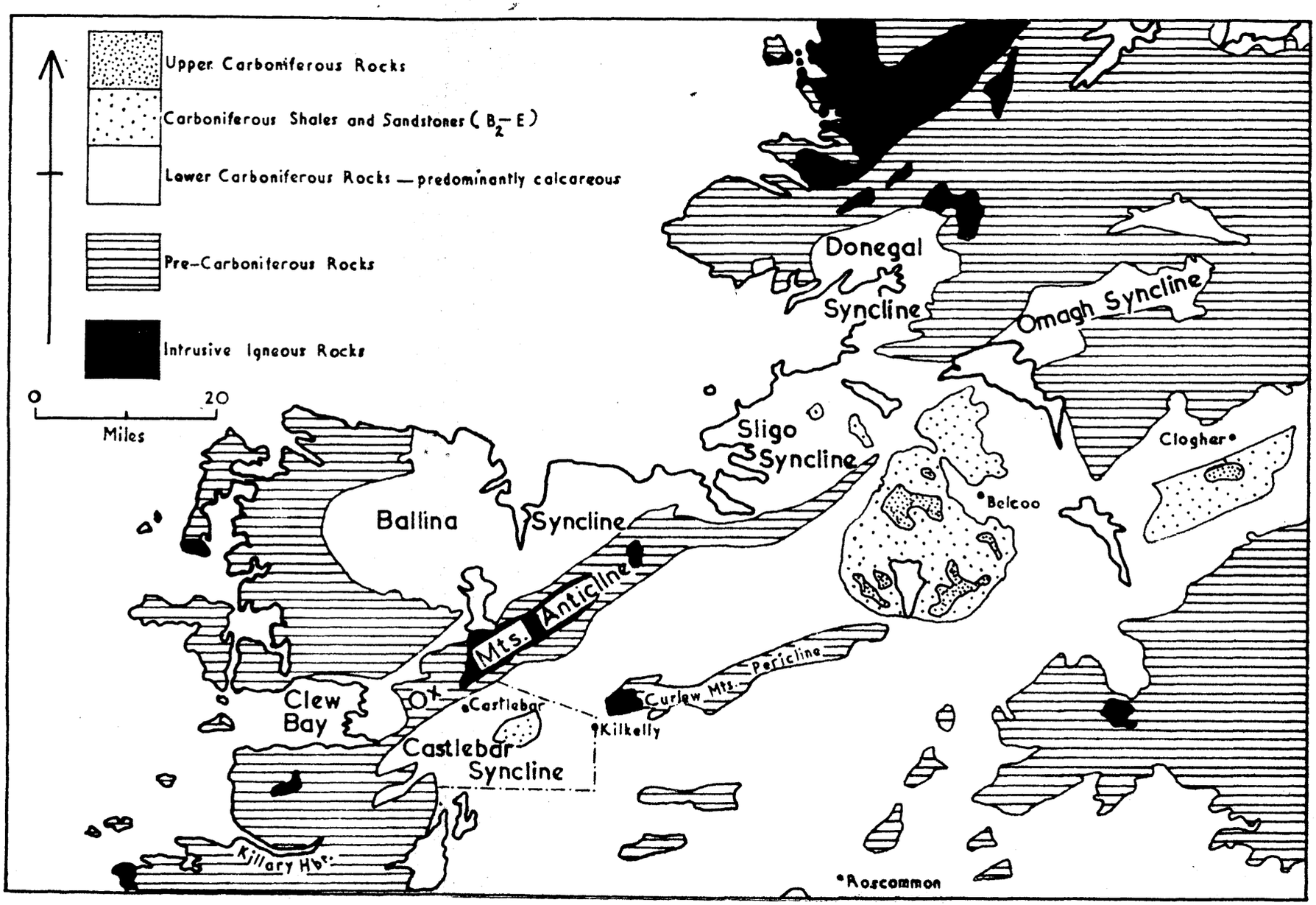

Figure 1. Outline map of the Geology of part of North-West Ireland

I. INTRODUCTION

The Castlebar syncline of Carboniferous rocks lies in the southern half of County Mayo, Eire, and forms a variably pitching downfold between the Ox Mountains anticline, and an echeloned extension of the Curlew Mountains pericline. The area mapped includes the Carboniferous rocks of the upper valleys of the Aille and Derrycraff rivers west of the Partry Mountains (Fig. 1. opposite).

The area, which is approximately 200 square miles in extent, is on Irish Ordnance Survey One-inch Sheets 74, 75, 76, 84, 85 and 86; and Six-inch Sheets Mayo 69-72, 77-81, 88-92, 98, 99 and 108.

Castlebar, the county town, is on the syncline near its northern edge.

The Carboniferous rocks lie everywhere with unconformity on a basement which is composed of the metamorphic rocks of the Ox Mountains and Partry Mountains, and the Devonian red sandstones and conglomerates of the western part of the Ox Mountains.

Two series of Carboniferous rocks are present:

1. A lower series, which, with the exception of a thin sandstone at the base, consists almost wholly of limestones, and reaches a thickness of approximately 2,000 feet. The limestones are all fossiliferous, and it seems probable from comparison with other areas that the whole thickness of the lower series, including the basal sandstone, was laid down in Visean times.
2. An upper series, which lies with an abrupt disconformable junction on the highest beds of the lower series in the east-central part of the area, and consists of sandstones and shales

/of Upper

of Upper Bollandian and Lower Namurian age. The total remaining thickness ranges from approximately 800 feet in the west of the outcrop (where the succession, with the exception of 100 feet of shales and mudstone at the base, is wholly of grits and sandstones), to approximately 1,100 feet in the east, where the total thickness is made up of shales, mudstones and rare siltstones.

No beds younger in age than Carboniferous are present on the area. The folding and faulting of the area are of Hercynian age. Over most of the area both folding and faulting show a general Caledonoid trend, parallel to the direction of the Ox Mountain and Curlew Mountain axes, probably reflecting structures in the underlying Pre-Carboniferous basement rocks. In the country south-east of Ballyhean, south of the Ballyhean-Bohola fault-line, the folding swings round from a NE.-SW. to a N.-S. direction, parallel to the axis of the Partry Mountains. East of the Partry Mountains a N.-S. fault throws down the Carboniferous rocks on its eastern side.

The topography of the country underlain by the basal sandstone and the limestones is gently undulating and low-lying, in contrast to the higher ground and more marked relief of the surrounding older rocks of the Ox and Partry Mountains. By far the greater part of the area where rocks of the lower series crop out lies between 100 feet and 300 feet above sea-level, and there are considerable tracts of ground above the 300 foot contour only south of Aghagower and in the valleys of the Upper Aille and Derrycraff Rivers; between Drunganagh and Bohola, immediately north of the Manulla fault; and in the region of Knock and Kilkelly - perhaps due to an exceptionally thick cover of glacial drift.

/By contrast,

By contrast, most of the area underlain by Upper Bollandian and Lower Namurian strata is over 300 feet above sea-level. In the east the shales form a north-south ridge which rises to a height of over 800 feet, the sandstones of the west make up a less elevated hill rising to over 600 feet. Relative to the rest of the area, the part underlain by rocks of the upper series is one of marked relief with steep scarps and deep gullies where the streams have cut into the soft shale beds - erosional features which form a marked contrast to the gentle slopes and wide, flat valleys of the lower, mainly limestone, country.

The area as a whole is drained by four major river systems.

1. The greater part of the area forms part of the catchment area of the River Moy. With the exception of the small, swift streams which descend from the high-ground area of the Bollandian and Namurian rocks, it is a region of characteristically slow and meandering rivers. Areas of still water are very numerous.
2. The extreme south-western tip of the area, is drained by the Derrycraff River, a tributary of the Erriff.
3. The Corveagh-Aghagower region is drained by the Carrowbeg River.
4. Much of the south-western part of the area forms part of the Lough Carra-Lough Mask drainage area. The Aille River flows underground for two and a half miles of its course south of Aille, and there is much obvious underground drainage in the region of Ballyhean.

Glaciation has left a thick cover of drift over most of the area, occasionally completely obscuring the exact nature of the underlying rock. Much of the drift is boulder clay, containing

/well-rounded

well-rounded fragments of the local rocks, but in the region south-west of Aghagower there are large areas where the drift consists mainly of fine sand. Drumlins are a common feature of the landscape.

In the extreme east of the area, an esker ridge some thirty feet in height, runs for two miles almost due south from Kilkelly.

Much of both high and low ground of the area as a whole is covered by extensive peat bogs.

II. HISTORY OF RESEACH

The first geological survey of this area was carried out by Richard Griffith whose "Geological Map of Ireland" was published in 1838.

In this area no differentiation was made between the Carboniferous sandstones lying beneath the "Carboniferous or Mountain Limestone" and the sandstones and shales, also of Carboniferous age, lying on the limestone, both being classed as "Yellow Sandstone and Conglomerate". The basal Carboniferous sandstone is depicted as a discontinuous deposit, overstepped by the succeeding limestone. The lower two-thirds of the sandstones of the south-west of the area are classed as "Old Red Sandstone and Sandstone Conglomerate", and the Carboniferous sandstones and limestones of Sraheen and Derrycraff become outliers of the main syncline.

The "Carboniferous or Mountain Limestone", ("including the Lower Limestone, Calp or black Shale and the Upper Limestone"), is shown as continuous with the limestones of the Clew Bay area, the two being connected by a mile-wide outcrop across the axis of the Ox Mountains 3 miles east of Westport.

Griffith purposely omitted minor intrusions from his map, and no igneous rocks are shown in this area.

A NE.-SW. fault south of Derrycraff, some 5 miles in length, may be inferred from the map.

On J. B. Jukes's "Geological Map of Ireland" of 1867, the basal Carboniferous sandstone of this area, except in the region of Kilkelly, is referred to the Old Red Sandstone series. The limestones are correctly termed "Carboniferous limestone", but the Bollandian-Namurian strata are classified as "Coal measures".

/The Castlebar

The Castlebar and Derrycoosh sills are marked.

The area was mapped by the Geological Survey of Ireland between the years 1860 and 1870 when the following succession of strata was established:

Coal Measures	1,000 feet
Cherty (Manulla) Limestones	200 feet
Main Limestone	1,200-1,400 feet
Calp	
Carboniferous Basal Limestone	100 feet
Carboniferous Basal Sandstone	150 feet

A fault, downthrown on the north-western side was postulated along the line Derrinkee-Killavally-Ballyhean, running further to the north-east. The Survey, however, were of the opinion that no fault was necessary south of the "Coal Measures". They assumed a ridge of sandstone drift at Ballinamore, south-west of the "Coal Measures", to be "Carboniferous Basal Sandstone" in situ; and that the average dip between this point and the edge of the "Coal Measures" to be 40 to 45 degrees in a north-westerly direction. This allowed the whole 1,700 feet of their succession to be accommodated between Ballinamore and the edge of the "Coal Measures". No other faults appear on the Survey map. The "Coal Measures" extend too far to the north-west, (where the junction with the limestone was thought to be a conformable one).

The area appears on the map which forms part of Kinahan's "Manual of the Geology of Ireland", published in 1878.

Hull's "Physical Geology and Geography of Ireland", also published in 1878, contains a small scale map which ignores both basal sandstone and "Coal Measures". Hull divides the Carboniferous Limestones into

/Upper

Upper Limestones

Calp

Lower Limestones

a scheme which however admirable elsewhere, cannot be extended into the area under discussion.

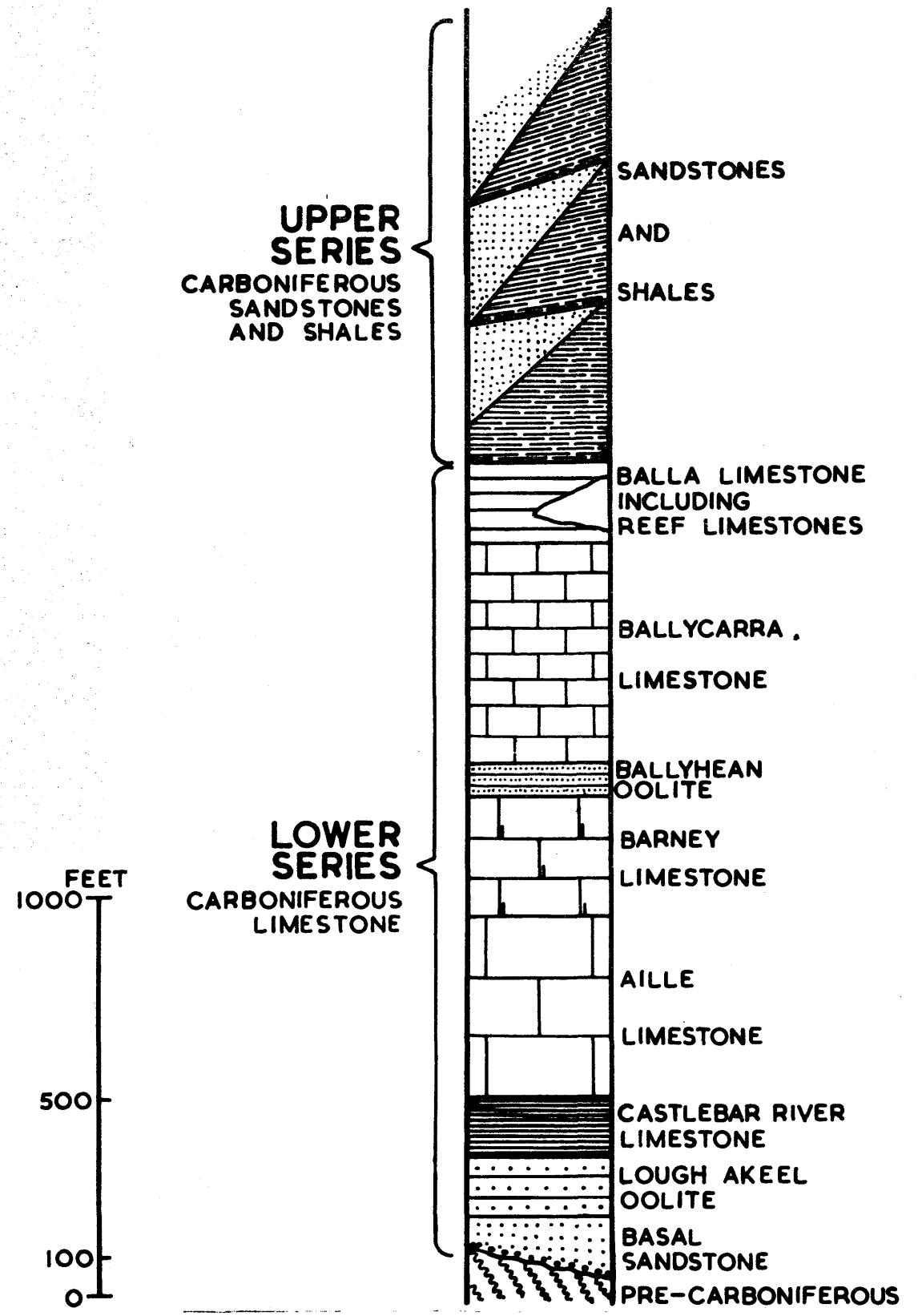

Figure 2. Vertical Section of the Carboniferous rocks of the Castlebar Syncline

III. THE LOWER SERIES - CARBONIFEROUS LIMESTONE

(a) GENERAL SUCCESSION

The conformable sequence of about 2,000 feet of predominantly calcareous, Visean strata which make up the Lower Series, is divisible on lithological and faunal grounds into a series of well-defined groups (Fig. 2. opposite).

The lowest beds, which rest unconformably on the metamorphic and Old Red Sandstone rocks of the basement, consist of a few feet of quartz conglomerate overlain by a varying thickness of sandstones. The sandstones pass upwards into sandy oolites which have quartz-pebble beds at their base in the north-east of the area. The Castlebar River Limestone is a shaly fine-grained deposit of calcite-mudstones with "mud-pellets" and fine-grained organic-fragmental limestones. Following on the Castlebar River Limestone lies about 1,400 feet of massive well-bedded, richly fossiliferous, crinoidal limestones, broken only by the relatively minor intercalations of the Ballyhean Oolite (about 80 feet thick) and about 30 feet of shaly, black, mud-pellet limestones about 50 feet above the base of the Ballycarra Limestone. The Balla Limestone is a shallow-water deposit of calcite-mudstones, "mud-pellet" limestones, fine-grained organic-fragmental limestones, shales and oolites, and includes a development of reef limestone.

The lowermost, non-calcareous, mudstones and shales of the Upper Series lie with an abrupt junction, and evident disconformity, on the Balla Limestone.

(b) BASAL SANDSTONE

The Basal Sandstone, which varies in thickness from about 80 to 150 feet, is everywhere unconformable on the underlying rocks. At no locality is the actual base of the Carboniferous seen. The mapped junction between the sandstone and the basement rocks is everywhere an obvious unconformity, except where it is faulted south of Corveagh and on the southern side of the valleys of the Derrycraff and Upper Aille Rivers. The sandstone is readily subject to erosion, due in part perhaps to possible decalcification, and its outcrop is marked by areas of low marshy ground, often recognised by strike streams and glacial lakes.

Almost everywhere the sandstone has at its base beds of quartz conglomerate of an estimated thickness of up to 15 feet. This conglomerate consists of partly rounded pebbles of pink and white quartz, up to 4 inches in diameter, set in an ill-sorted sandy matrix of sub-angular grains of quartz and felspars. Felspars mainly microcline, are present in minor amounts only. A small exposure of this conglomerate occurs 300 yards north-west of Tucker's Lough, 1½ miles north of Castlebar, and a bed of similar conglomerate 3 feet in thickness (underlying 2 feet of sandstone) is seen by the side of the road 1 mile south-south-east of Killavally.

Elsewhere the conglomerate occurs in the glacial drift overlying the lower beds of the Basal Sandstone. Especially notable examples are several boulders each 8 to 10 feet in diameter at Cloghan Bridge, 2 miles west-south-west of Aghagower. Pebbles of quartz up to 1½ inches in diameter, occurring both isolated and in lenses up to 8 feet long by a foot in thickness, are a

/common

common feature of the lowermost 20 to 30 feet of sandstones overlying the conglomerate.

The sandstone itself, on the northern, western and south-western sides of the syncline, is a well-bedded and jointed rock, having a general lateral and vertical uniformity. The beds range from a foot to four feet in thickness. There are no shale bands or shale partings. No graded-bedding, current-bedding, or slumped-bedding features were observed. The bedding surfaces are gently undulose, but reveal no trace of ripple-marks. Fresh specimens of the sandstone vary in colour from a pale cream to a pinkish-mauve, but at some localities in the south-west of the area the rock is of a richer, reddish hue. Weathering produces a brown or black outer layer on all varieties.

The sandstone is a fine-grained and, except for the rock at one exposure north of Turlough, an ill-sorted sediment. The grains in those beds without quartz pebbles rarely reach 1 mm. in size. Thin sections reveal the rock to be made up of sub-angular grains of quartz and felspars, with minor amounts of mica and ore minerals. Quartz makes up at least 90% of the rock in all sections studied. Sandstones from the valleys of the Upper Aille and Derrycraff Rivers contain fragments of the underlying slaty schists. The majority of the quartz grains are cracked and exhibit undulose extinction. The felspar content is made up of orthoclase, microperthite, microcline and sodic plagioclase. In most sections the microcline is little altered, but the other felspars sometimes show kaolinisation and sericitisation. Muscovite and weakly-pleochroic, chloritised, biotite are present in all sections. Iron ore in the form of small crystals of magnetite is common. The red colouration of some specimens is seen to be due to the presence of haematite.

