DINANTIAN ROCKS OF THE ARDFINNAN-MITCHELSTOWN SYNCLINE, COUNTY TIPPERARY

By

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CONTENTS

P L A T E S

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I. INTRODUCTION

The Ardfinnan-Mitchelstown syncline, containing rocks of Dinantian age, is situated in south county Tipperary, Ireland (see fig.1.).

Topographically the syncline forms a valley limited to the north and south by approximately east-west trending mountains of Old Red Sandstone, which are anticlinal — the Galtee mountains to the north and the Knockmealdown mountains to the south. Both ranges have peaks of over 2000 feet and are distinctive because of their steep northern faces and much more gradual southern slopes. The height of the Knockmealdowns gradually declines to the west, which is the direction of pitch of this complex Old Red Sandstone anticlinorium.

Except for small outliers of the Upper Shale Group forming elevations of up to 500 feet, the valley is composed of limestones and is less than 300 feet above sea level. Topographically there is a pronounced east-west grain which, though modified by glacial deposits, reflects the underlying Armorican fold system.

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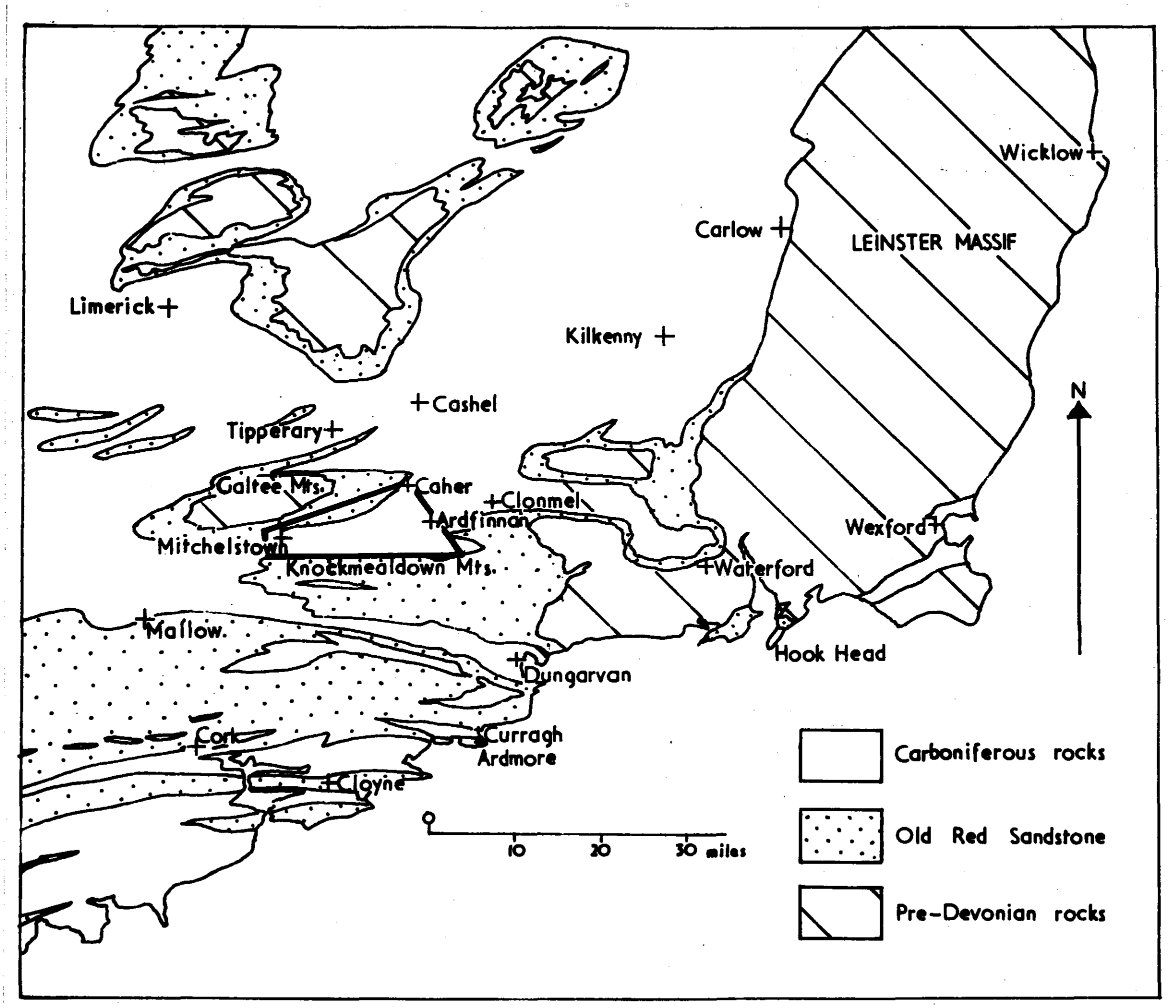

Fig.1.

A map to illustrate the setting of the Ardfinnan - Mitchelstown syncline in Southern Ireland.

At the eastern extremity of the area, defined by the river Suir, the floor of the valley is approximately eight miles wide, but narrows to three-and-a-half miles at Mitchelstown in the west. The valley progressively narrows in the direction of pitch of the synclinorium.

Dinantian rocks of the southern part of Ireland are little known apart from the primary investigations undertaken by the Geological Survey in the 1850's. The one mile map of the Ardfinnan-Mitchelstown syncline (sheet numbers 165 and 166) was published in 1857 and revised in 1879. No faults were recorded and the complexity of folding is not apparent from map or section.

In the memoirs accompanying these sheets (Geological Survey of Ireland, 1858, A and B) the Dinantian was divided into four units containing rock-suites described in terms of colour, coarseness of grain, bedding, fracture and presence or absence of chert. Fossils were not recorded. The sequence of these four rock groups is misleading, particularly with respect to the Lower Limestone of the Survey, which

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from descriptions of lithology and references to outcrop positions (as at Ardfinnan - Geological Survey 1858A, p.19) is clearly equated with Reef Limestone of this thesis. A comparison of the Geological Survey succession and that now proposed is seen in figs. 2 and 3.

Kinahan (1878, p.71) included a chapter on Lower Carboniferous rocks in which he described a succession for "Limerick and adjoining portion of Tipperary". With some differences of thickness, this succession was the same as that recorded by the Survey.

The only systematic stratigraphy since the Survey is that of Douglas (1909) on Clare, Smyth (1930) on Hook Head, Turner (1937) and (1939) on Cork and Ashby (1939) on Limerick, all areas where the sequence, though broadly uniform, differs in significant detail from that of the Ardfinnan-Mitchelstown ground.

In county Clare, Douglas (1909, p.542) recorded "massive grey and mottled limestones containing abundant bryozoa", from 450-1000 feet thick and of Waulsortian age (C zone). This rock type has been referred to as

/reef

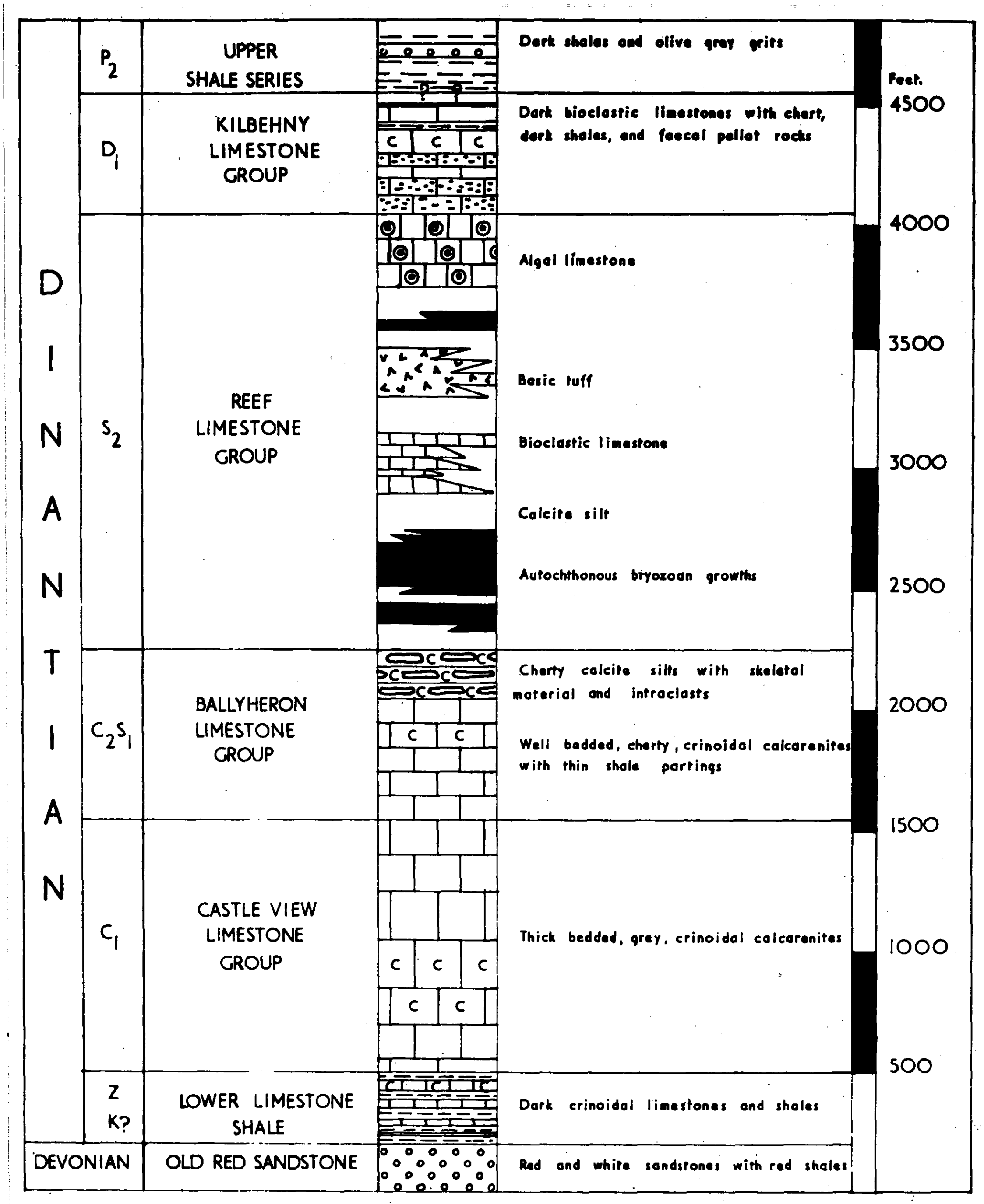

Fig.2.

A generalised succession of Dinantian rocks in the Ardfinnan - Mitchelstown syncline as proposed in this thesis.

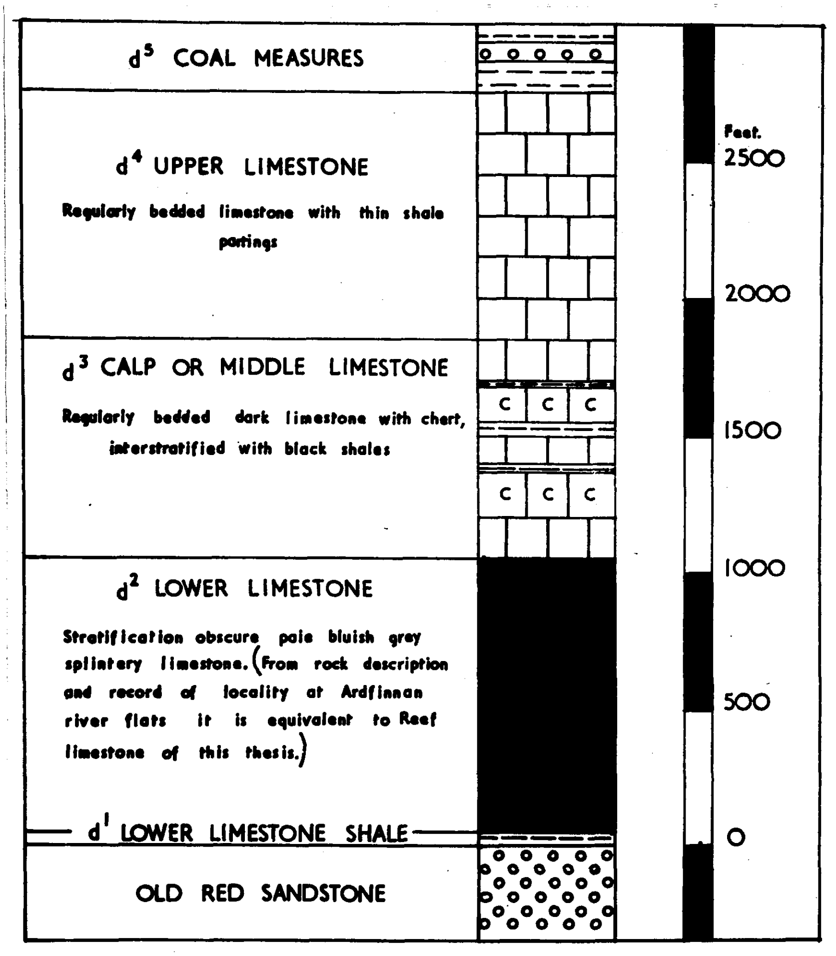

Fig.3.

Generalised succession of Dinantian rocks in the Ardfinnan - Mitchelstown syncline proposed by the Geological Survey 1858. The lettering of the rock divisions differs on the Survey map from the accompanying Survey memoir. The letters (d^1,d^2,d^3, d^4,d^5) shown on this figure are as contained in the memoir. On the one mile survey map, the corresponding figures are (d^1,d^2,$d^{2'}$,$d^{2''}$,d^3,).

reef limestone by later writers. 2000 feet of reef limestone recorded by Turner (1937, p.197) at Little Island Cork were also stated as belonging to C zone. Ashby (1939, p.324) named a lithological division "Fenestrellina Reef Limestone Group" (thickness 600 ft.) at Limerick and placed it in C zone.

To the north, west and south of the Ardfinnan-Mitchelstown syncline a thick development of reef limestone has been reported and in all cases assigned to C zone. Palaeontological evidence from macrofossils and microfossils indicates that the Reef Limestones (~~minimum~~ thickness 1500 feet) of the Ardfinnan-Mitchelstown syncline are to be included in S_2 zone.

II. SUCCESSION

A lithological subdivision of the rock sequence into stratal groups is probably of only local significance; but the groups are given local names to avoid the confusion arising from such general terms, differently used and applied to rocks of different ages in different areas, as "Calp", "Middle Limestone" and "Upper Limestone", of 19th century origin.

Though it is unfortunate that new stratal terms add to an already extensive terminology in Ireland for beds equivalent in age, only when a more accurate zonal stratigraphy is known may many of these local names be usefully eliminated and a more comprehensive synthesis made.

In Section III the fossil assemblages are outlined and these allow an approximate correlation of the lithological divisions with Vaughan's zones of the South Western Province.

A generalised subdivision of the Lower Carboniferous rocks of the Ardfinnan-Mitchelstown syncline proposed in this thesis is summarised in fig.2, and that proposed by the Geological Survey 1858 in fig.3.

1. Lower Limestone Shale

This term was used by the Survey for the limestone with shale beds overlying the Yellow Sandstone and is retained here, although time equivalence with similarly named units in other areas is not necessarily implied.

The contact between Old Red Sandstone and Lower Limestone Shale is not exposed within the Ardfinnan-Mitchelstown syncline, but is well displayed 7 miles south of Mitchelstown in a section above Araglin bridge. It is also exposed 4 miles east of Ardfinnan at Knocklofty bridge. In the Araglin bridge section an abrupt upwards change occurs from massive sandstone beds with no shale, to dark sandy shales with ribs of dark crinoidal limestone a few inches thick (see pl.1, fig.2.). There is no angular unconformity, but between the sandstone, and shale with limestone, there is a thin impersistent conglomerate with well rounded pebbles. In places the conglomerate is 6 inches thick, but within a few feet may thin away completely. Some 16 ft. above the conglomerate is a sandstone bed 2½ feet thick

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Plate 1.

Plate 1.

Fig. 1. Locality - north of Araglin bridge, 7 miles south of Mitchelstown. The photograph illustrates a $2\frac{1}{2}$ foot sandstone bed, which is 16 feet above the Sandstone-Limestone Shale contact seen in fig.2.

Fig. 2. Locality - as for fig.1. This illustrates the abrupt upwards change from massive sandstone beds (of "continental" Old Red Sandstone facies) to dark sandy shales, with ribs of dark crinoidal limestone a few inches thick.


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(see pl.1. fig.1.). In ascending the succession dark crinoidal limestone beds become thicker and more frequent, while the dark shales correspondingly thin. Approximately 200 feet above the conglomerate, shale partings are inconspicuous or absent and this is taken as the upper limit of the Lower Limestone Shale. At this point individual beds vary from 3 to 6 feet in thickness.

The Lower Limestone Shales are well exposed in a section south of Ardfinnan and immediately east of Lacken House, although not actually exposing the Sandstone-limestone Shale contact, and also at the Mitchelstown end of the syncline in a series of quarries near Geeragh bridge.

In hand specimen many of the crinoid ossicles in the dark shaly crinoidal limestone beds are pale coloured and stand out conspicuously against the darker matrix of the rock. Fossil corals and brachipods are silicified and weather out in relief along with chert ribs which follow bedding planes in the limestones. Bryozoan fragments are abundant in both limestone

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and shale. Weathered surfaces have an earthy or sandy brown appearance. The dark interbedded shales are sharply demarcated from the limestones and splinter along planes of fracture cleavage (see pl.2, fig.2.). Some of the thinner shales seen south of Ardfinnan are lenses and when traced laterally wedge out (pl.2, fig.1.).

In thin section the bulk of the detrital material in the limestone beds is seen to be skeletal fragments from crinoids, bryozoans, zaphrentoid corals and echinoids. These skeletal particles are in a silty matrix and the proportion of particles to matrix is highly variable. Foraminifera have a restricted distribution, but locally are abundant. Foraminifera and bryozoans are not silicified while commonly other fossil fragments are. Silt grade particles of quartz (10-15 u) and, less abundantly, plagioclase feldspar are distributed through the rock.

The matrix is dominantly shaly material and fine grained calcite (5-15 u). Sparry calcite occurs as a drusy growth within some bivalve shells, but is not

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present in the matrix of the rock as a cement (unlike the overlying Castle View Limestone). Rim cementation of crinoid ossicles is not apparent, not even where there is a concentration of coarse crinoid plates in contact. The shaly beds have a restricted content of skeletal material which is largely bryozoan and crinoid fragments, deformed by the more intense shearing which has affected these less competent beds (pl.2, fig.2.).

2. Castle View Limestone Group

The Lower Limestone Shales grade upwards into the Castle View Limestone, which is well exposed in an anticlinal structure along the west bank of the Suir between Castle View House, Ardfinnan, and Ballydrinan grave yard. At the core of this anticline the underlying Lower Limestone Shales are not seen, which makes the 800 feet of limestone exposed a minimum value for the thickness of this division.

The Castle View Limestone Group is composed of massive rocks in beds varying from 4 to 12 feet in thickness (see pl.2, fig.3.), grey crinoidal calcarenites

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with occasional irregular pockets of chert. Interbedded shales are absent or inconspicuous. Except for a content of coarser crinoid debris, the lower part of the group is similar in hand specimen to the upper. Orange coloured patches of iron stained dolomite are seen following shear planes and occupying the positions of pre-existing fossil structures, commonly small gasteropods. This patchy development of dolomite is also seen in the overlying Ballyheron Limestone.

Limestones from this group seen in thin section are largely composed of abraded crinoidal, and to a lesser extent foraminiferal, debris which in contrast to the material in the Lower Limestone Shale is cemented by clear sparry calcite (see pl.3, fig.1.). Rim cemented crinoid ossicles are abundant (see pl.5, fig.1.). As well as skeletal fragments there are dense rounded and elliptical masses composed of fine granular calcite, occurring both as separate structureless globules and in places surrounding and occupying spaces within abraded skeletal fragments (pl.3, fig.1.). This

/occurrence

occurrence partly as a coating to abraded skeletal particles is similar to oolitic structure except that in this case the coating is entirely granular and not fibrous. The well-defined and regular boundaries between granular calcite and sparry calcite suggests that these rims have a primary sedimentary significance, although there has probably been partial recrystallisation of both types of calcite. The masses of granular calcite, like the skeletal fragments, are set in a matrix of clear sparry calcite.

Thin sections of specimens at an average of 20 feet intervals throughout the Castle View Limestone Group, reveal that the lithology is of the same general type throughout. In the lower part of the group coarser crinoidal debris is more prominent.

In the southern limb of the Castle View - Ballydrinan anticline the limestones are sheared and have suffered extensive recrystallisation, one of the products of which is a texture of fine-grained calcite selectively replacing larger calcite plates along planes of shearing and twin planes (see p.55).

3. Ballyheron Limestone Group

The Ballyheron Limestone Group is well exposed in Lower Ballyheron Wood. It is also well exposed in Blackrock Wood, Cottagehill Wood and Cranna Wood. The Ballyheron Limestone is divided into an upper part 150 feet thick, and a lower part 500 feet thick, both of which are well bedded. Chert ribs following bedding are abundant in the upper part.

Hand specimens from the lower member are dark even textured calcaremites. They differ from the underlying Castle View Limestones in being better bedded, beds commonly 3 feet or less thick, in places having thin shale partings, and in being darker coloured. The very abundant rugose and tabulate coral fauna is a distinctive feature of this group. In a quarry 50 yards southeast of the Post Office Kilbehny, "lumpy" bedding is seen in beds of Ballyheron Limestone (pl.2, fig.4.).

The upper part of the Ballyheron Limestone is of particular interest because it grades upwards into Reef Limestone. This is seen in the section within Lower Ballyheron Wood. The sediments are well bedded,

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the beds being from 1 to 3 feet thick, and in hand specimen are seen as dark grey fine-grained limestones with dull lustre. Skeletal fragments are scattered through the finely crystalline matrix and the rock as a whole has a patchy appearance caused by a content of "pellets" of up to 2 centimetres length. There is a prominent development of chert ribs following bedding.

The bulk of the rock, seen in thin sections of lower Ballyheron Limestone (see pl.3, fig.2.), is composed of recognisable fragments of crinoids, corals, brachiopods, molluscs and echinoids. Foraminifera are numerous. Calcispheres and bryozoan fragments are present, but less abundant. Rim cementation of crinoid ossicles occurs and there is clear sparry calcite in the matrix along with finer grained calcite (grain size 5-50 μ). This finer grained calcite is scattered and does not form discreet particles or rims as in the Castle View Limestones. Much of it is secondary, and replaces organic fragments as well as larger calcite crystals along shear planes and twin planes; and it is the result of recrystallisation (see p.55).

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The upper part of the Ballyheron Limestone is 150 feet thick and grades upwards into Reef. It differs from the lower part in having "pellets" and in having reduced amounts of skeletal fragments and an absence of sparry calcite cement (see pl.3, fig.3.). Foraminifera are mainly tetrataxid forms. The rock is dominantly composed of fine-grained calcite (5-15 μ) in which there are skeletal particles including bryozoan and crinoid fragments, ostracods and tetrataxid foraminifera. Accompanying the skeletal fragments are irregularly rounded "pellets" composed of a similar material to the matrix, but conspicuous because of their darker colour. The similarity between "pellets" and matrix suggests that the "pellets" are penecontemporaneously reworked sediment. Objects simulating the appearance of these "pellets" can arise by recrystallisation processes, but this is not suspected in the present case because of their elongate and generally rounded nature and because of their orientation with long axes parallel to bedding.

4. Reef Limestone Group

Reef limestones are composed of organic structures in place of growth and their genesis is to be distinguished from detrital deposits, where fragments have undergone a greater or lesser degree of transportation. Interbedded bioclastics are placed within the Reef Limestone Group, although themselves not necessarily recognizable as "reef" or "reef-complex" deposits.

The important reef framebuilders of this group, which is approximately 1500 feet thick, are bryozoans and algae. The beds are massive, presumably of indefinite lateral extension, and without recognizable knoll-like structure, a development which is conveniently described as sheet-reef. Chert is usually absent, or, if present, only in small amounts. Patchy dolomitisation is extensive in places, for example at Ardfinnan.

The rock types comprising the bulk of the Reef Limestone Group are as follows:- fine-grained carbonate rocks with some skeletal material, reef rocks with bryozoan growths as the prominent framework, reef rocks

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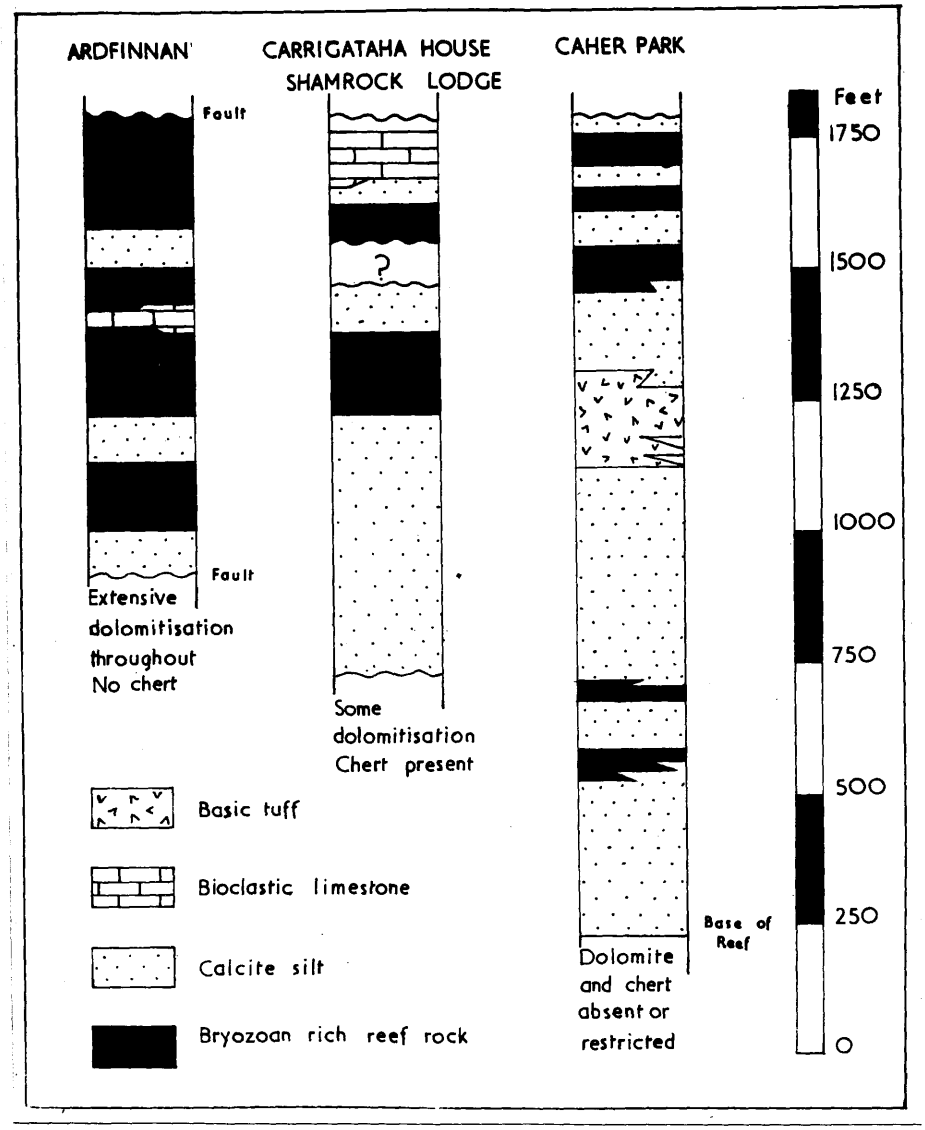

Fig.4.

