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G E O L O G Y

OF THE

B A L L I N A S Y N C L I N E

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SUMMARY.

In early Visean times subsidence began in the Ballina area, and a basin of sedimentation developed whose form and nature were largely controlled by the caledonoid structural lines of the basement. During the first phase of deposition most of the sediments which entered the basin were derived from the north-west, and accumulated in a large delta. Sedimentation and subsidence were greatest near Ballycastle where about 2,000 feet of sandstones, siltstones, shales and limestones are preserved. At Dromore West and Keenagh only a few hundred feet of deltaic deposits occur, and farther east, at Skreen only a few tens of feet. The beds of this delta are referred to the Carboniferous Sandstone. The fauna which they contain indicates a Visean age, probably C_2S_1.

The beds succeeding the deltaic sediments are referred to the Ballina Limestone, and are a series of bedded limestones with thin shale partings. The lateral variation in the thickness of the deltaic beds suggests that the Ballina Limestone facies spread north-westwards when the rate of supply of terrigenous material to the delta diminished. A sandy-oolitic facies of the Ballina Limestone which occurred near what is now the Ox Mountains Range suggests that a contemporary anticlinal

axis was located there. The fauna of the Ballina Limestone consists mainly of corals and brachiopods, and these indicate a lower Visean age, also probably C_2S_1.

Armorican earth movements caused the development of faults and folds in a pattern which was in large measure controlled by the Caledonoid structures of the underlying rocks. Structurally the Ballina Syncline is an area of Carboniferous rocks preserved by downthrow between large faults. In the western part folding is slight, but the rocks have been dislocated by large faults. In the east there are several folds, usually broad with low dips, but occasionally with dips as steep as 50°, and there are no large faults except those forming the boundaries of the area.