/The interstitial

The interstitial cement varies between clay minerals, resulting from the breakdown of the felspars, and limonite, often both cements are present in one thin section. The micas tend to wrap round the grains of quartz and felspar, and the quartz grains sometimes carry a partial coating of iron oxide. The uppermost 10 to 20 feet of the sandstones contain a small quantity of crystalline calcite as cementing material.

Six feet of a finer grained sandstone interbedded in sandstones of the type described above are exposed in the mill lade a little north of the dolerite sill, 2 miles north of Turlough. This is a well-sorted rock, the average grain-size is 0.1 mm., individual grains rarely reaching 0.2 mm. in size. Thin sections reveal that the rock is made up largely of angular grains of quartz set in a matrix of clay minerals with scattered flakes of muscovite mica. Very rare angular grains of unaltered microcline are the only felspars present.

The sandstones of the western tip of the Curlew Mountains west of Kilkelly are fine-grained, well-bedded sandstones of a pale colour, but exhibiting a marked iron-staining when weathered. The rock is ill-sorted, and the grains range in size up to 1 mm. Rocks from the outcrop 3 miles west of Kilkelly closely resemble those of the outcrops along the northern and western perimeters of the syncline, but the exposure 1 mile west of Kilkelly is of flaggy micaceous sandstones. Here the rock has thin bands rich in mica every few inches throughout its exposed thickness of 5 feet. Due to parting on these mica-rich beds the rock weathers into flags a few inches in thickness and a few square feet in area. Apart from these mica-rich layers thin sections reveal the rock to be petrographically very like that of the outcrops on the northern and western sides of the syncline.

/Muscovite

Muscovite is the principal mica present in the mica-rich bands, with smaller amounts of weakly-pleochroic chloritised biotite.

North and north-east of Castlebar the gradual passage of the Basal Sandstone into the lowest pebble beds of the overlying Lough Akeel Oolite is well exposed, the exposures at Sion Hill 1 mile north of Castlebar being typical. Here fine-grained Basal sandstones pass upwards into the pebbly limestones with a gradual upward increase in grain-size. The sandstones are partially cemented with crystalline calcite and weather easily to a friable condition. They contain specimens of bellerophontids up to 3 inches in diameter together with a sparse fauna of foraminifera. Solution of the bellerophontid shells and subsequent recrystallization of calcite in the moulds render a closer identification impossible. These were the only fossils found in the Basal Sandstone.

In view of the presence of these fossils in the upper beds of the Basal Sandstone, the absence throughout its thickness of any features suggesting a terrestrial or deltaic environment, and the undoubted marine origin of the rest of the Carboniferous Limestone succession, a marine origin is ascribed to the Basal Sandstone.

The transgression of the Carboniferous sea into the area appears to have been rapid, though the partly rounded nature of the pebbles of the basal conglomerate suggest coastal reworking of the sediments. The pebble beds in the sandstone are indications of a shallow-water origin and the nature of the succeeding shallow-water pebbly oolitic limestones appears to confirm that the Basal Sandstone was laid down also in fairly shallow-water, probably under conditions of relatively slow and uniform deposition.

(c) LOUGH AKEEL OOLITE

The 150 foot thick Lough Akeel Oolite, the lowest group of the limestone series, exhibits some variation in rock-type both laterally and vertically. The most frequent rock-type of the main outcrop is a fine-grained oolitic limestone, usually pale blue in colour and containing, on average, approximately 5% of non-calcareous sandy material. The latter consists of small sub-angular grains, most of which are quartz and the rest mainly alkaline felspars.

The limestone is well-bedded and massive, the beds varying from 3 to 8 feet in thickness and lacking shale partings. Current-bedding is characteristic and strikingly demonstrated by the quartz particles on vertical or steeply-inclined faces, which are left standing proud of the general surface wherever the rock is weathered.

North and north-east of Castlebar the lower half of the group contains beds up to 2 or 3 feet in thickness of quartz grit and quartz pebbles set in calcareous cement. Two such developments are seen in the quarry at Lough Akeel 2½ miles north-east of Castlebar, which is the finest exposure in limestones of this horizon. Here a succession of about 60 feet of typical oolitic, sandy, current-bedded limestones, is exposed on the eastern, (north-south), face of the quarry.

The succession is:-

	ft.	ins.
8. Pebble bed composed of angular white quartz pebbles up to 1½ inches across in a calcareous, gritty matrix.....	1	8
7. Sandy, pale blue oolitic limestones.....	28	0

/6. Pebble

	ft.	ins.
6. Pebble bed composed of spheroidal pebbles of white quartz ¼ to ½ inch in diameter in a matrix of sandy oolite.....	2	2
5. Sandy, pale blue oolitic limestone.....	17	0
4. Pebble bed composed of angular pebbles of white quartz up to 1½ inches across in a calcareous, gritty matrix.....		8
3. Sandy, pale blue oolitic limestone.....	3	0
2. Sandy, blue oolitic limestone with numerous crinoid ossicles, rare small zaphrentoids and rare athyrids.....		3
1. Sandy, pale blue oolitic limestone.....	7	0

The pebble beds of the group become coarser and thicker north-eastwards, suggesting that the source of the pebbles lay north and east of this area. In the Strade region the pebble beds become quartz conglomerates with pebbles up to 2½ inches in diameter set in a calcareous cement. The pebble beds may have had their origin in the anticlinal form on the Ox Mountains axis north-east of this area during early Visean times, which resulted in a thinning of the lower groups of the limestone succession at the eastern end of the Sligo syncline (Oswald 1955).

The oolitic nature of the rock is not very obvious in most hand-specimens, for the rock is indurated, is fractured across the ooliths (which are identical in colour with the matrix), and no ooliths are loosened by fracture. (Thin sections sometimes show deformed ooliths with axial ratios of 3 or 4, to 1). Nor is the fact that the rock is oolitic usually emphasised in any way by weathering.

/Thin

Thin sections reveal that though the ooliths in a particular specimens are usually well-sorted, yet the average size varies quite widely from specimen to specimen between 0.1 mm. and 0.5 mm. There appears to be no regular lateral or vertical gradation in the size of the ooliths.

In the majority of specimens the ooliths average 0.2 mm. to 0.3 mm. in diameter and are composed of concentric shells of calcite, each shell exhibiting a radial structure of calcite needles. Radially arranged patches of "algal dust" (Wood 1941) are seen in some ooliths. The nuclei of the ooliths, where observable, consists either of rounded and corroded grains of quartz, often showing undulose extinction; a similarly rounded and corroded grain of orthoclase, microcline or sodic plagioclase felspar; or occasionally a foraminiferal test. The cores of the ooliths are often completely recrystallized into a single crystal of calcite, and some ooliths have no recognisable nucleus. In many specimens the ooliths exhibit deformation with axial ratios of up to 4 to 1. Thin sections of specimens from the exposures immediately north-west of Castlebar often reveal two sizes of oolith to be present intermixed throughout the thin section: a small type, completely recrystallized, of an average diameter a little under 0.1 mm.; and a larger less numerous variety, having a diameter of approximately 0.25 mm. exhibiting a structure of concentric shells of radially disposed calcite needles.

The ooliths are accompanied throughout by rounded and often highly corroded grains of quartz and felspar. The grain size of these sandy materials is closely comparable in each case with the diameter of the accompanying ooliths. The quartzes are often cracked and corroded, and exhibit undulose extinction.

/Orthoclase,

Orthoclase, microperthite, microcline, and sodic plagioclase felspars are present, all equally corroded, and showing replacement with calcite. Ooliths and sandy materials are set in a matrix of clear crystalline calcite. In addition to the band in the Lough Akeel quarries, some specimens from Islandeady 5 miles west of Castlebar, contain a small percentage of crinoid and shell debris. These organic fragments lack oolithic filming.

Thin sections of the matrix of the pebble-beds reveal ill-sorted, rounded and corroded grains of quartz and felspars, together with ooliths up to 0.5 mm. in diameter, cemented with clear calcite.

Thin sections of the limestones of this group exposed south of Strade at the eastern end of the main outcrop, reveal alternating bands 4 mm. to 5 mm. in thickness of fine-grained oolitic limestone and finely-crystalline, "dusty", porcellanous limestone. The ooliths are usually highly deformed (with the long axes lying parallel to the bedding), and always completely recrystallized, no trace of original structure or nucleus being recognisable. The few undeformed ooliths average 0.25 mm. in diameter. The ooliths are accompanied by grains of quartz and felspar up to 0.3 mm. in diameter. The matrix is cryptocrystalline calcite. The bands of finely-crystalline limestone contain rare tiny angular fragments of quartz.

Thin sections of rocks from the two most westerly exposures of the main outcrop of this group, at Dooncastle 2¾ miles east of Westport, and on the railway at Meneen 2½ miles east-south-east of Westport, show secondary dolomitization of both ooliths and matrix. Rocks from both exposures contain a small percentage of quartz and sodic plagioclase felspar in the form of small

/subangular

subangular and apparently uncorroded grains averaging 0.05 mm. in diameter. The Dooncastle rock contains recrystallised and dolomitized "ghost" ooliths averaging 0.1 mm. in diameter, mostly showing slight deformation with axial ratios of 1.5 to 1. The Meneen rock is further dolomitized but the outlines of the original ooliths, averaging 0.1 mm. in diameter, are still discernible.

Fine-grained, massive, well-bedded, blue, rusty weathering limestones, presumed to be of this horizon from the fact that they lie immediately, and conformably, over the Basal Sandstone, and are of no great thickness, are exposed near Sraheen and Derrycraff in the valleys of the Upper Aille River and the Derrycraff River. Thin sections of specimens reveal a fine-grained mosaic of dolomite crystals, no trace of original structure remaining. Towards the base these dolomites contain a small percentage of quartz and alkaline felspars, occurring as small rounded grains averaging 0.1 mm. to 0.2 mm. in size. The quartz exhibits undulose extinction. Rare flakes of muscovite are present in one section. Higher in the sequence an occasional foraminiferal test, seemingly unaltered, is the only feature to break the uniformity of the dolomite mosaic. Some specimens contain appreciable quantities of limonite and haematite, usually as interstitial material between the dolomite crystals, though haematite (together with calcite) occurs in very narrow veins traversing the limestone at the exposures west of Derrycraff.

Chert is present at two exposures within 50 feet of the base of the limestone. At Sion Hill, 1 mile north of Castlebar, the development is of small, inconspicuous nodules of pale blue chert embedded in the limestone. A similar type of chert occurs in the quarry $\frac{1}{2}$ mile north of Raheens House, $2\frac{3}{4}$ miles west of

/Castlebar;

Castlebar; but in a much richer development. Chert occurs in the lower 8 feet of 10 feet exposed in the form of "rafts" up to 8 feet in length and 9 inches in thickness, making up as much as 30% of the total measured thickness of the rock.

Crinoid ossicles were seen in the rocks of this group at Rockfield 3½ miles north-east of Castlebar, at the Lough Akeel quarry, at Islandeady 5 miles west of Castlebar, and at the exposure a few yards north of the farm at Derrycraff. Fossils are few in these limestones, both in kinds and numbers. The following are recorded:

Fauna.

Syringopora reticulata Goldfuss

Small Zaphrentoids

Actinoconchus sp.

Athyrids (small)

Papillonaceous chonetids

Rhipidomella cf. michelini (L'Eveille)

Spiriferid

Schizophoria cf. resupinata (Martin)

Tylothyris laminosa (M'Coy)

Bellerophontids

Small, low-turreted, unidentified gastropods

(d) CASTLEBAR RIVER LIMESTONE

The rocks of this group, which is about 160 feet thick, form a marked contrast to those below, the non-calcareous terrigenous material being of mud, rather than sand, grade. The passage from the Lough Akeel Oolite is nowhere exposed. This is a relatively easily eroded group and its outcrop is marked by areas of low ground, by strike streams (of which the Castlebar River is the most notable example), and by a number of glacial lakes. Exposures of limestones of this group are frequent on the banks of the Castlebar River between Castlebar and Turlough.

The most frequent type of limestone is a very fine-grained, well-bedded, blue-black or black argillaceous limestone, usually massive but occasionally thinly-bedded. The beds range from 6 inches to 3 feet in thickness, usually, though not invariably, with intervening beds of calcareous shales up to 5 inches in thickness. At many exposures, ranging from the base to the top of the group, this is the only type of limestone present, but at several exposures on the Castlebar River, at the exposure on the railway 6½ miles south-west of Castlebar, and in the quarry ½ mile north-east of Killavally fine-grained dark blue limestones with finely comminuted crinoid debris occur together with the finer grained darker limestone. All the exposures showing two types of limestones are of beds in the uppermost 100 feet of the group.

At the exposures along the north crop of the group the two types of limestone alternate, usually with intervening shale beds or partings. The exposure on the Castlebar River at Ballynew 1½ miles north-east of Castlebar is typical:-

/5. Very

	ft.	ins.
5. Very fine-grained black limestone.....	1	8
Shale parting		
4. Fine-grained dark blue limestone with crinoid debris.....		6
3. Black calcareous shale.....		4
2. Very fine-grained black limestone.....	1	2
Shale parting		
1. Fine-grained dark blue limestone with crinoid debris.....	1	8

At the quarry north-west of Killavally the lower 9 feet of 24 feet of limestone exposed are very fine-grained, blue-black, muddy limestones, and the uppermost 15 feet fine-grained dark blue limestone with finely comminuted crinoid debris. Here there is no alternation of the two types. Both occur in beds from 6 inches to 2 feet in thickness with intervening shale bands.

Wherever exposed there is no sharp junction between a shale bed and the underlying and overlying limestones, but always a gentle gradation from limestone to shale and shale to limestone.

Thin sections of the very fine-grained, muddy, black limestone reveal a very fine-grained and well-sorted fragmental limestone composed of tiny fragments of cloudy recrystallized calcite, together with foraminiferal and ostracod tests, and occasionally dark, ovoid, calcareous "mud-pellets" set in a matrix of recrystallized cloudy calcite. Tiny flakes of mica and clay minerals were observed in many sections, in others the clay content is reflected only in the general "cloudiness" and lack of perfect translucency of the section. Very fine-grained carbonaceous matter and tiny crystals of iron ore are also frequent. Some

/sections

sections contain very rare tiny angular fragments of quartz. Some sections of these fine-grained dark limestones reveal a recrystallized rock often almost wholly composed of finely-crystalline calcite, little trace of the original structure remaining.

Thin sections of the fine-grained crinoidal limestones show an ill-sorted rock composed largely of comminuted organic detritus, including crinoid fragments up to 2 mm. in size, shell fragments, brachiopod spines, foraminiferal tests, and bryozoa, together with rare corroded quartz grains, set in a matrix of crystalline calcite. The crinoidal limestones from the Killavally quarry contain a small proportion of undeformed ooliths, approximately 0.5 mm. in diameter, composed of concentric shells of calcite, each shell exhibiting a radial structure of calcite needles. No nuclei were observed, the core of the ooliths in every case being recrystallized and occupied by a single crystal of calcite. This oolitic nature is a possible result of a shallower-water environment in the Killavally area than elsewhere where limestones of this group are exposed.

The only chert seen in these limestones occurs at the exposure in the Castlebar River north of Windsor House 3 miles downstream of Castlebar. Lenses of black chert from $\frac{3}{4}$ inch to $1\frac{1}{2}$ inches in thickness and ranging from a few feet in length occupy some of the bedding planes between the limestones. They make up no more than 2% or 3% of the measured thickness.

Apart from the crinoid debris, macrofossils in the limestones and shales of this group are both sparse and scattered and they were found at a few localities only. Recognisable macrofossils are most common in the very fine-grained black limestone, occurring in their greatest numbers immediately beneath a shale bed or

/parting.

parting. The only fossils found in the shales were rare ostracods.

Fauna.

Syringopora geniculata Phillips

Camarotoechia sp.

Dictyoclostus sp.

Small unidentified lamellibranchs

Gastropod fragments

Ostracods

(e) AILLE LIMESTONE

With the exception of the comparatively minor intercalation of the Ballyhean Oolite, crinoidal limestones, of which the Aille Limestone is the lowest group, occupy the next 1,400 feet - by far the greater part - of the limestone succession. The topography of the country underlain by these crinoidal limestones is one of gently-rolling low-lying plain (on which the many drumlins form the highest points), with numerous glacial lakes, and characteristically slow-flowing rivers. There is much underground drainage between Ballyhean and Aille.

The Aille Limestone, which reaches a thickness of approximately 450 feet, consists for the most part of fine-grained, dark-blue, crinoidal limestones. From 50 feet above the base, to the top of the group, coarse beds of crinoid debris occur, as developments from a few inches to two feet in thickness, interbedded in the limestones of the normal finer grain-size. The limestones are well-bedded and massive, the beds ranging up to 6 feet in thickness, with intervening deposits of calcareous shales, often as mere partings but occasionally as bands up to 6 inches in thickness. Little lateral variation was observed, but there is an overall increase in grain-size from the base to the top of the group, and in the higher beds the limestone becomes of a paler colour grading into the generally blue-grey limestones of the overlying Barney Limestone.

The actual base of the Aille Limestone is seen in the small quarry at Mount Gordon 1 mile south-west of Castlebar, where 2 feet of fine-grained dark blue crinoidal limestone rest on 6 feet of black muddy limestones and black shales of the Castlebar River Limestone. The crinoidal limestones contain spreading colonies

/of Thysanophyllum

of Thysanophyllum pseudovermiculare (M'Coy), in position of growth, up to 1½ feet in diameter and a foot in height. Between the spreading corallites the limestone is a very fine-grained black type, greatly resembling the limestone of the underlying beds of the Castlebar River Limestone, and appears to represent an original mud trapped by the branches of the coral which presumably prevented its being swept away. This very fine-grained black limestone, which stands out in marked contrast to the surrounding crinoidal limestone, contains a rich fauna of athyrid and spiriferid brachiopods. Apart from the crinoid debris, recognisable macrofossils are absent from the surrounding crinoidal limestone. Thin sections of the crinoidal limestones reveal an ill-sorted rock composed of crinoid and shell debris averaging under 0.5 mm. in diameter, together with ooliths, foraminifera, and a small percentage of rounded and corroded grains of quartz up to 0.4 mm. in diameter. The ooliths, which are not obvious in hand-specimen, make up about a quarter to one third of the rock. They average 0.3 mm. to 0.4 mm. in size and show no deformation. Their structure is one of concentric shells composed of radially arranged calcite needles. The nucleus, where observable, is a tiny grain of quartz or a foraminiferal test. Often no nucleus is seen, the core of the oolith being recrystallized and occupied by a single crystal of calcite.

This oolitic limestone at the base of the group may be only locally developed. It is not possible to trace it laterally as no other exposures exist of the extreme base of the group. Even if laterally constant it can only be a thin development as 10 feet of limestones exposed in a small quarry half a mile west-south-west of Mount Gordon are only about 20 feet higher in the succession, and these are well-bedded, massive, fine-grained,

/dark-blue

dark-blue crinoidal limestones (with infrequent shale partings), completely lacking in ooliths.

The Aille Limestone is well exposed in the Castlebar district, between Castlebar and Bohola, and in the country around Aille and Killavally in the west of the area. Between Castlebar and Aille exposures are few due to the thick cover of glacial drift and peat bogs.