Diagrammatic successions to illustrate the distribution of rock types within the Reef Limestone Group at three localities.

with algal growth and exogenous calcarenites. Other rock types of more local significance are:- breccias with selective dolomitisation of the matrix and an unusual rock of carbonate spherulites associated with volcanic ash, which happens to be interbedded in the Reef.

Fine grained carbonate rock:- In hand specimen this is a pale grey coloured, fine grained rock, splintering when fractured to give smooth surfaces with angular edges. Recognizable skeletal fragments are sparsely scattered through most specimens. Typically there are large irregular pockets of coarse calcite.

In thin section (pl.3, fig.4.) the rock is mainly fine grained calcite (5-15 u). The scattered bioclastic debris is mainly of ostracods, calcispheres, crinoid fragments and cyclostomatous and cheilostomatous bryozoans. Occasional "pellets" occur of the type described from the upper Ballyheron limestone.

Particularly distinctive are large "pockets" of coarse calcite, with sharply defined and in places

/angular

angular boundaries, which are not seen in the underlying Ballyheron limestone (see pl.3, fig.4.). These 'pockets' have no obvious supporting framework and it is not known if they are primary cavity fillings or the products of recrystallisation. The angularity of some of the boundaries and the absence of a supporting structure argue against their being original, while the abrupt and regular contact between 'pocket' and surrounding fine grained calcite make recrystallisation difficult to visualise.

Reef rocks with bryozoan growths:- Fronds of fenestelloid bryozoans in growth positions control the distribution of sedimentary textures. Surrounding the fronds there is dark granular calcite followed outwards by white fibrous calcite, giving the rock a distinctly mottled appearance. Associated pockets of light grey calcite silt show a distribution controlled by the bryozoan framework. Patchy dolomitisation is common and is seen to have selectively affected bryozoan stipes and the immediately surrounding areas (see pl.7, fig.3.). Within the rock are pockets of coarsely crinoidal material and pockets where fossils are extremely abundant, particularly brachiopods and molluscs.

Thin sections reveal that the fibres surrounding bryozoan stipes are very elongate, having a length to breadth ratio of 10:1, and taper towards the bryozoan stipes. Curved twin planes cross these crystals and are disposed with their convex surfaces towards the bryozoan framework, which presumably was the original centre of growth (see pl.4, fig.1.). Under crossed nicols undulose extinction spreads across the crystals roughly parallel to their long axes. This fibrous growth of calcite is texturally distinct from the drusy growths normally seen filling cavities, for example within bivalve shells. It is similar to the "radiaxial fibrous mosaic" of Bathhurst (1959, p.511), and to fibrous calcite growths associated with algal material (see Bradley 1928, pl.34 c.). The colour difference, so striking in hand specimen, of two zones of calcite surrounding the bryozoan stipes, is less spectacular in thin section. The zone

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immediately surrounding the stipe, dark blue in hand specimen, differs from the surrounding white fibrous calcite mainly by a difference of grain size. The material immediately surrounding the stipe is finer grained. The rock has an obvious porosity along the coarses of bryozoan stipes. In dolomitised portions, the stipes and immediately associated material have been selectively replaced, but not the fibrous mosaics.

Reef rocks with algal growth:- Algal colonies, the largest of which are around 1 centimetre by 2 centimetres are concentrated along bedding planes, with their long axes perpendicular to bedding (see pl.2, fig.5.). The colonies show a rhythmic distribution with a layer of small colonies followed upwards by progressively larger ones, and such a rhythm being repeated many times. The algal masses are of <u>Ortonella</u> and growth has been nucleated on skeletal particles and "pellets". The spaces between colonies are filled with finely divided calcite. In hand specimen it is a dark fine grained limestone.

/Three

Three basic textural elements are recognized in thin section.

Firstly, there are clearly recognizable algal filaments branching upwards roughly perpendicular to bedding (pl.3, fig.5.). These are dominantly of <u>Ortonella</u> with filaments ranging in diameter from 14.8 to 15.7 μ and with an angle of branching from 35-45°. Less obviously algal, there are many thin radial fibres of clear calcite in a matrix of microcrystalline calcite, which may be the casts of filamentous algae of a different kind.

Secondly, associated with the filamentous algae and filling the spaces between filaments are spongy masses of microcrystalline calcite. Apparently the algae were the active agents that localised the precipitation of this distinctive fine grained calcite. This is readily explained because plants extracting carbon dioxide from water can reduce the solubility of calcium carbonate to the point of precipitation.

Thirdly, occurring with spongy masses of microcrystalline calcite are layers of clear fibrous calcite

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(pl.4, fig.3.) similar to the texture already described surrounding bryozoan stipes. Within these layers of fibrous calcite neither organic structure nor microcrystalline calcite occurs and there is no evidence that the formation of this structure is definitely dependent on the algae, except that it is commonly associated with recognizable algal growths.

Between some of the algal colonies irregular fissures run approximately perpendicular to bedding and contain intraclasts and detrital fragments, including undamaged crinoid ossicles, set in a matrix of clear sparry calcite. The detrital particles indicate the penecontemporaneous nature of the fissures, while their elongate chambered form suggests they may be solution effects. That they are not primary spaces is clear because they sharply truncate algal filaments.

Breccia:- Seen locally for example 350 yards on a bearing N.153° from Carrigataha House, in a section exposed along the west bank of the Suir, angular and subrounded pebbles of calcilutite up to 4 centimetres diameter are set in a coarse dolomitised

/bioclastic

bioclastic matrix. Crinoid stems with up to ten linked ossicles are common in the matrix and skeletal particles as a whole are much less abundant in the mud pebbles than in the matrix. This breccia may be a result of shallow water wave action on reef rocks.

The distribution of rock types within the Reef Limestone Group is not precisely known throughout the Ardfinnan - Mitchelstown syncline and indeed may be highly irregular. Fig.4 illustrates the distribution of rock types within the Reef as exposed at Ardfinnan, Caher Park and an intermediate point. At higher horizons calcilutites, with at one horizon an abundant molluscan fauna including Leiopteria sp., are found and are succeeded by beds with rich algal growths.

5. Kilbehny Limestone Group

This division is named from its exposure in a quarry 1025 yards on a bearing N.116° from Kilbehny Post Office.

Dark bioclastic limestones are interbedded with pellet rocks and black shales. The detrital limestones

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in hand specimen are dark crystalline calcarenites. Many small gasteropods are locally present.

The pellet rocks are fine grained, dark coloured and have a dull appearance. There are small irregular pockets of clear calcite alined in the direction of bedding.

In thin sections the bioclastic limestones are seen to contain the remains of echinoids, ostracods, brachiopods, calcispheres, gasteropods and abundant foraminifera. These remains make up the bulk of the rock. The matrix is fine grained calcite with little or no sparry calcite.

The pellet rocks contain elongate pellets of calcite mud in line of bedding. Transverse and longitudinal sections reveal that they are elongate cylinders (average length 1 millimetre) with tapered ends, a form which suggests they are probably faecal pellets. The organisms responsible have not been identified but may have been molluscs or worms. Scattered through most of the pellets are euhedral, elongate, authigenic quartz crystals (40-160 u long) which may have grown

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from detrital quartz nuclei within the faecal pellets.

As well as the pellets, masses of fine granular calcite occur which do not have included silt particles and may be of algal origin. The pellets are set in a matrix of clear sparry calcite which encloses them in three dimensions.

6. Upper Shale Group

Dark shales near the base are succeeded upwards by regularly bedded olive grey grits interstratified with thin shales.

7. Spherulitic Limestone

This unusual rock type is of local development and is associated with a basic tuff which happens to be present within the Reef Limestone Group.

In hand specimen the spherulites, which commonly have a diameter of 1 millimetre or slightly more, appear dark and are set in a light coloured matrix of coarsely crystalline calcite. This rock type is exposed 1225 yards on a bearing N.341° from Garnavilla House.

In thin section the circular spherulites are seen to be composed of radiating fibres of calcite, while the intervening spaces are filled by euhedral quartz grains and a coarse calcite mosaic (pl.6, fig.4.). In patches some crinoid debris occurs. Where spherulites are in contact their boundaries are polygonal (pl.4, fig.2.). Some of the calcite spherulites are partly silicified. An exactly comparable texture is recorded by Muir & Walton (1957) in the East Kirkton Limestone, which occurs interbedded with olivine basalt lavas. Muir & Walton considered the spherulitic structures to have developed penecontemporaneously in a mud by hot-spring precipitation.

8. Basic Tuff

At the south end of Ballyheron Wood, one mile south of Caher on the east bank of the river Suir, a thick bed of basalt tuff crops out interbedded with reef limestones. The estimated thickness of tuff is 200 feet, yet it is not exposed elsewhere in the Ardfinnan - Mitchelstown syncline.

In thin section the lithic tuff is seen to have an abundant carbonate matrix. The rock fragments are of igneous types and are probably mainly from basaltic lavas. Some phenocrysts appear to have been of olivine, but are now represented by pseudomorphs in calcite, fibrous crysotile and magnetite. What were probably original feldspar microphenocrysts are now wholly replaced by calcite. A few crystal fragments can be recognized in addition to the lithic material; magnetite, some detrital quartz and a few grains of brown picotite spinel, which in one case shows approximation to octahedral outline and octahedral cleavage.

The orientation of lava fragments shows bedding direction. An indication that the ash constituent has been replaced locally to a considerable extent by calcite seems to be provided by the presence of two pale bands, in which the bulk of lithic fragments is lower than in the rest of the rock, which cross the bedding almost at right angles. These may well indicate the former positions of channels by which the carbonate

/solutions

solutions permeated the rock, and along which a higher degree of replacement of lava fragments resulted. The boundaries of these paler bands against the 'normal' rock are ill-defined.

Plate 2.

Plate 2.

Fig.1. Natural size. Lower Limestone Shale in Lacken House section south of Ardfinnan. A thin shaly band is seen wedging out to the right of the photograph.

Fig.2. Locality - as for fig.1. Illustrates fracture cleavage in a sequence of limestones interbedded with shales.

Fig.3. Massive beds of Castle View Limestone exposed at Garryclogher.

Fig.4. Lumpy bedding in Ballyheron Limestone exposed at Kilbehny.

Fig.5. Locality - quarry 1900 yards on a bearing N.205° from the R.C. Church Burncourt. Reef Limestone Group. Weathered surface illustrating colonies of Ortonella in line of bedding - also notice the small "mound-like" structure above hammer head.

Fig.6. Locality - 1000 yards on a bearing N.117° from Kilbehny Post Office. Kilbehny Limestone Group exposed at type locality: bioclastic limestones, shales and faecal pellet rocks.

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Plate 3.

Plate 3.

Magnification X 34. Microphotographs taken in ordinary light.

Fig.1. Castle View Limestone. Abraded crinoidal, and to a lesser extent foraminiferal, debris cemented by clear sparry calcite. As well as skeletal fragments there are dense, rounded and elliptical masses composed of fine granular calcite occurring both as separate structureless globules and in places surrounding and occupying spaces within abraded skeletal fragments.

Fig.2. Lower Ballyheron Limestone. Bioclastic limestone with sparry calcite and fine granular calcite in the matrix. The fine granular calcite is scattered and does not form discreet masses or rims, as in the Castle View Limestones. Much of it is secondary and the result of recrystallisation.

Fig.3. Upper Ballyheron Limestone. Differs from Lower Ballyheron Limestone in containing reduced amounts of skeletal fragments and in the absence of sparry calcite cement. Irregularly rounded "pellets" composed of a similar material to the matrix occur.

Fig.4. Reef Limestone Group. Fine grained carbonate rock with large irregular pockets of coarse calcite.

Fig.5. Reef Limestone Group. Filaments of Ortonella are seen. Intervening spaces are filled with finely divided calcite and clear sparry calcite.

Fig.6. Kilbehny Limestone Group. Faecal pellet rock. The pellets are in a matrix of clear sparry calcite.

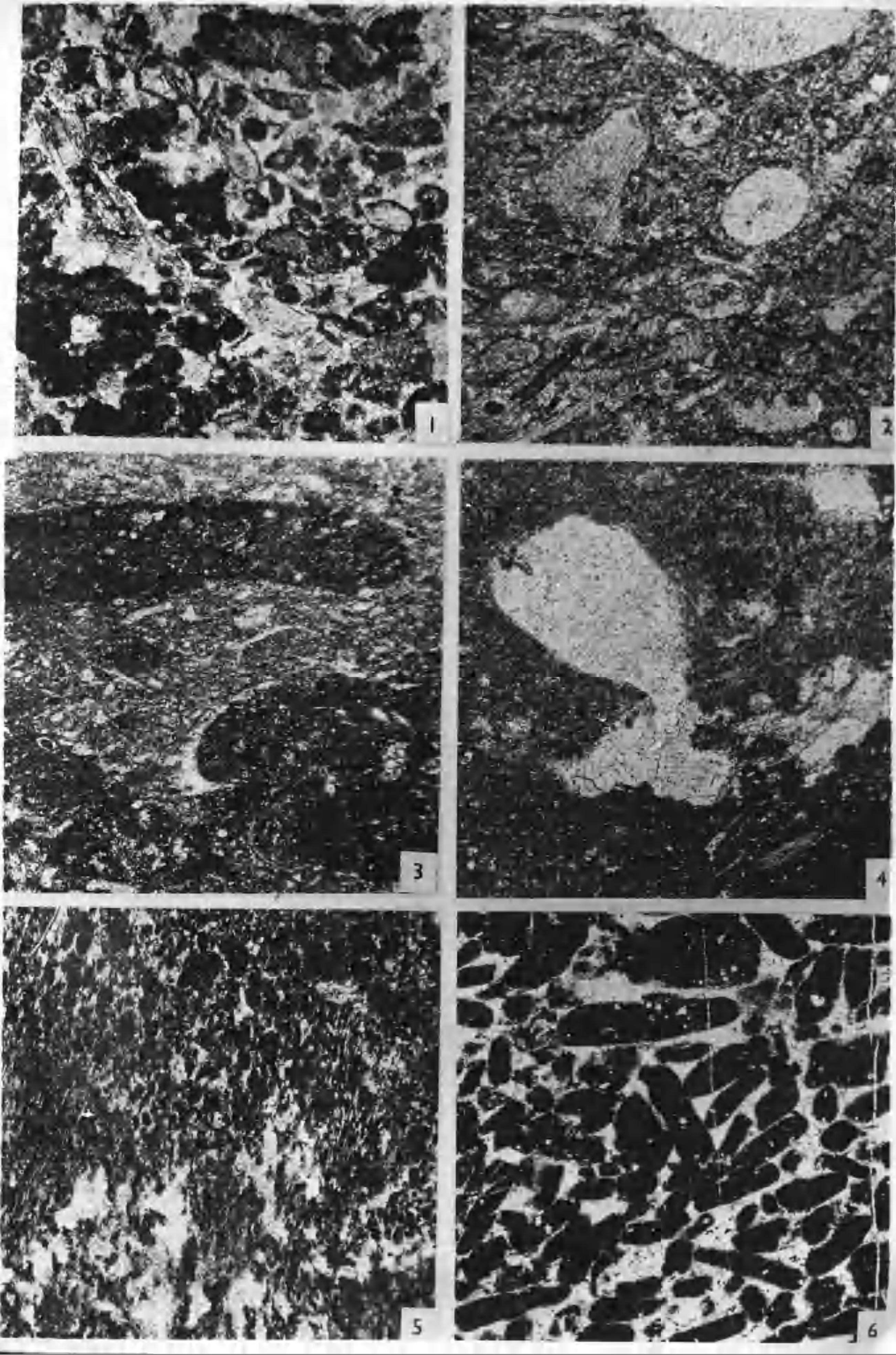
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Plate 4.

Plate 4.

Magnification X 34. Microphotographs taken under crossed nicols.

Fig.1. Reef Limestone Group - specimen from Ardfinnan. Fibrous calcite growth on bryozoan stipe. The position of the stipe is marked by a series of black patches at the base of the photograph. These are spaces and this is a region of high porosity.

Fig.2. Reef Limestone Group - specimen from Ballyheron Wood. Spherulitic limestone - an unusual rock type found associated with basic tuff. Where spherulites are in contact, as in this figure, their boundaries are polygonal.

Fig.3. Reef Limestone Group - specimen from Rochestown House section. Fibrous calcite is developed in bands. By analogy (with Bradley 1928) this texture may have formed in association with algal growth.

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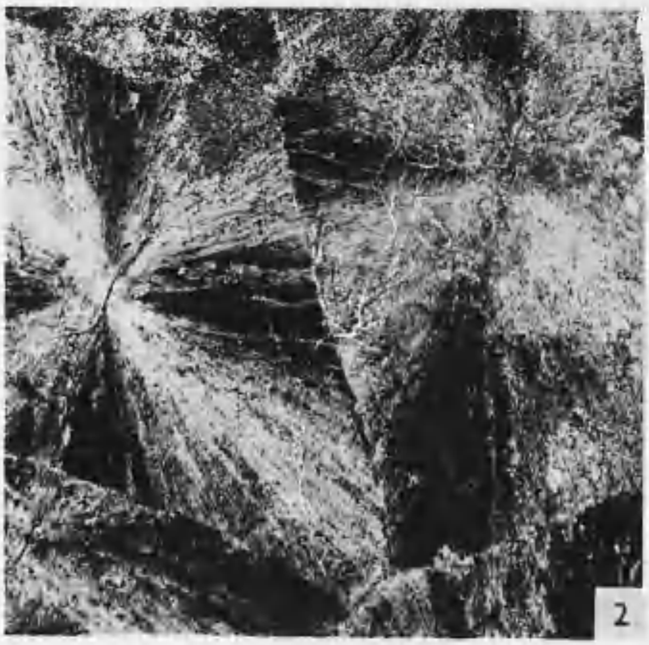

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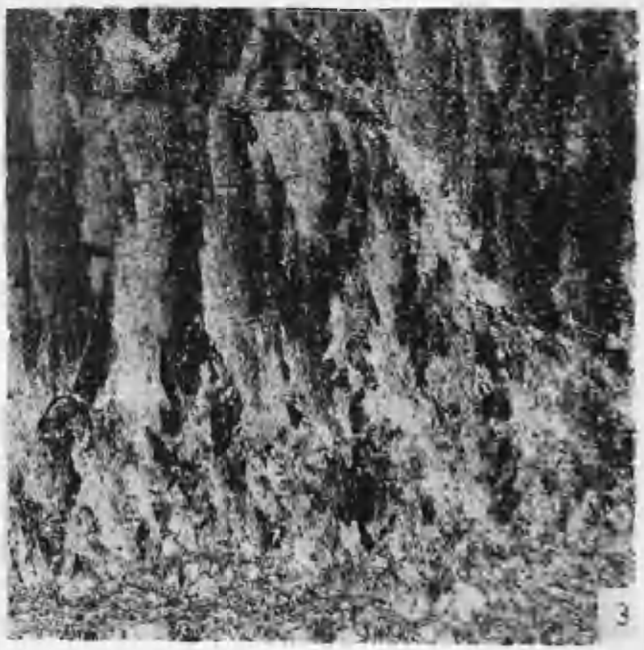


3

III. CORRELATION

The macrofossils and microfossils indentified are listed (pp.148-155) and in this section the fossil assemblages are outlined to support an approximate correlation of the lithological divisions with Vaughan's zones of the South-Western Province (see fig.2.). The changing faunal facies, and the inexact and imperfect bases on which the zones are established, tend to obscure the recognition of exact zonal boundaries.

At the present time the British Dinantian is being subdivided by Cummings on the basis of foraminiferal assemblages. As an aid in correlation, and to supplement the information provided by macrofossils, foraminiferal assemblages from limestones in the Ardfinnan - Mitchelstown syncline are compared with Cumming's assemblages from the South-Western Province.

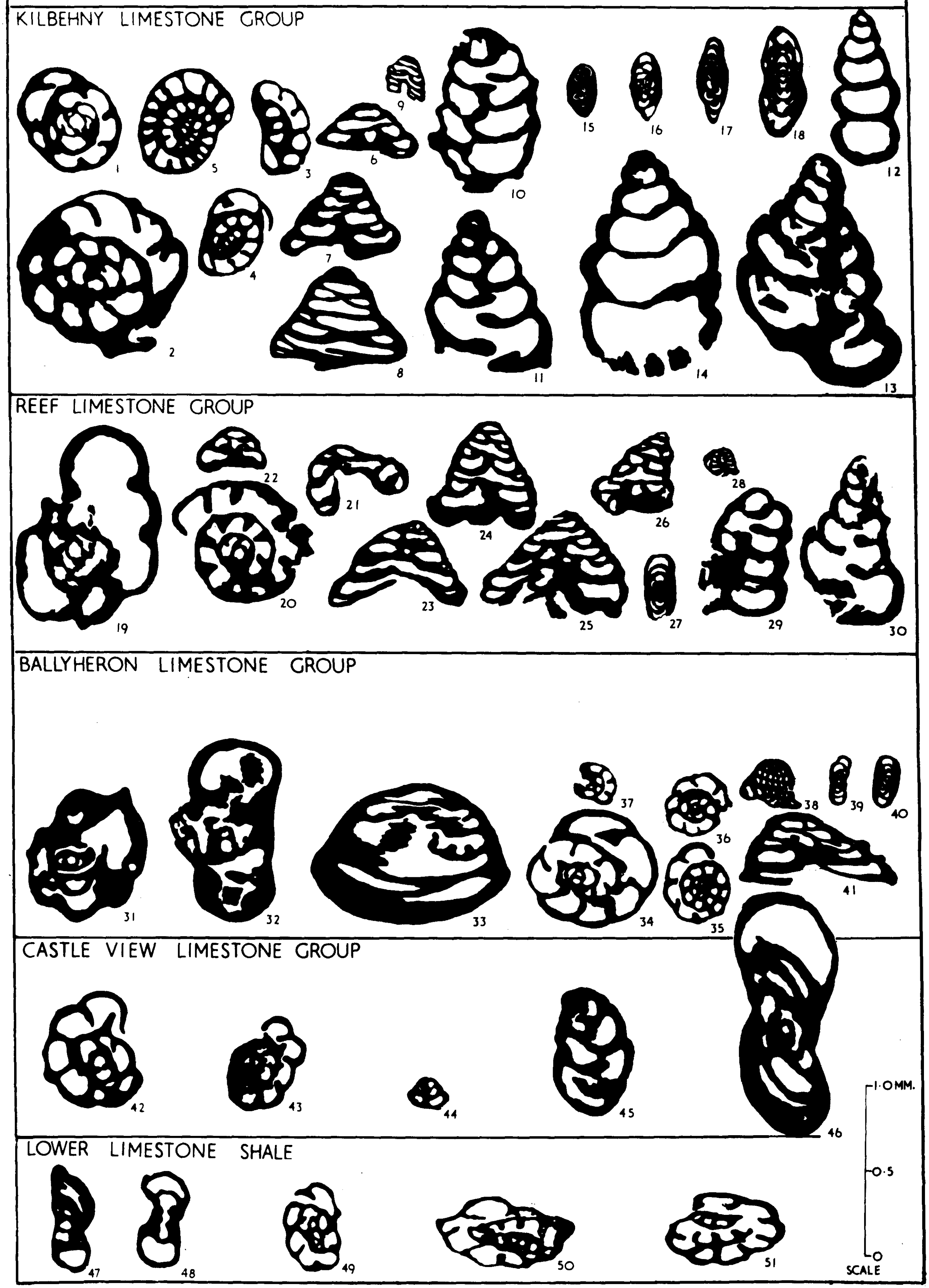
A diagram relating the occurrence of some important forms of foraminifera to the stratal divisions in the Ardfinnan - Mitchelstown syncline is given (see fig.5.).

Fig. 5.

Fig. 5.

1. Endothyranopsid.
2-4. Plectogyras.
5. *Eostaffella*.
6-8. Tetrataxids.
9. *Howchinia*.
10-13. Palaeotextularids.
14. *Climacammina*.
15-17. Archaediscids.
18. *Paramillerella*.
19. *Lituotubella*.
20. Endothyranopsid.
21. *Visariotaxis*.
22-26. Tetrataxids.
27. *Propermodiscus*.
28. *Turrispira*.
29-30. Palaeotextularids.
31-32. Lituotubellids.
33. ?
34-37. Plectogyrids.
38. Early valvulinellid
39-40. Archaediscids.
41. Tetrataxid.
42-43 Plectogyras.
44. *Globivalvulina*.
45. *Spiroplectammina*.
46. Lituotubellid.
47-48. Ammodiscids.
49. *Plectogyra*.
50-51. Tournayellinids.

FORAMINIFERAL ASSEMBLAGES



1. Fossil Assemblage of the Lower Limestone Shale

Within the Ardfinnan - Mitchelstown syncline the corals and brachiopods of the Lower Limestone Shale have a Tournaisian aspect. Zaphrentid corals are abundant, but the exact position of their incoming in relation to the underlying sandstone is not known. _Syringopora_ occurs, but _Michelinia_ and _Caninia_ are rare or absent. The brachiopod fauna includes _Spirifer tornacensis_, _Spiriferinella octoplicata_, _Actinoconchus expansus_, _Cleiothyridina_ cf. _royssii_ and _Rhipidomella michelini_. The foraminiferal assemblage includes earlandiids, ammodiscids and tournayellinids of Tournaisian (Z) type.

2. Lower Limit of Dinantian Succession

At the base of the limestone succession the marine Lower Limestone Shales rest on sandstones of "continental" facies without angular discordance. This contact is not exposed within the Ardfinnan - Mitchelstown syncline, but at Araglin bridge (see pl.1.) is seen with a thin impersistent conglomerate separating dark shales above from sandstones below. These

/white,

white, purple and green sandstones, with subordinate purple shales, were lithologically separated by the Geological Survey as "Upper Old Red Sandstone", which is roughly equivalent to Griffith's "Yellow sandstone series", but the discovery of a rich flora at Kiltorcan in 1851 led to the renaming of these beds (Jukes 1866, p.322.) at this locality as "Kiltorcan beds". The term "Kiltorcan beds" was used synonymously with "Upper Old Red Sandstone" on the one mile Geological Survey map sheets 165 and 166 of the Ardfinnan - Mitchelstown syncline, although time equivalence is far from certain.

Stratigraphically there are difficulties of interpretation because zonal positions of the upper part of the "continental" sandstone and the lower part of the marine shales are not accurately known in southern Ireland. The Kiltorcan flora was referred to Upper Old Red Sandstone without precise evidence. At Hook Head, Smyth (1930) placed the Transition Beds, Grey Sandstone Group and Fish Shales, strata amounting to 150 feet, in K zone above which a Zaphrentid phase

/is

is established, while in Clare, Douglas (1909, p.542) indicated that K beds are extremely thin or altogether missing on the basis of incoming Zaphrentid corals. Smyth distinguished the Transition beds from Old Red Sandstone as being Lower Carboniferous on the occurrence of Avonia bassa which is abundant in K zone of the Avon section. At Dungarvan the lowest recognizably Dinantian beds may be of Z age (Smyth 1939, p.318).

The absence of Avonia bassa from the sandstones underlying the Transition Beds at Hook Head could be the result of an unfavourable environment and merely a reflection of facies. There is no evidence that the sandstones underlying the Transition Beds might not be of Dinantian age. At Hook Head, then, the base of K zone is defined by a change of lithology rather than a zonal assemblage. Similarly the incoming of Zaphrentid corals, by which the base of zone Z is defined, may also be facies controlled.

Thus, the increased thickness of "marine" strata separating "continental" sandstones below from Zaphrentid phase limestones with shales above at Hook Head

/in

in the south east compared with Clare in the west, can be explained in more than one way.

If the incoming of Zaphrentid corals in different parts of Ireland is regarded as a time line, then either there is a non-sequence in Clare compared with Hook Head, and much or all of K zone is missing in the former locality, or else the "continental" sandstone is diachronous and in Clare is of Dinantian age and to be correlated with interbedded shales, limestones and sandstones at Hook Head (George 1958, p.246).