C O N T E N T S

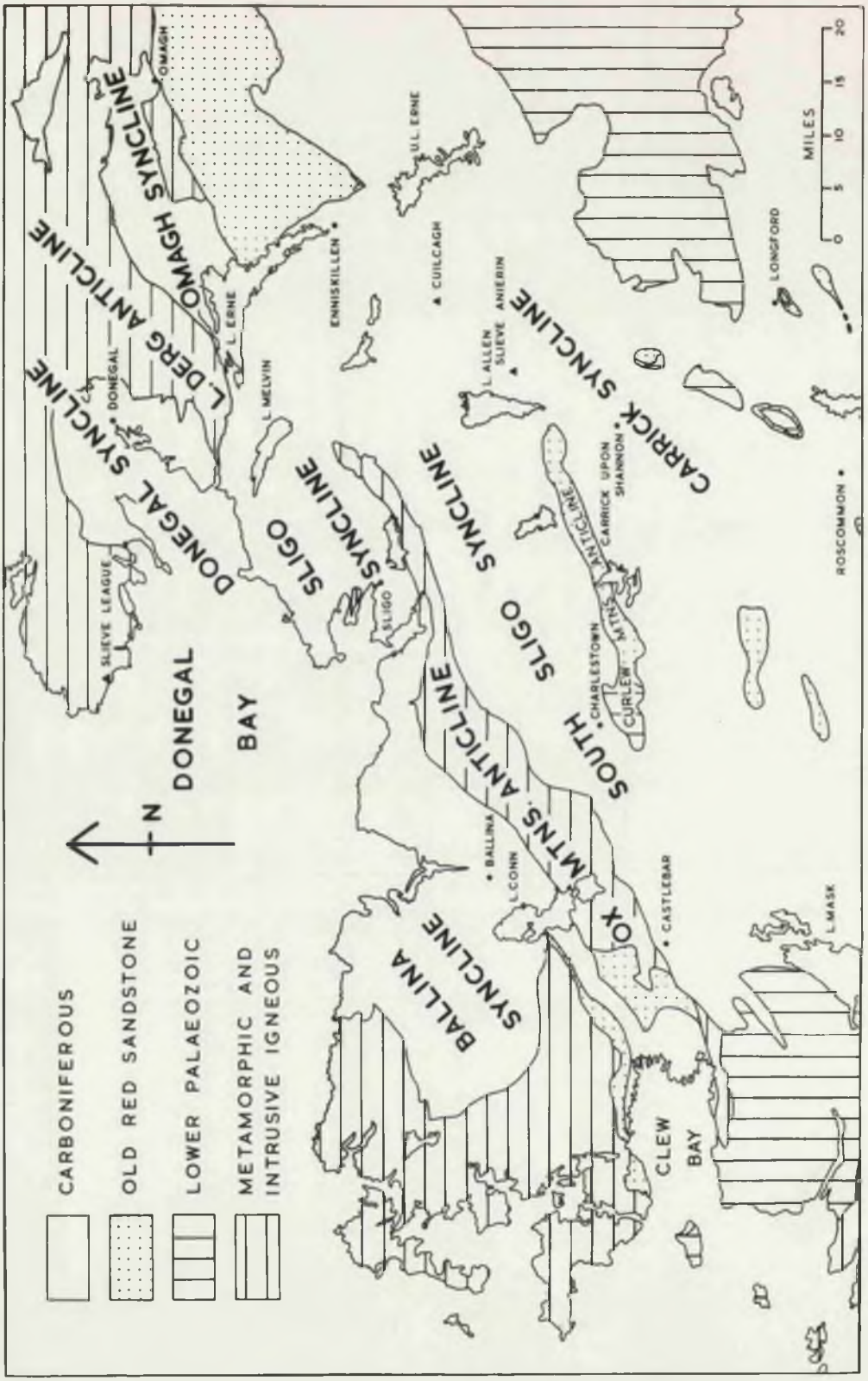

Fig. 1.

Sketch-map of north-western Ireland.

I INTRODUCTION.

The Ballina Syncline is a structure of caledonoid trend whose axis passes close by the town of Ballina (Co.Mayo). It preserves a prism of Lower Carboniferous sediments bounded on three sides by large faults along which the Carboniferous rocks are thrown down against Dalradian.

The topography of the Syncline falls naturally into two parts. The eastern part, which includes most of the area, coincides approximately with the outcrop of the Ballina Limestone and is a low undulating plain, seldom rising above 200 feet. Because of a veneer of drift the plain is mainly farmland, but where it is ill-drained, and where it rises above 200 feet as it does south of Easky, it is usually covered with peat bog.

The western part, which coincides with the outcrop of the basal Carboniferous deposits is generally higher ground, above 200 feet, with several hills exceeding 800 feet in the north west, and Maumakeogh reaching 1247 feet. This part is mainly covered by peat bog, with farms on the alluvial flats.

The Carboniferous plain is bounded on the south and west by high ground formed by the metamorphic and igneous rocks of the Ox Mountains and west Mayo. The semi-circle of hills is breached by large river valleys at

Ballysadare, Foxford, and Bangor Erris, and there are wind gaps in Glen Talt and Glen Nephin. Of these valleys only Glen Nephin is obviously related to the structure. It lies on the outcrop of a narrow strip of Carboniferous Limestone extending from Clew Bay to Lough Conn. The other valleys are cut through ranges of hills, are not apparently related to the geological structure, and are in all probability superimposed streams inherited from a drainage pattern whose origin is obscure.

The earliest account of the geology was published by Griffith in 1819. He distinguished between Primary and Secondary rocks, and discussed their distribution. The boundary between them is fairly accurately drawn on his map. He referred the lowest Carboniferous rocks (i.e. the Minnaun Sandstone of this account) to the Old Red Sandstone, and the overlying beds of basal Carboniferous near Bangor Erris he thought to belong to the "Coal Formation" and he evidently examined them carefully for coal deposits. Farther north Griffith grouped together everything above the Minnaun sandstone as "limestone which alternates with slate clay", and he stated that this is continuous from Keadough (= Keady) to Ballyshannon. He thought that these beds

belonged to "a different formation from that contained in the great valley" (i.e. the central Irish plain).