Numerous exposures of limestones from 30 to 150 feet above the base of the group occur east and west of Castlebar on the north-facing scarp overlooking the valley of the Castlebar River, where the rock has been extensively quarried. Typical of these exposures is the quarry at Fortlawn, ½ mile east of Castlebar, where 12 feet of well-bedded, fine-grained, dark blue crinoidal limestones are exposed approximately 100 feet above the base of the group. The limestone beds are from 3 to 4 feet in thickness and are divided by thin shale partings. The fauna includes caniniids, clisiophyllids, Michelinia, large chonetids, echinoconchids, large orthotetids and spiriferids. The highest concentration of recognisable macrofossils occurs on the uppermost bedding plane of each limestone bed immediately underlying the shale parting - into which the larger specimens project. This concentration of fossils on the bedding plane immediately underlying a shale bed or parting is a common feature in all the crinoidal limestones of the area including the Barney and Ballycarra Limestones.

Limestones about 250 feet above the base of the group are well exposed in the quarry 1 mile east-south-east of Ballyvary. Here 16 feet of well-bedded, fine-grained highly fossiliferous dark-blue crinoidal limestones are exposed in eight beds. The lowermost four beds are each about three feet in thickness and

/are divided

are divided by shale partings, but the four upper beds are only about a foot each in thickness and the intervening shales range from an inch to four inches in thickness. A 2 foot bed of very coarse crinoidal limestone occurs 7 feet above the base of the exposed rocks. This coarse band is extremely rich in corals and brachiopods, even more so than the rest of the limestones. Lithostrotiontid and clisiophyllid corals are common throughout, and caniniid and zaphrentoid corals are frequent in the uppermost 4 feet of limestone, being in their highest concentration immediately beneath each shale bed. Echinoconchids, linoproductids, productids, pustulids and spiriferids are common.

Limestones from about 300 to 350 feet above the base of the group contain a greater proportion of earthy and shaly beds than has been observed elsewhere within the group. A good exposure is that on the railway 1½ miles south-east of Castlebar where the following succession is exposed:-

	ft.	ins.
11. Fine-grained, blue-grey crinoidal limestone.....	7	0
10. Heavily weathered shaly blue-black crinoidal limestone.....		4
9. Fine-grained, dark blue crinoidal limestone.....		8
8. Shaly blue-black crinoidal limestone.....		2
7. Fine-grained, dark grey crinoidal limestone.....	2	0
6. Black calcareous shale.....		3
5. Fine-grained, grey crinoidal limestone.....	1	2
4. Earthy, black crinoidal limestone.....		6
3. Fine-grained dark blue crinoidal limestone.....	2	6
2. Earthy, black crinoidal limestone.....		2
1. Fine-grained blue-grey crinoidal limestone.....		6

/The most

The most frequent fossils in these rocks are Echinoconchus elegans (M'Coy) in the earthy and shaly beds together with Lithostrotion cf. martini Ed. and H., and L. cf. phillipsi Ed. and H., in the fine-grained crinoidal limestones. Similar rocks are exposed at Aghadrinagh House 2 miles south-south-west of Castlebar. Here they are overlain by massive grey crinoidal limestones, (with beds of coarse crinoidal debris), containing a rich fauna including fasciculate lithostrotiontids, large caniniids, large pustulids, linoproductids, spiriferids and gastropod fragments.

The deepened bed of the Manulla River at Gneeve 5 miles east of Castlebar affords a section through 50 feet of limestones ranging from about 350 to 400 feet above the base of the group. These are dark blue and grey-blue massively bedded crinoidal limestones in beds up to 6 feet in thickness with thin shale partings and infrequent beds up to a foot in thickness of coarse crinoid debris. The commonest fossils are species of fasciculate lithostrotiontids, caniniids, productids, linoproductids, pustulids and echinoconchids. Similar limestones are revealed in many small exposures in stream-valleys between Gneeve and Bohola.

Exposures of the uppermost 50 feet of the group are seen in the valleys of the streams 2½ to 3 miles south-west of Bohola and in the region south and south-east of Castlebar. In the latter district these are massive blue crinoidal limestones with occasional thin earthy beds, the latter containing small echinoconchids.

The exposures in the streams at Boleyard 2½ to 3 miles south-west of Bohola are of massive, well-bedded, blue crinoidal limestones. The lower beds of the 30 to 40 feet exposed contain

/bands

bands of black earthy and shaly limestone, but these decrease in frequency upwards, and the rock becomes purer, more coarsely crystalline and lighter in colour. Chert in the form of thin bands and small nodules is common. The rich fauna includes several species of fasciculate lithostrotiontids, Aulophyllum, linoproductids, spiriferids, Orthoceras, gastropods, and Dentalium.

The Aille Limestone is well exposed in the district around the village of Aille in the west of the area. A mile north-west of the village in the quarry at Mace, 20 feet of well-bedded, fine-grained, dark blue crinoidal limestones with thin shale partings are exposed. These are approximately 250 feet above the base of the group and contain a rich fauna of fasciculate lithostrotiontids, caniniids, large pustulids, linoproductids, orthotetids and spiriferids. At Aille Caves ¾ mile south-west of Aille, where the Aille River descends into a limestone cavern, 30 feet of well-bedded, massive fine-grained crinoidal limestones similar to those at the Mace quarry and at about the same level in the succession are exposed. The most common fossils are fasciculate lithostrotiontids, large zaphrentoids, linoproductids and large orthotetids.

Many exposures of limestones from 250 to 400 feet above the base of the group occur in the country south-east of Aille village. These are well-bedded, generally massive, crinoidal limestones with a rich fauna of corals and brachiopods - rocks similar in lithology and fauna to the limestones of equivalent horizons on the north crop of the group. At approximately 300 to 350 feet above the base of the group the limestones again contain a higher proportion of shaly and earthy beds than at higher or lower levels in the group. Exposures of limestones

/of this

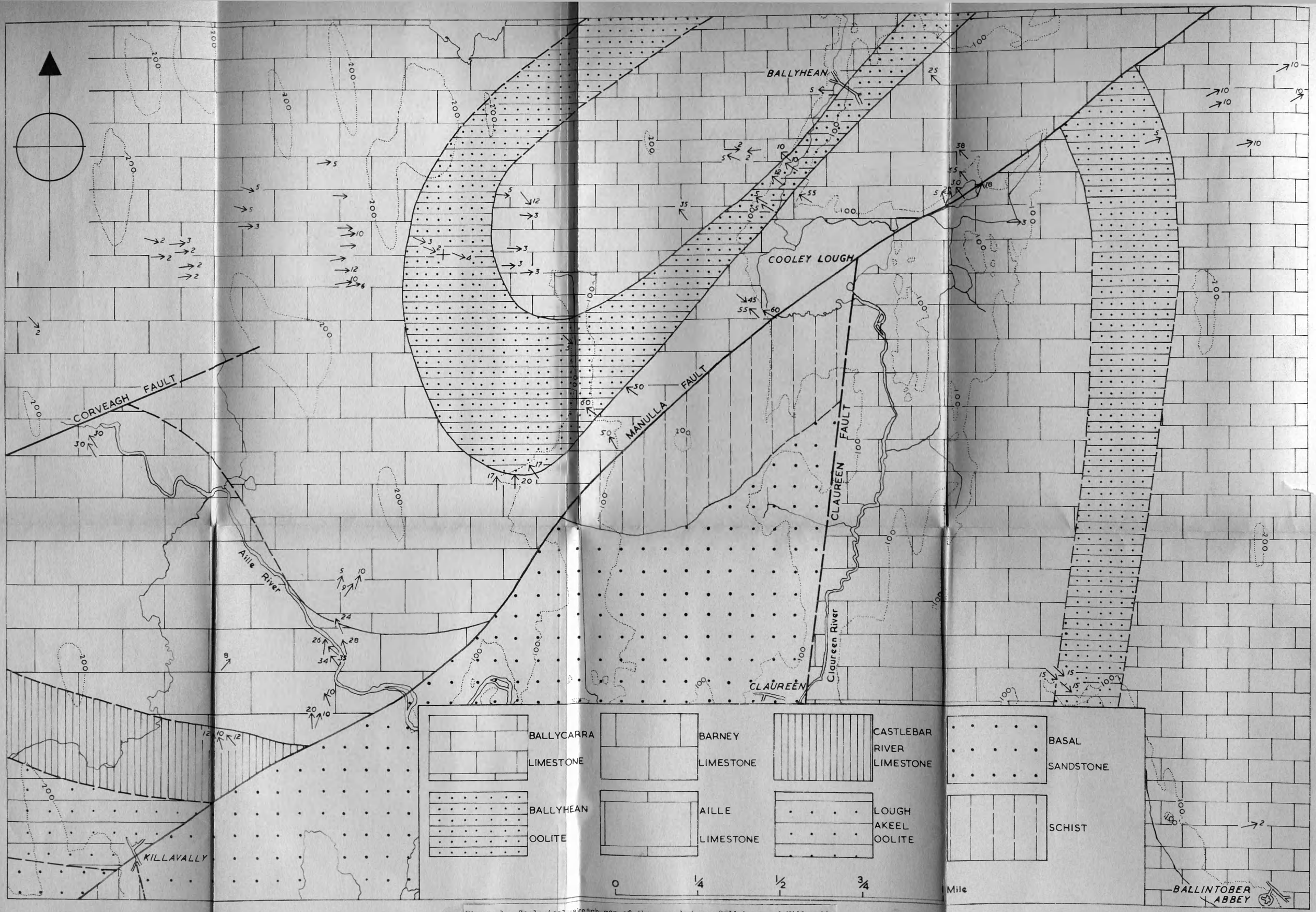

Figure 3. Geological sketch-map of the area between Ballyhean and Killavally

of this type are seen 300 yards south of Aille village, and 300 yards north of Hazelrock Lodge, ¾ mile south-east of Aille. Higher than this the limestones contain a progressively greater proportion of beds of coarse crinoidal debris and become lighter in colour.

A large number of exposures of limestones of this group are seen in the valley of the lower Aille River between ½ and 1 mile north-east of Killavally, where the thickness of the group is reduced to about 300 feet (Fig. 3, opposite). This thinning, together with the higher dips (up to 34°), have resulted in a marked narrowing of the outcrop of the group where it meets the fault. The limestones differ in no way lithologically from those of the group exposed elsewhere, being well-bedded, fine-grained, crinoidal limestones with shale partings and shaly beds - the latter being most prominent approximately 200 feet above the base of the group. The limestones have a rich fauna of corals and brachiopods, including one (undescribed) species of fasciculate lithostrotiontid which has not been found elsewhere in the group.

Examination of numerous thin sections of limestones of this group reveals a general similarity throughout. The limestones are ill-sorted and composed largely of crinoid and shell debris (the former predominating in all sections examined), together with the remains of foraminifera, bryozoa, ostracoda and other organic debris, set in a matrix of calcite. Occasionally the matrix is clear and crystalline, but usually it and the rest of the rock have suffered some recrystallization. Tiny rounded and corroded grains of non-calcareous sandy materials (usually quartz, less often alkaline and plagioclase felspars) are common throughout.

/Limestones

Limestones from Aille Caves contain a small percentage of ooliths, possibly indicating that conditions during the deposition of limestones of this horizon were somewhat shallower in that region than elsewhere on the present outcrop. The ooliths, which are undeformed, have suffered recrystallization, so that only traces of an original concentric structure remain. The cores of the ooliths are completely recrystallized and no original nuclei were observed.

A common feature in thin sections of the coarser limestones of this group is the partial replacement of the calcite of the larger crinoid ossicles by aggregates of microcrystalline quartz.

Surface dolomitization of the limestones due to weathering is common, especially at the exposures south-west of Bohola and in the Aille and Killavally regions.

Chert is comparatively rare in the limestones of this group. It occurs in bands a few inches thick and in small nodules in the exposures at Boleyard 3 miles south-west of Bohola, in a band a few inches thick at Cushinsheeaun 1½ miles north-west of Aille, and in the form of small nodules near Ballyvary. Between Castlebar and Turlough, (at Liscromwell and Monument Park), chert occurs in the form of small lenses and nodules, making up but a small percentage of the rock as a whole. The chert is usually pale-coloured and shows a tendency to weather to a sandy material.

As a whole this is the most richly fossiliferous group of the whole Carboniferous succession of the area. Fasciculate lithostrotiontids, caniniids, large zaphrentoid and carcinophyllid corals are characteristic, as are productid, pustulid, large orthotetid and spiriferid brachiopods. Apart from the crinoid debris the levels containing the greatest numbers of

/recognisable

recognisable macrofossils are those immediately underlying the shales and shale partings between the beds of massive limestone, together with the horizons of comparatively coarse crinoidal material interbedded in the normal limestones of finer grain-size. Elasmobranch teeth were found in Gilmartin's quarry 1⅓ miles south-west of Castlebar, where they occur in a single 2 foot bed of coarse crinoid debris which overlies 5 feet of fine-grained dark blue crinoidal limestones.

Fauna.

Cf. Arachniophyllum simplex Smyth
Aulophyllum sp.
Caninia cylindrica Scouler
Caninia cf. cylindrica Scouler
Caninia cf. benburbensis Lewis
Caninia sp.
Carcinophyllum simplex Garwood
Carcinophyllum cf. simplex Garwood
Carcinophyllum sp.
Clisiophyllum cf. dublinense Smyth
Diphyphyllum cf. fasciculatum (Fleming)
Diphyphyllum lateseptatum (M'Coy)
Diphyphyllum cf. lateseptatum (M'Coy)
Koninckophyllum sp.
Lithostrotion affine (Fleming)
Lithostrotion cf. affine (Fleming)
Lithostrotion cf. caswellense Howell
Lithostrotion irregulare (Phillips)
Lithostrotion cf. irregulare (Phillips)
Lithostrotion martini Edwards and Haime

Lithostrotion cf. martini Edwards and Haime

Lithostrotion phillipsi Edwards and Haime

Lithostrotion proliferum Thomson and Nicholson

Lithostrotion scoticum Hill

Lithostrotion scoticum Hill (Diphymorphic type)

Lithostrotion cf. scoticum Hill

Lithostrotion cf. sociale (Phillips)

Lithostrotion spp.

Michelinia cf. megastoma (Phillips)

Michelinia sp.

Palaeosmilia multilamellata M'Coy

Palaeosmilia sp.

Syringopora distans (Fischer)

Syringopora geniculata Phillips

Syringopora ramulosa Goldfuss

Syringopora reticulata Goldfuss

Syringopora sp.

Thysanophyllum pseudovermiculare (M'Coy)

Amplexizaphrentis enniskilleni Edwards and Haime

Amplexizaphrentis cf. enniskilleni Edwards and Haime

Hapsiphyllum cf. koninckì Edwards and Haime

Actinoconchus sp.

Lamellose athyrid

Papillonaceous chonetids

Composita cf. ambigua (J. de C. Sow)

Daviesiella cf. destinesi (Vaughan)

Dictyoclostus hindi Muir-Wood

Dictyoclostus cf. multispiniferous Muir-Wood

Dictyoclostus semireticulatus (Martin)

Dictyoclostus sp.

Dielasma antiqua de Koninck

Dielasma sp.

Echinocoonchus elegans (M'Coy)

Echinoconchus punctatus (Martin)

Echinoconchus cf. subelegans (Thomas)

Echinocoonchus cf. venustus (Thomas)

Eomarginifera setosa (Phillips)

Linoproductus cf. hemisphaericus (J. Sow)

Linoproductus sp.

Phricodothyris sp.

Orthotetids

Productus garwoodi Muir-Wood

Productus cf. productus (Martin)

Pugnax pugnus (Martin)

Pustula cf. interrupta Thomas

Pustula pyxidiformis (de Koninck)

Pustula pustulosa (Phillips)

Pustula cf. pustulosa (Phillips)

Rhipidomella michelini (L'Eveille)

Spirifer cf. ventricosus de Koninck

Spirifer spp.

Syringothyris sp.

Striatiferoid productid

Tylothyris laminosa (M'Coy)

Orthoceras sp.

Fenestella sp.

Aviculopecten sp.

Bellerophontid

Straparollus sp.

Dentalium sp.

Trilobite

Elasmobranch teeth

(f) BARNEY LIMESTONE

Distinction between this and the underlying group has been made partly on grounds of a difference in lithology, and partly on the basis of a marked alteration in the faunal assemblage which accompanies the less noticeable change in rock type. The prominent fossils of the Barney Limestone are several species of cerioid Lithostrotion, accompanied by species of Linoproductus. The base of the group has been drawn at the level at which cerioid lithostrotiontids first appear.

The Barney Limestone is approximately 300 feet thick. The limestones resemble those of the underlying group in that they are well-bedded, massive, crinoidal limestones. They differ in that they are coarser, and usually of a paler blue or blue-grey, colour. Except at the extreme base the group contains a very much smaller proportion of interbedded shaly material than does the Aille Limestone, and at many exposures there is little trace of any shale partings between the beds of massive limestone. There is little lateral variation in the group, but in the uppermost 150 feet some beds contain a proportion of ooliths, and in these beds the particles of crinoid and shell debris which make up the bulk of the rock often carry a thin "oolithic skin" of calcite on their external margins. These oolitic horizons become increasingly prominent towards the top of the group. Limestones with a rich fauna of gastropods are common throughout.

Limestones near the base of the group are exposed at several localities south of Castlebar, at an exposure 1½ miles north-north-east of Manulla, and in the valley of the Aille River a mile north-east of Killavally.

/The quarry

The quarry at Curry 2 miles south of Castlebar shows 8 feet of well-bedded, massive, blue crinoidal limestones, within a few feet of the base of the group. Thin bands of coarse crinoid debris are frequent, and two beds of shaly material, each a few inches in thickness are interbedded with the massive limestones. Colonies of cerioid lithostrotiontids are numerous and the fauna includes syringoporiids, linoproductids and gastropods. Similar limestones are exposed near Hawthorn Lodge 2 miles south-south-east of Castlebar, on the railway 2½ miles south-east of Castlebar and at Middletown 1½ miles north-north-east of Manulla. At each of these localities cerioid and fasciculate lithostrotiontids, syringoporiids, large linoproductids, small pustulids, and gastropods were collected, and, in addition to these, Michelinia, Brachythyris, Composita, large orthotetids and spiriferids at the exposures 2½ miles south-east of Castlebar.

Limestones of the lower half of the group are exposed at Barney and at several localities north and north-east of that village, north of the fault 2 miles north-east of Manulla, 1½ miles east of Aille, and in the valley of the Aille River 1 mile north-east of Killavally.

At Barney 40 feet of well-bedded, massive, light blue-grey crinoidal limestones, devoid of shale partings, are exposed in the cliff on the north-western side of a small rounded hill a little south-east of the village, and on the south-east facing dip-slope behind the cliff. These limestones range from about 80 to 120 feet above the base of the group, and contain a rich fauna of cerioid lithostrotiontids and large linoproductids. The hill carries little drift or overburden and the limestones of the dip-slope are weathered into deep "grikes" on the joint planes.

/Limestones

Limestones slightly lower in the group are exposed in the stream south of Lough Nabo 1¼ miles north-east of Barney. These are massive blue crinoidal limestones with occasional thin shale partings. Cerioid lithostrotiontids in colonies up to 2 feet in diameter are the most common fossils, the fauna also including fasciculate lithostrotiontids, caniniids, clisiophyllids, large linoproductids, productids, and gastropods.

At Drunganagh 2 miles north-east of Manulla massive blue-grey crinoidal limestones about 100 feet above the base of the group are exposed. These are without shale partings and yielded a fauna of cerioid lithostrotiontids, syringoporiids, large linoproductids and gastropods.