If the incoming of Zaphrentid corals is regarded as being dependent on facies, then there may be faunal diachronism and no time significance can be attached to the incoming of this fauna. It cannot then usefully be used in zonation.

3 Fossil Assemblages of the Castle View Limestone Group

Corals and brachiopods are less abundant in the thick bedded light grey crinoidal Castle View Limestone than in the dark limestones with shales both below and above. The lower part of the group contains *Caninia cornucopiae*, *Koninckophyllum tortuosum*, *Syringopora* spp.

Syringothyris cuspidata and undifferentiated orthotetids. Occasional specimens of giant caniniids and *Michelinia megastoma* are found in the upper part of this group. On the evidence of corals and brachiopods the greater part of the Castle View Limestone may lie in the Lower Caninia Zone (C1), but at present there is no reliable way of distinguishing Z from C1 by the use of these fossils.

The upper part of the Castle View Limestone Group is of particular interest because it contains a foraminiferal assemblage which is not found in the South Western Province and which may indicate the deposition of sediments in this part of Ireland during a period of non-deposition in the South Western Province. The lower part of the group, exposed near the axis of an anticline between Castle View House and Ballydrinan Grave yard, is typified by the occurrence of *Globivalvulina* and is probably high Tournaisian. The upper part of the group also contains *Globivalvulina* but *Spiroplectammina* is the dominant member and it is this part of the sequence which may not be represented by sediments

/of

of equivalent age in the South Western Province.

If the upper part of the Castle View Limestone has no time equivalents in the South Western Province it may either represent a prolongation of Tournaisian sedimentation or the earlier onset of Visean.

Overlying the upper part of the Castle View Limestone is Ballyheron Limestone of undoubted Visean age.

4 Fossil Assemblage of the Ballyheron Limestone Group

In the dark coloured Ballyheron Limestone, which is a less pure carbonate rock than the underlying Castle View Limestone, there is the appearance of an abundant coral fauna which is undoubtedly Visean. *Lithostrotion martini* and *Diphyphyllum lateseptatum*, occurring 300 feet below the base of the overlying reef, large forms of *Palaeosmilia muchisoni*, *Carcinophyllum simplex*, variants of *Caninia cylindrica* and *Caninia benburbensis*, several species of both *Cravenia* and *Koninckophyllum*, *Michelinia megastoma* and *Hexaphyllia*. Among the brachiopods *Cleiothyridina globularis*, *Leptaena analoga* and species of *Actinoconchus*

/and

and Striatifera are identified.

The rocks of the Ballyheron Limestone Group contain Visean foraminifera. Archaediscids appear and become abundant along with tetrataxids and endothyrids. The occurrence of early valvulinellids below the base of the reef suggests the latter is basal S_2 or uppermost C_2S_1.

5 Fossil Assemblages of the Reef Limestone Group

The lithological contrast between the Reef Limestone and the underlying Ballyheron Limestone is reflected in the fossil content. Against 25 species of corals identified from the Ballyheron Limestone only 2 are recorded from the Reef, these being Lithostrotion and Amplexus. On the other hand, in the Reef there is a greatly increased brachiopod and molluscan fauna. Five species of brachiopods are identified from the Ballyheron Limestone while 37 species are identified from the Reef. Brachiopods and molluscs are not widely dispersed through reef-rocks but occur in comparitively restricted pockets presumably reflecting particularly favourable, and perhaps protected, environments.

Fenestelloid bryozoans are extremely common and act as an important frame-builder in large tracts of the Reef. Algal growths, predominantly spherical growth of <u>Ortonella</u>, are typical of higher levels in the Reef.

<u>Beyrichoceras</u> ? <u>micronotum</u> is identified, but is not considered to be of zonal value (see p.146). Trilobites of the <u>Weberides</u> <u>barkei</u> group occur and Dr. R. Goldring (personal communication) has commented on the age of these forms:- "<u>Weberides</u> I do not think appears before the Visean (S) and this species may be even younger".

Although there is an abundant brachiopod fauna, it provides few reliable indications of age. Referring to faunas in reef limestones in east central Ireland, Nevill (1958, p.292) points to a fundamental difficulty in the use of many macrofossils in zonation. He says:- "When names are assigned to the fossils many of the distinguishing features are obscured because the range of variation of species, as they are known at present, is too wide".

/The

The occurrence of _Lithostrotion_ and _Diphyphyllum_ 300 feet below the base of the Reef is of importance and suggests that the oldest parts of the Reef are no older than high C_2S_1 or even S_2.

Within the Reef Limestone Group foraminifera occur locally and tetrataxid forms are the most abundant. In bioclastic lenses within the upper part of the Reef large palaeotextularids, _Tetrataxis_ and _Turrispira_ are found in the assemblage and suggest upper S_2 age.

6 Fossil Assemblage of the Kilbehny Limestone Group

Chaetetes septosus, _Lithostrotion pauciradiale_ and productids of the _Gigantoproductus_ group occur and suggest high Visean age, but are insufficient to define Seminulan or Dibunophyllum zones.

Abundant foraminiferal remains are found within this group. Large palaeotextulariids (length greater than 1 millimeter), _Paramillerella_, _Howchinia_ and _Eostaffella_ suggest low D_1 age. This is the youngest foraminiferal assemblage identified within the syncline.

7 Fossil Assemblage of the Upper Shales Series

An abundant goniatite fauna mainly of *Neoglyphioceras spirale* is of P_2 age. Associated with the goniatites is a fauna including *Conularia elegans*, *Posidoniella* cf. *corrugata* and *Martinia glabra*. The martinias occur as casts with a preservation comparable to that recorded by George (1927, p.106) from the Upper Limestone Shales (D_2 - D_3 zones) in South Wales.

As stated the uppermost beds of the Reef Limestone Group contain a foraminiferal assemblage typical of high S_2 beds in the South Western Province, while the overlying Kilbenny Limestone contains a foraminiferal assemblage indicating low D_1 age. These beds are the youngest of the limestones exposed and must lie within 200 feet of the base of the Upper Shales, although nowhere within the Ardfinnan - Mitchelstown syncline is the contact exposed. The Upper Shales, not more than 300 feet from their base, are of P_2 age. This suggests either an unconformity at the base of P_2, or else a very thin and condensed sequence of rocks of Upper D_1 and D_2 - P_1 age.

IV. PALAEOGEOGRAPHY AND CONDITIONS OF SEDIMENTATION

Within the Lower Limestone Shale, as well as calcareous rocks, detrital quartzes and shales are important constituents of the sediment and suggest erosion of, and transportation from, a land source.

The massive beds of the succeeding Castle View Limestone Group are free from detrital quartz and shales are absent or inconspicuous, indicating a reduction in the influx of terrigenous detritus and an increase in importance of lime-secreting organisms contributing carbonates to the sediments, which accumulated in a shallow shelf sea with well aerated waters. The abraded nature of much of the bioclastic debris suggests reworking of the sediment within the environment of deposition and the change of conditions from Lower Limestone Shale times was probably caused by gentle and continued subsidence. The Castle View Limestone Group, although not containing the same variety of sediments, may be compared with the Tournaisian Main Limestone of the South Western Province, in particular of Pembrokeshire, and

/with

with Hook Head where there is a similar thick sequence of crinoidal limestones, but having more prominent interbedded shales.

Within the Ardfinnan - Mitchelstown syncline these upper Tournaisian rocks are not Zaphrentid phase limestones, that is dark crinoidal limestones with interbedded shales, but purer well-washed and abraded carbonates with no evidence to suggest laterally changing facies within the area of the syncline. The interbedded mudstones present in south Pembrokeshire are not found here.

Oolites are absent from the sediments of the Ardfinnan - Mitchelstown syncline, although within the Castle View Limestone there are abraded crinoid ossicles with an apparent granular coating simulating ooliths. No current bedding has been observed in these rocks. The absence of oolites suggests deeper water conditions away from the very shallow water of near shore banks where oolites form. Oolites are not recorded from Hook Head but a sectioned specimen of the Hook dolomite contained approximately 10 per cent. ooliths and

/abraded

abraded bioclastics with fibrous oolitic coatings.

No dolomite horizon to compare with that recorded from Hook Head and in Pembrokeshire is seen within the Tournaisian rocks of the syncline.

There is a lithological break between the Castle View Limestone and the overlying definitely Visean lower division of the Ballyheron Limestone Group, but whether this is to be equated with the mid-Dinantian break of the South-Western Province is at present not certain. Evidence from foraminiferal assemblages may, with more detailed analysis, prove sedimentation in this part of Ireland during a period of non-deposition or erosion in the South-Western Province.

The lower division of the Ballyheron Limestone Group is of dark well-bedded bioclastic limestones, with some shale partings, and containing a very abundant Visean coral fauna. In the upper part of the Ballyheron Limestone the increased content of fine grained calcite, though partly the result of recrystallisation, and the decreased bioclastic content in the

/sediment,

sediment, provides a transition from the bioclastic limestones below to fine grained carbonate rocks with minor amounts of recognizable skeletal debris above, which lie within the succeeding Reef Limestone Group.

It is likely that the bryozoans forming the autochthonous reef rock grew in very shallow water at depths only a fraction of the total reef thickness and this indicates subsidence of the order of at least 1000 feet.

At Curragh, on the south coast of Ireland north of Ardmore, reef limestone rests on dark thin bedded "Michelinia favosa type rocks" of Tournaisian age. There is a transition zone between reef and bedded bioclastic limestones where reef beds 2 - 3 feet thick are interbedded with coarse crinoidal limestones offering no suggestion that the junction is the result of faulting.

The evidence at Curragh then, suggests that to the south of the Ardfinnan - Mitchelstown syncline reef growth was established at an earlier date and that the base of the reef is diachronous, transgressing

/higher

higher zones northwards between Cork and Caher. The establishment of reef conditions in southern Ireland is as old as high Tournaisian and in places, for example the Ardfinnan - Mitchelstown syncline, is Visean. There is no evidence as yet to suggest the thick sequence of sandstones and shales which make up the Culm might not be entirely Tournaisian, which could mean the trough of Culm southwards from Cork was no longer deeply subsiding during the apparent northwards advance of the reef between Ardmore and Caher. Presumably the source of the sandstones and shales of the Culm was in a land mass to the south.

At Limerick to the north-east, Ashby (1939, p.324) places the Fenestrellina Reef Limestone Group in C zone and does not record lithostrotion below the overlying Seminula Limestone. Similarly, Douglas (1909 p.551) places his Lower Unstratified Limestone ("Massive grey and mottled limestones containing abundant bryozoa") in C zone and does not record lithostrotion below the overlying Upper Limestone. This may mean that to the north-east, as well as to the south of the Ardfinnan -

/Mitchelstown

Mitchelstown syncline the base of the reef occurs at a lower horizon and lithostrotion is not recorded below this base.

At the present time there is no simple way of explaining the development of this thick sheet reef covering an extensive area from Kerry and Clare through Limerick, Tipperary, Waterford, Kilkenny and Cork. If the establishment of reef growth in the area of the Ardfinnan - Mitchelstown syncline was at a later date than in the surrounding areas to the northwest and to the south, then a control of only local significance must have been operative. The nature of this control is not known.

The local establishment of abundant algal growths, notably masses of Ortonella at high horizons in the Reef suggests shallow undisturbed water and may indicate a shallowing of the clear waters which had prevailed over the gently subsiding shelf through much of Dinantian time.

The pellet rocks of the overlying Kilbehny Limestone also suggest shallow waters and the associated

/content

content of silt grade quartz particles and interbedded shales are the first noticeable terrigenous materials since early Dinantian times. The overlying sandstones and shales of the Upper Shales Group (P_2 age) are probably abruptly transgressive and suggest a time gap (D_1 - D_2 P_1) during which there was non deposition or deposition and later removal of sediments.

V. DIAGENESIS

In this section the changes in calcite, silica and dolomite during diagenesis are described as revealed by microscopic examination.

Many of the limestones are highly modified and altered compared with their original form at deposition and a study of post-depositional changes is helpful in interpreting the nature of the original sediment.

The chemical processes acting within a loose sediment, or lithified rock, are such as to cause an approach to a stable ordering of mineral grains in a given unchanging context, and it is presumably the initial lack of a stable ordering between grains, plus continual upsetting of approaches to a stable ordering, which results in the mineralogical changes and replacements included under the heading of diagenesis.

Use of the words primary and secondary in the description of textures is often confused and without qualifications these terms can seldom be used with clarity. In this thesis they are used in the following sense. A primary texture implies that the

/mineral

mineral grains involved have their original form. A direct replacement of one mineral by another, or the re-ordering of an existing lattice results in a texture described as secondary. The terms primary and secondary do not have a time connotation unless this is stated. Thus, in the case of sparry calcite filling the spaces between skeletal particles by deposition from solution, the resulting texture may be described as primary, although in a time sense it is secondary to the skeletal particles. Similarly vein dolomite, in filling the space provided by a fracture, is primary to the fracture although in a time sense it is secondary to the sediment through which the fracture passes.

The use of the word "grain" is restricted for any single crystal and therefore a multigranular detrital particle is not a grain. This is the accepted usage of the term grain in crystal physics.

1. Diagenesis of Calcite

(a) Rim cementation and granular cementation.

Examples are the cementing textures filling primary spaces, as between detrital particles, or

/in

in spaces within organic structures such as shells. The process needs little explanation. It is described by Bathhurst (1958, p.14). The main conclusion is that primary spaces between multigranular sedimentary particles are filled by a mosaic of cement, whereas a single crystal, for example a crinoid plate, forms a single rim in lattice continuity which is called rim cement (see Pl.5, fig.1).

(b) Partial recrystallisation of large calcite plates.

A specific example of this commonly occurring texture is described. Plate 5, fig. 2, illustrates a large (3 m.m. diameter) calcite plate with bent twin lamellae, certain portions of which are obliterated by distinct patches of calcite in optical continuity along twin planes. The lattices of these patches are unstrained although the twin planes themselves are bent. In places these patches meet along curved grain boundaries so that the large plate is completely obliterated. (bottom ~~right corner~~ of pl.5, fig.2.)

This is an example of a partly recrystallised calcite crystal in which the twin lamellae have

/started

started growing and interpenetrate (see, Voll, 1960, fig.4d). The unstrained nature of the recrystallised lattice, while the host crystal has bent twin lamellae, indicates a period of deformation, followed by a mineralogical re-ordering and after this re-ordering no pronounced deformation to produce further straining. The association of sheared calcite crystals, having bent twin lamallae, with shear planes in the rock which show a relation to folds, suggests that this deformation may have occurred during folding. The deformation which folded and sheared the limestones upset the ordering of mineral grains and the resulting residual strain energy constituted the potential for recrystallisation. After the deformation new ordered lattices grew until they had consumed part or all of the strained host. These areas of recrystallisation are seen to have very irregular shapes and generally to have curved boundaries. Recrystallisation is related to strain and presumably the host plate was not uniformly strained and therefore growth velocities differed in different directions.

When recrystallisation is complete and the recrystallised grains are in contact, boundary migration due to interfacial tensions on grain boundaries may begin. This process is quite distinct from grain enlargement during recrystallisation and is known as grain growth. The mutual interference of grain boundaries during grain growth produces a pronounced ordering with respect to grain size and intergrain boundary angles. As no such ordering is seen, there is no evidence for grain growth.

(c) <u>Recrystallisation of calcite to a fine grained mosaic (5-30 μ)</u>.

Original sedimentary features such as pellets, crinoid ossicles, shell fragments and bryozoan stipes are frequently partially obliterated by fine granular calcite which has replaced the pre-existing structure (pl.5, fig.4.). A distinction is made from the previous example of recrystallisation because of the fine grained nature of the resulting texture (5-30 μ). This process of recrystallisation can transform a calcarenite into a rock with calcite silt-sized grains and it is important to recognize that this is a product

/of

of alteration and not a primary sediment.

Fine granular calcite is commonly found in sheared limestones with the small grains banded in the plane of shearing (pl.5, fig.6.) and is also seen invading the fractures of sheared calcite crystals (pl.5, fig.5.). These shear planes within large single crystals are not parallel to the main planes of shearing. Plate 5, fig.3, illustrates large calcite crystals with bent twin lamellae being replaced by fine granular calcite which shows a sensitively selective relation to twin planes.

These observations are interpreted in the following way. The planar texture of the fine granular calcite exactly aligned with shear planes in the limestone suggests its development was controlled by the shearing. In part, however, the replacement took place after some shearing had occurred because the fine granular calcite is replacing large deformed calcite plates along shear fractures (pl.5, fig.5.) and also selectively along twin planes (pl.5, fig.3.). The shear fractures and twin planes must have been present

/before

before the formation of fine granular calcite. A similar texture was illustrated by Voll (1960, fig.4 a,b,c.).

There is evidence that this fine grained mosaic is at least in part younger than the formation of dolomite rhombohedra and this is dealt with in the section on dolomite, page 72 .

2. Diagenesis of Silica

Microcrystalline, chalcedonic and megaquartz are the three types of siliceous material that occur commonly in limestones. Chert nodules, or bands, are largely composed of microcrystalline quartz with scattered patches of chalcedonic quartz as the other siliceous component. Megaquartz is not generally found within chert nodules but has a widespread distribution in the limestones as isolated crystals or groups of crystals.

Microcrystalline quartz occurs as dense masses of interlocking crystals the majority of which have a grain size less than 15 μ. These grains have undulose extinction and constitute a dark ground mass with

/crossed

crossed nicols (pl.6, fig.2, and pl.7, fig.2.). Microcrystalline quartz has been described by Keller (1941). Folk and Weaver (1952), using petrographic, electron microscope, X-ray and differential thermal analysis techniques, have examined chalcedonic quartz.

Chalcedonic quartz seen with nicols crossed is fibrous and in some cases grades into microcrystalline quartz. The fibre axis of the chalcedony is the a - axis (pl.6, fig.2.).

Megaquartz is seen as coarse-grained, frequently euhedral crystals (pl.6, fig.4.). It is not fibrous and its large size and euhedral form distinguish it from microcrystalline quartz.

(a) <u>Calcite replaced by silica</u>.

That silica replaces calcite is demonstrated by the entire and partial silicification of structures known originally to have been of carbonate, such as crinoid ossicles and brachiopod shell fragments (pl.6, fig.3.). In the chert masses studied, most if not all the silica is clearly a replacement and therefore secondary. These replacements appear to have been volume for volume with silica being deposited while calcite was removed. Within chert masses there are generally recognizable partially digested fragments of primary organic carbonate structures.

(b) Euhedral quartz crystals replaced by calcite.

Although silica has commonly replaced calcite, there is also evidence that calcite has replaced silica. Plate 6, fig.4, illustrates calcite replacing and occurring as pseudomorphs after euhedral quartz. This euhedral quartz is seen around the margins of carbonate spherulites (see page 28) and may be a primary deposit on a cavity wall; some of the calcite associated with it may be the final infilling of cavity space, but the important point is that calcite can in places be seen occurring as pseudomorphs after quartz. In this case it is necessary to realise the possibilities which could lead to a misinterpretation of a texture of this type:-

(i) Calcite infilling spaces after an initial drusy growth of quartz crystals - the calcite might then be forced to occupy a space already defined by quartz

/crystal

crystal boundaries.

(ii) Calcite crystals, which by the chance of section, may merely be overlying a portion or the whole of a quartz crystal and not actually replacing it.

(iii) That quartz is replacing calcite and the calcite seen within quartz crystals is residual material not replaced.

None of these points would explain calcite occupying the hexagonal quartz forms of the present example. The euhedral quartz crystals seen have commonly undergone some replacement by calcite.

(c) Microcrystalline quartz replaced by calcite.

In this case two generations of calcite are distinguished with an intervening generation of microcrystalline quartz.

Plate 6, fig.5, illustrates a deformed calcite crystal (possibly crinoid ossicle) with bent twin lamallae, having the central region occupied by microcrystalline quartz. At the strained calcite plate - microcrystalline quartz junction, which is irregular, there is a development of calcite with no sign of straining.

/The

The strained calcite plate has suffered partial replacement by microcrystalline quartz and probably subsequent to this there has been a regrowth of calcite at the expense of microcrystalline quartz.

An alternative interpretation is as follows. There existed in the calcite plate a secondary cavity around the walls of which calcite crystallised, partly filling the cavity space. Presumably due to some change in the condition of the solutions filling the cavity, microcrystalline quartz then crystallised out and filled the remaining cavity space. This explanation seems unlikely because of the scattered nature of the unstrained calcites through the microcrystalline quartz (pl.6, fig. 6.) which would suggest precipitation of calcite and quartz together.

Apparent regrowth of calcite as a replacement of microcrystalline quartz is also a feature commonly seen within chert masses (pl.7, fig.1.). A strained twinned calcite plate, partially replaced by microcrystalline quartz is seen to have an untwinned, undeformed rim. It is probable that the strained

/calcite

calcite plate was a remnant of undigested carbonate matter within the chert mass, which at a later stage regrew at the expense of microcrystalline quartz. As this regrowth has no signs of the straining manifested in the host plate, it is also suggested that it formed after the deformation causing this straining.

The evidence provided by calcite veins within chert masses may also illustrate the possibility of calcite regrowth at the expense of silica. Plate 7, fig.2, illustrates a calcite vein passing through a matrix of microcrystalline quartz. The development of rhomboid crystal faces of calcite at the outward margin of the vein, and the fact that some twin lamellae do not persist into these extensions, suggests their secondary nature. As the veins are infilled fracture spaces (organic structures can be seen displaced on either side of some of the veins), it is not likely the original vein margin had the present form.

It may be said in conclusion, that although

/quartz

quartz replaces calcite, calcite also commonly replaces both megaquartz and microcrystalline quartz.

(d) <u>Distribution of chert</u>.

Chert ribs do not occur in the autochthonous bryozoan-rich reef rock, although occasionally small silica patches, typically euhedral crystals of authigenic quartz, may be seen in thin sections of this rock. There are calcite silts and bioclastic limestones interbedded with the reef growth which in places contain chert masses. The zone of well-bedded limestones immediately underlying the reef has prominent associated cherts, which follow the bedding.

In the massive or thick-bedded crinoidal limestones of the Castle View Limestone Group chert commonly occurs in large irregular detached nodular masses, in contrast to the more continuous ribs of the better bedded limestones.

Within the Lower Limestone Shales, in addition to chert ribs, there is pronounced silicification

/of

of fossils. The brachiopods and corals are almost without exception silicified, even when they are not associated with a chert mass. Silicification of fossils is seen in the overlying limestones, but never as consistently as in the Lower Limestone Shales.

The distribution of chert shows a general, if not precise, relation to the contrasting rock types. The most striking aspect of chert distribution is its absence from bryozoal reef, while it may be present in the interbedded detrital limestones.

(e) Relation of deformed chert ribs to structure.

Some chert ribs have finger-like elongations in the plane of developed cleavage (pl.8, figs. 3 and 4). This cleavage has a constant relation to bedding. In the illustrated beds dipping at 70°, the shear planes are developed at 35° to bedding. Thin section and varnished surfaces of material illustrated in the above plate show pronounced shearing in the limestone as well as elongation of the chert. The planes of these two textures coincide exactly and are presumably the products of the same deformation.

Mineralogically this chert is of microcrystalline and chalcedonic quartz. That it is present as a replacement of carbonate is clear because of the silicified sedimentary particles such as crinoid ossicles, as well as the undigested remnants of carbonate matter. The quartz appears to have flowed and been stretched. It has not deformed as a brittle substance where displacements by microfaulting might be expected, but appears to have flowed plastically. Sheared organic fragments are seen extending from areas of limestone into chert.

Whether the chert was present as siliceous material concentrated into ribs before deformation, or whether the deforming processes caused the concentration of previously disseminated silica is not known. The possibility, however, that the chert developed after deformation, replacing existing deformation textures in the limestone is not accepted, because parts of the chert consisting of chalcedonic quartz are deformed (they are stretched in the direction of shearing) and also the process of silica replacement

/would

would have to be very sensitively selective to show such finely preserved minor structures as a replacement.

(f) Calcite veins in chert.

Chert masses are frequently cut by numerous calcite veins which do not persist into the surrounding limestone. The distribution of the veins shows a relation to the chert masses.

(i) Calcite veins are very abundant in the chert compared with the surrounding carbonate.

(ii) A thick vein in chert frequently thins and becomes divided into several smaller veins near the chert carbonate contact, and most of these smaller veins do not persist into the carbonate.

(iii) The vein calcites appear to have a preferred orientation and are consistently seen with twin planes developed slightly obliquely across the fracture planes (pl.7, fig. 2.).

(iv) The calcite veins cut each other, indicating that they were not all formed together.

/As

As the abundance and form of calcite veins shows a relation to chert masses this is taken as evidence that the cherts were in existence before vein formation. The fact that the veins are cutting silicified organic structures in the chert is not proof, because it could be argued that the veins were present before silicification and that the selectiveness of silica replacement has left them unreplaced, while it has replaced the other carbonate material.

Displacements of silicified sedimentary structures on either side of the calcite veins are seen, but not commonly. It is suggested that the calcite veins in chert are not replacements, but the infilling of fractures and that their abundance in the chert, as compared with the surrounding carbonate, indicates a relative shrinkage or contraction effect in the chert at the time of vein formation. This conclusion seems evident and it may be that this contraction in volume within the silica occurred during the change from gel to microcrystalline quartz.

(g) Source of siliceous material, its precipitation and concentration.

What the original sources of siliceous material

/were,

were, and how the silica became concentrated into chert ribs is not known. Extrusive vulcanism and silica transported by rivers to the sea are the two main sources of siliceous material in marine sediments. Of these, direct precipitation in association with extensive extrusive vulcanism is unlikely, as the only volcanic material in the area is basic tuff at one horizon within the Reef Limestone Group, in an area immediately south of Caher, which is probably an off-shoot of the much thicker Limerick group of volcanics to the north. In the Limerick area there are basaltic tuffs and lavas interbedded with the limestones and it is possible that these volcanoes provided silica made available in solution over a wide area, but this could only be a very brief and temporary source. Of the second source, that is silica transported by rivers to the sea, what can be said is that detrital quartz is largely absent from the limestones above the Lower Limestone shale, though to what extent silica may have been transported in solution or suspension is not known.

/As

As much, if not all, the silica in chert masses is seen to be present as a replacement, this implies two phases of concentration. Firstly, the diffuse silica of sea water must be concentrated by bio-chemical, or by chemical precipitation and incorporated in the newly-deposited sediment. Secondly, another concentration of the silica into chert masses is necessary.

No siliceous organisms have been found in the limestones although it is possible that they were present and that their remains have been obliterated by recrystallisation and replacements. Of the "second concentration", that is the concentration of disseminated silica in the limestone into chert masses, no conclusions have been reached. Certainly there must have been some agency or agencies causing the precipitation of silica and the solution of calcite or vice-versa, but this agency is unknown. In recent experimental work pH. conditions, and the factors affecting pH. conditions, have received the most attention.

3. Diagenesis of Dolomite

Certain stains are useful in confirming the presence of calcite and dolomite and in making their distribution readily apparent in thin sections. The stain found to be most effective, Alizarin red S in acid solution, selectively stains calcite but not dolomite. This stain in an alkaline solution selectively stains dolomite but not calcite. Some dolomite stained with Alizarin red S in acid solution shows a zonation of stained and unstained layers indicating calcitic and dolomitic portions in a single crystal.

Dolomite is found in various rock types throughout the succession, but has a maximum development in the Reef Limestone Group, where its presence is commonly obvious in hand specimen. Reef limestones marginal to the syncline form two belts which are strongly dolomitised while those in the central area of the syncline are not as consistently dolomitised.

The following evidence is collected from forty thin sections containing dolomite.

(a) Dolomite is a secondary texture.