In 1838 in the Report of the Railway Commissioners Griffith's generalised account of the Geology of Ireland includes no special reference to the Ballina Syncline, but the map (the 1837 edition of Griffith's celebrated "Geological Map of Ireland") published to accompany the report indicates that the broad distribution of rock types was known at this time. The sedimentary rocks of the Ballina Syncline were referred to Old Red Sandstone, Yellow Sandstone and Conglomerate, and Carboniferous Limestone.

In 1840 Verschoyle published an account of the Geology of north Mayo and Sligo. He established the succession and distribution of Carboniferous rocks, and gave an account of some of the more interesting geological features, especially along the coast. He subdivided the Carboniferous rocks into :

(A) Carboniferous Limestone.

(B) Oolite of the Carboniferous Limestone.

(C) Calcareous and Argillaceous Shale and Grit.

(D) Old Red Sandstone and Conglomerate.

The Old Red Sandstone and Conglomerate includes beds at Lahardaun which are referred to Old Red Sandstone in the

present account, but also includes beds along the north side of the Ox Mountains and at Bangor Erris which are referred to Carboniferous. Verschoyle remarked on the resemblance between the basal Carboniferous of Mayo and the strata which accompany coal, but stated that the Mayo beds "lie decidedly below the great limestone". He estimated the thickness of the basal Carboniferous to be 1700 - 1800 feet.

Haughton (1863) discussed the age of basal Carboniferous red sandstones and shales in the north-west part of this area. He remarked that they had been coloured as Devonian by Griffith; but explained that Griffith was of the opinion that they were of Carboniferous age, while agreeing not to pursue the limits of the Carboniferous below the last (i.e. lowest) occurrence of plants. Haughton regarded the beds to be of Carboniferous age, but approved of the distinction between the red beds at the base, and the rest of the basal Carboniferous.

Hull (1881) remarked that Griffith had given up the idea that "Old Red Conglomerate" is represented at Glenlossera.

Jukes (1868) published a Geological Map of Ireland which indicated knowledge of the existence of limestone formations in the basal Carboniferous. Their

boundaries were not accurately traced, but it is clear that they represented the Downpatrick Limestone and the Kilcummin Limestone of the present account.

The Survey Officers in publications between 1876 and 1885 divided the sedimentary rocks of this area into Lower Carboniferous Sandstone and Lower Limestone. The boundary between the two series was that adopted by Verschoyle, but the Survey Officers were the first to trace accurately the inland courses of this boundary and the boundary of Carboniferous against metamorphic rocks. They also mapped some of the more conspicuous faults in the area, and thus provided the first outline of the structure.

In a short paper Clark (1923) sought to demonstrate the existence of two tear-faults near Dromore West by correlating dykes which cross the foreshore. In a later paper (1924) he concluded from the coral fauna that the beds above the basal Carboniferous sandstones were of Z_1,Z_2, and C age, and that there was no evidence of their being Visean (but see Oswald, 1955, pp 184, 185).

In 1928 Charlesworth described the glacial geology of a region which included the Ballina Syncline. He showed that it was overridden by ice from Leitrim and Conemara, and in particular drew attention to the conspicuous recessional moraines deposited on the coastal plain.

Acknowledgements.