A total of 10 feet of massive, blue crinoidal limestones are exposed 1½ miles east of Aille. These limestones which are about 70 to 80 feet above the base of the group have a fauna of cerioid lithostrotiontids, large linoproductids and gastropods. In the quarry on the left bank of the Aille River 1 mile north-east of Killavally (Fig. 3, page 29) 30 feet of limestones a few feet above the base of the group are exposed. These are massive, richly fossiliferous blue crinoidal limestones with infrequent interbedded thin shales.

Thin sections of limestones from the lower half of the group reveal ill-sorted rocks composed largely of crinoid and shell fragments together with foraminifera, bryozoa and other organic debris, set in a matrix of calcite. Most sections contain a small amount of quartz and felspars, occurring as tiny rounded and corroded grains. Occasionally the calcite of the larger crinoid fragments is partially replaced by aggregates of microcrystalline silica. Ooliths were observed in thin sections from one locality only - the more easterly of the two exposures

/1½ miles

1½ miles east of Aille. The ooliths, which make up only a minor percentage of the limestone, average about 0.3 mm. in diameter. They have suffered partial recrystallization but traces of a structure of concentric shells remain discernable. Films of "algal dust" on the exterior of the calcite shells are frequent. A foraminiferal test has served as a nucleus in some ooliths, but often no nucleus is perceptible.

Limestones of the upper half of the group are exposed in a small area between 1½ and 2 miles west of Ballyhean; and over a relatively narrow NE.-SW. belt some 3½ miles in length, south of Ballyhean.

About 2 miles west-south-west of Ballyhean massive blue crinoidal limestones without shale partings are revealed at several exposures of strata ranging from 160 to 180 feet above the base of the group. The fauna consists of gastropods and fragmentary brachiopods (principally pustulids and spiriferids). About 1¾ miles west-south-west of Ballyhean 5 to 6 feet of limestones approximately 200 feet above the base of the group are exposed. These are massive, blue-grey, secondarily dolomitized crinoidal limestones with thin bands of coarse crinoid and shell debris, and a sparse fauna of fragmented spiriferids. A few feet of limestones about 270 feet above the base of the group. are exposed 1½ miles west-south-west of Ballyhean, these too are secondarily dolomitized. They are coarse, pale blue-grey, massive limestones composed of well rounded crinoid debris and shell fragments - both often carrying thin "oolithic skins" of calcite, set in a calcite matrix. There are no shale partings and the identifiable macrofossils other than the crinoid and shell fragments are absent.

The exposures from 1½ to 2 miles east-north-east of Ballyhean

hean are of richly fossiliferous limestones from about 200 to 240 feet above the base of the group. Thin bands of limestones with ooliths are frequent. At Buncam East 1½ miles north-east of Ballyhean 3 beds, each about a foot in thickness of heavily-weathered, coarse brown dolomite occur. These are about 200 feet above the base of the group. The two exposures of horizontally-lying strata 3 miles north-east of Ballyhean are of massive blue-grey crinoidal limestones about 200 feet above the base of the group. Cerioid and fasciculate lithostrotiontids, caniniids, linoproductids, pustulids and gastropods occur in these limestones.

Massive blue-grey crinoidal limestones all in the uppermost 50 feet of the group are exposed along a narrow belt of country stretching from 1¼ miles south-west of Ballyhean to 1¼ miles east-north-east of Ballyhean. Oolitic beds, and bands of coarse crinoid debris are frequent throughout. The rich fauna includes cerioid and fasciculate lithostrotiontids, caniniids, clisiophyllids linoproductids and gastropods. Composita ficoides (Vaughan) associated with a species of Linoproductus resembling Vaughan's Linoproductus Ø occurs in limestones a few feet below the top of the group at Buncam West, 1½ miles north-east of Ballyhean. Massive blue-grey limestones with a rich fauna of gastropods are exposed south of the fault ¾ mile south-east of Ballyhean.

The uppermost 30 feet of the group are well exposed in the quarry 1½ miles south-west of Ballyhean (Fig. 3, page 29), where they are seen underlying 8 to 10 feet of the Ballyhean Oolite. These uppermost beds of the Barney Limestone are massive, well-bedded, blue-grey crinoidal limestones without shale partings. Thin sections reveal that the particles of organic detritus - crinoid debris, shell fragments, bryozoa and foraminifera - often

/carry

carry thin "oolithic skins" of calcite. Beds up to several feet in thickness of coarse crinoid and shell debris occur. A 3 foot bed composed of coarse crinoid debris and tiny brachiopods, about 15 feet from the top of the group, exhibits graded-bedding structures. The limestones have a rich fauna of cerioid and fasciculate lithostrotiontids, clisiophyllids, large linoproductids and spiriferids.

Thin sections of limestones from the upper half of the group show every gradation to be present from ill-sorted, often coarse, fragmental limestones (composed of crinoid and shell fragments and other organic debris) completely lacking oolithic developments; and limestones composed of ooliths, and organic debris all of which carries "oolithic skins" of calcite. Tiny rounded and corroded grains of quartz and felspars are frequent throughout. Recrystallization was observed in many specimens. The matrix of the rock is usually clear crystalline calcite. The ooliths, where present, normally range between 0.4 mm. and 0.6 mm. in size, and exhibit a structure of concentric shells, each shell being composed of radially disposed needles of calcite. The nucleus is usually a calcite fragment, a foraminiferal test, or more rarely a tiny grain of quartz. Concentric films of "algal dust" are a common feature of both ooliths and the "oolithic skins" of the organic detritus.

The fasciculate lithostrotiontids in this group are fewer in kinds and numbers than in the Aille Limestone, as are the other corals and brachiopods (except cerioid lithostrotiontids and linoproductids).

/Fauna

Fauna.

Caninia cf. cylindrica Scouler

Caninia sp.

Carcinophyllum cf. kirsopianum Thomson

Carcinophyllum simplex Garwood

Carcinophyllum sp.

Clisiophyllum sp.

Diphyphyllum fasciculatum (Fleming)

Diphyphyllum cf. lateseptatum (M'Coy)

Lithostrotion aranea (M'Coy)

Lithostrotion cf. irregulare (Phillips)

Lithostrotion cf. martini Edwards and Haime

Lithostrotion portlocki (Bronn)

Lithostrotion cf. portlocki (Bronn)

Lithostrotion m'coyanum Edwards and Haime

Lithostrotion scoticum Hill

Lithostrotion cf. sociale (Phillips)

Lithostrotion sp. (cerioid)

Michelinia tenuisepta (Phillips)

Palaeosmilia multilamellata M'Coy

Syringopora cf. geniculata Phillips

Syringopora ramulosa Goldfuss

Syringopora reticulata Goldfuss

Syringopora cf. reticulata Goldfuss

Syringopora sp.

Athyris sp.

Brachythyris sp.

Cleiothyridina cf. royssii (L'Eveille)

Composita cf. ambigua (J. de C. Sow)

Composita ficoides (Vaughan)

Composita sp.

Dictyoclostus sp.

Echinoconchus elegans (M'Coy)

Echinoconchus punctatus (Martin)

Linoproductus cf. ø Vaughan

Linoproductus "corrugato-hemisphaericus" cf. mut. S_2 Vaughan

Linoproductus cf. rhenanus Paeckelmann

Linoproductus sp.

Orthotetid

Papillionaceous chonetids

Pustula pyxidiformis (de Koninck)

Spirifer spp.

Thomasia sp.

Bellerophontids

Euomphalus sp.

Naticopsis sp.

Loxonema sp.

Straparollus sp.

Bryozoa

Trilobite

(g) BALLYHEAN OOLITE

Following on the Barney Limestone, and to some extent foreshadowed by the oolitic developments in the upper beds of the latter, lies this 80 feet of oolite, occurring in three outcrops - one to the north and the others south of the Manulla fault - in the south-west of the area. The oolite is a well-bedded and well-jointed, massive limestone, devoid of shale partings, and shows little or no lateral or vertical variation other than a slight vertical variation in the size of the ooliths. It is a dull blue colour when freshly broken, and light grey where subjected to weathering. The outcrop of the group is usually marked by a low ridge, except where this is obscured by deep drift or cut by streams.

The base of the group is exposed in the quarry 1½ miles south-west of Ballyhean (Fig. 3, p. 29), where 30 feet of the uppermost beds of the Barney Limestone are exposed, overlain by about 10 feet of oolite. One group grades into the other without a sharp junction. The uppermost beds of the Barney Limestone contain a proportion of ooliths, and the particles of organic debris often carry "oolithic skins" of calcite. The base of the group is also exposed 1 mile south-west of Ballyhean, (where 4 feet of oolite is underlain by 4 to 5 feet of crinoidal limestone containing ooliths); and at the quarry 2 miles south-south-east of Ballyhean (where the lowermost few feet of about 20 feet exposed are crinoidal limestones, these being overlain by 14 to 15 feet of oolite.

About 1¼ miles west-south-west of Ballyhean 40 feet of oolite are exposed ranging from approximately 10 feet to 50 feet above the base of the group. At Kinturk Castle ¾ mile north-

/East

east of Ballyhean about 40 feet of oolite also ranging from about 10 to 50 feet above the base of the group are exposed. Slightly higher beds are exposed 1¼ miles south-west of Ballyhean and 1 mile east-south-east of Ballyhean (where the oolite has suffered slight secondary dolomitization).

The uppermost 10 to 20 feet of the group, and the upward passage into the crinoidal limestones of the Ballycarra Limestone, is seen at the exposures on the steep scarp ¼ to ⅛ a mile south-west of Ballyhean, (Fig. 3, p. 29). The passage from oolite to crinoidal limestone is a gradual one, and there are developments of oolitic bands up to a foot in thickness in the lowermost few feet of the Ballycarra Limestone.

Thin sections show the oolite to consist of ellipsoidal and spheroidal ooliths in a calcite matrix. The ooliths average 0.3 mm. to 0.4 mm. in size in rocks from near the base of the group, and there is a gradual upwards increase in average size to about 50 feet from the base where the average is 0.7 mm. to 0.8 mm., followed by a slight upward decrease, until, in the uppermost beds, the ooliths average approximately 0.5 mm. in diameter. The ooliths are composed of concentric shells of calcite, each shell exhibiting a structure of radially disposed needles of calcite. Many shells carry an outer film of "algal dust", and in some ooliths this "algal dust" extends into the shells in radially disposed wedge-shaped dusky patches tapering inwards and continuous with the outer film. Many ooliths have no recognisable nucleus, others have nuclei of small fragments of calcite - a fragment of brachiopod shell, crinoid ossicle, bryozoan, or commonly a complete foraminiferal test. In a few ooliths a quartz grain, rounded and corroded, has served as a nucleus for deposition. The matrix of the rock consists of

/clear,

clear, finely-crystalline calcite which often contains rounded and corroded of detrital quartz, and occasionally fresh angular felspars, neither showing oolithic filming.

As might be expected in rocks of this type, recognisable macrofossils are very rare. Only two specimens were found, both at the large exposure of oolite 1¼ miles west-south-west of Ballyhean, (1 mile due west of Cooley Lough).

Fauna.

Lithostrotion cf. irregulare Phillips

Syringopora geniculata Phillips

(h) BALLYCARRA LIMESTONE

At the top of the Ballyhean Oolite there is a reversion of rock type to crinoidal limestones, often closely resembling in lithological type, and in faunal facies, the crinoidal limestones lower in the succession. The main outcrop of these limestones forms a great spread in the southern and eastern parts of the area, and a small outlier of the lower beds, just over one square mile in extent, occupies the core of the syncline whose axis runs north-east - south-west through Ballyhean.

The Ballycarra Limestone is about 550 feet thick. The most frequent rock type is a fine-grained, well-bedded, massive, blue or dark blue crinoidal limestone, with shale partings. Very fine-grained black "mud-pellet" limestones are developed about 50 to 80 feet above the base of the group, and beds of coarse crinoid debris are common in the upper 450 feet of the group. There appears to be little lateral variation.

The upward passage from the Ballyhean Oolite into the crinoidal limestones is a gradual one. The ill-sorted, fine-grained crinoidal limestones of the lowermost 15 to 25 feet of the group contain a small proportion of ooliths, and occasional bands of oolite a few inches in thickness are developed. Numerous exposures of these beds occur at the western end of the outlier, about 1 mile west-south-west of Ballyhean (Fig. 3, p. 29). The ooliths average 0.3 mm. to 0.4 mm. in diameter, and have a structure of concentric shells, each shell being made up of radially-disposed calcite needles. Many ooliths have no perceptible nucleus, but where a nucleus is observable, it consists of a fragment of calcite, a foraminiferal test, or a corroded grain of quartz. Rounded and corroded grains of quartz are present in

/the matrix

the matrix of the rock also.

About 40 to 50 feet of the lowermost beds of the group are preserved on the outlier, and it is only on the outlier, (at Derrew, 600 yards south-west of Ballyhean), that beds at the extreme base of the group are exposed. They are well-bedded, massive, fine-grained, blue crinoidal limestones containing a small proportion of ooliths. The rich fauna of corals and brachiopods includes Composita ficoides (Vaughan), and Davidsonina carbonaria (M'Coy). The latter was collected from a single 3 foot bed of fine-grained crinoidal limestone about 15 feet above the base of the group.

Between 50 and 80 feet above the base of the group about 30 feet of very fine-grained, well-bedded, black limestones with intervening calcareous shales are developed. The best exposure in these limestones is the quarry at Liscunnell 1¼ miles east-south-east of Ballyhean, where about 20 feet of well-bedded, fine-grained, secondarily dolomitized, black limestones are seen. The limestones are in beds from a foot to 3 feet in thickness, with interbedded black calcareous shales from an inch to 6 inches in thickness. No macrofossils were found in limestones or shales. About 6 feet of similar strata are exposed ¼ mile north of Ballintober Abbey where the limestones contain a sparse fauna of bellerophontids. Thin sections of limestones from Liscunnell and Ballintober reveal very fine-grained limestones containing small dark ovoid "mud-pellets", occasional recrystallized micro-ooliths, finely-comminuted organic debris, and the remains of numerous ostracods; together with rare, tiny, rounded and corroded grains of quartz; in a matrix of cloudy, cryptocrystalline calcite.

At Liscunnell the very fine-grained dark limestones are overlain by about 20 feet of secondarily-dolomitized, fine-grained,

/ill-sorted,

ill-sorted, blue-grey crinoidal limestones with a brachiopod fauna including athyrids, productids, and spiriferids. At Ballintober the dark very fine-grained black limestones are overlain by fine-grained blue crinoidal limestones comtaining Michelinia, productids and pustulids.

Limestones from about 100 to 300 feet above the base of the group are well exposed in that part of the area north and east of Ballintober Abbey and south and west of Ballycarra. The rocks are well-bedded, massive, crinoidal limestones with thin shale partings. Developments of coarse crinoid debris up to 10 feet or so in thickness are common, and good exposures of these coarse beds are seen at Knockaraha $\frac{3}{4}$ mile north-north-east of Ballintober, at Newtown $1\frac{3}{4}$ miles north-east of Ballintober, at Ringarrun $1\frac{1}{2}$ miles east of Ballyhean, and at Cloonconragh $2\frac{1}{2}$ miles east of Ballyhean. Both the finer-grained limestones and the coarser beds of crinoidal debris have a rich fauna of corals and brachiopods. Limestones from about 250 to 300 feet above the base of the group are especially rich in fossils. Good exposures of these limestones occur at several localities about 2 miles east of Ballyhean. A total of about 16 feet of crinoidal limestones are exposed. The fauna includes caniniids, fasciculate lithostrotiontids (in colonies up to 3 feet across), Palaeosmilia, large zaphrentoids, athyrids, Camarotoechia, chonetids, productids, pustulids, Spiriferina, Tylothyris, and gastropods.

The deepened bed of the Manulla River at Ballycarra affords a section through about 30 feet of well-bedded, massive, fine-grained, blue crinoidal limestones with thin shale partings and occasional bands of coarse crinoidal debris up to a foot in thickness. The lowest rocks exposed in this section are about

/300 feet

300 feet above the base of the group. The limestones contain a rich fauna of caniniids, fasciculate lithostrotiontids, Syringopora, large zaphrentoids, small chonetids, linoproductids, large orthotetids, Tylothyris, and gastropods. Fine-grained, secondarily-dolomitized, crinoidal limestones containing a similar fauna are exposed 1 mile north-west of Ballycarra.

Limestones between 350 and 450 feet above the base of the group are exposed in the Manulla district, south of Ballycarra, east of Balla, and near Mayo.

In the quarry at Manulla village 12 feet of massive blue crinoidal limestones with shale partings are exposed. The lower 4 feet consists of coarse, current-bedded, crinoidal limestones with thin shale partings which follow the current bedding. The upper 8 feet are well-bedded, fine-grained crinoidal limestones with black chert in nodules up to a foot long. The rich fauna includes Dibunophyllum, Lithostrotion junceum, Lithostrotion pauciradiale, Palaeosmilia, Syringopora, small zaphrentoids, gigantellid productids, and gastropods.

The more southerly of the two exposures 1⅛ miles south of Manulla is of 6 feet of coarsely crystalline current-bedded crinoidal limestone with a sparse fauna including Palaeosmilia, Syringopora, small zaphrentoids, and Daviesiella carinata. The more northerly exposure is of beds a few feet higher. Five feet of well-bedded dark blue crinoidal limestones with thin shale partings and rare nodules of black chert are exposed. The fauna includes caniniids, Dibunophyllum, Michelinia, zaphrentoids, chonetids, gigantellid productids, linoproductids, pustulids, Orthoceras, Conocardium, gastropods, and bryozoa.

South of the Manulla fault 2 miles south-west of Manulla, (where the regional dip has been reversed by movements on the

/fault

fault plane), about 8 feet of blue crinoidal limestones with thin shale partings are exposed in a small crag feature rising from the surrounding peat-bog. The fauna includes Dibunophyllum fasciculate lithostrotiontids, Syringopora, and small linoproductids.

Six feet of well-bedded, coarse, crinoidal limestones exposed 2 miles south of Ballycarra, have a fauna of fasciculate lithostrotiontids, Michelinia, Daviesiella, orthotetids, productids and pustulids. Half a mile south-west of Mayo 8 feet of fine-grained, well-bedded, blue crinoidal limestones are exposed near the bridge over the Manulla River. These yielded a fauna including caniniids, Dibunophyllum, fasciculate lithostrotiontids, Daviesiella carinata, linoproductids, productids, and pustulids.

Towards 450 feet above the base of the group the limestones gradually become paler in colour and the shale partings become less frequent. Simultaneously with this change in lithology cerioid lithostrotiontids appear in the fauna. Limestones of this type are exposed north of New Dublin ¾ mile north-west of Ballycarra, and at the more easterly of the exposures 2 miles east-north-east of Balla. The fauna in addition to cerioid lithostrotiontids includes Dibunophyllum, fasciculate lithostrotiontids, linoproductids, productids and bellerophontids. These limestones pass upwards into purer, blue-grey, massive well-bedded crinoidal limestones devoid of shale partings. The limestones which probably total no more than 20 feet in thickness are well exposed north of New Dublin 1 mile north-west of Ballycarra, at the more westerly of the exposures 2 miles east-north-east of Balla, and at several small exposures in the streams 1¼ miles south-west of Bohola (south of the Manulla Fault). The prominent fossils are abundant colonies of cerioid lithostrotiontids accompanied by

/linoproductids

linoproductids and productids. The cerioid lithostrotiontids all belong to a single species Lithostrotion portlocki (Bronn).