Euhedral dolomite rhombohedra occur abundantly as replacements of bryozoan stipes, ostracod shells, crinoid fragments and of other particles which are known to have a primary sedimentary nature (pl.7, fig.3.). These secondary dolomite crystals replacing pre-existing carbonate fabrics provide an example of perfect euhedral crystals occurring in a replacement capacity. Even in severely dolomitised rocks there is no noticeable porosity. The dolomite replacement appears to be volume for volume.

(b) Dolomite is deformed by earth movements which produced folding.

The evidence may be summarised as follows:-

(i) Dolomite rhombohedra are cracked and show glide planes but are not twinned (pl.7, fig.4.).

(ii) Where dolomite rhombohedra occur within twinned calcite plates these plates have pronounced strain shadows, sometimes seen elongated in the direction of twinning, occurring about the dolomite rhombohedra (pl.7, fig.5.).

(iii) Dolomite rhombohedra show undulose extinction indicating straining other than could be produced by the growth of the dolomite lattice itself.

(iv) The fine granular calcite (formed at least in part in association with the folding and shearing - (see page 56) shows a distribution relation to the dolomite rhombohedra indicating the prior presence of the dolomite (pl.7, fig.6.).

Evidence (i), (ii) and (iii) illustrates that the dolomite is deformed. That this deformation was caused during folding, and not at some later date, is suggested by evidence (iv). Dolomite was present as a replacement during the shearing which was associated with folding. If the strain shadows about the dolomite rhombohedra in the calcite plates are due to the same deformation, then this is added evidence that the dolomite existed before deformation.

(c) Calcite replaces dolomite.

Portions of dolomite rhombohedra are seen to be irregularly obscured by fine granular calcite (pl.7, fig.6.) and any one dolomite rhombohedron may consist

/of

of several portions separated by fine granular calcite.

This fine-grained calcite is replacing dolomite. The converse argument that the dolomite is growing at the expense of, and replacing, the fine granular calcite is not acceptable because the fine granular calcite is younger than the dolomite (evidence b,(iv) above).

(d) Dolomitisation is probably pre-chertification.

Dolomite rhombohedra situated in the micro-crystalline quartz of chert ribs frequently have corroded margins. This evidence does not prove that dolomite is older than chert, but in rocks which are both dolomitised and silicified the size and distribution of dolomite rhombohedra appears to be the same within the chert masses as it is in the unsilicified regions of carbonate. This would be improbable if the dolomitisation was younger than the chertification, because it would mean that dolomite was replacing calcite with the same facility as quartz to give a product which was indistinguishable. Some dolomite, then, appears to be older than chert.

(e) <u>Distribution of dolomite</u>.

(i) Thin sections reveal that dolomite replaces the matrix of a rock and less commonly affects large calcite plates, particularly crinoid ossicles (pl.8, fig.2.).

(ii) Bryozoan structures, providing a framework for the development of clear fibrous calcite, are invariably invaded by dolomite rhombohedra while the associated clear fibrous growth of calcite is not affected (pl.7, fig.3.).

(iii) The lithological distribution of dolomite referred to on page 70 .

The distribution of dolomite is not random either on a microscopic or formational scale; there is a selective element. The question arises: Is the 'selective element' the result of certain portions of limestone having had an increased magnesium content which they carried since deposition, or a short time after deposition (before lithification) and that dolomite has later formed at these sites, or is it

/that

that magnesium material was introduced in some form after lithification, being selective in its replacement?

Had there been the necessary extensive introduction of magnesium in some form post lithification, why in general should ~~whole~~ formations like the Castle View Limestone have largely escaped dolomitisation, while the Reef has suffered so much replacement by dolomite?

Evidence e (ii) above, stating that dolomite is consistently found at the sites of bryozoan stipes, but never in the surrounding ~~drusy growth~~ fibrous mosaics, make it tempting to call upon an original magnesium content in the bryozoa (magnesium carbonate percentage in bryozoa, .2 - 11.1; Pettijohn 1956, p.385, from Clarke and Wheeler 1922) which eventually found expression in the formation of dolomite rhombohedra. This, however, is not a high magnesium carbonate percentage compared with other organisms - crinoids have from 7.9 - 13.7 per cent, but the bulk of the crinoidal limestones have no associated dolomite.

/Dolomite

Dolomite forming at the sites of bryozoal stipes, but not in the associated fibrous calcite, could simply be a manifestation of evidence e.(i) above. That is dolomite tends not to invade large calcite crystals until the finer grained matrix has been severely replaced.

(f) Conclusions.

Before making generalisations it is necessary to realise the possibility that not all the dolomite was formed in the same way or at the same time. The collective evidence from forty thin sections suggests that much of the dolomite has a similar form and bears a consistent relation to the other textures seen in thin section.

(i) Dolomite is a secondary replacement of pre-existing carbonate textures.

(ii) The dolomite rhombohedra were deformed during the earth movements which produced shearing and folding and are therefore older than some of these movements.

(iii) The finely granular calcite texture at least in

/part

part younger than the dolomite rhombohedra, is seen replacing the dolomite.

(iv) Some dolomitisation appears to be pre-chertification.

(v) Whether the dolomite rhombohedra are merely a recrystallisation of pre-existing dolomite, or the recrystallisation of pre-existing magnesian material to form dolomite, or whether they are caused by a selective post-lithification introduction of magnesium in some form, is not known. The lithological restriction of dolomite may favour the theory that it is a redistribution or secondary segregation of existing (pre-lithification) magnesian material, and not a post-lithification metasomatic introduction.

4. Diagenesis - the following conclusions are considered of special importance

(a) A re-ordering of calcite lattices has occured, resulting in a textural decrease of grain size. Grain enlargement by grain growth is not recognized in the limestones studied.

(b) Fine granular calcite (10μ range) is seen to have ~~observed~~

/replacing

replacing and obliterating:

(i) coarser-grained calcite crystals,

(ii) dolomite rhombohedra.

(c) Silica has commonly replaced calcite. There is also evidence that calcite has replaced both mega- and microcrystalline quartz and that there ~~are~~ have been cycles of calcite and silica replacement.

Plate 5.

Plate 5.

Fig.1. X21, nicols crossed. Section of Castle View Limestone illustrating rim cementation of crinoid ossicles.

Fig.2. X38, nicols crossed. A large deformed calcite crystal, partly recrystallised, in which the twin lamellae have started growing and interpenetrate.

Fig.3. X114, nicols crossed. Fine granular calcite obliterating twinned calcite crystals. That this replacement took place after the formation of twin planes is clear because of the sensitively selective nature of the replacement relative to these planes - for example, in area marked A.

Fig.4. X60, nicols crossed. The ghost of a bryozoan stipe partially, and in places, completely obliterated by recrystallisation to fine granular calcite.

Fig.5. X66, nicols crossed. The calcite textures illustrated in fig.6, are seen here under a higher magnification. Banding of fine granular calcite occurs along the line A - B, which is the plane of shearing in the limestone and is oblique to bedding. A crinoid ossicle is partially obliterated by fine granular calcite replacing it selectively along shear planes which are oblique to those in the limestone as a whole (see, fig.6.).

Fig.6. X21, nicols crossed. Thin section of sheared limestone with pronounced cleavage illustrated in plate 9, fig.3. Deformed fluorspar, appearing black under crossed nicols, has been involved in the shearing. Fine granular calcite is banded in the plane of shearing. In the bottom ~~right~~ left corner of the illustration a crinoid ossicle is very much extended in the plane of shearing in the limestone and has its own set of shear planes oblique to those in the limestone as a whole.

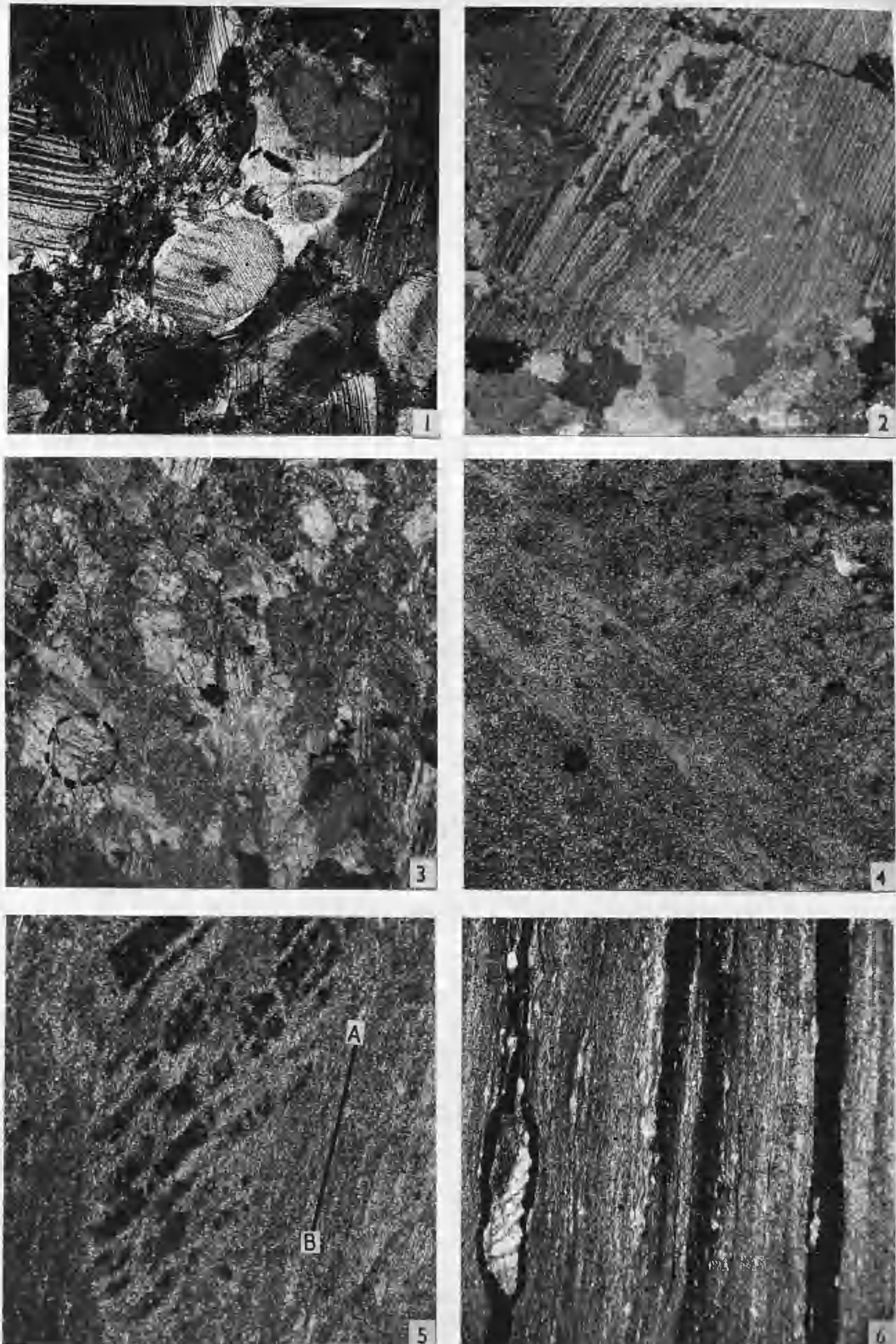

1
2
3
4
A
B
5
6

Plate 6.

Plate 6.

Fig.1. X21, ordinary light. Recrystallisation to fine granular calcite has almost completely obliterated a large calcite plate.

Fig.2. X60, nicols crossed. Fibrous chalcedonic quartz occurring in a ground mass of microcrystalline quartz.

Fig.3. X21, ordinary light. Microcrystalline quartz replacing the carbonate of a crinoid ossicle.

Fig.4. X60, nicols crossed. Illustrates calcite having replaced, and occurring as pseudomorphs after, euhedral quartz. In the areas outlined quartz forms, now occupied by calcite, can be seen. (At point A there is a basal section of a hexagonal quartz form now occupied by calcite) Elsewhere the quartz crystal boundaries are corroded by calcite.

Fig.5. X38, nicols crossed. A. - strained calcite crystal

B. - microcrystalline quartz

C. - unstrained calcite.

A deformed calcite plate, with bent twin lamellae, in which the central region is occupied by microcrystalline quartz. At the strained calcite plate - microcrystalline quartz junction, which is irregular, there is calcite with no sign of straining.

Fig.6. X38, nicols crossed. A, B and C as for fig.5. Notice the intimate association of calcite C with microcrystalline quartz B.

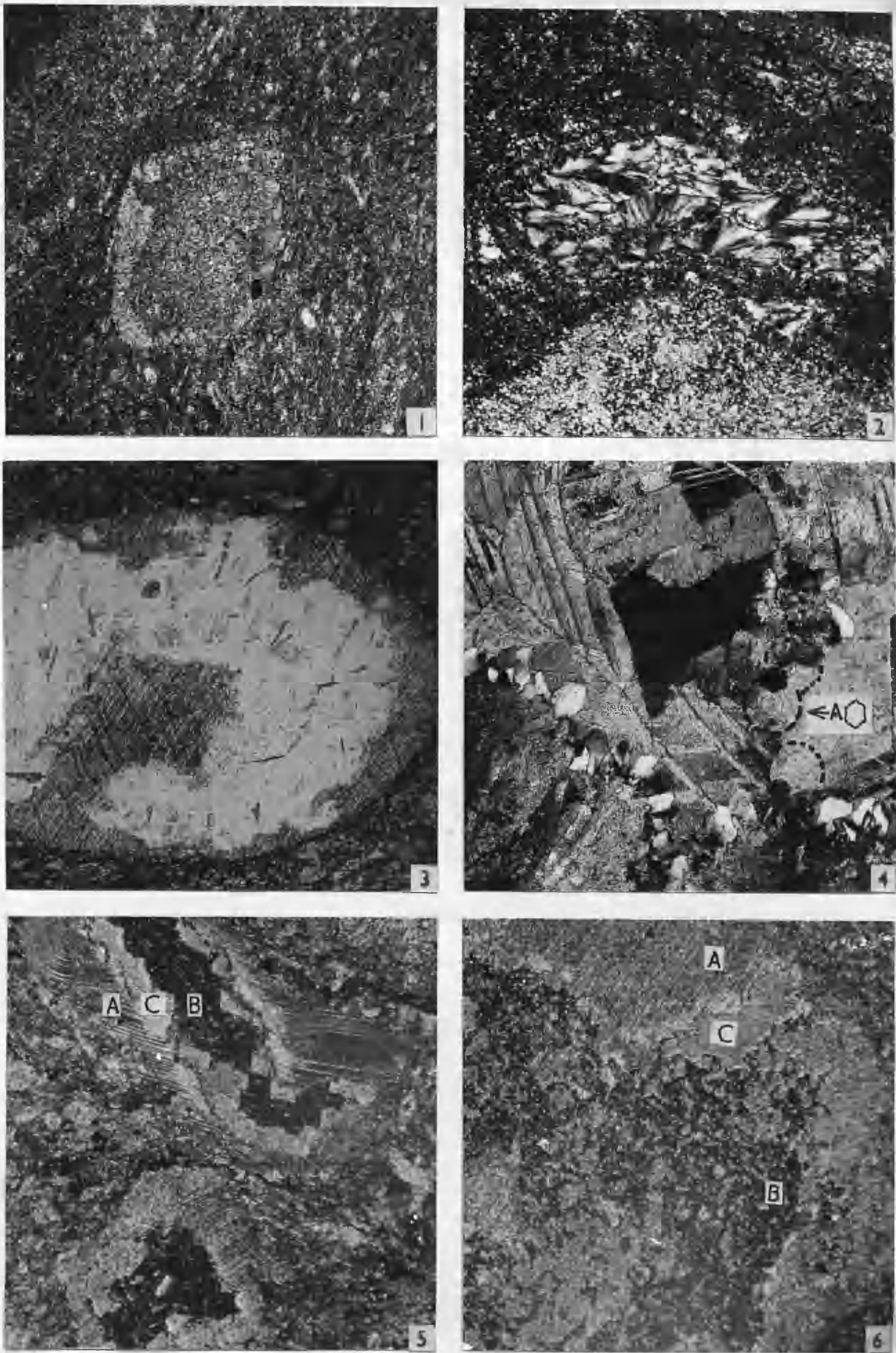

1
2
3
A
4
A C B
5
A
C
B
6

Plate 7.

Plate 7.

Fig.1. X38, nicols crossed. A, B and C as for plate 6, fig.5. A strained twinned calcite plate (A) within a chert nodule has been partially replaced by microcrystalline quartz (B), but is seen to have an untwinned, undeformed rim (C) separating it from microcrystalline quartz.

Fig.2. X38, nicols crossed. This vein is an infilled fracture, but notice the rhomboid crystal faces of calcite at the outward margin of the vein (marked by arrows). The calcite twin lamellae lie obliquely across the vein and many do not persist into the rhomboid crystal ends - as, for example, at A.

Fig.3. X21, ordinary light. Section through bryozoan stipe which is seen at centres A, B and C. An ostracod shell is also seen in section. At the points of section through the bryozoan stipe and ostracod shell dolomite rhombohedra occur (marked by arrows). The organic structures are cemented by a coarse grained fibrous mosaic of calcite. Plate 3, fig.1. illustrates this fibrous calcite under crossed nicols.

Fig.4. X114, nicols crossed. Dolomite rhombohedra are deformed. Dolomite crystal at A is cracked.

Fig.5. X114, nicols crossed. There is a strain shadow in the calcite plate about the dolomite rhombohedron A.

Fig.6. ~~X61, nicols crossed. Dolomite rhombohedra have replaced the matrix of a limestone, but not the crinoid plates~~.

Fig.6. X114, nicols crossed. Fine granular calcite banded in the direction of shear planes and showing a relation to the dolomite rhombohedra indicating the prior presence of the dolomite.

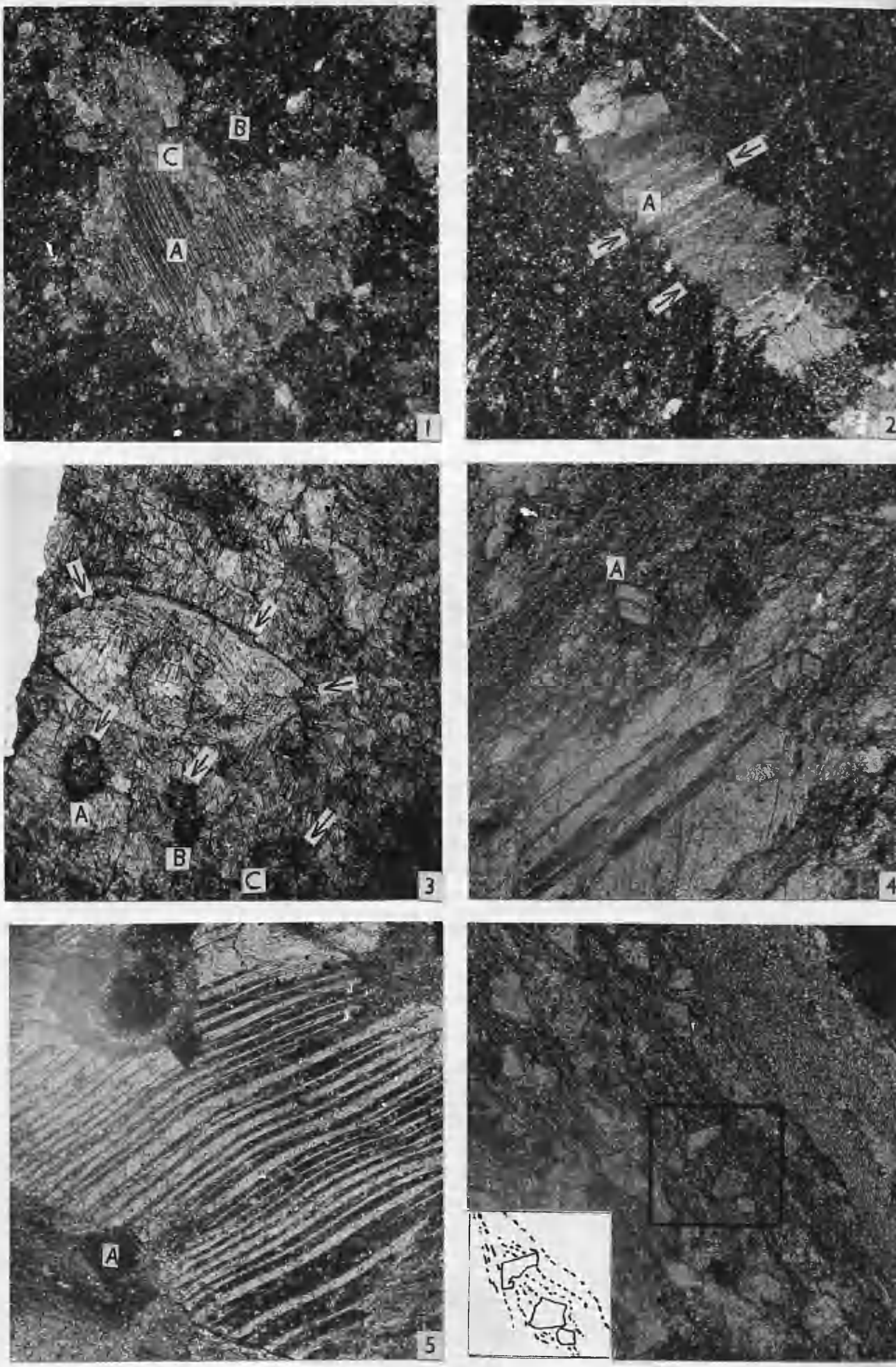
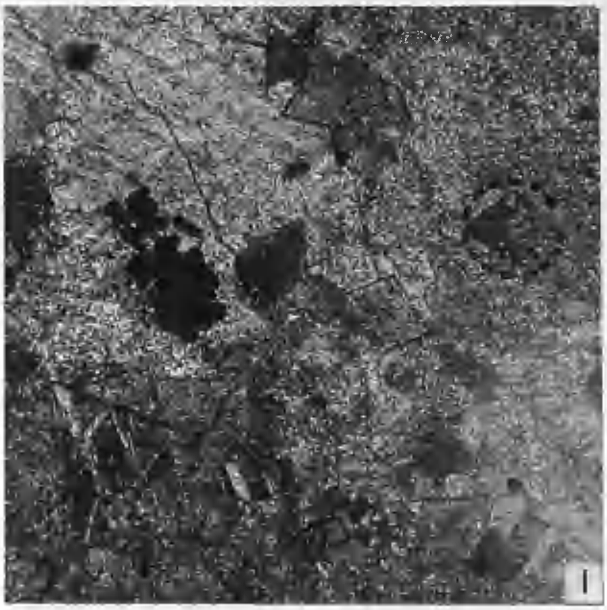

A
B
C
1
A
2
A
B
C
3
A
4
A
5

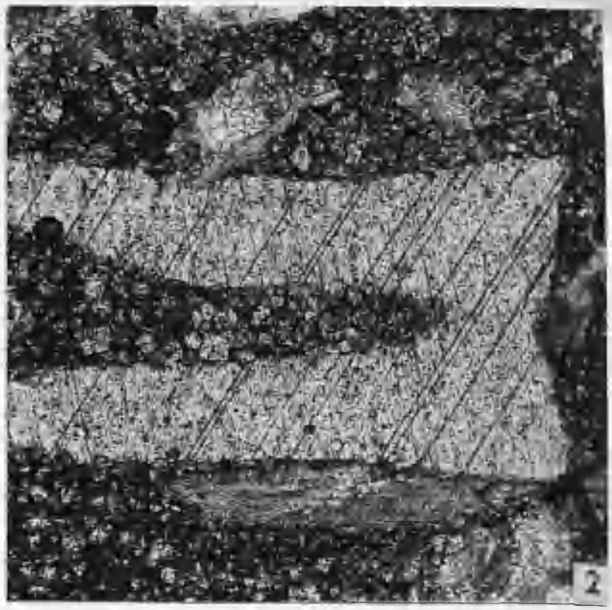
Plate 8

Plate 8.

	x114 nicols crossed
Fig. 1.	Fine granular calcite obscuring portions of dolomite rhombohedra.
	x 61 nicols crossed
Fig. 2.	Dolomite rhombohedra replacing the matrix of a limestone while a large crinoid plate is largely unaffected.
Figs.3&4.	Illustrate finger-like elongations of chert extended in the direction of shear planes in a limestone bed. Locality - 450 yards on bearing N.212^{o} from Duneske (south of Caher).
Figs. 5&6.	Illustrate the deflection of approximately north-south "a - c" joints on passing through a chert rib. Exposure on south bank of Shanbally river 1800 yards on a bearing N.106^{o} from R.C. Church, Burncourt.



1



2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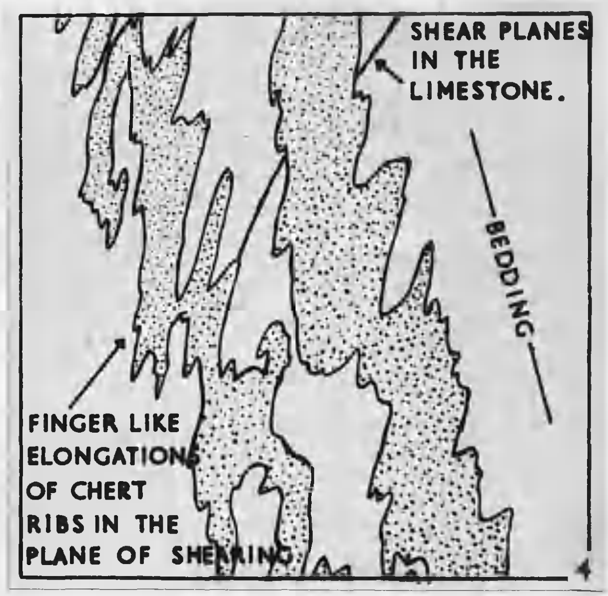
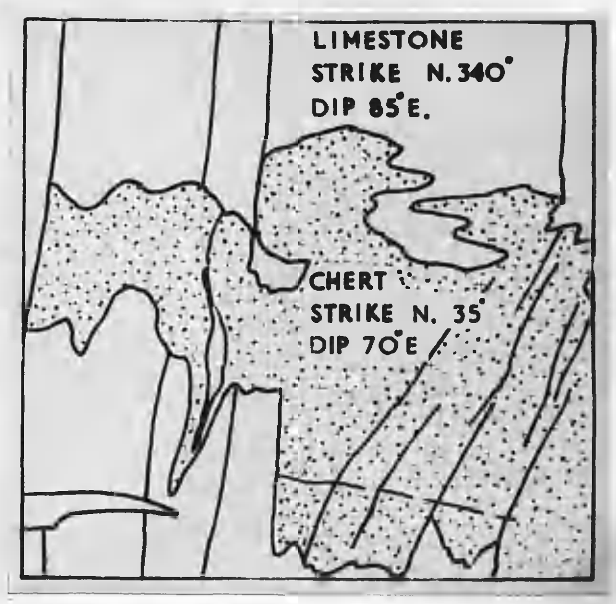
3


SHEAR PLANES IN THE LIMESTONE.
BEDDING
FINGER LIKE ELONGATIONS OF CHERT RIBS IN THE PLANE OF SHEARING

4

5


LIMESTONE
STRIKE N. 340°
DIP 85°E.
CHERT
STRIKE N. 35°
DIP 70°E

VI. STRUCTURE

The approximately east-west striking Ardfinnan-Mitchelstown synclinorium is bounded to the north and south by complementary anticlines which expose Old Red Sandstone. The Dinantian limestones of the syncline form a prominent valley, which is limited to the north and south by approximately east-west trending mountains of Old Red Sandstone, the Galtee mountains to the north and the Knockmealdowns to the south. The low ground of the valley, marked by the occurrence of limestones, is approximately eight miles wide at the river Suir in the east, and narrows to three-and-a-half miles at Mitchelstown in the west. Outcrop distribution indicates that the major part of the synclinorium pitches to the west, but there is a limited area south of Caher where the pitch apparently is eastwards towards Upper Shales exposed north of Clonmel.

On a regional scale this composite syncline, which is one of many en echelon folds, was produced by compression of Armorican age. The folding involved

/Westphalian

Westphalian rocks of the Leinster coalfield. In pattern and intensity it compares with the folds, projected along the strike, of south Pembrokeshire and south Wales, which are demonstrably of pre-Triassic age.

1. Folding

The southern boundary of the Dinantian outcrop strikes east-west, while the strike of the northern boundary swings from N.240° at Caher in the east to N.260° at Mitchelstown in the west. This means that there is a progressive narrowing of the limestone outcrop to the west, which is also the direction of pitch of the synclinorium (except for the limited area south of Caher). The contrary form of the limestone outcrop in relation to the direction of pitch of the synclinorium can be explained by a change of fold pattern, and also by slightly oblique strike faulting in the western part of the synclinorium. Strike faulting at the sandstone-limestone junction has clearly taken place, for example south-east of Clogheen, and is recorded below (p.91) under faulting,

/but

but a change of fold pattern is the more likely explanation of this narrowing, for the following reasons.

Firstly, towards Mitchelstown in the west the number of fold axes within the synclinorium decreases while the average dip of their limbs increases. The tighter folding at the Mitchelstown end of the syncline can be appreciated by comparing the two section drawings accompanying the geological map at the end of the thesis.

Secondly, the fact that the minor fold axes within the synclinorium follow the major swing of strike suggests a change in the form of the fold pattern is the reason for narrowing rather than a truncation by slightly oblique strike faulting. The swing of strike in the northern half of the Ardfinnan-Mitchelstown synclinorium could be partly due to the influence of pre-existing Caledonoid structures, such as have affected the trend of folding eastwards in the Balingary and Castlecomer areas. The strike of

/rocks

rocks in the Knockmealdown mountains is N.270° while in the Galtees it is N.260° (see fig.1), and Caledonoid structures may have influenced the slight tendency towards a northeast-southwest trend seen in the Galtees compared with the Knockmealdowns.

For six miles south from Caher along the banks of the Suir the exposure is almost continuous. These extensive dip sections have made possible detailed profiles, at present levels of erosion, of the structures of this region. Within the synclinorium there are "large" folds with wavelengths in the region of 1000-1500 yards and superimposed on these is a series of "smaller" folds with wavelengths in the region of 100-500 yards. The "smaller" folds tend to have an uneven distribution on the "larger" folds. (For example, southern limb of the Castle View - Ballydrinan anticline.) In the western part of the area, where extensive dip sections are not exposed, the fold pattern is less certain.

The structure between Ballydrinan graveyard and Castle View House is broadly anticlinal. About 1300 feet of strata below the reef are exposed in sections

/both

both on the west and east banks of the river Suir and include the Ballyheron and Castle View Limestones. The structure north of the main anticlinal axis is simple, while that to the south is complicated by intricate minor folding. Northwards from the main anticlinal axis the structure can be divided into three parts. For 100 yards the dip is maintained at approximately 50°, then for 500 yards the dips vary between 20° and 25°, to be followed by an average dip of 58° over a further distance of 300 yards. The northern limb, then, includes a large structural terrace. 250 yards south of the main anticlinal axis there is a subsidiary anticline, followed southwards by a series of at least three smaller anticlines in a distance of 500 yards. Three east-west strike faults with narrow well-developed zones of fault breccia occur, but the throws have not been estimated. Immediately to the north of Castle View House a periclinal nose pitches to the west. There are other regions, for example Caher Park, Cranna Wood and Lacken House sections, where the wavelength of the

/smaller

smaller folds is commonly 500 yards or less.

By contrast, south of Castle View House Reef Limestones dip southwards at an average of 25° for 800 yards and show no signs of minor folding. Similarly, south of Ballydrinan graveyard, as described above, for 800 yards a northward dip is maintained in Castle View and Ballyheron Limestones. It is clear that there are regions of constantly dipping strata associated with regions complexly contorted by minor ripples.

The irregularities in fold pattern may be caused both by differences in lithology and also by faulting. Faulting as well as folding is an expression of deformation and there is evidence that faults and folds may have developed together as complementary structures (see p. 88).

In the Suir section, where the attitude of the axial planes of folds may be determined they always dip to the south, even in the northern part of the synclinorium. This is seen in the Cranna Wood, Cottage Hill Wood, Ballyheron Wood and Lissawan Wood sections. With the qualification that an absolute

/displacement

displacement cannot be recognized and only a relative displacement of one block compared to the next, this arrangement of axial planes may be said to indicate an overall push from south to north.

Measurement of individual limestone beds on the limbs and axes of folds, where both are exposed, indicates that there are no appreciable differences in thickness and that the visible folding is therefore largely open and concentric, and may have a limited vertical development. The strongly cleaved Lower Limestone Shales may have acted incompetently as a plane of minor shear between the competent limestones above and sandstones below, but the structure of the Old Red Sandstone is a complex series of minor folds, as in the limestone, demonstrating that the underlying sandstone has been involved in a similar type of folding.

2. Faulting

Both thrust faults and wrench ~~strike~~ faults are displayed in the Suir section southwards from Caher. The

/vertical

vertical exposures of fault planes are too small to make predictions about the general dip of the faults trustworthy.

(a) Cottage Hill Wood fault

Within Caher Park this fault, striking N.160° (to within 5°) passes to the east of Cottage Hill Wood, almost following the line of the river Suir. The outcrop of the fault plane is straight and marked by a zone of fault breccia. It is clear from sections to the east and west of the fault and parallel to it, that there is structural as well as lithological contrast on either side of the fault plane. West of the fault, beds of Ballyheron Limestone are folded into a composite anticline with slightly asymmetrical ripples (axial planes dipping south) and a variable wavelength in the region of 200 yards. East of the fault massive Reef Limestones maintain a general dip of 20° to the north. The fault is 5° oblique to the direction of dip of bedding (see fig.6)

The structural contrast may result from a purely vertical component of movement only if the Reef

/Limestone,

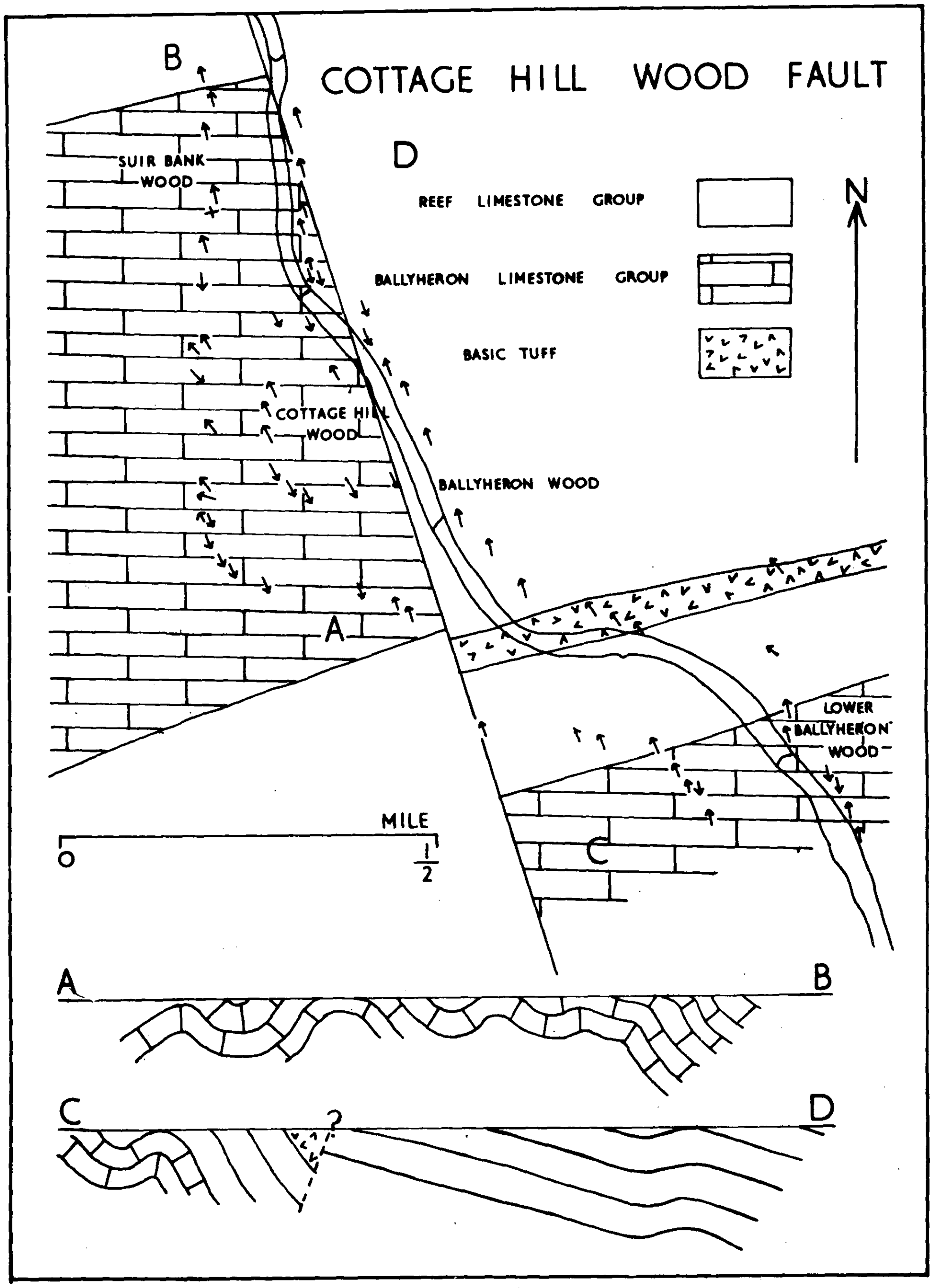


Fig. 6.

To illustrate the structural contrast as well as the contrast of rock types on either side of the Cottage Hill Wood Fault. (Caher Park, south of Caher)

Limestone, gently and uniformly dipping, was underlain by differentially deformed Ballyheron Limestone complexly folded on a small scale. It is more likely that there has been an important horizontal component of movement. The magnitude of this movement cannot readily be estimated since it is difficult to match structure and lithology on opposite sides of the fault anywhere along its traceable length. Slickensided surfaces in minor structures, associated with the main fault, and indicating its sense of movement, have not been observed.

This fault may be similar to wrench faults recorded in Dinantian rocks of Pembrokeshire and the Gower. George (1940, p.145) in connection with the Caswell fault states:- "The folding, thrusting and cross faulting were therefore reciprocal adjustments for the relief of a single system of pressures: they were contemporaneous and interdependent".

(b) Ardfinnan and Lacken faults

These two faults appear to be related (fig.7.). 100 yards south-east of the Roman Catholic Church at

/Ardfinnan

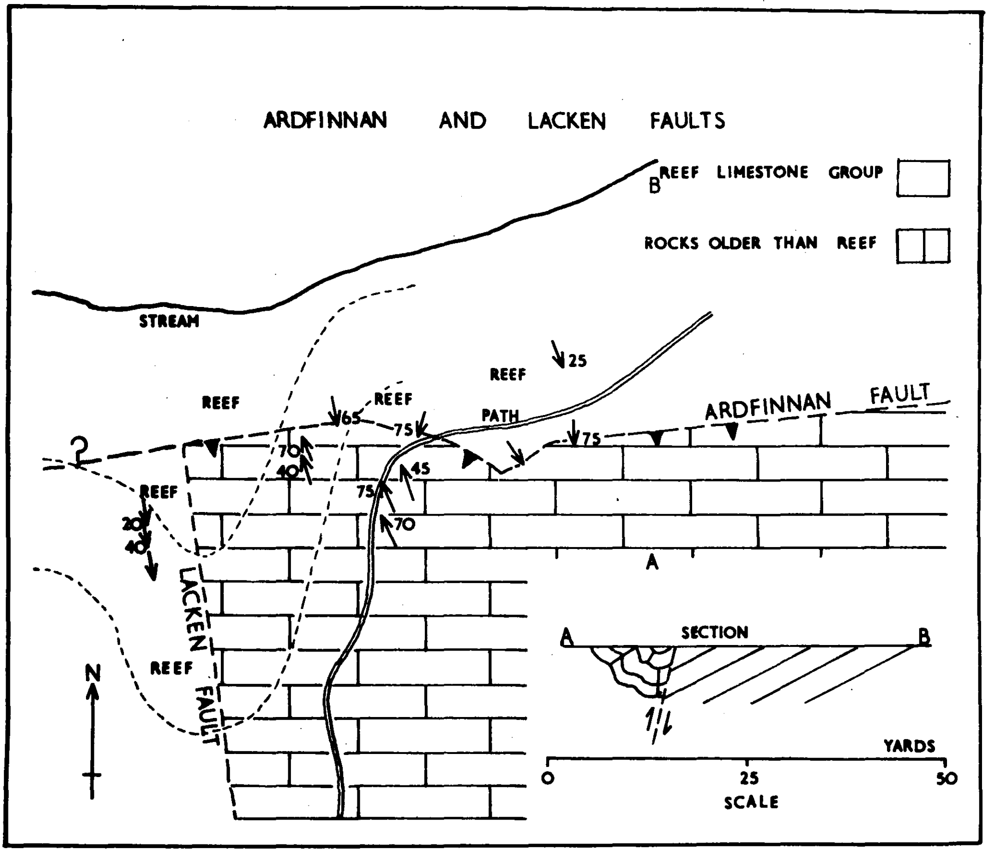


Fig. 7.

The Ardfinnan and Lacken faults as displayed south of the Roman Catholic Church Ardfinnan. The Ardfinnan fault is exposed but not the Lacken fault. The Lacken fault plane is shown in a formalised way as a straight line, although it probably trails into the Ardfinnan fault in the area illustrated.

Ardfinnan the Ardfinnan fault striking N.90° crops out over 30 yards. The fault plane dips 70° south and is sharply defined by a contrast of lithology, beds from below the Reef being upfaulted. There is no fault breccia. The Ardfinnan fault appears to terminate westwards at the Lacken fault, which strikes N.150° (inferred from outcrop distribution), and is 25° oblique to bedding strike. The Lacken fault is expressed topographically by a small gulley south-west of the Ardfinnan Roman Catholic Church.

There was a vertical component of movement greater than 1000 feet in the strata south-east of these faults, as well as a horizontal component. The Ardfinnan fault is a high angle reverse fault. Along the Lacken fault there has been a vertical component of movement as well as a sinistral horizontal movement, but the extent of the latter is not known although it may be considerable. From field evidence the Lacken and Ardfinnan faults appear to be confluent. Fault relationships of this type are recorded in Pembrokeshire (Geol. Surv. of England and Wales, one mile map, sheet 245).

/North

North of the reverse fault, beds of Reef maintain a constant dip of 25° south over 800 yards and if the folding and faulting are associated, the deformation of this region may have been expressed in faulting rather than folding.

(c) Tullaghorton fault

Along the southern margin of the synclinorium Reef Limestone is brought into contact with Old Red Sandstone by strike faulting. In the northern part of the synclinorium exposure is insufficient at the sandstone-limestone junction to be certain whether faulting occurred or not.

Within the region to the south of Clogheen and Goats Bridge, Reef Limestones are seen cropping out in proximity to the sandstones (within 150 yards in the area south-east of Goats Bridge). The sandstone has been upfaulted relative to the limestone (stratigraphically the base of the Reef is over 1500 feet above the sandstone). Two possibilities are suggested in explanation.

(i) That this east-west strike fault is a thrust

/produced

produced during compression by movement of sandstone upwards and northwards over limestone. The incompetent shales of the Lower Limestone Shales might influence the initiation of a fault between the competent sandstones below and the competent limestones above.

(ii) That this faulting is normal or antithetic and the result of north-south tension produced by a release of the north-south regional compressional stresses.

As there is evidence that the sub-parallel Ardfinnan fault is a high angle reverse fault, this may be the more likely explanation of the Tullaghorton fault.

The Cottage Hill Wood and Lacken faults are almost normal to the strike of bedding while the Ardfinnan and Tullaghorton faults are approximately parallel to strike. All these faults are interpreted as expressions of the north-south regional compressive stresses.

(d) Longitudinal crest faults

An example of a fault probably caused by locally induced stress conditions is well displayed in a quarry 1900 yards on a bearing N.205° from the Roman Catholic

/Church

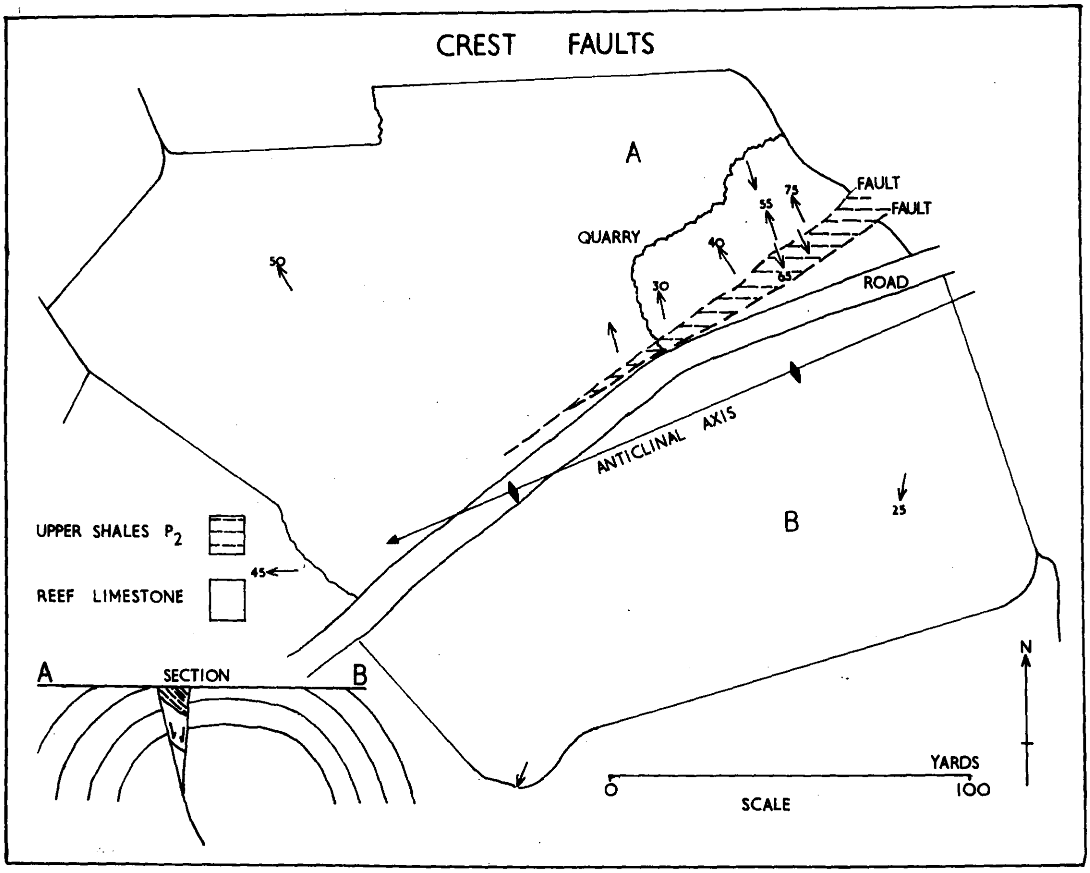


Fig. 8.

Crest faults observed in a quarry 1900 yds. on a bearing N.205° from the Roman Catholic Church Burncourt.

Church Burncourt (see fig.8.). The main quarry is situated to the north of the road and to the north of an anticlinal axis. Two converging faults have caused a block of the overlying Upper Shales to be downfaulted near the axis of an anticline in Reef Limestone. The faults are interpreted as a late stage feature in the development of this anticline, caused by tension in the outer arc of the fold. Similar faults are described by de Sitter (p.201) as longitudinal crest faults.

3. Cleavage

(a) Fracture cleavage

Half-a-mile south of Ardfinnan dip sections of Lower Limestone Shale begin and continue for one mile to the south. Competent limestone beds alternate with relatively incompetent shaly layers (pl.2, figs. 1 and 2). Fracture cleavage, striking parallel to bedding, is developed in both the limestone and the shale. This cleavage has a consistent relationship to the folds, converging upwards towards the top of an anticline (see fig.9.). The angle cleavage makes with bedding

/is

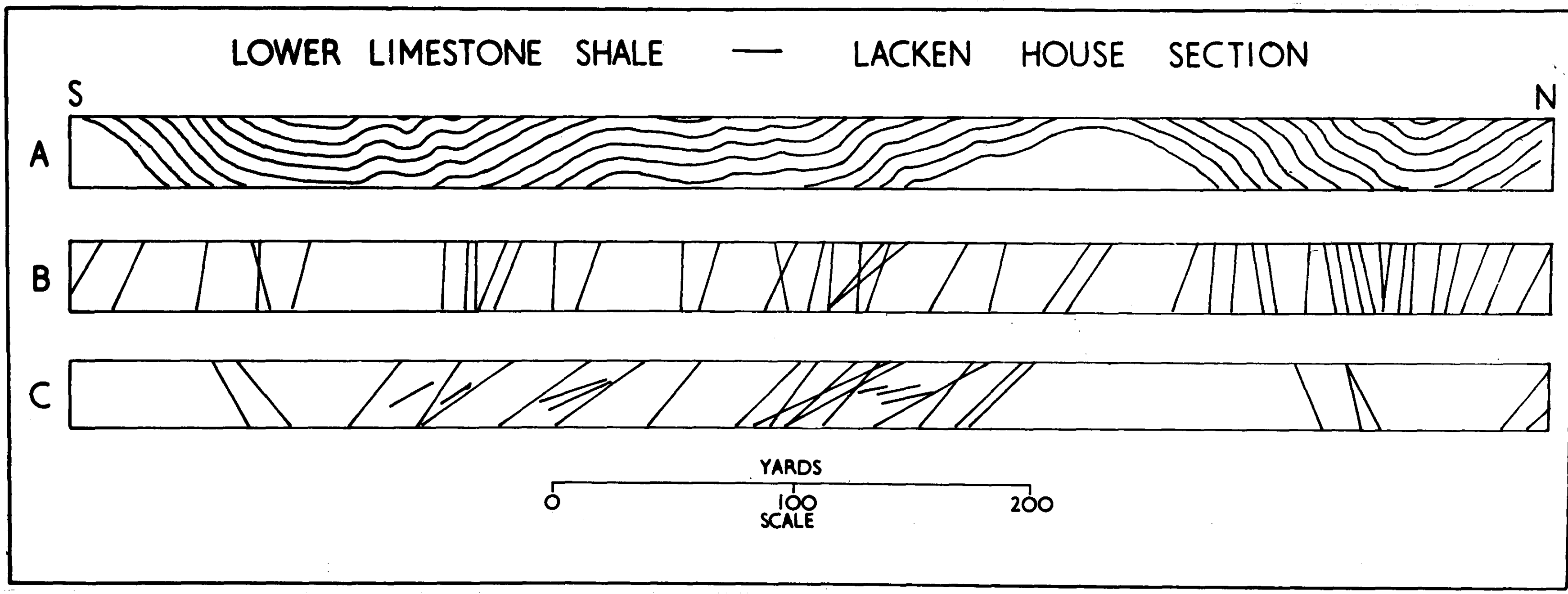


Fig. 9.

The figure illustrates the relation of fracture cleavage to folds in beds of Lower Limestone Shale. The northern end of the section commences 850 yds. on a bearing N.120° from the Roman Catholic Church, Ardfinnan.

A. - illustrates the pattern of folding.

B. - " " relation of cleavage planes to bedding, in competent limestone beds.

C. - " " relation of cleavage planes to bedding, in less competent shaly beds.

is greater in the competent limestones than in the less competent shales. Cleavage planes are refracted on passing from one lithology to the other. In any one bed several intersecting fracture planes are usually developed and disturbed cleavage is seen. This does not necessarily indicate more than one phase of compression.

Although fracture cleavage fanning down from the axes of anticlines is normally the relation throughout the area, close-spaced jointing is observed with a contrary relation - that is apparently converging downwards to an anticlinal core. This is seen in a quarry 1000 yards south-west of Cahergal Bridge (pl.9, fig.2.). If the close-spaced jointing has a similar origin to fracture cleavage this would be the relation expected in the inverted limb of a fold - though inversion is not suspected in the present case.

(b) Cleavage

A type of cleavage, distinguishable from fracture cleavage, occurs in massive competent beds, particularly

/of

of Reef Limestone (fig.10). This type of intense shearing is not uniformly developed, but is restricted to scattered regions and within a single quarry may vary in intensity. It is not consistently related to attitude, for steeply dipping beds are not always sheared.

This cleavage differs from fracture cleavage in having greater displacements along the many closely packed shear planes. Shearing surfaces are commonly strongly slickensided or show an obvious lineation perpendicular to strike. The direction of elongation of sheared particles is parallel to the cleavage planes, unlike fracture cleavage where the elongation direction of such particles is oblique to the cleavage planes.

South of Shanbally Castle and immediately north and south of Carrigmore this cleavage is well-displayed in continuous dip and strike sections of massive Reef Limestone (pl.9, fig.3.). The relationship of bedding to cleavage is difficult to establish, because massive Reef Limestones commonly give few clear indications

/of

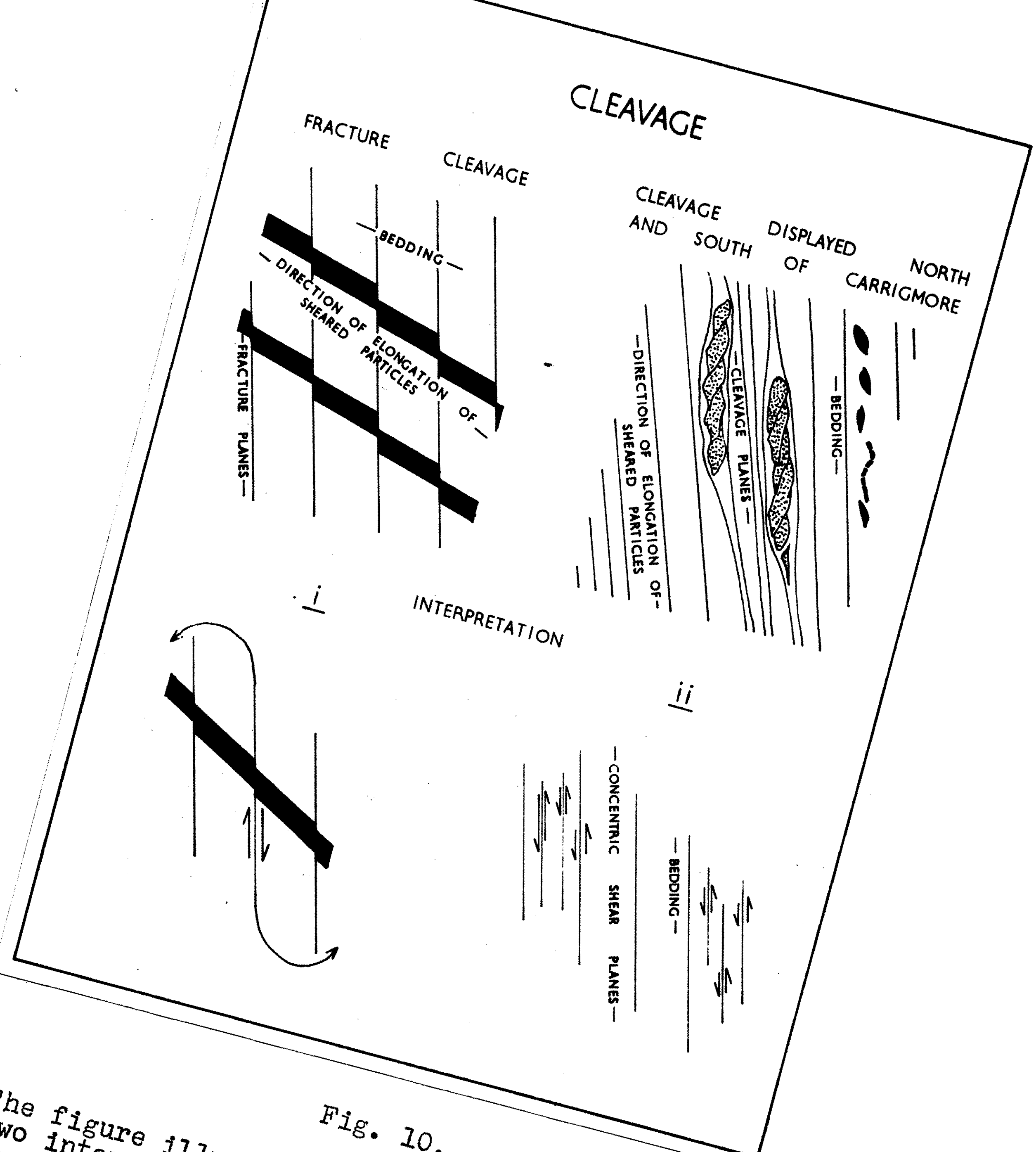


Fig. 10.