The pale limestones pass upwards into well-bedded, fine-grained, dark-blue crinoidal limestones, with shale partings and beds up to several feet in thickness of coarse crinoidal debris. These uppermost limestones of the group are exposed south-west of Bohola, south-south-east of Manulla (at the south-western tip of the outcrop of the Upper Series), south-east of Ballycarra and south of Balla.

About 1¼ miles south-west of Bohola several small exposures, each of a few feet of dark fine-grained crinoidal limestones, occur in the northward-flowing streams. The fauna consists of small caniniids, fasciculate lithostrotiontids, and linoproductids.

About 1½ miles south-south-east of Manulla, a total of 20 feet of well-bedded dark blue crinoidal limestones are exposed, with a 3 feet bed of coarse crinoidal debris 4 feet from the top of the section. The lower 8 feet exposed are iron-stained and contain cubes of pyrite. The fauna includes Syringopora, zaphrentoids, Actinoconchus expansa, productids and pustulids. Many of the brachiopods are beekitised.

In the bank of the Manulla River 2 miles south-east of Ballycarra 5 feet of secondarily-dolomitized, fine-grained well-bedded crinoidal limestones are exposed. The fauna includes small zaphrentoids, and fragmentary brachiopods.

A mile south of Balla 9 feet of well-bedded, fine-grained, dark crinoidal limestones are exposed in the quarry at Ardboley, with a 4 inch band of shale 5 feet above the base of the section. No identifiable macrofossils were found in these limestones which are very near the top of the group.

Thin sections of limestones higher than 100 feet above the

/base

base of the group show in every case an ill-sorted rock composed of crinoid and brachiopod fragments and other organic debris including bryozoa and foraminifera, together with a small percentage of rounded and corroded grains of quartz, in a matrix of calcite. The matrix is usually cloudy and recrystallized but occasionally clear and crystalline.

The fauna of the Ballycarra Limestone as a whole is relatively rich. Fasciculate lithostrotiontids, caniniids, large productoids, pustulids, and chonetids are characteristic. Carcinophyllum simplex, Chaetetes septosus, Composita ficoides, and Davidsonina carbonaria were found only in the lowermost 40 feet of the group.

Fauna.

Caninia benburbensis Lewis
Caninia cf. cylindrica Scouler
Caninia subibicina M'Coy
Caninia sp.
Carcinophyllum simplex Garwood
Carcinophyllum cf. kirsopianum Thomson
Carcinophyllum sp.
Chaetetes septosus Fleming
Diphyphylloid clisiophyllid
Dibunophyllum bipartitum bipartitum (M'Coy)
Diphyphyllum cf. fasciculatum (Fleming)
Diphyphyllum spp.
Koninckophyllum sp.
Lithostrotion cf. affine (Fleming)
Lithostrotion irregulare (Phillips)

Lithostrotion junceum (Fleming)
Lithostrotion martini Edwards and Haime
Lithostrotion cf. martini Edwards and Haime
Lithostrotion pauciradiale M'Coy
Lithostrotion cf. pauciradiale M'Coy
Lithostrotion phillipsi Edwards and Haime
Lithostrotion cf. phillipsi Edwards and Haime
Lithostrotion portlocki (Bronn)
Lithostrotion cf. proliferum Thomson and Nicholson
Lithostrotion cf. scoticum Hill
Lithostrotion sp.
Michelinia cf. favosa Goldfuss
Michelinia cf. megastoma (Phillips)
Palaeosmilia multilamellata M'Coy
Syringopora geniculata Phillips
Syringopora cf. geniculata Phillips
Syringopora ramulosa Goldfuss
Syringopora cf. reticulata Goldfuss
Zaphrentoids (small)
Amplexizaphrentis cf. enniskilleni Edwards and Haime
Amplexizaphrentis sp.

Actinoconchus expansa
Athyris spp.
Camarotoechia sp.
Chonetes cf. papillonaceus Phillips
Chonetes laguessianus de Koninck
Composita ficoides (Vaughan)
Davidsonina carbonaria (M'Coy)
Daviesiella carinata (Garwood)

Daviesiella cf. destinezi (Vaughan)

Dictyoclostus sp.

Echinoconchus punctata (Martin)

Gigantellid productid

Krotovia cf. spinulosa (Martin)

Linoproductus aff. corrugatus (M'Coy)

Linoproductus cf. hemisphaericus (J. Sow)

Linoproductus cf. rhenanus Paeckelmann

Linoproductus sp.

Orthotetid (large)

Pustula pustulosa (Phillips)

Pustula pyxidiformis (de Koninck)

Spirifer sp.

Spiriferina sp.

Stenocisma kingii (Davidson)

Tylothyris laminosa M'Coy

Orthoceras sp.

Conocardium hibernicum (J. Sow)

Bellerophontids

Straparollus sp.

Bryozoa

Trilobite

Ostracods

(i) BALLA LIMESTONE

The Balla Limestone, which is about 200 feet thick outcrops in four areas:

1. About 1¼ miles north-east of Manulla, overlying the reef limestones.
2. A narrow belt of country between Manulla and Ballinamore, south of, and bordering, the outcrop of the sandstones and shales of the Upper Series.
3. Around Ballintleva in the southern part of the area.
4. The region of Magheraboy and Ballyhowley House, 1½ miles south-west of Knock, in the south-eastern part of the area.

Except in the region north-east of Manulla where reef limestones are developed in the group, the country underlain by the Balla Limestone is flat and low-lying. The outcrop of the rocks of the Upper Series, except on the northern side where the boundary is a faulted one, is ringed by a strip of low ground, forming a marked contrast to the steep hillsides produced by erosion of the overlying shales, mudstones and sandstones.

Considerable lateral and vertical variation is exhibited by the group. Four types of limestone are present:

1. Very fine-grained black calcite-mudstones, sub-porcellaneous in texture, containing numerous ostracod fragments, and more rarely finely comminuted crinoidal and shell debris.
2. Fine-grained, black limestones composed of "mud-pellets", ostracod remains, and nodular colonies of stromatoporid and codiacean algae, in a matrix of finely-crystalline calcite. The "mud-pellets" are small ovoid and elongate ovoid bodies of very fine-grained, dark, calcareous mud.
3. Fine-grained dark-blue crinoidal limestones, composed of

/finely

finely comminuted ill-sorted crinoid and shell debris, foraminifera and other organic detritus, together with rare, tiny, rounded and corroded grains of quartz, in a matrix of finely-crystalline calcite. Films of muddy material, parallel to the bedding, are frequent in thin-sections of this type of limestone.

4. Fine-grained oolites, usually dark blue in colour, but occasionally dove-grey (as at the quarry at Rockstown ½ mile north-east of Balla).

At all exposures the limestone is well-bedded, and usually very dark. The limestone beds range from 6 inches to 4 feet in thickness, and, except where an exposure is made up wholly of oolite, the limestones are separated by black calcareous shales, sometimes as mere partings, but often as bands of 5 or 6 inches in thickness. Usually each bed is made up wholly of one type of limestone - inveriably so if the limestone is of the fine-grained crinoidal type. Occasionally calcite-mudstones, "mud-pellet" limestones with algae, and oolite, occur in the same bed in bands from a fraction of an inch to several inches in thickness. An example of this occurs in the uppermost bed of the quarry at Carrowntobereighter 1½ miles south-east of Manulla. Eight feet of fine-grained limestones are exposed, in beds from 8 inches to 3½ feet thick with interbedded shales up to 3½ inches thick. Productus redesdalensis Muir-Wood occurs in great numbers in a band 5 inches thick 2½ feet above the base of the exposed strata. The lower 6 feet of limestones exposed are very fine-grained calcite-mudstones with lenses of "mud-pellets". The uppermost bed, some 14 inches in thickness, is made up as follows:

	ins.
3. Fine-grained, dark blue oolite.....	6
2. Current-bedded "mud-pellet" limestone with numerous ostracods.....	1½

/1. Very

	ins.
1. Very fine-grained calcite-mudstone with lenses of "mud-pellets".....	6½

The oolite is composed of spheroidal and ellipsoidal ooliths averaging 0.3 mm. to 0.4 mm. in diameter, together with ostracod fragments showing oolithic filming, in a matrix of finely-crystalline calcite. The ooliths have a concentric structure of shells of calcite, each shell made up of radially disposed calcite needles. The exterior of most shells carries a film of "algal dust" which extends into the shell in wedge-shaped, radially disposed patches, tapering inwards and continuous with the film on the exterior. The cores of the ooliths are often recrystallized and occupied by a single crystal of calcite, but a small proportion have a visible nucleus consisting of a fragment of ostracod test.

Other exposures show the different types of limestone in alternating succession, with intervening shale bands. At the more easterly of the two exposures at Ballintleva the following section is exposed:

	ft.	ins.
7. Secondarily-dolomitized, black, sub-porcellaneous calcite-mudstone with ostracod fragments.....	2	0
6. Black calcite-mudstones alternating with black shales, each in beds to 1½ inches thick (heavily weathered).....	1	0
5. Fine-grained, dark blue crinoidal limestones (showing films of mud in thin-section parallel to the bedding). Brachiopod fragments in lower half.....	3	0

/4. Black

	ft.	ins.
4. Black calcareous shale.....		
4. Black calcareous shale.....		6
3. Fine-grained black limestone composed of "mud-pellets", ostracod fragments, and colonies of calcareous algae up to 1 cm. in diameter.....	1	6
2. Black calcareous shale.....		5
1. Black sub-porcellaneous calcite-mudstone with ostracod fragments.....	1	0

The limestones of the 5 feet of strata exposed west of Ballintleva are all black calcite-mudstones with rare ostracod remains.

The exposures due north of Balla are each of a few feet of fine-grained, dark-blue oolitic limestones devoid of shale partings. At the exposure ½ mile north of Balla lenses and bands of mottled and banded cherts up to 6 inches in thickness occur. Petrographically the oolites are similar to the oolite at Carrowntobereighter. At Rockstown ½ mile north-east of Balla about 25 feet of fine-grained blue-grey oolite is exposed. The spheroidal ooliths average 0.2 mm. to 0.3 mm. in size. In common with the rest of the rock they have suffered recrystallization, but it is possible tc discern an original concentric structure of shells of calcite around a calcite fragment, quartz-grain or foraminiferal test nucleus. The ooliths, together with foraminifera and ostracod fragments (both carrying oolithic films of calcite), and tiny rounded and corroded grains of quartz, are set in a matrix of finely-crystalline calcite. Pyrite crystals up to several millimetres in size are common.

The exposure 1¾ miles east-north-east of Balla, north of the western end of the Ballinamore fault, is of 6 feet of fine-grained dark limestones with rare crinoid ossicles and numerous colonies

/of Lithostrotion

of Lithostrotion junceum. In thin section the rock is revealed as recrystallized to a fine-grained mosaic of calcite in which the organic remains - corals, crinoid fragments, brachiopod spines and ostracod fragments - though also recrystallized, have retained their identity. At Ballinamore House about 2 feet of black sub-porcellaneous calcite-mudstone with a sparse fauna of productids is exposed in the bed of the Pollagh River.

At Magheraboy 1¾ miles south-west of Knock 10 feet of flat-lying limestones with interbedded shales are exposed. Apart from an 18 inch bed of black "mud-pellet" limestones with fragmentary gastropods 6 feet from the base of the exposed strata, all the limestones are the dark blue fine-grained crinoidal type. The fine-grained crinoidal limestones exposed at the small quarry ¼ mile north-west of Magheraboy contain nodules of black chert up to a few inches in length. North of Ballyhowley House, 1¼ miles south-west of Knock, 10 feet of fine-grained, very dark, crinoidal limestones are exposed, with a sparse fauna of athyrids and productids.

On the eastern side of the reef limestone 1½ miles north-east of Manulla (Fig. 4, p. 62) there are a number of exposures each of a few feet of the approximately 60 feet of bedded limestones of this group overlying the reef. These are well-bedded calcite mudstones - dark-grey and lacking shale partings in the lowest beds, but becoming black in the higher beds which have interbedded shaly bands.

The exposures ¼ mile south of Bohoge are of dark-grey bedded calcite mudstones 10 to 15 feet above the reef limestones. They are devoid of shale partings and bands of black chert a few inches thick are frequent. The limestones contain rare specimens of Dibunophyllum, athyrids and spiriferids. Beds 25 to 50 feet

/above

above the reef are exposed 50 to 150 yards south-west of Bohoge. These are black calcite mudstones in beds up to a foot or two in thickness with thin shale partings. The limestones have a sparse fauna of productids and the shales contain rare lamellibranchs. A small exposure 100 yards north of Bohoge shows about 5 feet of well-bedded dark-grey and black calcite mudstones with thin shale partings and rare nodules of blue chert. Several thin bands of crinoid debris occur. The most prominent fossils are partially silicified spiriferids.

No macrofossils were seen in oolites of this group. In addition to the specimens in the quarry at Carrowntobereighter fragments of Productus redesdalensis were obtained from the exposures near Ballintleva. Small zaphrentoids, Michelinia and Syringopora occur in the 3 feet of black, calcite-mudstones exposed ¼ mile east of the Carrowntobereighter quarry.

Fauna.

Dibunophyllum bipartitum bipartitum (M'Coy)
Lithostrotion junceum (Fleming)
Michelinia favosa (Goldfuss)
Syringopora reticulata Goldfuss
Zaphrentoids (small)

Athyris sp.
Productus redesdalensis Muir-Wood
Productus sp. (small)
Spirifer sp.

Ostracods

Fragmentary gastropods

Lamellibranchs, possibly Myalina sp.

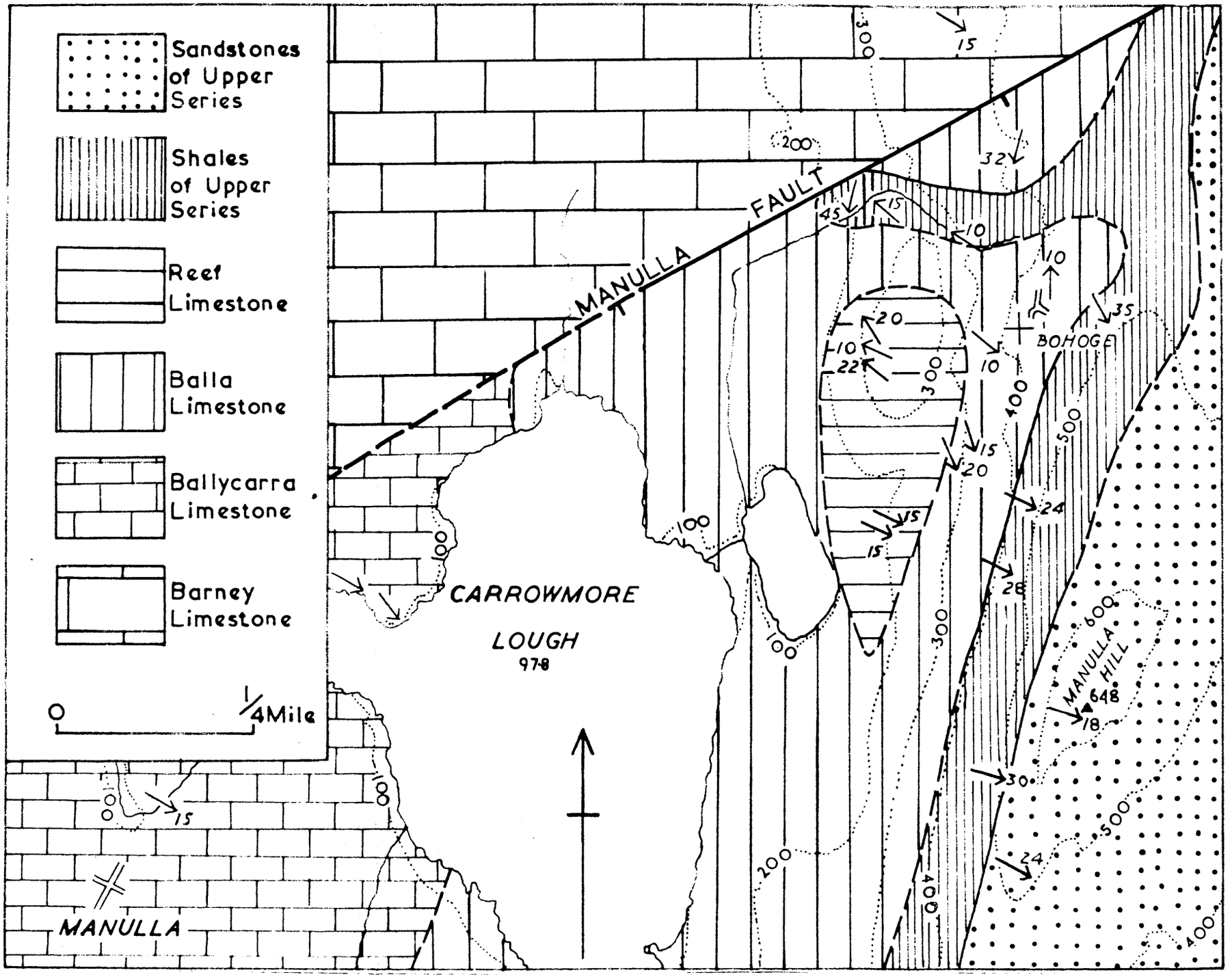

Figure 4. Geological sketch-map of the area between Manulla and Manulla Hill

(j) REEF LIMESTONE

Reef limestones are developed in the Balla Limestone at Bohoge 1¼ miles north-east of Manulla, (Fig. 4, opposite), where they have an oval outcrop measuring about ½ mile north to south by 300 yards in an east-west direction. At its northern end, where it exhibits quaquaversal dip, the reef rises from the plain to the west in knoll-like form. Further south the reef has suffered deeper erosion particularly on the western side, but the slope up to the base of the overlying well-bedded limestones is broken at the exposures 600 yards south-south-west of Bohoge by a low north and south cliff of the upper beds of the reef. This cliff has behind it, on the eastern side, a dip slope made up of the upper beds of the reef, before the general westward slope of the ground is restored by the outcrop of the overlying bedded dark calcite mudstones of the Balla Limestone. Movements on the plane of the Manulla fault north of the reef limestone have resulted in steep synclinal folding on an ENE.-WSW. axis of the limestones and the overlying shales, and the preservation of a tongue of the latter on the axis of the syncline. This folding has augmented the quaquaversal dip of the reef limestones at the northern end of their outcrop.

Neither upward nor lateral passage from bedded to reef limestones is exposed. The thickness of the reef limestones is unknown, though they are at least 100 to 125 feet thick. The knoll-like topography of the northern part of the outcrop apparently represents part of the original upper surface of a lenticular deposit. Bedding structures can be seen following the surface topography at the group of exposures at the north-western

/end

end of the reef (¼ mile west of Bohoge), which are of limestones within only a few feet of the top of the reef. The massive, grey, porcellaneous limestones contain numerous large colonies of Lithostrotion pauciradiale, Diphyphyllum fasciculatum, and an unidentified species of Diphyphyllum in addition to rarer specimens of Dibunophyllum and brachiopods. The fossils are partially silicified where they are exposed to atmospheric weathering, but are not silicified where still embedded.