The figure illustrates two types of cleavage. Two interpretations of the cleavage seen at Carrigmore are suggested (see p.100) (see also, pl. 5, fig. 6. and pl.9, fig.3.).

of bedding and what indications there were are largely obscured by shearing.

To the south of Carrigmore, at two points where shearing is locally less intense, small brachiopods having their dorso-ventral axes parallel to each other, and presumably perpendicular to bedding, indicate that bedding is approximately (to within 20°) in the same direction as developed cleavage (70°-80° south). To the north of Carrigmore waterfall a cleavage dipping 70°-80° north occurs. There are several points along this dip section where the shearing is less intense and where a texture, supposedly bedding, can be seen. This may be merely an orientation stamped by the deformation producing cleavage; but the evidence of fragments of crinoid stems with up to fifteen linked ossicles, presumably lying along bedding, but also running parallel to the direction of shearing, and strings of occasional small brachiopod shells, confirm the plane of shearing is coincident with bedding (to within 20°).

In the southern part of the Carrigmore section

/fluorspar

fluorspar is abundant as veins often a quarter-of-an-inch thick and following the direction of cleavage. Thin section examination shows that the fluorspar is deformed and invariably follows, and is intimately involved in, the sheared structures which constitute the cleavage. In no case is the very intricate pattern of minor structures disrupted by fluorspar.

Two interpretations of this distinctive cleavage are suggested (fig.10.).

(i) In the case of fracture cleavage, the direction of particle elongation is oblique to the fractures developed and in the example illustrated the movement on each side of fracture planes is clockwise. If the movement of the fracture surface during development was anticlockwise it would tend to align itself with the direction of elongation of the sheared particles, and this occurring with exaggerated movements along shear planes might explain the particle elongation coincident with the shear planes.

(ii) The cleavage may be developed in the plane of bedding during folding by movement along concentric

/shear

shear planes. This could explain sedimentary particles elongate in the direction of cleavage and not disrupted by the shearing. This process, occurring in competent strata, is described by de Sitter (p.74) as elastico viscous flow.

4. Joints

Throughout the Ardfinnan - Mitchelstown syncline there is a prominent set of near vertical joints trending approximately north-south (pl.9, fig.1) and detailed measurements were made at forty localities. There appears to be only one prominent set of these "a - c" joints and not paired sets. They are parallel to tear faults and are within 10^{o} of being perpendicular to bedding strike. Where bedding strike swings from N.240^{o} at Caher in the east to N.260^{o} at Mitchelstown in the west there is a corresponding swing in the joint strikes. As the joints show a relation to the strike of folding this may indicate a related stress condition causing both.

The joint surfaces are quite straight and sharp and nowhere is an irregular or torn appearance seen.

/Slickensides

Slickensides were not observed on joint surfaces. Where the joints pass through layers of varying competence they are deflected. Plate 8, figs. 5 and 6 illustrate "a - c" joints being deflected where they pass through chert ribs.

Joints cutting across bedding and striking parallel to bedding are widespread and unlike the "a - c" joints usually occur in paired sets, three types of which are illustrated (pl.9, figs. 4,5 and 6).

Plate 9.

Plate 9.

Fig.1. Locality - south of Caher, 750 yards on a bearing N.352° from Waterloo Cottage. The photograph illustrates north-south striking "a - c" joints.

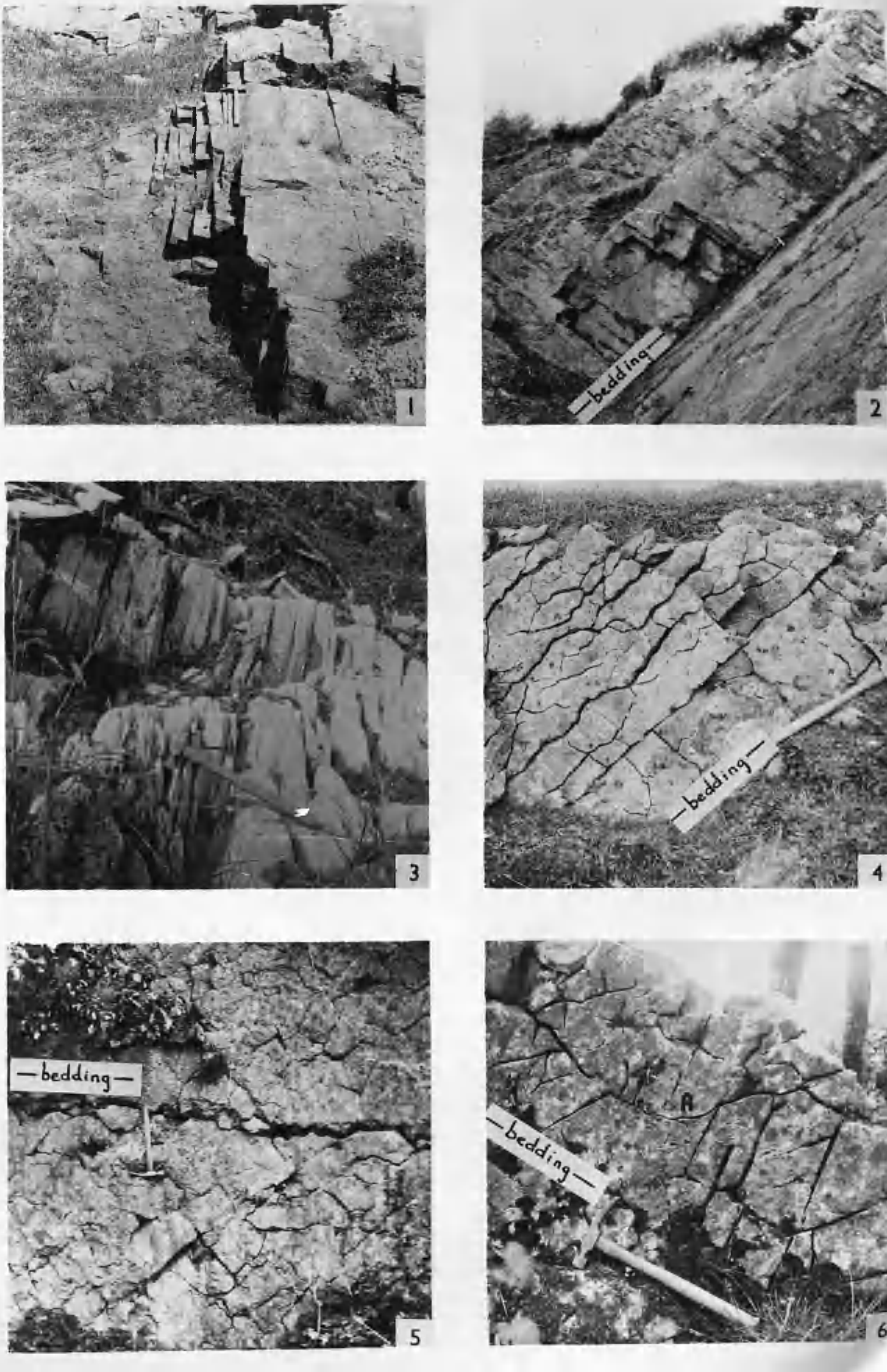
Fig.2. Locality - quarry 1050 yards on a bearing N.213° from Cahergal bridge. Close spaced jointing apparently fanning down to the core of an anticline. This is a contrary relation compared with normal fracture cleavage where the cleavage planes fan down from an anticlinal axis.

Fig.3. Locality - south of Shanbally Castle and south of Carrigmore waterfall. Highly sheared Reef Limestone with pronounced cleavage.

Fig.4. Locality - 2000 yards on a bearing N.207 from R.C. Church Burncourt. Irregular fractures are seen, some of which are in the plane of bedding while others form paired sets making an acute angle with bedding. These joints, and the others illustrated in figs. 5 and 6, strike parallel to bedding strike.

Fig.5. Locality - 2200 yards on a bearing N.105° from R.C. Church Burncourt. Two sets of joints at right angles are seen making an angle of 45° with bedding.

Fig.6. Locality - 1300 yards on a bearing N.289° from Ballylooby Post Office. Two sets of joints approaching a direction perpendicular to bedding are illustrated. At point A a joint trails into a bedding plane.


1
—bedding—
2
3
—bedding—
4
—bedding—
5
A
—bedding—
6

VII. PALAEONTOLOGY

1. Caninia cylindrica and Caninia benburbensis

In the Ballyheron Limestone there occurs an abundant fauna of caninioid corals including the species Caninia cylindrica and benburbensis along with forms apparently intermediate in type.

(a) Discussion of specific names

(i) Caninia cylindrica (Scouler) was first recorded in print by Griffith (1842, p.9.) and described by M'Coy (1844, p.187.) as Siphonophyllia cylindrica. In the same year Michelin described a similar fossil as C. gigantea, his figured specimen coming from Tournai. Priority of C. cylindrica over C. gigantea has long been one of doubt (see Salee 1910, p.27; and Carruthers 1911, p.321.).

Some authorities (O'Connell 1914, p.177; Hill 1938, p.102-103.) have favoured the continuation of the generic name Siphonophyllia for certain large corals of cylindrica type on the basis of the 'siphonal' depression of tabular elements in the fossula.

Lewis (1927, p.376.) pointed out that "no fossular difference exists between Caninia and Siphonophyllia" and consequently that the name Siphonophyllia cannot be retained. Carruthers (1908, p.158.) showed down-bending of tabulae into the fossula of C. cornucopiae (type species for Caninia). This downbending was the basis for separating Siphonophyllia as a genus.

The type of C. cylindrica was sectioned and the internal characters as seen in transverse sections were described by Smyth (1927, p.374.).

(ii) C. benburbensis was first described by Lewis (1927, p.378). The holotype is from the Carboniferous Limestone, Benburb, Co. Tyrone. Only the characters of the ephebic stage were described.

(b) A review of the morphology of Caninia cylindrica and benburbensis.

The type specimens of C. cylindrica and C. benburbensis are fragmentary and in neither case is the ontogeny known. C. cylindrica and C. benburbensis, as described by Lewis (1927), are not significantly different with regard to the following characters.

(i) size or shape of corallum or width of dissepimental zone;

(ii) fossular character and form of cardinal septum;

(iii) number of septa at a given intrathecal diameter;

(iv) size, length or thickening of septa intrathecally;

(v) tabular form or spacing.

The essential difference between C. cylindrica and C. benburbensis lies in the dissepimental tissue and extrathecal-septal development. C. cylindrica has large and irregular interdissepimental spaces; the largest occur a little way from the epitheca and become on the whole smaller inwards. Tooth-like septal ridges may be seen on dissepiments, but these do not join up to form continuous septa outside the theca. Minor septa may project intrathecally for about 2 m.m.

C. benburbensis is quite different. Extrathecally the major septa are more or less sinuous and extend to the epitheca. The minor septa usually extend from the theca in a somewhat discontinuous

/manner

manner for about half to two thirds the width of the zone. The interseptal spaces are partitioned by concentric or herringbone dissepiments. Minor septa typically do not project intrathecally.

Types structurally intermediate between C. benburbensis and C. cylindrica have been described (Lewis 1927, p.380.) from Humphrey Head near Grange and Silverdale near Arnside.

(c) Evolutionary relationships

Vaughan (1915, p.38, pl.III) illustrated a series of septal dissepimental relationships from a wholly lonsdaleoid condition in mut. K Endophyllum transitorium to a concentric dissepimental pattern with extrathecal septal development, seen in mut. S Caninia cylindrica, and suggested that this represented the theme of a true phylogenetic sequence. Lewis (1927, p.380) suggested that the ancestry of C. benburbensis was to be sought among the earlier variants of C. cylindrica and therefore that lonsdaleoid dissepiments were replaced in time by

/concentric

concentric dissepiments. This is in accord with Vaughan's earlier statement, but is the reverse of Lang's (1923, p.127) "lonsdaleoid" trend, where lonsdaleoid dissepiments were regarded as being the advanced condition.

(d) Use of Caninia cylindrica and benburbensis groups in Stratigraphic Correlations

Hill (1938, p.103) stated "Siphonophyllia is characteristic in the Tournaisian of western Europe and continues in the Lower Visean, but has died out by Upper Visean times". In fact these large caninioid corals are found in the Upper Visean. In Northern Ireland large caninias of cylindrica type are recorded throughout the Seminulan and lower part of the Dibunophyllum zones (Oswald 1955, p.181; ~~and Caldwell~~ and Caldwell 1958). Variants of C. cylindrica have been recorded from Lower Tournaisian to Upper Visean horizons and are therefore of limited zonal use.

Records of Caninia benburbensis appear to be restricted to the Visean. It is recorded by Hill (1938, p.10) from S_2 - D_2 beds and by Lewis (1927, p.378) from D_1 - D_2 beds in North Wales.

(e) Caninia cylindrica and benburbensis from the Ardfinnan - Mitchelstown syncline.

In the following section a variety of types of Caninia falling within the species C. cylindrica and C. benburbensis, collected from the basal 500 feet of the Ballyheron Limestone Group, are described.

The study is based on sections of 62 specimens, in most of which the proximal portions are missing.

A study of the morphology of an individual specimen requires taking into consideration the changes of appearance which result from different planes of section, as well as from the structural modifications occurring during ontogeny.

Seven main groups of these caninioid corals are recognized (A,B,C,D,E,F and G) and these are illustrated in plates 10, 11 and 12.

Plate 10 Groups A, B and C.

" 11 Groups D and E.

" 12 Groups F and G.

The basis of this grouping depends upon observations of the following:-

(i) size of coral and relation of number of septa to intrathecal diameter (see fig. 11.). Total diameters were not measured because of irregularities in the thickness of the dissepimental zone, portions of which are frequently missing. Where specimens are deformed the average diameter was taken.

(ii) length and thickening of major septa;

(iii) development of minor septa;

(iv) form of cardinal fossula and type and distribution of major septa about the fossula;

(v) form of dissepiments;

(vi) tabular arrangements.

Obviously both the number of septa and the diameter are variable in a single specimen and will depend on the stage of development of the coral. A distinction between different individuals on the basis of size and number of septa (that is observation e.i above) is justified for the following reasons. Firstly, because corals reach the cylindrical condition at different intrathecal diameters with different numbers

/of

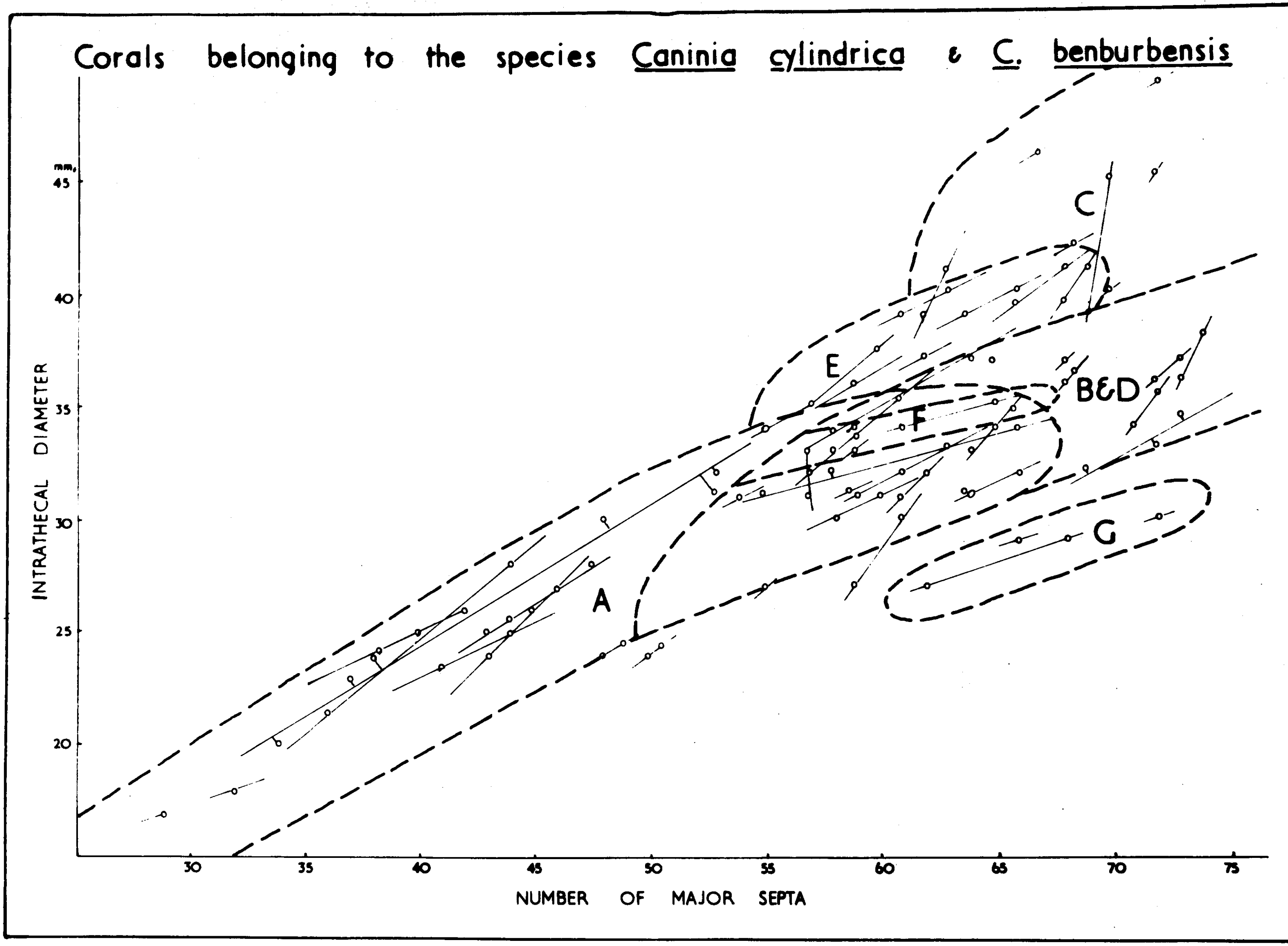


Fig.11. The graph illustrates the relations between intrathecal diameter and number of major septa for corals belonging to the species Caninia cylindrica and benburbensis. The letters A to G refer to the coral groups described in the text and illustrated in plates 10, 11 and 12. The broken lines show limits for these groups, but are largely arbitrary and are not projected back where the proximal portions of corals are missing.

of septa, and, secondly, because a study of ontogeny reveals that at corresponding intrathecal diameters proximal sections of large forms are not in fact equivalent to distal sections of small forms, either with regard to septal number or other characters.

<u>Group A</u> (pl.10)

A differs from both B and C by being smaller and having fewer septa in the mature cylindrical condition. The tabulae of A_1 are more widely spaced and domed than those of A_2.

<u>Group B</u> (pl.10)

In B the dissepimental zone is relatively narrower than in C (.75 cm. in B as against 1 - 1.5 cm. in C) and this, combined with the smaller intrathecal diameter of B compared with C, makes the corolla distinctly smaller in the adult cylindrical stage. In B there is one short, thickened cardinal septum bounded by parallel or slightly converging major septa, linked at their axial ends by a tabular intersection. Stereoplasmic thickening of septa is variable, but

/never

never pronounced. Dissepiments are of concentric or herringbone type except for a narrow zone, discontinuously developed at the periphery of some specimens, where septal development in places failed and blister-like lonsdaleoid dissepiments occur.

Group C (pl.10)

C contains large forms with a wide dissepimentarium. The dissepiments are of lonsdaleoid and concentric types with the former commonly unevenly distributed around the periphery. Minor septa normally extend intrathecally for 1 to 2 m.m. and are discontinuous on dissepiments immediately extrathecally.

Group D (pl.11)

The relation of number of septa to intrathecal diameter is similar to that in B, but in D there is heavy stereoplasmic thickening of septa. There are also differences of fossular character and tabular form which are not due to the chance of section and which are maintained throughout the cylindrical portion of the coral. The fossula of D_1 differs from B. In

/D_1

D_1 the cardinal septum is crowded by the two adjoining septa, which taper together and are not strongly or obviously linked by a tabular intersection. Stereoplasmic thickening is heavy compared with B_1, particularly so in the cardinal half. Along with stereoplasmic thickening, which is reduced during ontogeny, there is an axial restriction of tabulae in D_1 and D_2 compared with B. Lonsdaleoid dissepiments occur in irregular patches.

In D_2 the cardinal septum is not as confined by the bounding major septa as was the case in D_1. There is a wider fossula and in this respect it is similar to B. It differs from B, however, in that the bounding and adjacent major septa taper markedly at their ends and curve about the fossula. It also differs from B in having heavier stereoplasmic thickening of septa.

<u>Group E</u> (pl.11)

E_1 differs from B by having relatively fewer septa at corresponding intrathecal diameters, a prominent development of lonsdaleoid dissepiments and

/heavy

heavy stereoplasmic thickening of septa. The tabulae are slightly domed, and occupy a restricted central area between the axial ends of thickened septa in the cardinal half, and theca in the counter cardinal half.

E_2 is similar in size, septal number and dissepimental pattern to E_1 but lacks heavy stereoplasmic thickening. The tabulae are flatter and less restricted axially than in E_1. During the ontogenies of E_1 and E_2 irregular lonsdaleoid dissepiments give way to smaller more regular concentric types.

<u>Group F</u> (pl.12)

F is intermediate in character between A and B regarding the relations of size to septal number, but distinguishable from A and B as well as other groups (except G) by the very shortened unthickened nature of the septa.

<u>Group G</u> (pl.12)

In G, as in F, there is a tendency towards the breviseptate condition, but there are many more septa

/at

at corresponding intrathecal diameters, for example:

F	G	
57	68	numbers of major septa at intrathecal diameter of 2.9 cm.

The general trends noted in the ontogenies of these caninioid corals are as follows:-

(i) increase in size;

(ii) decrease in length of septa with an increase in their number;

(iii) decrease in stereoplasmic thickening, which tends to become restricted to the cardinal half;

(iv) tendency for septa bounding fossula to become straight and regular;

(v) tendency for concentric to replace lonsdaleoid dissepiments in ontogeny.

Taxonomy of the Groups described.

A is similar to C. benburbensis, but is smaller than the type specimens.

B is similar to the holotype of C. benburbensis, but has less heavy stereoplasmic thickening.

C_1 and C_2 are similar to the 'transitional forms' intermediate in character between C. cylindrica and C. benburbensis referred to by Lewis (1927, p.380).

/D_1

D_1 and D_2 are forms intermediate between *C. cylindrica* and *C. benburbensis*.

E_1 is a form of *C. cylindrica* with heavy stereoplasmic thickening. E_2 is typical of *C. cylindrica*.

F and G are breviseptate forms more typical of *C. benburbensis* than *cylindrica*.

These seven groups of corals, which include a considerable variety of forms, are all to be included in the species *C. cylindrica* or *C. benburbensis*. In order to establish a phylogenetic pattern of change, if this is significantly present within the 500 feet of Ballyheron Limestone in which the corals are abundant, an accurate stratal correlation from one fossiliferous locality to another is essential. This is hindered by the limitations of exposure and the complexities of structure.

Until further work has been done on the nature and proportions of concentric and lonsdaleoid dissepiments, the septal conditions and changes associated with them, and the nature and distribution of stereoplasmic thickening, and while the ontogenies are not

/fully

fully known, and the phylogeny is unknown, it is not considered that the limits of these two species can be defined. What has been done here is to illustrate the variety of forms which, on the present taxonomy of Caninia, must be included in the groups cylindrica and benburbensis. This is a study of variation among corals falling within the C. cylindrica and C. benburbensis groups, collected from a restricted stratal unit. It cannot be a study of evolution and neither can a morphological type described here be related to a stage in an evolising plexus, for no such plexus has been described satisfactorily.

In Dinantian times, no reliable morphological pattern of change, applicable over the area of Britain and Ireland, has yet been defined for the C. cylindrica or C. benburbensis groups of corals, or for that matter any other coral group. This means that no evolising plexus of corals has been defined in which the morphological characters, changing with the passage of time, are successfully and dependably related to particular

/stratal

Plate 10.

Plate 10.

All figures natural size

A_1 and A_2. - specimens similar to *Caninia benburbensis*, but smaller than the type material.

B_1 and B_2. - similar to the holotype of *C. benburbensis*, but have less heavy stereoplasmic thickening of septa.

C_1 and C_2. - similar to "transitional forms" between *C. cylindrica* and *C. benburbensis* referred to by Lewis (1927, p.380).

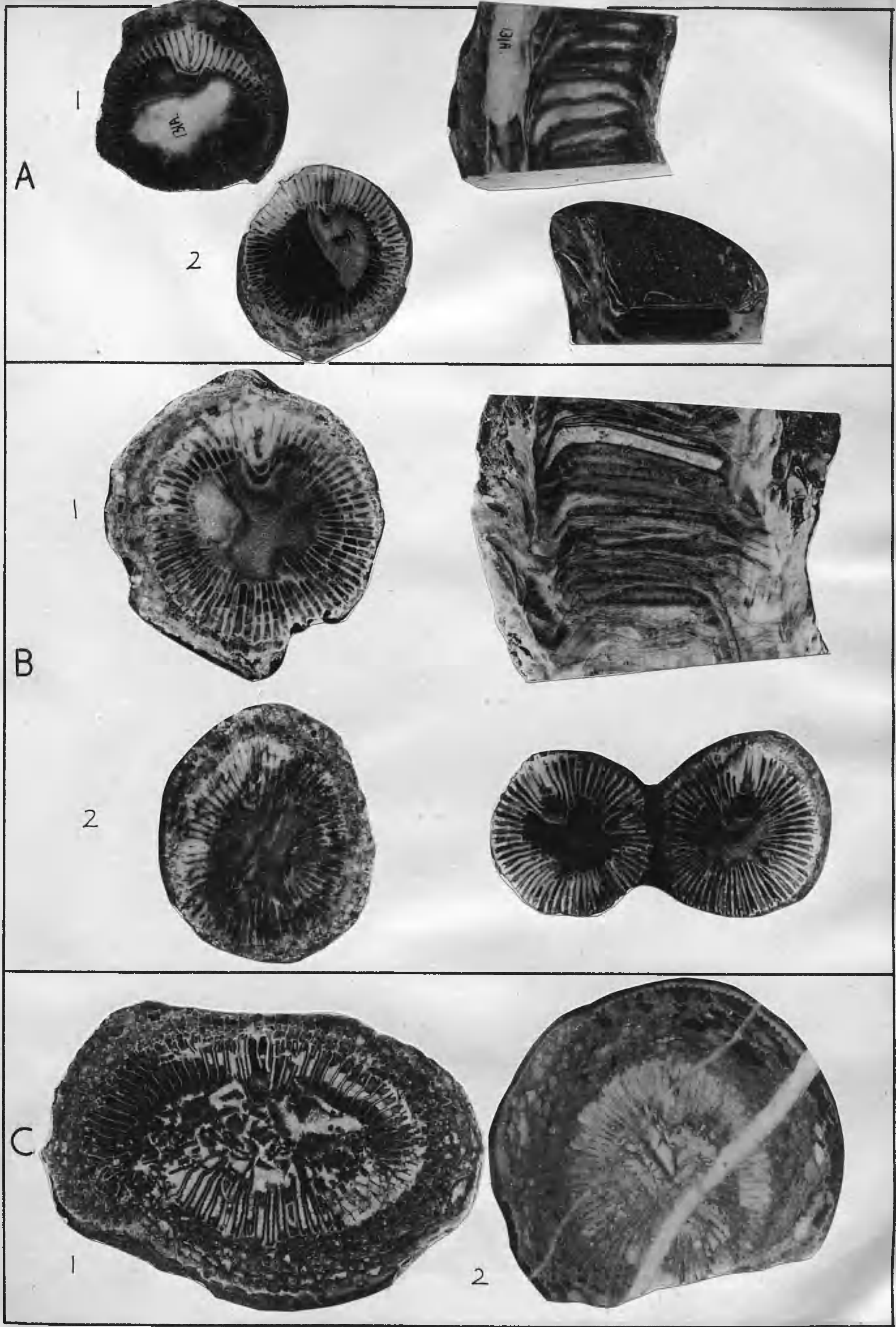

A
1
2
B
1
2
C
1
2

Plate 11.

Plate 11.

All figures natural size

D_1 and D_2. - are forms intermediate between <u>Caninia cylindrica</u> and <u>Caninia benburbensis</u>.

E_1. - is a form of <u>C. cylindrica</u> with heavy stereoplasmic thickening.

E_2. - is typical of <u>C. cylindrica</u>.

D1

D2

E1

E2

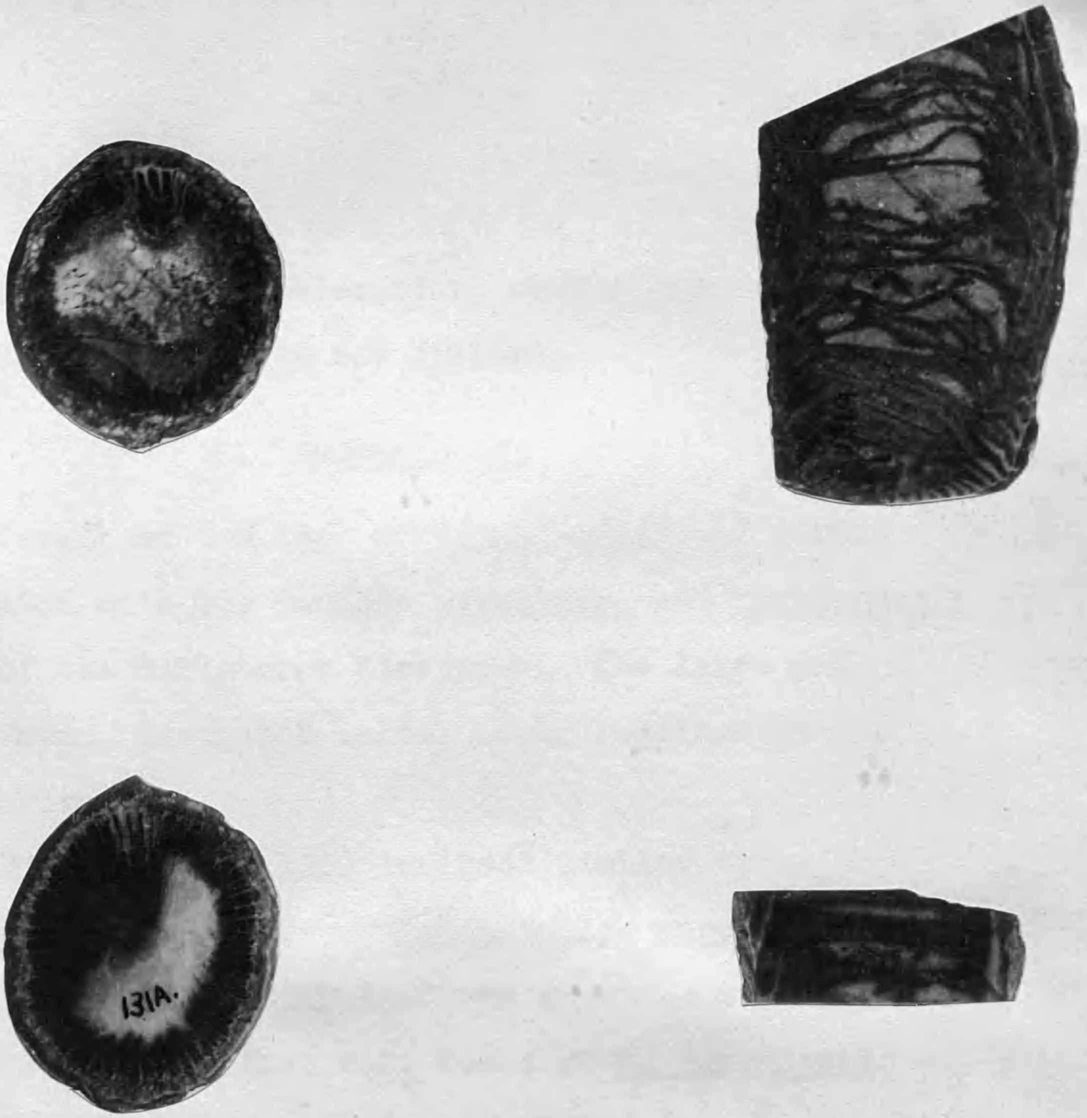
Plate 12.

Plate 12.

All figures natural size

F and G. - are breviseptate forms more typical of _Caninia_ _benburbensis_ than _Caninia_ _cylindrica_.

F



G

stratal zones in the Dinantian, over a geographic area embracing Britain and Ireland.

2. Palaeosmilia

Corals of the type of Palaeosmilia are found associated with the Caninia cylindrica and benburbensis fauna of the Ballyheron Limestone. The large and small forms, described below, occur together at the same horizon.

Hill (1938, p.120) included similar types in the range of variation of Palaeosmilia murchisoni. She also pointed out (p.120) the weakness of Vaughan's (1905) suggestion that C_2S_1 forms of P. murchisoni (Cyathophyllum Ø) can be distinguished from P. murchisoni of the D zone. In fact, no reliable distinction has yet been made between forms occurring at different Visean horizons.

As the calices of the small forms are seen they are complete individuals and their small size is not due to a missing distal portion. The graph (fig.12) relates septal number to intrathecal diameter.

/Intrathecal

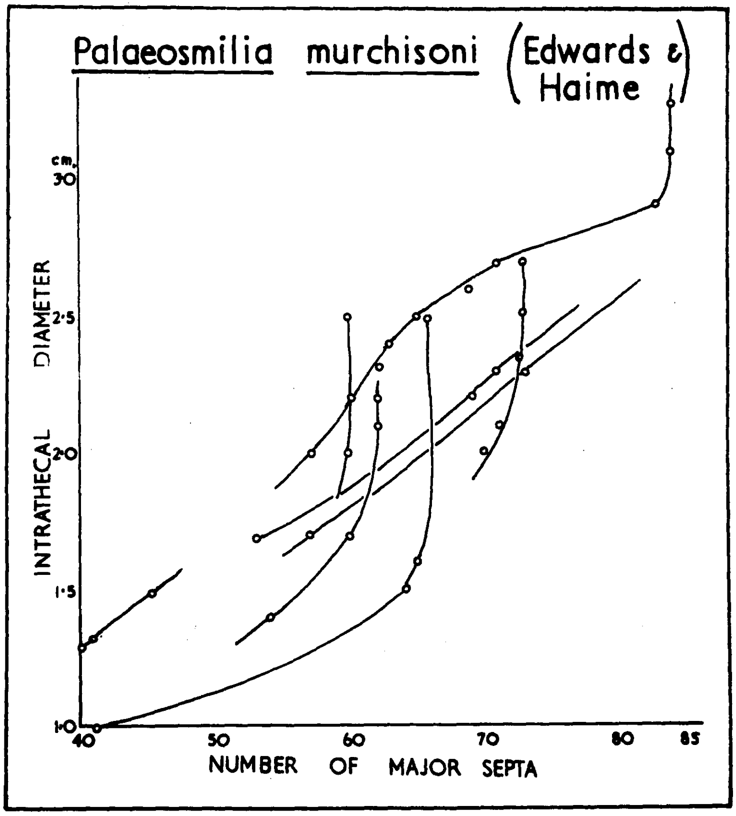


Fig. 12.

The graph illustrates the relations between intrathecal diameter and number of major septa for large and small forms of <u>Palaeosmilia</u> <u>murchisoni</u>.

Intrathecal and not total diameters are measured as this avoids the irregularities generally common to dissepimental zones. It appears that the small forms are not merely juvenile stages. The small forms reach a condition where there is an increase in diameter without an increase in the number of septa at a stage with many fewer septa than in large forms. Up to the stage of maximum septal development, however, the small forms have a greater number of septa, at equivalent intrathecal diameters, than the large forms (fig.12).

(a) Small forms (pl.13, figs. 1,2 and 3)

A small form of Palaeosmilia, with intrathecal diameter about 2 cm. having 62 major septa, is closely similar to P. multilamellata M'Coy described by Lewis (1930, p.274, pl. XXII, figs. 14 a-e) from the C_2S_1 zone of the Isle of Man. An essential feature appears to be the arrangement of tabellae which, seen in longitudinal sections of the central zone, sag medially and are arched slightly peripherally. The Manx forms are said to have 50 major septa at 2 cm. diameter.

Garwood (1912, p.562 and pl.L, figs. 5-7) described and illustrated P. multilamellata from the Michelinia zone of Arnside, but made no mention of the tabular structures recorded by Lewis. The figured section has 75 major septa at an intrathecal diameter of 2 - 2.5 cm. Garwood figured a transverse, but not a longitudinal, section of M'Coy's type.

Hill (1938) did not recognize P. multilamellata M'Coy as a species distinct from P. murchisoni, and pointed out the great variation in appearance, according to the plane of section, of the tabular structures in longitudinal sections.

(b) Large forms (pl.13, figs. 4 and 5)

Large forms of Palaeosmilia typical of P. murchisoni occur in association with small forms, and according to Hill (1938) are not specifically different.

The maximum diameter of the large forms is 6.5 cm. The proximal ends are generally broken off, but the approximate length of such forms is 7 cm. The septa are of two orders and the number varies with diameter (see fig.12). Major septa extend almost to the axis

/and

and are of slightly unequal length. Near the axis some of the major septa converge in groups. At 6 cm. diameter the minor septa reach to within 1.3 cm. of the axis. Where the minor septa terminate they are generally connected to the major septa by dissepiments, but occasionally they are seen to curve towards, and fuse with, major septa. The two minor septa on either side of the cardinal septum are not longer than the others.

The dissepimentarium extends as near to the axis as the minor septa. The dissepiments are small and regular except for a peripheral zone in distal sections, where the dissepiments are of lonsdaleoid type and not penetrated by septa. The wall between the dissepimentarium and tabularium is sharply defined. Tabulae seen in longitudinal sections (pl.13, fig.5) have narrow upturned edges, and slight axial sag. Globose convex tabellae are commonly seen replacing tabulae. There is a sharp demarcation of tabularium and dissepimentarium in longitudinal sections.

An important feature of this coral is the

/possession

possession of an outer zone of lonsdaleoid dissepiments. Similar forms are recorded by Hill (1938, p.119) from the D_2 zone of Bristol. The Irish forms are from a much lower horizon (C_2S_1).

The eight specimens serially sectioned are insufficient to provide information for generalisations to be made, but show a considerable range of variation within the genus Palaeosmilia collected from the Lower part of the Ballyheron Limestone. At one locality large and small forms were found in the same bed. The relation between intrathecal diameter and number of septa illustrated in figure 12, suggests that there is overlap between large and small forms and that they may in fact be conspecific. That is there is no well-defined difference of form between P. murchisoni and P. multilamellata.

Plate 13.

Plate 13.

All figures X 1.5 negative photographs of cellulose peels.

Figs. 1 & 2. Transverse sections of a small form of <u>Palaeosmilia</u> similar to <u>P. multilamellata</u> (M'Coy) described by Lewis (1930, p.274).

Fig.3. Longitudinal section of coral illustrated in figs. 1 and 2.

Fig.4. Transverse section of <u>Palaeosmilia murchisoni</u>.

Fig.5. Longitudinal section of coral illustrated in fig.4.

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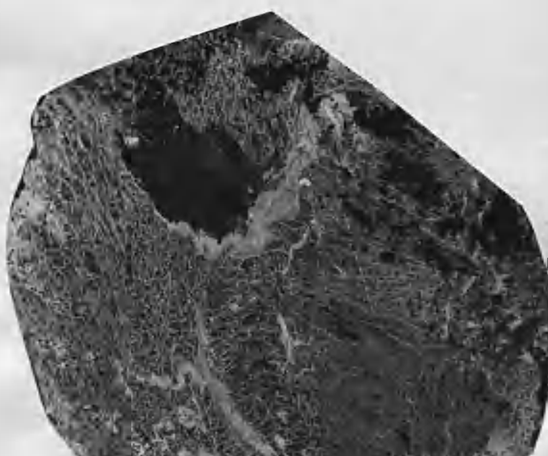

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VIII. SYSTEMATIC PALAEONTOLOGY

The fossils described below were collected personally from the Ardfinnan - Mitchelstown syncline and this material is in the keeping of the Hunterian Museum, Glasgow University.

Koninckophyllum tortuosum (Michelin) Carruthers 1913 (pl.14, fig.1.)

Relation of number of septa to size for distal sections through 6 specimens.

No. of major septa	33	36	36	34	32	36
Diameter in m.m.	11	10	10	12	9	12

These are small solitary corals with zaphrentoid early stages and later a structure generally similar to *Lithostrotion*. In ephebic sections the septa are withdrawn from the columella and a narrow dissepimentarium appears. The specimens are closely similar to *Lophophyllum tortuosum* (Michelin), described by Carruthers 1913. Carruthers *K. tortuosum* was from Z_2 and C horizons of Tournai, Belgium. At Hook Head Co. Wexford (Smyth 1930, p.540) recorded the species

/from

from the Upper Michelinia favosa beds (γ). Carruthers (1913, p.52) stated that "K. tortuosum appears to be a characteristically Tournaisian species", but at the same time he refers to its occurrence in the Lower Limestone of Castletown, Isle of Man where, "it seems to be well up in the Visean". This Lower or Castletown Limestone of the Isle of Man is later (Lewis 1930, p.238, fig.1) referred to S_1 - D_1 zones. K. tortuosum, then, has been recorded from Z_2 to D_1 zones.

Koninckophyllum praecursor (Howell)
(pl.14, figs. 2 - 6)

38 major septa at 17 m.m. diameter. Dissepimental zone 2 - 3 m.m. wide.

The dissepiments are of concentric and angulo-concentric types and there are about six rows in the dissepimentarium. The minor septa are over half the length of the major septa. The axial structure is cuspidate towards the counter and cardinal septa. In transverse sections a stout central rod can be seen with radiating lamellae and 4 to 6 concentric tabellar intersections. This "open" axial structure is

/typical

typical of Howell's "carrutherselloid" variant (Howell 1938, p.14). The radial lamellae are about as numerous as the major septa and often meet the distal ends of the major septa, except in the region of the cardinal fossula. Here the column is surrounded by unbreached tabellar intersections.

Howell 1938 in defining the new species K. praecursor distinguished it from Carruthersella compacta (Garwood) on the following grounds.

(i) The consistent development of minor lamellae opposite the minor septa in C. compacta is not obtained in K. praecursor.

(ii) The radial lamellae of K. praecursor, though well cemented with sclerenchyme, can easily be discerned under a hand lens.

(iii) No specimen of K. praecursor shows proximal retreat of calicular septa, a feature considered to be of generic rank in Carruthersella.

Considering these three points of difference made by Howell.

(i) It appears wrong to imply that minor lamellae

/occurring

occurring opposite minor septa is a diagnostic feature of C. compacta. In Garwood's (1912, p.556) words, "occasionally, additional lamellae appear to be inserted, and occupy positions facing the minor septa". In fact these additional lamellae are not a distinctive feature of Garwood's illustrated sections. Even so, Howell implied earlier in his paper that K. praecursor had 46 major septa and later stated in connection with the carrutherselloid variant, that about 80 radial lamellae ~~are~~ were present. This indicates that lamellae do occupy positions facing minor septa as well as major, and this is illustrated in his first plate (pl.1, fig.14).

(ii) The columella of K. praecursor holotype appears closely similar to that of C. compacta.

(iii) Howell stated that no specimen of K. praecursor showed proximal retreat of calicular septa, but as no complete specimens were found and the calyx was not described, it may not have been present. The holotype ~~consists of~~ is illustrated by a single transverse section of a mature corallite.

Overlooking the above difficulties of comparison, it seems that a distinction may be made on the grounds that C. compacta has an outer zone of lonsdaleoid type dissepiments, where the septal ends are not continuous to the wall.

K. praecursor is a characteristic species from the Caninia Oolite throughout Gower and the western part of the Vale of Glamorgan, but persists in reduced numbers into the Upper Caninia zone. It is very rare in S_1.

Koninckophyllum cf. proprium (Sibley)
(pl.14, figs. 7 and 8)

42 major septa at 2.4 cm. diameter.

A prominent feature of this specimen is the solid, isolated, apparently non-dentate columella seen in the ephebic stage. Of the described Koninckophylla its combined structural features are most closely similar to those of K. proprium (Sibley 1908). Its smaller size and the nature of the dissepimental area distinguish it from K. magnificum (Thompson and Nicholson). K. proprium (Sibley) is similar in size and septal

/numbers

numbers to _K. columatum_ (George), but the latter has a more restricted septa-free central area, a dentate columella and close packed herringbone dissepiments extrathecally.

Koninckophyllum cf. _columatum_ (George)
(pl.14, fig.9)

41 major septa at 2.5 cm. diameter.

The general form and proportion of dissepimentarium, tabularium and axial structure is similar to _K. magnificum_, but the specimens are smaller and have fewer septa. (_magnificum_ has 59 major septa at 4.0 cm. diameter) The septa are not dilated in the tabularium as in _magnificum_.

K. scarlettense (Lewis 1930) differs by having the septa thickened intrathecally and more closely set (54 major septa at 3 cm. diameter).

The Irish specimens are similar to _K. columatum_ (George 1927) except for the peripheral lonsdaleoid dissepiments recorded in _columatum_. Hill (1939, p.89) considers _K. columatum_ to include three distinct species. _K.θ_ Vaughan (1905, pl.XXIII, fig.4) is not noticably

/affected

affected by secondary thickening and does not possess a lonsdaleoid border. These Irish specimens are closely similar to K.θ Vaughan, which is included by George (1927, p.88) as a synonym, and possibly slightly earlier time variant, of K. columatum.

K.θ Vaughan 1905 was recorded from D_1 zone.
K. columatum (George 1927) was recorded from D_2 zone.

Koninckophyllum ? carlyanense (Smyth 1915)
(pl.14, figs. 10 - 12)

40 major septa at 2 cm. diameter.

This specimen has a dentate columella and numerous tabellar intersections with apparently discontinuous lamellae. The dissepimentarium is largely stripped off, but in places up to three rows of dissepiments are visible. The septal and dissepimental arrangement is similar to Rylstonia, but Rylstonia has a distinctively large central columella.

The general form and relation of number of septa to size is similar to K. carlyanense (Smyth 1915), but the latter has a mesial plate continuous with the counter septum, while in the present specimen it is

/apparently

apparently discontinuous. Also the major septa of K. carlyanense are less thickened and taper to a point, in contrast to the blunt septal ends of the Irish specimens. K. carlyanense has less numerous tabellar intersections.

Koninckophyllum sp. (pl.14, fig.13)

The dissepimental zone occupies approximately one third, the major septa two thirds and the axial structure one third, of the radius of the corallum. The axial structure appears to be an axial plate continuous with a major septum, and to be elongate perpendicular to the cardinal - counter cardinal axis. Six radial lamellae are seen linked by three tabellar intersections.

Six to eight rows of concentric or herringbone dissepiments are present extrathecally. Most of the minor septa are degenerate, but a few are half the length of the major septa. Five series of tabellar intersections are seen between the theca and the axis.

K. vesiculosum (Garwood 1912) and K. ashfellense (Garwood 1912) are small forms in which the proportions

/of

of the axial zone, major septa and dissepimentarium are similar to the present specimen.

	No. of major septa	Diameter in mm.
Present specimen	44	13
Garwood's figured K.ashfellense	45	17
K. vesiculosum (Garwood)	38	20

The present specimen differs from vesiculosum in the absence of a non-septate marginal dissepimental zone. It differs from K. ashfellense in having a greater septal number at a smaller diameter, and also in the form of the axial structures. In K. ashfellense the columella is very thin and lath-like.

? Koninckophyllum sp. (pl.14, figs. 14 and 15)
40 major septa at 1.9 cm. intrathecal diameter.

The dissepiments of this coral are angulo-concentric or herringbone and are disposed with bilateral symmetry about the cardinal-counter cardinal axis. Minor septa are degenerate. The septal-dissepimental arrangement is similar to Dibunophyllum. The axial structure, consisting of a thickened median plate

/confluent

confluent with a major septum, is circumscribed by tabellar intersections giving the axial structure a rhomboid form.

The short minor septa and dissepimental pattern are not typical of Koninckophyllum, while the absence of obvious radial lamellae in the axial structure is not typical of Dibunophyllum.

Koninckophyllum sp. (pl.14, figs. 16 - 19)
44 major septa at 3 cm. diameter.

This specimen has a relatively wide dissepimental zone and narrow axial zone. The minor septa are about half the length of the major septa, while the axial zone is about one fifth of the total diameter. The septal and dissepimental arrangement is clisiophyllid. The axial structure is not clisiophyllid because of its restricted size and because the lamellae are discontinuous elements while the tabellae are continuous. This is a koninckophylloid character.

The axial structure has an irregular bounding wall and an outer zone of an irregular vesicular nature. A median plate, discontinuous with cardinal and counter

/cardinal

cardinal septa, is seen with attached lamellae and circumscribed by tabellar intersections.

The longitudinal section pl.14 (fig.19) is konincko-phylloid and has complete tent shaped tabellae with discontinuous lamellae between.

<u>Carcinophyllum</u> <u>simplex</u> (Garwood)
(pl.15, fig.1)

The axial structure is composed of thick irregularly twisted vertical lamellae, some of which are continuous with the inner ends of the major septa. The thickened axial structure remains attached to one thickened major septum, the counter septum. The major septa are short and blunt. There are 32 at a diameter of 11 mm. These are confluent at their bases to form a thick wall. The minor septa are small and do not penetrate this wall. One, or in places, two rows of dissepiments are seen outside the thickened theca and are of concentric type.

This specimen is very like <u>Carcinophyllum</u> <u>simplex</u> (Garwood 1912). Garwood stated (p.557) that this form had 28 major septa at 17 mm. diameter, although

/he

he figured a specimen (pl.XLVIII, fig.4a) 17 mm. in diameter which has 35 major septa. His figure shows one, or in places, two rows of concentric dissepiments. Garwood pointed out that it is not until late growth stages in the genus *Carcinophyllum* that non-septate dissepiments appear.

The fact that the major septa are not strongly continuous with the lamellae, and that dissepiments are present, may indicate that this is not a proximal section. It differs from *C. medipense* (Sibley 1906, p.369), which has a circular and strongly bounded central area and from *C.*θ (Vaughan 1905) which has a greater development of the peripheral vesicular zone and from *Rylstonia preacuta* (Howell 1938) because *preacuta* has no dissepiments.

Carcinophyllum simplex is a fairly dependable indication of the Upper Caninia zone.

Cravenia cf. *lamellata* (Howell)
(pl.15, fig.3.)

The structure of this coral is closely similar to *Cravenia lamellata* described by Howell (1938). The

/main

main point of difference is the greater number of septa and slightly larger size of the present specimens.

	No. of major septa	Diameter cm.
Irish specimen	45	2.1
" "	45	2.3
C. lamellata holotype	42	2.1

The distinctive features are the short unthickened medial plate confined to the central part of the column, the twisted lamellae which are more numerous than the major septa, and the absence of dissepiments. There is no indication that dissepiments have ever been present. The outer wall of the specimen is the epitheca.

Cravenia is typically a C_2S_1 genus.

Cravenia cf. rhytoides (Hudson)
(pl.15, figs. 4 - 6)

No. of major septa	30	31	34
Diameter in mm.	13	14	17

The small minor septa, few tabulae in septal area, absence of dissepiments and large central complex, suggests this specimen is Cravenia. The thick regular

/outer

outer wall suggests that the absence of dissepiments is not due to their removal. The central column is about half the width of the corallum and enclosed in a cuspidate bounding wall. There are about five tabular intersections radiated by many lamellae. A dentate columella gives way in the ephebic stages to a thickened form. This columella has greater thickening than Hudson's figured type. The axial structure and minor septal development distinguish it from C. tela and C. lamellata.

Cravenia sp. (pl.15, fig.2.)

The general structure of this specimen is similar to C. rhytoides, but there is an absence of an obvious wall limiting the central area and the medial plate is unthickened.

Caninia cf. cornucopiae (Michelin) in Vaughan 1905 (pl.15, figs. 7 and 8)

37 septa at 1.6 cm. diameter.

These specimens are closely similar to described and illustrated material in Vaughan (1905, p.303, pl. XXII, fig.3b). As in Vaughan's illustrated material,

/the

the fossula is situated on the convex side of the corallum.

Caninia sp. (pl.15, figs. 9 and 10)

41 major septa at 1.8 cm. diameter.

Five or six rows of angulo-concentric or herringbone dissepiments are present in the counter, but not in the cardinal half. Minor septa are not present. The major septa reach almost to the axis and in the cardinal half are greatly thickened at their bases, but taper centrally where they become sinuous. A longitudinal section reveals flat tabulae spaced approximately 1 mm. apart and downturned marginally.

A transverse section has the general aspect of C. minor (Lewis 1930), but the longitudinal section does not have the inclined "zaphrentoid" tabulae of that species.

Caninia cf. subibicina (M'Coy)
(pl.15, figs. 11 and 12)

34 major septa at 2.2 cm. diameter.

Major septa unthickened and extending just over half way to the axis. Minor septa one third the

/length

length of major septa and having 2-4 concentric dissepimental intersections. Fossulae are not prominent. A longitudinal section reveals flat tabulae, downturned marginally, with approximately 1 mm. spacing.

Generally similar to C. subibicina (M'Coy), but much smaller in size and septal number. It is more closely similar to C cf. subibicina (M'Coy) in Wilmore (1910, pl.XXXIX, fig.3).

Caninia cf. caninoides (Sibley)
(pl.15, fig.13)

30 major septa at 2.3 - 2.4 cm. diameter.

The one section of this coral available is similar to C. caninoides (Sibley) except for its fewer major septa. The narrow completely non-septate dissepimental zone is a distinctive feature.

? Caninia sp. (pl.16, figs. 1 and 2)

60 major septa at 4 cm. diameter.

This coral has a "zaphrentoid" form in as much as minor septa and dissepiments are absent and the major septa are long, reaching almost to the axis of the coral. The tabulae are not inclined with their

/highest

highest points at the inner edge of the fossula, as in "*Zaphrentis*" but are flat with downturned margins as in *Caninia*. The fossula is not conspicuous. The septa have greatly thickened bases and taper markedly.