Towards the southern end of the outcrop (600 yards south-south-west of Bohoge) about 25 feet of grey porcellaneous reef limestones are exposed in the westward facing north and south cliff and on the dip slope behind the cliff. The uppermost beds are within a few feet of the top of the reef limestone and in them bedding structures are easily traced. In the lower 10 to 15 feet exposed bedding is not apparent in the limestone, but may be followed from the dip and strike of the numerous beds of chert in the limestone. Fossils are few at these exposures and only rare specimens of Dibunophyllum and brachiopods were obtained.

In thin section the reef limestone is revealed as an extremely pure, very fine-grained crystalline calcite-mudstone. Rarely it contains fragments of brachiopod shells, productid spines and crinoid ossicles. No algae or polyzoa were observed and secondary dolomitization is absent at all exposures.

The reef limestones contain considerable amounts of black chert which is present at all exposures and usually makes up 30% to 50% of the exposed thickness. The chert occurs in bands and beds from a few inches to a yard in thickness, and there are numerous semi-vertical sheet-like connections between the beds, indicating a secondary origin. The overlying sandstones of the

/Upper

Upper Series suggest themselves as a possible source of silica, though separated from the reef limestone by a total thickness of about 150 feet of limestones and shales.

There is no continuous exposure showing the upward passage of reef limestone into the overlying bedded, shale-parted, dark calcite-mudstones of the Balla Limestone, but this upward passage is obviously a gradual one. The reef limestones have bedding structures in the upper layers, and the difference between the uppermost reef limestones and the lowermost few feet of the overlying limestones (exposed only on the eastern side of the reef) lies chiefly in the well bedded nature, the darker colour, and the smaller proportion of interbedded chert in the latter as compared to the reef limestone. About 15 to 20 feet above the reef limestones the bedded limestones contain shale partings and these are a constant feature through the rest of their exposed thickness.

The average slope of the ground between the highest point of the reef-knoll, and the bed of the stream in the valley cut in the shales on the axis of the syncline, is much less than the average (northerly and north-westerly) dip of the underlying rocks, presumed to be between 10 and 20 degrees from the dips of the uppermost beds of the reef limestones west of Bohoge, and the shales exposed in the banks and bed of the stream. In view of this, and the absence of evidence elsewhere of an unconformity at the base of the shales, the bedded limestones overlying the reef limestones on the eastern side have been drawn as a continuous exposure underlying the shales on the northern side of the reef. The single exposure between the tongue of shales and the fault is a bed of blue chert 3 feet thick. The base of the shales is not exposed.

/Fauna.

Fauna.

Dibunophyllum bipartitum bipartitum (M'Coy)

Diphyphyllum cf. fasciculatum (Fleming)

Diphyphyllum sp.

Lithostrotion pauciradiale (M'Coy) (Diphymorphic type)

Brachythyris sp.

Camarotoechia pleurodon (Phillips)

Productus productus Martin

Spirifer sp.

(k) STRATA OF UNCERTAIN AGE

Two isolated exposures, both in the eastern part of the area, at Castleroyan, on the Trimoge River, 4 miles west of Kilkelly; and half a mile south-east of Bruff Cross Roads, $2\frac{3}{4}$ miles south of Kilkelly; are of limestones whose relations with the rocks to the west are uncertain.

At Castleroyan, well-bedded, dolomitized, crinoidal limestone, containing Lithostrotion cf. affine (Fleming) and Lithostrotion sp. may belong to the Aille Limestone.

At Bruff, a quarry showing twelve feet of current-bedded, fine-grained, oolitic limestone, with sparsely distributed crinoid ossicles, and rare small brachiopods, may be equivalent to the Ballyhean Oolite of the western part of the area.

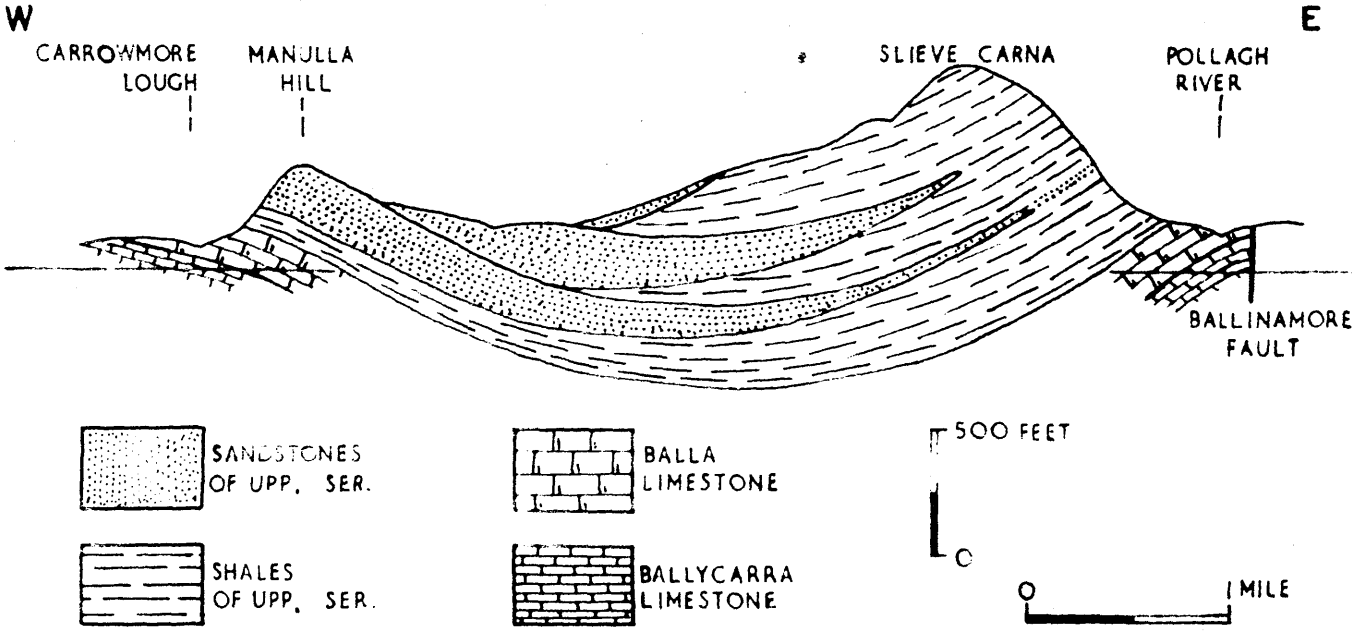

Figure 5. Reconstructed section of the rocks of the Upper Series, on an E.-W. line $\frac{1}{4}$ mile south of Manulla

IV. THE UPPER SERIES - SANDSTONES AND SHALES

(a) GENERAL

The contact between the Balla Limestone and the overlying rocks of the Upper Series is nowhere exposed, and the relation between the two Series has been disclosed solely by mapping. Exposures only a few feet each side of the junction show no alternation of facies, and though no limestone breccias have been observed in the shales, the abrupt change in lithology and fauna, from shallow-water limestones with a fauna of corals and brachiopods, to non-calcareous shales and mudstones with a fauna of goniatites and lamellibranchs, suggests in itself a stratigraphical break and probable disconformity.

The Upper Series as a whole exhibits considerable lateral and vertical variation. The lowest group, consisting of shales and mudstones, is about 100 feet thick in the west of the outcrop and thickens eastward reaching a thickness of about 400 feet at the eastern side of the outcrop. In the west of the outcrop the shales and mudstones are overlain by several hundred feet of grits and sandstones, divisible into three groups. The sandstones thin eastwards and north-eastwards, dividing into three distinct beds with intervening shale groups north-east of Balla. The eastward thinning of the sandstone beds continues, the lowest being the most persistent. Each shale group thickens eastwards, and in the east and north-east of the outcrop the Upper Series is made up of shales and mudstones, with rare siltstones (Fig. 5, opposite).

Except in the valley of the stream north of Balla, the base of the Upper Series lies at the foot of a steep scarp. Erosion

/of the

of the sandstones usually gives rise to a steeper scarp than that underlain by shales and mudstones, and where the shales have interbedded sandstones, as on the hillsides north-east of Balla, the outcrop of the sandstones may be recognized by the steeper portion of the scarp which they underlie.

The elevated nature of the ground underlain by the rocks of the Upper Series (ranging up to 868 feet in the north-east of the outcrop), the steep slopes, and the deep gullies where the streams have cut into the softer shales, form a marked contrast to the surrounding low-lying, gently-undulating, limestone country.

(b) THE SHALES

Just as the Upper Series as a whole displays considerable lateral and vertical variation, so do the shales and sandstones exhibit less spectacular variations in themselves. The general term "shales" is intended to cover all strata other than the pale-coloured gritty sandstones of the west and south of the outcrop of the Upper Series.

At the western side of the outcrop the shales reach a thickness of about 100 feet where they underlie the lowest sandstone group east of Manulla (Fig. 4, p. 62). The lowest beds seen are exposed on the tongue of shales north of the reef limestone, 300 yards north-west of Bohoge village. They are blue mudstones a few feet above the base of the Upper Series. They are weathered to a soft blue clay, and contain a sparse fauna of goniatites, chonetids and trilobite fragments.

These blue mudstones, which probably total no more than 15 feet in thickness, are overlain by 50 to 60 feet of alternating black, well-bedded, closely jointed, hard and compact mudstones, and ferruginous, fissile, black shales with occasional sooty carbonaceous partings. Individual beds in the mudstones range from an inch to three inches in thickness. Rottenstones up to 6 inches in thickness are interbedded with the shales and mudstones. The road cutting through the scarp 250 yards east of Bohoge (Fig. 4, p. 62) exposes a section the base of which is about 25 feet above the base of the Upper Series. The succession is:-

	ft.	ins.
4. Black well-bedded mudstones.....	26	0
3. Rottenstone.....		6

/2. Black

	ft.	ins.
2. Black fissile shales.....	4	0
1. Black well-bedded mudstones.....	6	0

The base of the section in the roadside quarry ½ mile south of Bohoge is about 40 feet above the base of the Upper Series. The succession is:-

	ft.	ins.
7. Black fissile ferruginous shales.....	6	0
6. Rottenstone.....		4
5. Black well-bedded mudstones.....	3	0
4. Black mudstones, extensively veined with calcite, and with slump-bedding structures.....	1	8
3. Black well-bedded mudstones.....	2	0
2. Black mudstones with spheroidal pyritous bullions up to 18 inches in diameter.....	2	0
1. Black well-bedded mudstones.....	6	0

The alternations of mudstone and shale pass up into brittle thinly bedded slightly ferruginous black shales underlying the lowest sandstone group. About 4 feet of these shales are exposed 1 mile east of Manulla.

The lowest exposed beds on the southern side of the outcrop are seen at several exposures, each of a few feet of shales, just north of the Ballinamore Fault 1 mile west-south-west of Ballinamore. These are soft, papery, sooty-black shales between 20 and 40 feet above the base of the group. These gradually pass up into harder ferruginous, brown-weathering black shales well exposed in the stream section 1¾ miles west-south-west of Ballinamore, where two beds of tough blue siltstones each about

/a foot

a foot in thickness are exposed about 200 feet above the base of the shales. The junction between the base of the lower sandstone bed and the underlying shale is exposed in this stream section and in the stream 1 mile west of Ballinamore. At both exposures the junction between shale and sandstone is sharp and at the more westerly exposure there is no alternation of the two facies. The exposures about 1 mile west of Ballinamore is near the tip of the lower group of the sandstone, and from the discontinuous exposures it is possible to reconstruct the following succession:-

	Approximate thickness in feet
6. Fine-grained, pale, iron-stained gritty sandstone.....	10
5. Flaky, brittle, thinly bedded black shales.....	12
4. Fine-grained, pale, iron-stained gritty sandstone.....	20
3. Ferruginous fissile black shales.....	25
2. Fine-grained, pale, iron-stained gritty sandstone.....	8
1. Ferruginous fissile black shales.....	40

The base of the section is about 300 feet above the base of the shales, and only the junction between 1. and 2. is exposed.

The shales between the lower and middle sandstone beds are exposed 1½ and 2 miles north-east of Balla. They are brittle, flaky, closely-bedded, slightly ferruginous black shales, of a harder and more compact appearance than the shales below the

/sandstone

sandstone group , and with a slighter tendancy to become brown on weathering.

Shales between the middle and upper sandstone beds are exposed 1¾ miles south-south-west of Bohamore where 4 feet of waterlogged and rotten black ferruginous shale are exposed in the bed of a small stream.

In the east and north-east of the outcrop the shales reach a total thickness of about 1,100 feet. The lowest beds exposed are seen in the stream immediately south of Bushfield, and in another smaller stream 1 mile north-north-east of Bushfield. Beds estimated to be 40 to 70 feet above the base of the Upper Series are exposed at several places in the banks of the stream 200 to 450 yards south-south-east of Bushfield. Well-bedded, hard compact mudstones, greatly resembling those near the base of the Upper Series at Bohoge in the west, occur in beds up to 4 feet in thickness, in alternating succession with fissile, ferruginous, brown-weathering, black shales, in beds up to at least 18 to 20 feet in thickness. Due to the discontinuous nature of the exposures and the highly varied dips it has not been possible to reconstruct the succession. The shales have a rich fauna of crushed goniatites and lamellibranchs, together with rarer chonetids and trilobite fragments. About 1 mile north-north-east of Bushfield several exposures each of a few feet of well-bedded black mudstones are seen in the bed of the stream. No shales are exposed but the profile of the stream and the topography of the valley suggest that the mudstones may be in alternating succession with softer strata.

The alternating series of shales and mudstones passes upwards into brown-weathering ferruginous black shales, with occasional beds of very soft black carbonaceous mudstones up to

/several

several feet in thickness between 150 and 250 feet above the base of the Upper Series. A 3 foot bed of this mudstone, exposed in the stream ¼ mile west of Bushfield, about 200 feet above the base of the Upper Series, has a rich fauna of crushed goniatites and plant fragments.

Higher than about 300 feet above the base of the group the shales become less ferruginous, harder, flakier and more brittle than those below, and have a slighter tendency to become brown on weathering. At about 400 feet above the base of the Upper Series 1 mile south-south-west of Bushfield two beds of tough blue siltstones are exposed; the lower bed is about a foot in thickness and is separated by an estimated 30 feet of black flaky shales from the upper bed of siltstone which is about 4 feet thick. These siltstones may be an eastward continuation of the lower sandstone group though there are no exposures between the two. No siltstones were observed at this level in the succession farther north. Exposures of shales higher than 550 feet above the base of the Upper Series are few.

At Carrowntleva 1¼ miles north-east of Bohamore beds about 650 feet above the base of the Upper Series are exposed in a small stream where 8 inches of silty micaceous shale is seen underlying 1 foot of current-bedded, rusty-weathering, muddy, micaceous siltstone. The exposures ¾ mile north-west of Bohamore are of beds about 850 feet above the base of the Upper Series. These are slightly ferruginous black shales and shaly mudstones, with occasional beds up to a foot in thickness of blue mudstones with cubes of pyrite, and flattened pyritous concretions about an inch in diameter. About 1 mile south of Bohamore black, fissile, slightly ferruginous shales about 900

/feet

feet from the base of the Upper Series are exposed at the lower end of a stream gully.

The highest beds, exposed on the axis of the syncline at Bohamore are slightly ferruginous, thinly bedded, flaky black shales, with occasional beds up to a foot in thickness of black shaly mudstones.

Fossils are scarce in the shales and mudstones, except at a few localities, all within 300 feet of the base of the Upper Series. Goniatites and lamellibranchs are crushed, and (apart from the goniatites of the lowest mudstones exposed near Bohoge) both goniatites and lamellibranchs are partially replaced by limonite. The brachiopods (all small chonetids), though uncrushed, have been totally replaced by ferruginous substances, as have the rare trilobite fragments. Identifiable fossils were found at only five localities. These were:

1. At Bohoge, 300 yards north-west of Bohoge village, 1½ miles north-east of Manulla, where a bed of heavily weathered, soft, blue mudstone a few feet above the base of the Upper Series, is exposed on the northern side of the steep-sided valley cut by the small stream. The mudstone contains weathered and crushed specimens of goniatites of the Neoglyphioceras spirale (Phillips) group, together with small chonetids and rare trilobite fragments.

2. A little south of the smithy at Bushfield, where from ferruginous shales of the northernmost exposure in the stream - about 50 feet above the base of the Upper Series - the following fauna was collected:

Chonetid (small)

cf. Aviculopecten losseni von Koenen

Posidonia corrugata R. Etheridge, Jun.

cf. Pseudamusium concentrico-lineatum Hind

Goniatites of Neoglyphioceras spirale (Phillips) group possibly Glyphioceras granosum (Portlock)

Sudeticeras sp. (finely crenulate and with radial striae)

Trilobite fragments

3. About ¼ mile north-west of Bushfield smithy, where in soft black mudstones approximately 200 feet from the base of the Upper Series Sudeticeras sp. was found in association with plant fragments.

4. A quarry south of the road 2 miles south of Bohola, where Posidoniella cf. laevis (Brown) was collected from the 12 feet of ferruginous shales about 250 feet above the base of the Upper Series.

5. An isolated exposure north of the road 2 miles south-south-west of Bohola, where from 4 feet of brittle, thinly-bedded, slightly ferruginous, black shales about 300 feet above the base of the Upper Series Posidoniella cf. laevis (Brown) and an unidentified species of Eumorphoceras of a low E_1 type were collected.

Black ferruginous shales about 300 feet above the base of the Upper Series exposed in the stream ¾ mile north of Bushfield yielded unidentifiable plant fragments and a few fragments of

/lamellibranchs

lamellibranchs. Lamellibranch fragments were also collected from black ferruginous shales at the exposures 1¾ miles north of Bushfield and 1½ miles north-north-east of Bushfield.

No fossils are recorded in shales or mudstones at higher horizons.

(c) THE SANDSTONES

The sandstones are divisible into three groups, each group reaching its greatest thickness in the south-west of the outcrop, on the axis of the syncline south-east and east of Manulla. Here the lowest group is about 240 feet thick and the middle group about 300 feet thick. The uppermost group is not exposed but probably has a maximum thickness of about 200 feet. Traced northwards the groups thin rapidly until they meet the Manulla Fault. Eastwards the groups thin more slowly in the country north of Balla, but north-east of Balla the thinning is more rapid, and the groups become separated by black shales. The rapid eastward thinning of the sandstones continues, the lowest group being the most persistent. Much of the northward and eastward thinning appears to take place by lensing of individual beds of sandstone, for only at the eastern tip of the lowest sandstone group is there any appearance of interfingering and alternation of shales and sandstones, and lateral passage of the sandstone into siltstones exposed south-west of Bushfield.

The sandstones are massive, well-bedded (occasionally current-bedded), and well-jointed rocks, usually suffering from limonitic staining, though unweathered specimens are occasionally of a uniform pale cream colour. Usually the rock is stained throughout, but the coarser beds of the western outcrop of the lowest group show typical incipient spheroidal "blue-hearted" weathering. There is a general eastward diminution in grain-size in each of the two lower groups. The numerous large boulders of sandstone in the drift overlying the outcrop, suggest that an eastward diminution in grain-size takes place in the

/upper

uppermost group also.

At the west of the outcrop the lowermost and uppermost few feet of the lowest sandstone group are finer grained than the beds lying between. Beds a few feet above the base of the group are exposed at Carrowkeel 1 mile south-east of Manulla. The grains in these ill-sorted sandstones rarely reach 0.4 mm. in size. These basal beds, which are estimated to be only 15 to 20 feet in thickness, are overlain by coarse felspathic grits well exposed between Carrowkeel and the summit of Manulla Hill. The grains in these grits often reach 1.5 mm. in size and this coarseness is maintained through almost the full thickness of the group where exposed on slopes of Manulla Hill. Current-bedding occurs in the exposure $1\frac{1}{4}$ miles due east of Manulla.

The sandstones exposed at the foot of the eastern slope of Manulla Hill $1\frac{1}{2}$ miles east-north-east of Manulla are near the junction of the lower and middle sandstone groups. In these beds the grains rarely reach 0.3 mm. in size and there are rare partings of fissile, micaceous, silty, black shales between the beds of ferruginous sandstone. Erosion of these fine-grained beds gives rise to a well-marked north and south valley feature - a feature which is repeated to the east, $1\frac{1}{2}$ to $2\frac{1}{2}$ miles north of Balla, at the junction of the middle and upper sandstone groups, though the underlying strata are not exposed.

A gradual overall diminution in grain-size in the sandstones of the lower group takes place between the exposures north-north-east of Balla - where the largest grains measure about 0.7 mm., eastwards to the tip of the lower group - where the grains rarely reach 0.4 mm.

Exposures of beds in the lower half of the middle sandstone group $1\frac{3}{4}$ miles east-north-east of Manulla are ill-sorted grits

/with

with grains up to 1.5 mm. in size. The exposure 1¾ miles west of Ballinamore is of 10 feet of current-bedded rusty sandstones in which the grains rarely reach 0.4 mm. in size.

Petrographically the sandstones of the Upper Series differ from those of the Lower Series in a higher concentration of felspars (mainly microcline and microperthite, often heavily weathered), and in the greater angularity of the quartz grains. The fine-grained sandstones at the junction of the lower and middle sandstone groups have thin films of mud between the grains. The fine-grained sandstones at the eastern tip of the lowest group have a matrix of clay minerals, but thin section reveals that this has resulted from a breakdown of the felspars.

No fossils were found in the sandstones.

The crescentic outcrop of "Carboniferous Basal Sandstone" marked on Ordnance Survey One Inch Sheet 75 at Ballinamore is a ridge of glacial drift unusual in consisting of large, angular boulders of sandstone set in a matrix of almost pure sand of similar colour and grain-size. No rock occurs <u>in situ</u>, but in their comparatively high felspar content, the angularity of the fragments and the limonitic staining, they resemble the sandstones of the Upper Series rather than the Basal sandstones of the Lower Series, and were derived from the "solid" outcrops to the north.

V. THE AGE OF THE STRATA

Of the faunas of the Basal Sandstone, the Lough Akeel Oolite and the Castlebar River Limestone, no single fossil, nor the assemblages as a whole, give any exact indication of the horizon. (Tylothyris is found in beds ranging up to, and including, those of a demonstrable D zone age, both in this and other areas in north-western Ireland).

The first fossil which gives any indication of the age of the containing limestone is Thysanophyllum pseudovermiculare, which is found at the base of the succeeding Aille Limestone, which suggests, by comparison with beds in the north-west of England, an horizon low in the Composita gregaria sub-zone of Garwood's Athyris glabistria zone. Species of lithostrotiontids are found, in limestones of suitable lithology, throughout the rest of the limestone succession, i.e. in all limestones higher than the top of the Castlebar River Limestone.

There is no proof of the age of the beds below this Thysanophyllum pseudovermiculare horizon; but there is a continuity of sequence from the basal sandstone upwards, and the basal unconformity may thus be correlated with the widespread mid-Avonian (sub-Visean) unconformity seen elsewhere in Ireland and across the Irish Sea, the Basal Sandstone and the two succeeding Limestones being laid down within Visean times.

The association of species of fasciculate lithostrotiontids with large caniniids in the Aille Limestone suggests in itself a high C_2S_1 age, supported by the presence of Carcinophyllum simplex.

The fauna of the succeeding Barney Limestone, consisting principally of many species of cerioid and fasciculate

/lithostrotiontids

lithostrotiontids, and several species of Linoproductus, (including one comparable with Vaughan's Linoproductus corrugato-hemisphaericus mut. S_2) suggests a mid-Visean horizon. Carcinophyllum simplex is found in the lower beds, and Composita ficoides in the uppermost beds, only. In the Sligo syncline, north of the Ox Mountains, Lithostrotion portlocki was collected by Oswald from the Ballyshannon Limestone, to which he ascribes a C_2S_1 age.

The Ballyhean Oolite fauna of one species of fasciculate Lithostrotion and one species of Syringopora sheds no light on the exact age of that horizon. However, the occurrence of Davidsonina carbonaria in association with Composita ficoides in the immediately overlying, lowest, beds of the Ballycarra Limestone would seem to indicate unequivocally an S_2 age for that part of the succession.

Oswald records no fossils giving a direct indication of an S_2 age for any of the rocks of the Sligo syncline, but he was able to correlate the Mullaghmore sandstone lying midway in his 4,000 foot, principally calcareous, succession, with the Kesh Sandstone of the Omagh Syncline, in which Davidsonina carbonaria was discovered by Simpson.

The succeeding Ballycarra Limestone falls into a zone certainly not older than S_2, yet at many horizons the fauna possesses facies similar to that of the Aille Limestone, and the fauna is at first glance deceptively like that of the lower Caninia zone. The association of fasciculate lithostrotiontids, caniniids, large pustulids, and Tylothyris is familiar from beds eight hundred feet beneath the Ballycarra Limestone. In detail the assemblage differs. Lithostrotion pauciradiale is found throughout the whole thickness of this group , Caninia subibicina

/in the

in the uppermost 250 feet, and Lithostrotion junceum and Dibunophyllum bipartitum bipartitum in the uppermost 150 feet. A D age may be ascribed with certainty to the uppermost 150 feet of the Ballycarra Limestone at least. An interesting occurrence is that of Daviesiella carinata in beds of coarse crinoid debris about 100 feet below the top of the group, (in association with Dibunophyllum bipartitum bipartitum amongst other fossils), a fossil recorded in, and indeed diagnostic of, rocks belonging to the C_2S_1 zone in the north of England. The position of the dividing-line between the S_2 and D zones is no clearer than that of the division between the C_2S_1 and S_2 zones lower in the succession.

The occurrence of Dibunophyllum together with Lithostrotion junceum in the Balla Limestone indicates that it too falls into the D zone. Productus redesdalensis found in these limestones, is found in rocks of D_1 and D_2 age, including the Hurlet Limestone, in Northumberland and Scotland. Dibunophyllum occurs also in the reef limestones.

In the Sligo syncline, Oswald's Mullaghmore Sandstone is succeeded by a calcareous shale, the Benbulben shale. The shale is overlain in turn by the Glencar Limestone from which Oswald records a single specimen of Dibunophyllum. The Glencar Limestone like the Ballycarra Limestone, contains a facies fauna highly reminiscent of the Caninia zone. The succeeding Dartry Limestone has developments of reef limestone within it. The Dartry Limestone itself contains Lithostrotion junceum, and Oswald collected Dibunophyllum from below the reef limestones.

Goniatites of the Neoglyphioceras spirale group occurring a few feet above the base of the Upper Series are indicative of a P_2 horizon. There is no marked unconformity between lime-

/stones

stones and shales, and an indeterminate thickness of the upper part of the limestone succession may have been laid down in D_2 times.

The occurrence of a species of Sudeticeras in association with goniatites of the Neoglyphioceras spirale group 50 feet above the base of the shales, and of Sudeticeras alone 200 feet above the base of the shales, confirms that the lowermost 200 feet of the Upper Series, at least, belong to the P_2 zone. In shales 300 feet above the base of the Upper Series, specimens of a species of Eumorphoceras of a type suggesting a low E_1 zone occur. The precise position of the P_2-E_1 boundary is uncertain; and the age of the higher strata, from which no fossils have been obtained, remains unknown.

VI. THE SILLS

Five sills of olivine dolerite are intruded into strata of the Lower Series. All seem to be non-transgressive, the strike in each case running with that of the surrounding country rock.

The lowest, in terms of stratigraphical horizon, occurs between Lough Mallard and Derrycoosh, some 2½ miles west of Castlebar. The sill is just over ½ mile in length, and reaches a maximum thickness of approximately 35 feet. It is intruded at the base of the Carboniferous Basal Sandstone, and lies between it and the underlying pebbly sandstones of the Old Red Sandstone series.

A sill exposed for a mile with a maximum thickness of approximately 30 feet is intruded into the Basal Sandstone some 40 feet above the base, ¼ mile south of the village of Park 5 miles north-east of Castlebar.

Two sills follow the junction of the Lough Akeel Oolite and the Castlebar River Limestone. Of these the smaller lies just south of Dooncastle, 2½ miles east of Westport, and is just over ½ mile in length, and about 30 feet in maximum thickness. The larger runs a total distance of 4⅝ miles east-north-eastwards to the village of Turlough. It reaches a maximum thickness of about 100 feet. Its outcrop follows a topographically long, low ridge.

The fifth sill is intruded into the limestones of the Aille Limestone group, 200 feet above the base of the group, at Knockatemple, 2½ miles west-south-west of Bohola. It is ¾ mile in length, and reaches a maximum thickness of approximately 40 feet.

The sills are all composed of the same type of olivine

/dolerite.

dolerite. The augite in all sections examined is titaniferous, the colouring being sufficiently strong in some sections to warrant use of the term "titanaugite". The augite encloses the laths of plagioclase in typical ophitic texture. The olivine is quite unaltered in unweathered specimens.

An exposure in the bed of the Clydagh River at the eastern end of the northern side of the sill south of Park, 5 miles north-east of Castlebar, shows a contact of the sill with the Basal Sandstone. The effects of the sudden chilling of the magma extend for several feet into the sill, with the formation of a black, almost opaque, basic glass, containing small crystals of plagioclase and augite, in imperfect variolitic texture near the contact, and in intersertal texture farther away.

The contact-metamorphic effects of the sill extend for only a few inches into the sandstone, which is indurated and the original bedding is obscured. Thin sections reveal the rock to have been shattered close to the contact, most noticeably along a series of planes inclined at a low angle away from the sill. These shatter-planes are infilled by calcite. Boundaries between quartz and felspar are crenulate, due to corrosion. The felspars themselves are clouded, an effect which seems to be due to the growth of a great number of tiny inclusions.

Close to the contact the spaces between the sandstone grains are often occupied by "strings" of small magnetite crystals, and large skeletal crystals of ore material, are developed in the sandstone at the actual contact.

No contacts between sills and limestones were seen on the area, everywhere they are obscured by drift or overburden.

Dolerites of a similar petrographic type to those of the sills are represented both in areas of Carboniferous and of

/Tertiary

Tertiary igneous activity in Britain. The sills possess no feature which would lend itself to their being ascribed to one period rather than the other.

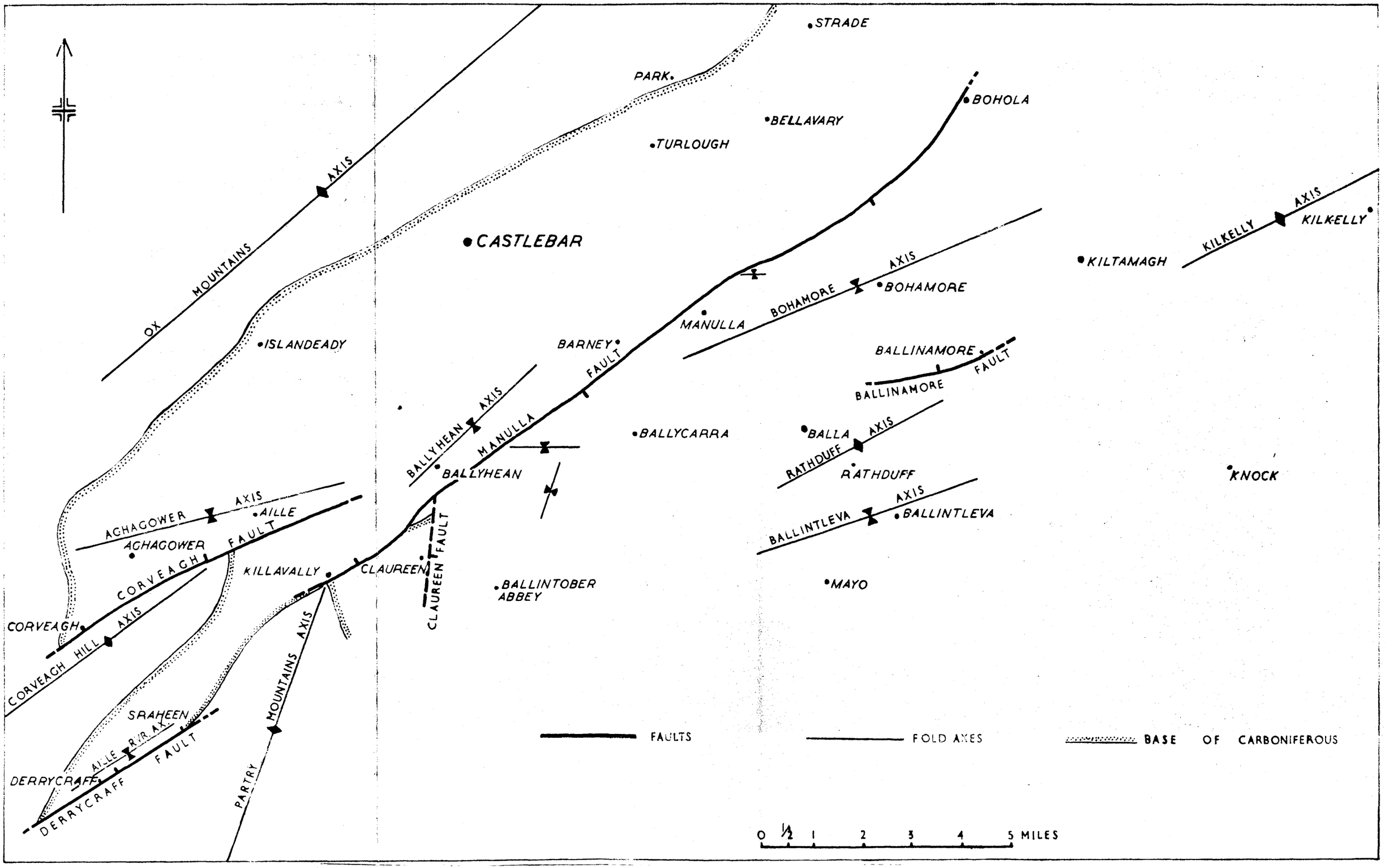

Figure 6. Structural map of the Castlebar Syncline showing fold-axes and faults

VII. STRUCTURE

(a) GENERAL

The map reveals the structure of the area to be essentially that of a syncline having a variable degree of pitch in a general east-north-easterly direction. In detail a number of subsidiary folds complicate the major structure, and there has been some disturbance by faulting. The structures are of Armorican age, however, over most of the area both folding and faulting show a general Caledonoid trend paralleling the Ox and Curlew Mountain axes (Fig. 6, opposite).

The Carboniferous rocks of this part of North-West Ireland overstepped the axes of the Ox, Curlew and Partry Mountains. During one or more phases of the Armorican orogeny strong NW.-SE. compression on the metamorphic basement rocks first resulted in the folding of these basement rocks and the overlying Carboniferous strata into a number of broad synclines with intervening anticlines. The synclines, of which the Castlebar syncline is one, are now occupied by Carboniferous strata, while erosion has removed much of the Carboniferous cover over the anticlinal axes. Thus the northern side and western tip of the Castlebar syncline are bounded by a rim of metamorphic rocks, except in the region a few miles north-west of Castlebar, where the metamorphic rocks still carry a cover of Old Red Sandstone strata.

When the faults of the area are studied in a direct relationship to the Carboniferous strata they affect they sometimes exhibit considerable obliquity to the strike of the latter, nevertheless they show a general parallelism to the anticlinal axes of the Ox and Curlew Mountains over most of the

/area

area and to the axis of the Partry Mountains in the south-west of the area. With respect to the overall pattern of folding they are in fact strike faults, fracture having taken place parallel to the uprising anticlinal axes. The Corveagh Fault is associated with the uprising of the Corveagh Hill axis; the Manulla Fault east of Ballyhean with the uprising of the Ox Mountains axis; the Ballinamore Fault with the uprising of the Curlew Mountains axis; and the Manulla Fault west of Ballyhean, the Claureen Fault, and the Derrycraff Fault with the uprising of the Partry Mountains axis. The faulting took place after the initial gentle synclinal folding, as a result either of fracture in the basement rocks consequent on increasing deformation or of differential movement of the basement and the overlying Carboniferous rocks. The Ox Mountains are bounded on their northern side by a fault parallel to their axis (Oswald 1955), and a series of faults parallel to the axis exists in the Ox Mountains themselves.

The structures in the basement of relatively rigid metamorphic rocks were therefore the major controlling influence in the development of structures in the overlying Carboniferous rocks of this area.

In the south-west of the area, in the Ballintober-Ballycarra region, the folding swings through a NW.-SE. to a N.-S. direction; again controlled by the underlying structures, the nature of which is revealed in the metamorphic rocks of the nearby Partry Mountains, whose axis has a general NNE.-SSW. direction. The rocks of the Partry Mountains have many faults parallel to the axis, and it is to this series of faults that the Claureen Fault belongs, mechanically at least, and possibly in age also.

(b) THE FAULTING

Five normal faults affect the rocks of the area (Fig. 6, p.87):-

1. The Corveagh Fault at the western end of the area. The maximum measurable throw of this fault is approximately 500 feet, in the region south of Aille.
2. The Derrycraff Fault, in the extreme south-west of the area. The throw of this fault is at least 100 to 150 feet, east of Derrycraff.
3. The Claureen Fault, south of Ballyhean. The downthrow on the eastern side of this fault remains roughly constant at approximately 900 feet throughout the whole of that part of the fault lying inside the area.
4. The Manulla Fault, which extends across the area from Killavally in the south-west to Bohola in the north-east.

West of the junction of the fault with the Claureen Fault (Fig. 3, p.29), the downthrow is to the northern side, being at a maximum of at least 900 feet immediately west of the junction. Westwards from the junction the throw gradually decreases and the fault is thought to die out in the Carboniferous Basal sandstones of the Aille River valley south-west of Killavally.

Immediately east of the junction with the Claureen Fault the throw is probably very slight. There are no exposures to the southern side of the Manulla Fault here, and it is impossible to be sure which side is downthrown. The presence and position of the fault are clearly indicated by the course of a valley produced by erosion along the fault plane. This valley has to its northern side a persistent low fault scarp. Tracing the

/fault

fault still further eastwards into the country south-west of Ballyhean, it is possible to say with certainty that the southern side of the fault is the downthrow side. Further east the southern side of the fault remains the downthrow side until the fault leaves the area at Bohola. The throw reaches a maximum at Boleyard, approximately 3 miles south-west of Bohola, where it is approximately 1,600 feet. From this point the throw shows a gradual diminution eastward, and at Bohola it is approximately 900 feet.

An exposure of the fault-plane itself, the only exposure of a fault-plane on the area, occurs ½ mile east-south-east of Ballyhean, (Fig. 3, p. 29). The exposure measures approximately 20 feet in a direction at right angles to the fault and is wholly composed of brecciated limestone, (originally crinoidal limestones of the Barney Limestone), which has been recemented by calcite. No trace of original bedding or other structures remains, the limestone fragments are extensively recrystallised, and the only fossils observed were rare comminuted crinoid fragments.

The effects of the Claureen Fault, and of the Manulla Fault west of the junction of the two faults, are closely connected. Between them lies a triangular horst-like block of schistose Lower Paleozoic rocks, carrying over much of their surface an unconformable thin "skin" of Carboniferous Basal sandstone.