"*Zaphrentis*" cf. *constricta* (Carruthers)
(pl.16, fig.3.)

25 major septa at 11 cm. diameter.

These specimens are closely similar to *Z. constricta* (Carruthers 1910, pl.LXVI, fig.5a) but are of slightly larger size (ephebic constricta 7 mm. diameter). A developmental stage of *Allotropiophyllum* in Hill (1940 pl.VII, figs. 17 and 18) is similar but has shorter minor septa.

"*Zaphrentis*" cf. *constricta* (Carruthers) in Smyth 1930.
(pl.16, fig.4.)

Similar to Z. constricta (Carruthers) in Smyth 1930 with the difference that the present specimen is slightly larger and the septa-free axial space is wider.

~~Lithostrotiontidae~~

Lithostrotion *martini* (Edwards and Haime)
(pl.17, fig.1.)

Five specimens are sectioned and the range of diameter and septal number is:-

Irish specimens	24-26 major septa at 8.5 - 10 mm. diam.
Edwards & Haime's figured material	26 " " " 9 mm. diameter.

The Irish specimens are closely similar to L. martini as described and figured by Edwards and Haime (1854, p.197, tab. XL.).

Further colonies were found (see pl.17, fig.2.) which have the basic martini structure but are smaller than Edwards and Haime's described specimens. The diameters range from 6 to 8 mm. and the septa vary in number from 21 to 28.

Lithostrotion pauciradiale (M'Coy)
(pl.17, fig.3).

The specimens conform closely to L. pauciradiale (M'Coy) in Hill (1939, pl.IX, figs. 1 and 2). There are 18-20 major septa at a diameter of 4 mm.

Diphyphyllum lateseptatum (M'Coy)
(pl.17, fig.4)

17 to 23 major septa at 3.5 to 4.5 mm. diameter.

One, or in places, two rows of dissepiments are seen, but commonly the dissepiments are damaged or missing. The thickening of the major septa intrathecally

/distinguishes

distinguishes this specimen from _D. fasiculatum_ (M'Coy).

Michelinia megastoma (Phillips)
(pl.16, figs. 6 and 7)

The large size of this specimen, combined with an absence of irregular lobate pores, is diagnostic of _M. megastoma_.

Michelinia cladophora (Smyth 1930)
(pl.16, figs. 8 and 9)

The largest corallites have a diameter of 1 cm. They have a circular outline and are in clumps of up to about six in number. Some of the corallites are free except at their origin.

Chaetetes septosus (Fleming)

Colonies of up to 10 cm. diameter, composed of radiating corallites, were collected. The corallites are polygonal and average 0.7 mm. in diameter. This form is larger than _C. depressus_ in which the corallites are less than 0.2 mm. In Smith and Lang (1930, pl.XIII, figs. 1 and 2) _Chaetetes septosus_ and _C. depressus_ are incorrectly labelled.

Heterocoralla

Hexaphyllia sp. (Stukenberg)
(pl.16, fig.10)

A slender tube of 1 mm. diameter with six septa.

/The

The septal grouping is characteristic of *Hexaphyllia*.

Brachiopods

Spirifer tornacensis group

Spirifer attenuatus (Sow.), *S. tornacensis* (de Kon.) and *S. clathratus* (M'Coy) are closely similar forms and indeed were all included by Davidson (1858, p.19) in the synonomy of *S. striata* (Martin).

Spirifer aff. *clathratus* (M'Coy & Vaughan) in Douglas 1909. (pl.18, figs. 3 and 4)

The illustrated specimen is closely similar to *S.* aff. *clathratus* (M'Coy & Vaughan) in Douglas (1909, pl.XXVI, fig.6) from the "Syringothyris zone". The Irish material, which is associated with *S. konincki* and *S. attenuatus*, is from the Reef Limestone Group and is of upper C_2S_1 or S_2 age. Neville (1958, p.300) recorded *S.* aff. *clathratus* (M'Coy) from the "Upper Series of C_2 Knoll-Reefs" of E-central Ireland. Smyth (1930, p.543) recorded *S. tornacensis* from the Chonetes

/beds

beds of Hook Head, which are stated to be of C_2 age.

Spirifer attenuatus (Sowerby)

This specimen is distinguished from S. tornacensis by its bifurcating ribs. Frequently one of the branches of a divided rib is thicker than the others. This is particularly noticeable on the ventral valve. The length is 23 mm. and the width 13 mm. This specimen most resembles S. attenuata (Sow.) although the width does not exceed twice the length. It may be a young form of this species.

Spirifer cf. tornacensis (de Koninck)
(pl.18, fig.1)

This specimen differs from the above in having a less pronounced sinus and ribs in the ventral valve which are uniform and unbranched. It is similar to S. tornacensis (de Kon.) and is of Tournaisian age, coming from within 200 feet of the base of the Dinantian succession south of Ardfinnan.

Spirifer konincki (Douglas)
(pl.18, figs. 5 and 6)

The specimen illustrated is closely similar to

/material

material figured by Douglas (1909, pl.XXVI, figs. 1a and 1b). The distinct grooves bounding the median fold of the dorsal valve are clearly seen.

Goniatites

Goniatite fauna from P_2 shales. (pl.19, figs. 1 & 2)

A goniatite fauna in shales was found 1275 yds. on a bearing N.295° from Garrymore crossroads. All the goniatites found belong to one group, which is either Neoglyphioceras spirale (Phillips) or Goniatites granosum (Portlock). In either case it indicates beds of P_2 age. Goniatites granosum is a type intermediate between Neoglyphioceras sp. and Goniatites sp. The difficulty in distinguishing between N. spirale and G. granosum arises because their ornament is very similar and the specimens found lack visible sutures. A combination of suture and ornament is necessary to make identification certain. Shell-shape, umbilicus and ornament being well preserved, there is no doubt of the specimens falling into one or other of these species.

Goniatites from the Reef.

Three well preserved specimens of goniatites were found at a locality 900 yds. on a bearing N.210° from Ballygorman, Ardfinnan. The sutures are quite clearly seen, but not the ornament. A combination of ornament and suture is necessary to make specific identification certain.

The conclusion from the form of the goniatites and their sutures is that they belong to the genus *Beyrichoceras* and are near *B. micronotum* (Phillips)

The zonal use of *Beyrichoceras* is doubtful. The similarity of the C_1C_2 forms of *Beyrichoceratoides implicatum* (Phillips) and cf. *Beyrichoceras obtusum* in George and Howell (1939, p.545) to similar forms in B zone (S_2D_1) make it unwise to use the genus *Beyrichoceras* as necessarily implying B zone.

Conulariids

Conularia cf. *elegans* (Slater)

The specimens have longitudinal ridges with a transverse ornament on either side, in places offset.

/The

The longitudinal ridges are too regular to be a result of squashing. The ornamentation is of narrow, fine, regular ridges separated by wider furrows. The furrows in places are clearly seen to be crossed by evenly spaced bar-like structures. The ridges appear to be smooth. There is an average of 66 transverse ridges in 1 cm.

The fine transverse sculpturing is a feature common among the conulariids, but is also seen on cephalopods as, for example, Orthoceras crebriliratum (Girty 1909). Smyth (1950) figured a specimen of this species from P_2 shales in North County Dublin, where the spacing of the striae (60 per cm.) compares closely with that of Clogheen specimens. However, the longitudinal grooves and bars crossing the furrows indicate Conularid and not Cephalopod affinities.

Slater in her monograph describes five species of Dinantian Conulariids. Her species C. elegans (pl.V, fig.14) is closely similar to the Irish specimens except for a wider spacing of transverse ridges (50 per cm. as against 66 in the Irish specimens).

Plate 14.

Plate 14.

All figures X 1.5 - negative photographs of cellulose peels.

Fig.1. Koninckophyllum tortuosum (Michelin) in Carruthers (1913).

Figs.2-6. Koninckophyllum praecursor (Howell). Five transverse sections of a single specimen.

Figs.7 & 8. Koninckophyllum cf. proprium (Sibley).

Fig.9. Koninckophyllum cf. columatum (George).

Figs.10-12. Koninckophyllum ? carlyanense (Smyth).

Fig.13. Koninckophyllum sp.

Figs.14&15. Koninckophyllum sp.

Figs.16-19. Koninckophyllum sp.

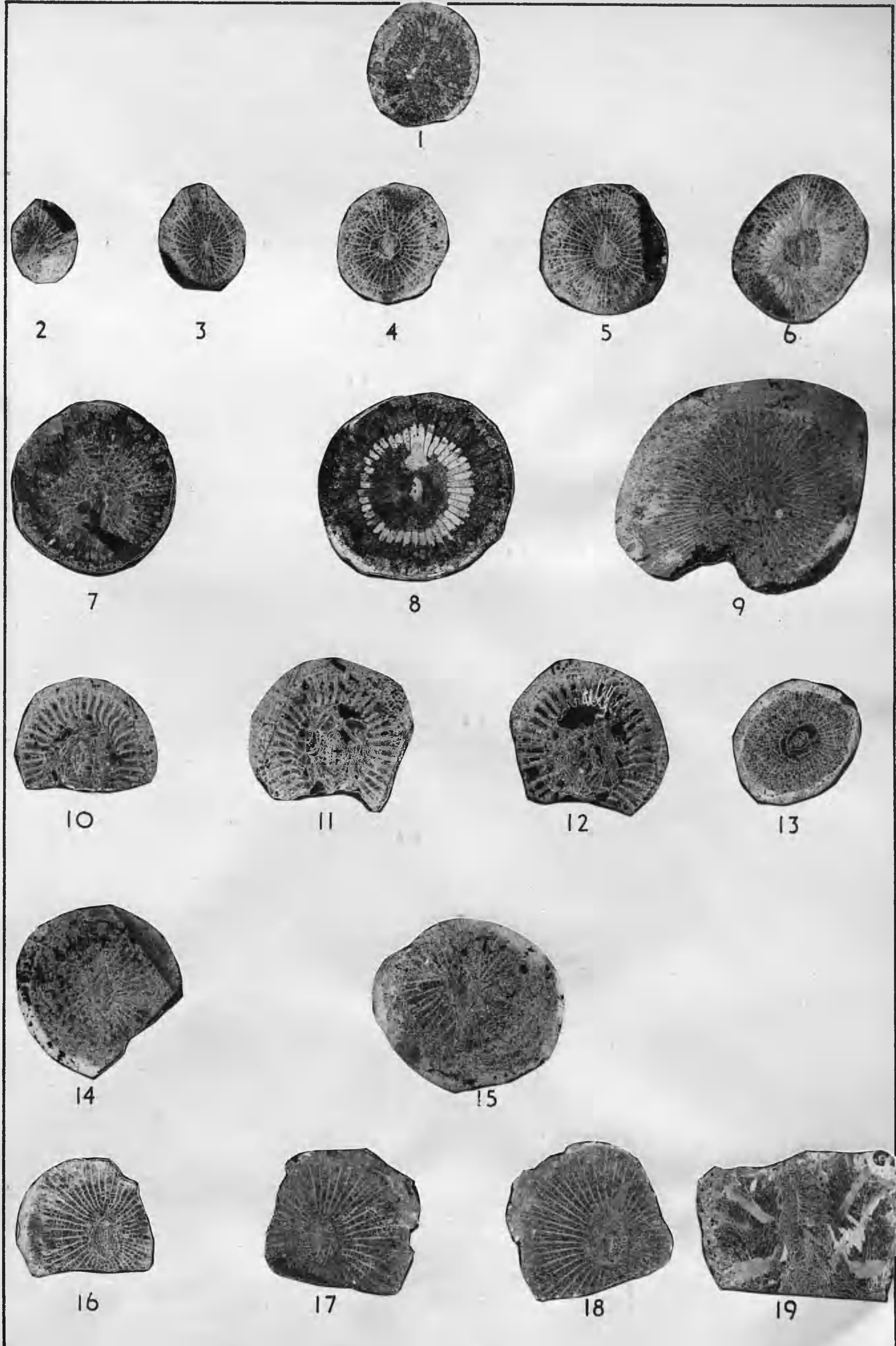
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Plate 15.

Plate 15.

All figures X 1.5 - negative photographs of cellulose peels.

Fig. 1. *Carcinophyllum simplex* (Garwood).

Fig. 2. *Cravenia* sp.

Fig. 3. *Cravenia lamellata* (Howell).

Figs.4 - 6. *Cravenia* cf. *rhytoides* (Hudson).

Figs.7 & 8. *Caninia cornucopiae* (Michelin).

Figs.9 & 10. *Caninia* sp.

Figs.11 & 12. *Caninia* cf. *subibicina* (M'Coy).

Fig. 13. *Caninia* cf. *caninoides* (Sibley).

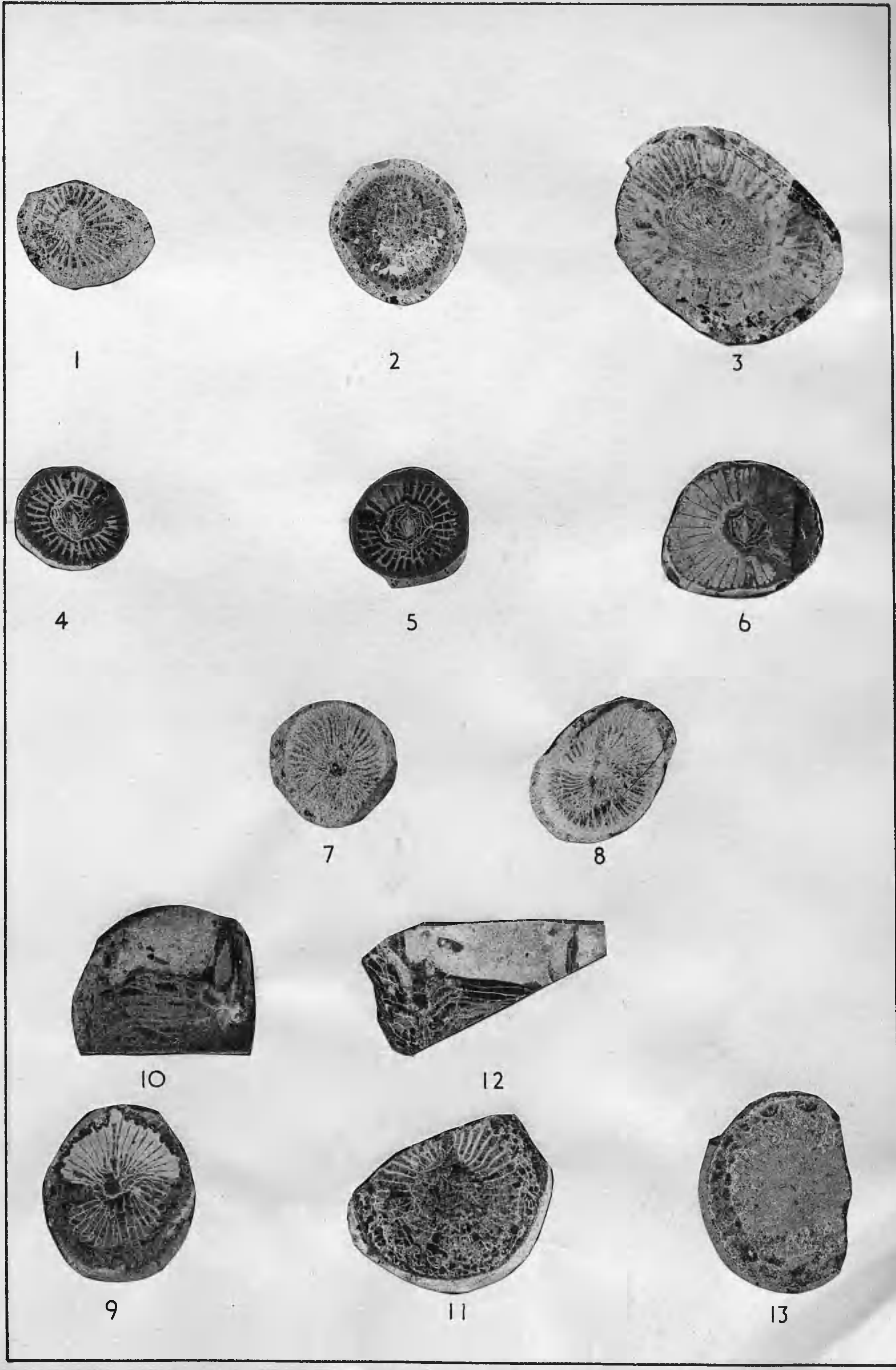
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Plate 16.

Plate 16.

All figures X 1.5 except fig. 10 - negative photographs of cellulose peels.

Figs. 1 & 2. ? <u>Caninia</u> sp.

Fig. 3. "<u>Zaphrentis</u>" cf. <u>constricta</u> (Carruthers).

Fig. 4. "<u>Zaphrentis</u>" cf. <u>constricta</u> (Carruthers) in Smyth (1930).

Fig. 5. "Zaphrentis" ambigua var. a Smyth (1915)

Figs. 6 & 7. <u>Michelinia</u> <u>megastoma</u> (Phillips).

Figs. 8 & 9. <u>Michelinia</u> <u>cladophora</u> (Smyth).

Fig. 10. x24 <u>Hexaphyllia</u> sp.

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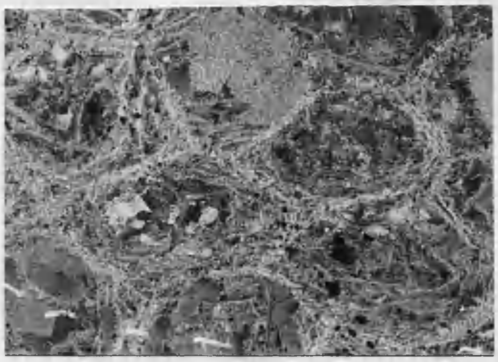

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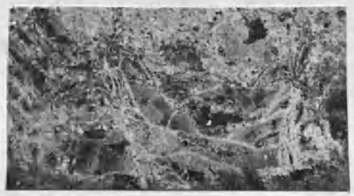

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Plate 17.

Plate 17.

All figures X 2. - negative photographs of cellulose peels.

Fig. 1. <u>Lithostrotion</u> <u>martini</u> (Edwards & Haime)

Fig. 2. <u>Lithostrotion</u> cf. <u>martini</u> " "

Fig. 3. <u>Lithostrotion</u> <u>pauciradiale</u> (M'Coy).

Fig. 4. <u>Diphyphyllum</u> <u>lateseptatum</u> (M'Coy).

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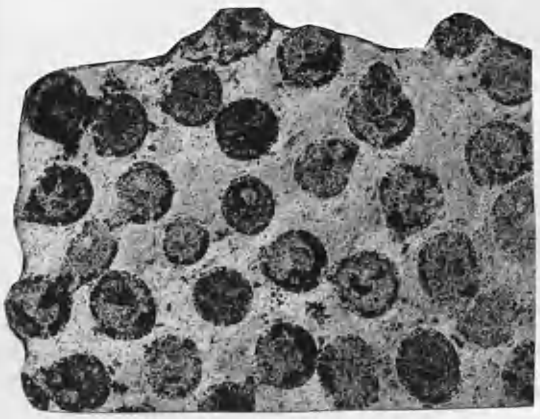

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Plate 18.

Plate 18.

All figures natural size.

Fig. 1. *Spirifer* cf. *tornacensis* (de Koninck).

Figs.2 - 4. *Spirifer* aff. *clathratus* (M'Coy and Vaughan) in Douglas 1909.

Figs.5 & 6. *Spirifer konincki* (Douglas).

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Plate 19.

Plate 19.

Figs. 1 & 2. X 2, <u>Neoglyphioceras</u> <u>spirale</u> (Phillips).

Fig. 3. X 2, <u>Weberides</u> <u>barkei</u> (Woodward) group.

Fig. 4. Natural size, unidentified fish scale.


1


2


3


4

IX FOSSIL LISTS

The following lists record the fossils collected by the author from the rocks of the Ardfinnan - Michelstown syncline and summarise their distribution.

The columns are numbered as follows.

6. Upper Shale Series.
5. Kilbeheny Limestone Group.
4. Reef Limestone Group.
3. Ballyheron Limestone Group.
2. Castle View Limestone Group.
1. Lower Limestone Shale.

(a) Corals

	1	2	3	4	5	6
Amplexus sp.				x		
Caninia caninoides (Sibley)			x			
Caninia benburbensis (Lewis)			x			
Caninia cf. *cornucopiae* (Michelin) (see Vaughan 1905)		x	x			
" *cornucopiae dumonti stage* (Carruthers 1908 Pl.VI fig. 1b,c.)		x				
Caninia cylindrica (Scouler)		x	x			
" cf. *cylindrica* (Scouler)		x	x		x	
" *hettonensis* (Wilmore)			x			
" *subibicina* (M'Coy) (see Wilmore 1910)	x					
Carcinophyllum simplex (Garwood)			x			
Chaetetes septosus (Fleming)					x	
Cravenia lamellata (Howell)			x			
" *rhytoides* (Hudson)			x			
" cf. " "		x	x			
" *tela* (Hudson)			x			
Diphyphyllum lateseptatum (M'Coy)			x			
Heterophyllia sp.			x			
Hexaphyllia sp.			x			
Koninckophyllum cf. *carbyanense* (Smyth)		x				
" *columatum* (George) (early form = K θ Vaughan)			x			

	1	2	3	4	5	6
Koninckophyllum cf. densum (Smyth)	x					
" praecursor (Howell) (Carruthselloid variant)			x			
" cf. proprium (Sibley)						
" tortuosum (Michelin)		x	x			
" sp.			x			
Lithostrotion martini (Edwards and Haime)			x	x	x	
" cf. " "		x?				
" pauciradiale (M'Coy)					x	
Michelinia cladophora (Smyth)			x			
" megastoma (Phillips)		x	x			
" sp.		x				
Palaeosmilia murchisoni (Edwards and Haime)			x			
Rylstonia sp.		x				
Syringopora sp.	x	x	x			
Zaphrentis constricta (Carruthers)			x			
" cf. enniskilleni (Edwards and Haime)			x			
Zaphrentoid corals	x					

(b) Brachiopods

	1	2	3	4	5	6
Actinoconchus expansus (Phillips)	x					
" cf. *ingens* (de Koninck)			x			
" cf. *planosulcatus* (Phillips)			x	x		
" *planosulcatus* var. *obtusus* (M'Coy) see Davidson 1858 Pl.XVI fig. 12				x		
Argentiproductus margaritaceous (Phillips)				x		
Athyrids				x		
Brachythyris hemisphericus (M'Coy) see Davidson Pl.IX fig. 25				x		
" *ovalis* (Phillips)				x		
Brachythyrids (undifferentiated)				x		
Cancrinella undata (Defrance)				x		
Cleiothyridina glabristria (Phillips)				x		
" *globularis* (Phillips)			x			
" *royssii* (L'Eveille)	x		x	x		
Dictyoclostus cf. *hindi* (Muir-Wood)				x		
" cf. *teres* (Muir-Wood)				x		
" *vaughani* (Muir-Wood)	x					
" spp.				x		
Dielasma hastata (Sowerby) see de Koninck Pl.III fig. 19				x		
" *sacculus* (Martin)				x		

	1	2	3	4	5	6
Gigantoproductus *giganteus* (Martin) Group					x	
Leptaena *analoga* (Phillips) and similar forms			x	x		
Linoproductus cf. *corrugatus* (M'Coy)				x		
" cf. *hemisphaericus* (Sowerby)				x		
" sp.				x		
Martinia *glabra* (Martin				x		x
Orthotetids (undifferentiated)	x	x	x	x		
Plicatifera *carringtoniana* (Davidson)				x		
" *mesoloba* (Phillips)				x		
" thomasi (Paeckelmann)				x?		
" sp.				x		
Productus sp.				x		
Pugnax *pugnus* (Martin)				x		
Pustula *pustulosa* (Phillips)				x		
Pustulid (large form)				x		
Rhipidomella *michelini* (Leveille) and similar forms.	x			x		
Schizophoria *resupinata* (Martin)				x		
Spirifer *attenuatus* (Sowerby) Douglas 1909 Pl.XXVI fig.7				x		
" cf. *bisulcatus* (Sowerby) group				x		

	1	2	3	4	5	6
Spirifer cf. *clathratus* (M'Coy) Douglas 1909 Pl.XXVI fig.6				x		
" cf. *convoluta* (Phillips)				x		
" *furcatus* (M'Coy)				x		
" *konincki* (Douglas)				x		
" *tornacensis* (de Koninck) group	x					
Spiriferinella octoplicata (Sowerby)	x					
Striatifera sp.			x			
Syringothyris cuspidata (Martin)		x				
Tylothyris laminosa (M'Coy)	x					

(c) Families and Genera of Foraminifera

	1	2	3	4	5	6
Ammodiscidae	x					
Archaediscidae						
Archaediscus			x	x	x	
Propermodiscus			x	x		
Bradyinidae						
Endothyranopsis				x	x	
Earlandiidae	x	x	x		x	
Endothyridae						
Endothyra			x		x	
Eostaffella					x	
Paramillerella					x	
Plectogyra	x	x	x	x	x	
Lasiodiscidae						
Howchinia					x	
Turrispira				x		
Vissariotaxis				x		
Lituotubellidae		x	x			
Lituotubella				x		
Mstinia				x		
Palaeotextulariidae						
Climacammina					x	
Cribrostomum					x	
Palaeotextularia			x	x	x	
Spiroplectammina		x				
Tetrataxidae						
Globivalvulina		x				
Stachea					x	
Tetrataxis			x	x	x	
Valvulinella			x			
Tournayellinidae						
Tournayellina	x	x				
Tuberitina			x		x	

(d) Fossils other than Corals, Brachiopods and Foraminifera

	1	2	3	4	5	6
Algae						
Ortonella sp.				x		
Spongiostromoid algae				x		
Ammonoidae						
Beyrichoceras ? *micronotum* (Phillips)				x		
Neoglyphioceras spirale (Phillips)						x
Gasteropoda						
Conularia cf. *elegans* (Slater)						x
Euomphalus sp.				x		
Lamellibranchia						
Aviculopecten clathratus (M'Coy)				x		
Leiopteria sp.				x		
Lithophaga sp.						x
Posidoniella cf. *corrugata* (Etheridge)						x
Nautiloidea						
Orthoceras sp.				x		
Vestinautilus sp.				x		
Trilobita						
Bollandia cf. *globiceps* (Phillips)				x		
Bollandia sp.	x					
?*Cummingella* sp.				x		
Weberides barkei group (Woodward)				x		
Unidentified *fish* scale (illustrated Pl. 19.)						x

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1858(B) Data and descriptions to accompany quarter sheet 45SW.

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GEOLOGICAL MAP OF THE ARDFINNAN—MITCHELSTOWN SYNCLINE
BASIC TUFF WITHIN REEF LIMESTONE
UPPER SHALE SERIES
KILBEHENY LIMESTONE
REEF LIMESTONE
BALLYHERON LIMESTONE
CASTLE VIEW LIMESTONE
LOWER LIMESTONE SHALE
OLD RED SANDSTONE
UNCERTAIN DIPS
N
52°21′
52°17′
CAHER
WATERLOO COTTAGE
COTTAGE HILL WOOD
CARRYCLOGHER
BALLYHERON WOOD
CARNAVILLA HOUSE
CRANNA WOOD
SHAMROCK LODGE
ROCHESTOWN HOUSE
CARRIGATAHA HOUSE
BALLYLOOBY
BALLYDRINAN
BURNCOURT
CASTLE VIEW
ARDFINNAN
LACKEN HOUSE
KILBEHENY
GARRYMORE
SHANBALLY CASTLE
CARRIGMORE
CLOGHEEN
BALLYPOREEN
MITCHELSTOWN
NO EXPOSURE
TULLAGHORTON FAULT
GOATS BRIDGE
A
B
C
D
0 1 2 3 miles
W. LON.
8°0′
7°52′