5. The Ballinamore Fault. Where this fault brings limestone of the Ballycarra Limestone against shales of the Upper Series the throw is approximately 400 feet.

Much of the outcrop of the shales and sandstones of the Upper Series lies in the graben between this fault and the eastern part of the Manulla Fault.

/On the

On the geological map of north-west Ireland as a whole, the sandstones and shales of the Upper Series, the highest beds of the Castlebar syncline, appear to lie on a westward continuation of the Curlew Mountains axis. However, the anticlinal axis at the eastern end of the Curlew Mountains turns fron an E.-W. to an almost NE.-SW. direction, and the rocks of the Upper Series lie on the axis of the syncline between the anticlinal axes of the Ox and Curlew Mountains. The position of the rocks in the graben between the faults has assisted in their preservation in their present position. The two faults lie sub-parallel to the strike of the general folding and are related to the latter, the Manulla Fault east of Ballyhean being a fracture associated with the uprising of the Ox Mountains axis, and the Ballinamore Fault with that of the Curlew Mountains axis. Unfortunately owing to lack of exposures there is no evidence as to how far the Ballinamore Fault continues into the limestone country around Kiltamagh.

(c) THE FOLDING

Seven subsidiary fold axes may be recognised (Fig. 6, p.87):-

1. The Aille River synclinal axis in the extreme south-west of the area. At the south-western end of this axis associated minor anticlinal and synclinal axes to the north-west have resulted in a marked widening of the outcrop of the Carboniferous basal sandstones.
2. The Aghagower synclinal axis at the western end of the area. This unites with the axis of 3. below, west of Ballyhean.
3. The Ballyhean synclinal axis.
4. The Bohamore synclinal axis, running NE.-SW. across the outcrop of the Upper Series.
5. The Kilkelly anticlinal axis, at the eastern end of the Curlew Mountains.
6. The Rathduff anticlinal axis, south of Balla. This appears to be a continuation of the Kilkelly axis, but there are no exposures between Rathduff and the Carboniferous basal sandstones of the western tip of the Curlew Mountains.
7. The Ballintleva synclinal axis, north of Mayo. This axis may run eastwards into the region of the exposures south-east of Knock.

In addition to the above many relatively minor fold axes affect the rocks of the area. Prominent among these are the N.-S., NE.-SW., and E.-W. axes of the region south of the Manulla Fault west of Ballycarra. The folding on E.-W. axes south of the Manulla Fault 2 miles west of Ballycarra, is secondary folding produced by movement on the fault-plane. Between the

/northern

northern end of the reef limestone and the Manulla Fault (2 miles north-east of Manulla), a small syncline with an ENE.-WSW. axis is also a secondary folding effect produced by movements on the fault-plane (Fig. 4, p. 62). The dips on the limbs range up to 45° and the shales of the Upper Series are preserved on the axis of the syncline. A little east of Barney movement on the Manulla Fault has produced a reversal of regional dip on each side of the fault-plane. Elsewhere the effect of the faults has been a steepening of an already-existing regional dip.

Except in the neighbourhood of the faults the angle of dip is usually low. Five to ten degrees of dip is usual for rocks of the Lower Series where these crop out, except the reef limestones which exhibit dips up to twenty five degrees. Up to fifteen degrees of dip is usual on the outcrop of the Upper Series, except at the western end of the outcrop, where the shales rest on the bedded limestones overlying the reef, and where the dip averages twenty five to thirty degrees.

The shales of the Upper Series, as mapped, appear to show, considerable local folding. The apparent diversity of dips occasionally exhibited over quite a small area may be due to puckering of the incompetent strata, and in part to surface disturbance of the strata by glacial action.

VIII. HISTORY OF DEPOSITION

Though the conglomerate at the base of the Carboniferous rocks of this area is quite thin, and the basal sandstone of only moderate thickness and lacking current bedding; yet the pebble beds of the basal sandstone and the coarse deposits of angular quartzes which overlie the basal sandstones in the north of the area, and the current-bedded nature of the Lough Akeel Oolite, suggest that the sea which covered the area in Mid-Avonian times could not, at first, have been of any great depth. At this stage of the geological history the deposits were accumulating in a sea, which though shallow, overstepped the pre-Carboniferous rocks of the present-day Ox Mountains, as well as those of the mountains of the country south of Clew Bay, as is shown by the presence of the two outliers of Carboniferous basal conglomerate on the Fornamore plateau, 6 miles south-west of Derrycraff, which rest horizontally and with unconformity on the Lower Paleozoic rocks (Turner 1952). Deposition was at this time taking place north of the Ox Mountains in the Clew Bay, Ballina, and Sligo synclines.

The Carboniferous limestones accumulated in what finally became a deep basin of sedimentation, the limits of which extended far beyond the confines of the area which forms the subject of this thesis. Oswald (1955) has noted that in the eastern part of the Sligo syncline the Ox Mountains axis exerted an anticlinal effect during the deposition of the strata, resulting in a thinning of the lower members of his succession. The axes of the Ox and Curlew Mountains did not make their presence felt in the Castlebar area during the laying down of the sediments, but the pebble beds of the Lough Akeel Oolite,

/which

which thicken northeastwards, suggest a source of detritus lying north-east of their present outcrop, and are a possible reflection of the anticlinal effect noted by Oswald. The Aille Limestone in the region between the faults north of Killavally appears to be reduced to two-thirds of the thickness developed on the north crop of the group between Aghagower and Bohola, though the rocks do not differ lithologically from those of the north crop. The "mud-pellet" limestones of the Castlebar River Limestone, the abundant coral faunas of the Aille and Barney Limestones, the presence of oolitic horizons, and the frequency of detrital quartz throughout these members, are a demonstration of the shallow-water nature of the deposition.

That conditions during Mid-Visean times became even more shallow is indicated by the development of oolitic horizons in the upper beds of the Barney Limestone, and by the occurrence of graded-bedding structures in the fragmental limestones, consequent on sharp changes in current velocity in a shallow-water environment. These features foreshadow the conditions under which the Ballyhean Oolite was laid down. The beds both immediately underlying and overlying the Ballyhean Oolite contain Composita ficoides, the overlying beds having Davidsonina carbonaria also. There therefore seems a possibility of the correlation of the Ballyhean Oolite with the shallow-water "Calp" sandstones of the Sligo and Omagh synclines (Oswald 1955 and Simpson 1955). In the Omagh syncline the Clonelly ("Calp") Sandstone, a mainly calcareous sandstone, contains developments of sandy oolitic limestone, and from it Simpson records Davidsonina carbonaria and Composita cf. ficoides.

Following this phase there was a gradual return to conditions of rather deeper water. The lower beds of the Ballycarra

/Limestone

Limestone have thin beds of oolite, and there is a development of shallow-water, mud-pellet limestones 50 to 80 feet above the base of the group. As during the laying down of the Aille and Barney Limestones, conditions during the deposition of the rest of the Ballycarra Limestone remained relatively shallow. Detrital quartz is a constant feature of the limestones, which have a rich fauna of corals, none of which show evidence of having moved far, if at all, from position of growth. The fine-grained crinoidal limestones of all but the lowest 100 feet contain beds consisting largely of coarse crinoid debris. The rapid changes in grain size in these beds, both laterally and vertically suggest the equally abrupt changes in current velocity associated with a shallowing of deposition.

The latter conclusion is strengthened by consideration of the types of lithology exhibited by the strata of the Balla Limestone. These fine-grained dark limestones, which have developments of oolite, mud-pellet rocks, and calcareous shales throughout, have all the appearances of a shallow-water deposit laid down under relatively tranquil conditions. The fauna, though sparse, is however that of an open-sea rather than an estuarine, brackish, or lagoonal deposit.

No exposure showing lateral or vertical passage of the bedded Balla Limestone into reef limestone exists, but the vertical passage from reef limestone into bedded limestone is seen at the western side of the reef. The knoll-like form of the reef is a sedimentation feature, the bedding at the northern end of the reef closely follows surface topography (Fig. 4, p.62), and the present topography represents to some extent at least the original upper surface of the reef.

The succeeding shales show little or no angular unconformity

/with

with respect to the Balla Limestone, yet the junction, though nowhere exposed, must be an abrupt one. If, as in the Sligo syncline to the north (Oswald 1955), the reef and the bedded limestones in which it is developed are of D_1 age, then the stratigraphical break between limestone and shale represents at least the whole of the D_2 (P_1) zone. If limestones of D_2 age are present here, then the break is relatively smaller.

The Bollandian and Namurian rocks of this area are typical shallow-water shales, mudstones, siltstones and sandstones, having in the lowermost third a sparse goniatite-lamellibranch fauna. The lowest mudstone-shale group appears to be persistent, unlike the lowest shales of the Glenade beds in the Sligo syncline (Oswald 1955) which are overstepped by the succeeding sandstone.

The onset of this sandstone-shale sedimentation phase in North-Western Ireland is diachronous, being later in this area than in the Cuilcagh and Clogher-Slieve Beagh areas (Padget 1953, 1951), 50 to 80 miles to the east. The fauna of the lowest shales of the "Yoredale Beds" of the Clogher-Slieve Beagh area, about 80 miles east-north-east of Castlebar, (Padget 1951), is indicative of a B_2 age for the beds. On Cuilcagh mountain 50 miles east-north-east of Castlebar the lowest shales, which overlie 300 to 400 feet of "Yoredale sandstone", contain a P_{1b} zone fauna, (Padget 1953). Padget suggests that the underlying sandstone may be, in part at least, of P_{1a} age. In the Castlebar syncline the lowest shale is of P_2 age. Thus the onset of the phase seems from a consideration of the three areas, to be progressively later westwards - an offlap phenomenon implying relative uplift, first in the east and then travelling westwards with a gradual retreat of the sea to the west.

/The fact

The fact that the sandstones of the Upper Series become finer in grain-size, thin, and finally die out to the north and east suggests a source of supply of material to the south-west of the present outcrop, possibly in the region of, or beyond, the Galway massif.

IX. ACKNOWLEDGEMENTS

The writer wishes to express his gratitude to his supervisor, Professor T. Neville George, for his guidance, and a wealth of constructive criticism at every stage of the work. He wishes to express his thanks also to Dr. E. D. Currie and Dr. J. Weir for their assistance in the identification of the Bollandian and Namurian faunas.

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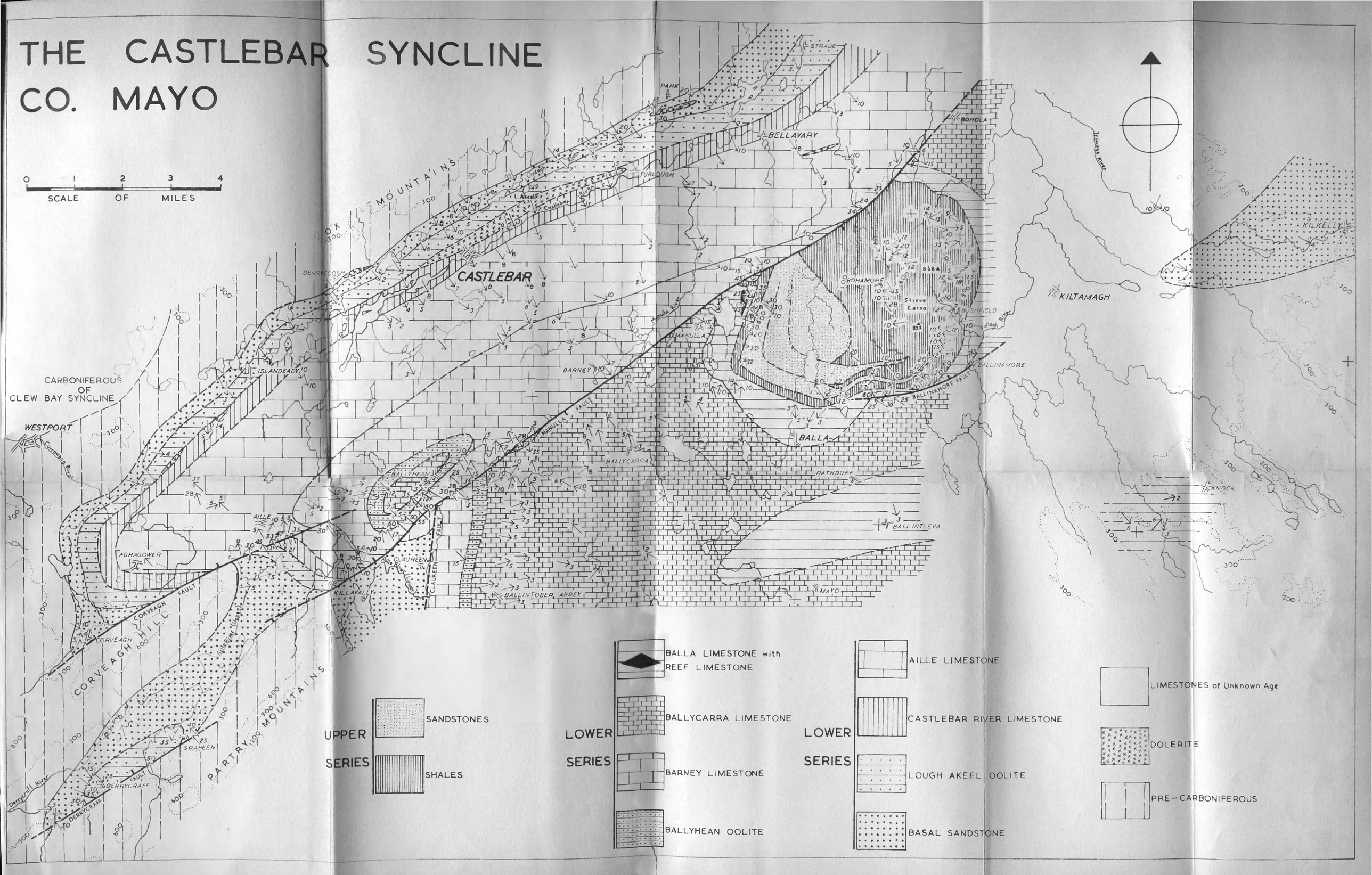
THE CASTLEBAR SYNCLINE
CO. MAYO



THE GEOLOGY OF THE CASTLEBAR SYNCLINE, CO. MAYO.

by

JOHN E. BRINDLE.

SUMMARY

The Castlebar syncline of Carboniferous rocks lies in the southern half of County Mayo, Eire, and forms a variably pitching downfold between the Ox Mountains anticline and an echeloned extension of the Curlew Mountains anticline. The area mapped extends from the village of Strade in the north to an east-west line running a little south of the town of Mayo, and also includes the Carboniferous rocks of the upper valleys of the Aille and Derrycraff Rivers, west of the Partry Mountains. The area as a whole is low-lying, the greater part being less than 300 feet above sea level. The sandstones and shales of the highest beds form two north-and-south ridges in the east-central part of the area, the eastern ridge, which rises to over 800 feet above sea level, being the highest ground of the area.

The Carboniferous strata rest unconformably on a basement of Dalradian schists, Silurian schists and schistose grits, and pebbly red sandstones and conglomerates of the Old Red Sandstone period.

The following succession of Carboniferous rocks has been established:

	14. Sandstone 200 to 0 feet.	LOWER
	13. Shale 0 to 350 feet.	NAMURIAN
UPPER	12. Sandstone 300 to 0 feet.	AND
SERIES	11. Shale 0 to 350 feet.	UPPER
	10. Sandstone 240 to 0 feet.	BOLLANDIAN
	9. Shale 100 to 400 feet.	
	DISCONFORMITY	
	8. Balla Limestone (including reef limestones) 200 feet.	
	7. Ballycarra Limestone 550 feet.	
	6. Ballyhean Oolite 80 feet.	CARBONIFEROUS
LOWER	5. Barney Limestone 300 feet.	LIMESTONE
SERIES	4. Aille Limestone 450 feet.	(VISEAN)
	3. Castlebar River Limestone 160 feet.	
	2. Lough Akeel Oolite 150 feet.	
	1. Basal Sandstone 80 to 150 feet.	

The fossils of the Basal Sandstone are confined to the uppermost beds. Fossils are scarce in the two Oolites and in the fine-grained, shaly Castlebar River Limestone. The Aille, Barney, and Ballycarra Limestones are crinoidal limestones having a rich coral-brachiopod fauna throughout, that of the Aille Limestone indicating a C_2S_1 age for that part of the succession. Typical S_2 zone fossils are present in the upper levels of the Barney Limestone and in the lower beds of the Ballycarra Limestone. The uppermost 150 feet of Ballycarra Limestone, together with the Balla Limestone (a shallow-water deposit of calcite-mudstones, oolites, "mud-pellet" rocks and thin shales, contain a D zone fauna, as do the reef limestones.

In the west of their outcrop, with the exception of the shales and mudstones of the lowest group, the whole thickness

/of the

of the Upper Series is made up of unfossiliferous sandstones divisible into three groups. Each sandstone group thins eastwards, and the sandstones finally divide into three distinct beds with intervening shales. Each sandstone group shows a gradual eastward diminution in grain-size. In the east of the outcrop the full thickness is made up of black shales, mudstones and rare siltstones.

The shales and mudstones have a sparse fauna of goniatites and lamellibranchs. Goniatites collected from the lowermost 200 feet of shales, both in the east and west of the outcrop indicate an Upper Bollandian (P_2) age for the containing beds. About 250 feet above the base of the shales low E_1 zone goniatites were collected from an exposure in the north of the outcrop. No fossils were found at any higher horizons and the age of the upper beds remains uncertain.

The rocks of the area are folded into a series of major and minor folds. The fold axes generally have an ENE.-WSW. or NE.-SW. trend, except in the south of the area, just east of the Partry Mountains, where the fold axes swing round to a N.-S. direction, paralleling the axis of the Partry Mountains.

Five major normal faults are present. Of these, four have the general ENE.-WSW. or NE.-SW. trend. The fifth, in the district east of the Partry Mountains referred to above, is a N.-S. fault.

Except in the neighbourhood of the faults, dips generally are slight, ranging up to 10 degrees in the Lower Series, where these crop out, and up to 20 or 25 degrees on the outcrop of the Upper Series.

The geological history of the area begins with a mid-Avonian marine transgression, noted elsewhere in North-Western Ireland.

/The rocks

The rocks of the Lower Series were laid down under open-sea, fairly shallow-water conditions. During Mid-Visean times conditions became temporarily even more shallow, when the Ballyhean Oolite was deposited. At about this time the shallow-water Calp Sandstone was being laid down elsewhere in North-Western Ireland. The cross-bedded nature and rapidly fluctuating grain-size of the highest beds of the Ballycarra Limestone are an indication of shallow-water conditions. The deposition of the Balla Limestone, a shallow-water sediment with mud-pellet rocks and fine-grained oolites in addition to the very fine-grained black calcite-mudstones, and a development of reef limestone north-east of Manulla, brought to a close conditions of calcareous sedimentation. Though no marked angular unconformity is apparent the lowermost shale of the Upper Series rests with an abrupt junction on the Balla Limestone.

Apart from the glacial deposits, (mainly boulder clay), and the extensive developments of peat - both of which obscure the nature of the underlying rocks in some parts of the area - no deposits younger than Carboniferous exist in the area.

Five non-transgressive sills of olivine dolerite, which may be of either Permo-Carboniferous or Tertiary age, are intruded into the rocks of the Lower Series near the northern edge of the syncline.