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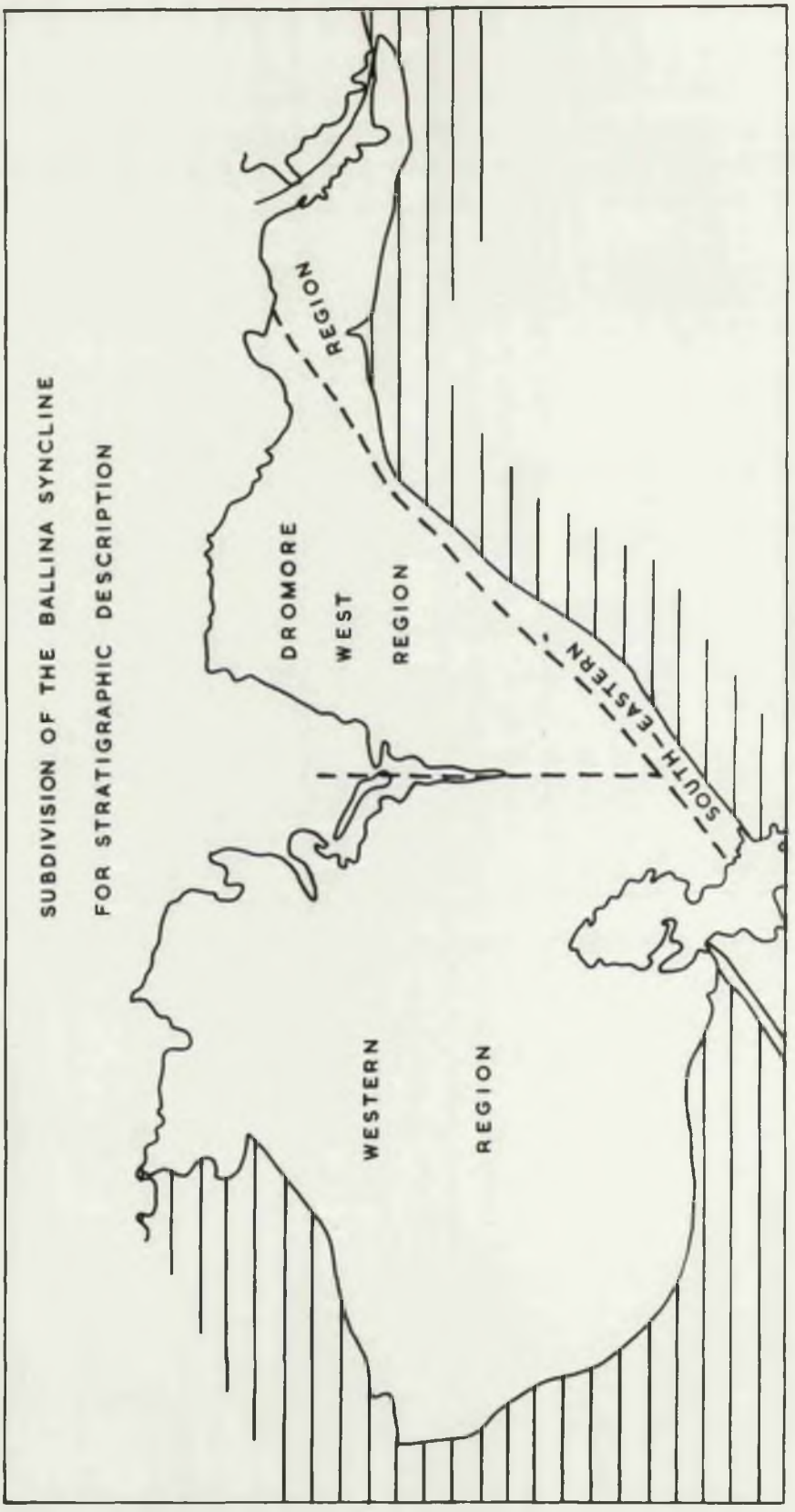

Fig. 2.

Subdivision of the Ballina Syncline for stratigraphic description.

II OUTLINE OF STRATIGRAPHY.

(a) General.

The Ballina syncline is a broad, gentle fold with regional dips of less than 10 degrees. The present outcrop of Carboniferous rocks has been preserved by downthrow between faults, and contains representatives of only the lower part of the original succession of deposits of the syncline.

The rocks of the syncline are probably all of Visean age. Few fossils have been found in the basal grits and conglomerates, but the earliest which can be referred to coral-brachiopod zones contain a Visean fauna.

The succession is divided lithologically into Carboniferous Sandstone, which comprises the Carboniferous basal beds and an overlying group of arkoses, silts, shales and limestones, and Ballina Limestone, which is a marine limestone with shale partings.

The Carboniferous Sandstone varies in thickness from about 2,000 feet in the north-west, to a few tens of feet in the east. This rapid lateral variation, together with the structural pattern of the area, makes it convenient to describe the succession in three regions separately before considering correlation. They are the Western Region, including basal deposits of greatest thickness; the Dromore West Region, which contains basal deposits of moderate thickness, and the South Eastern

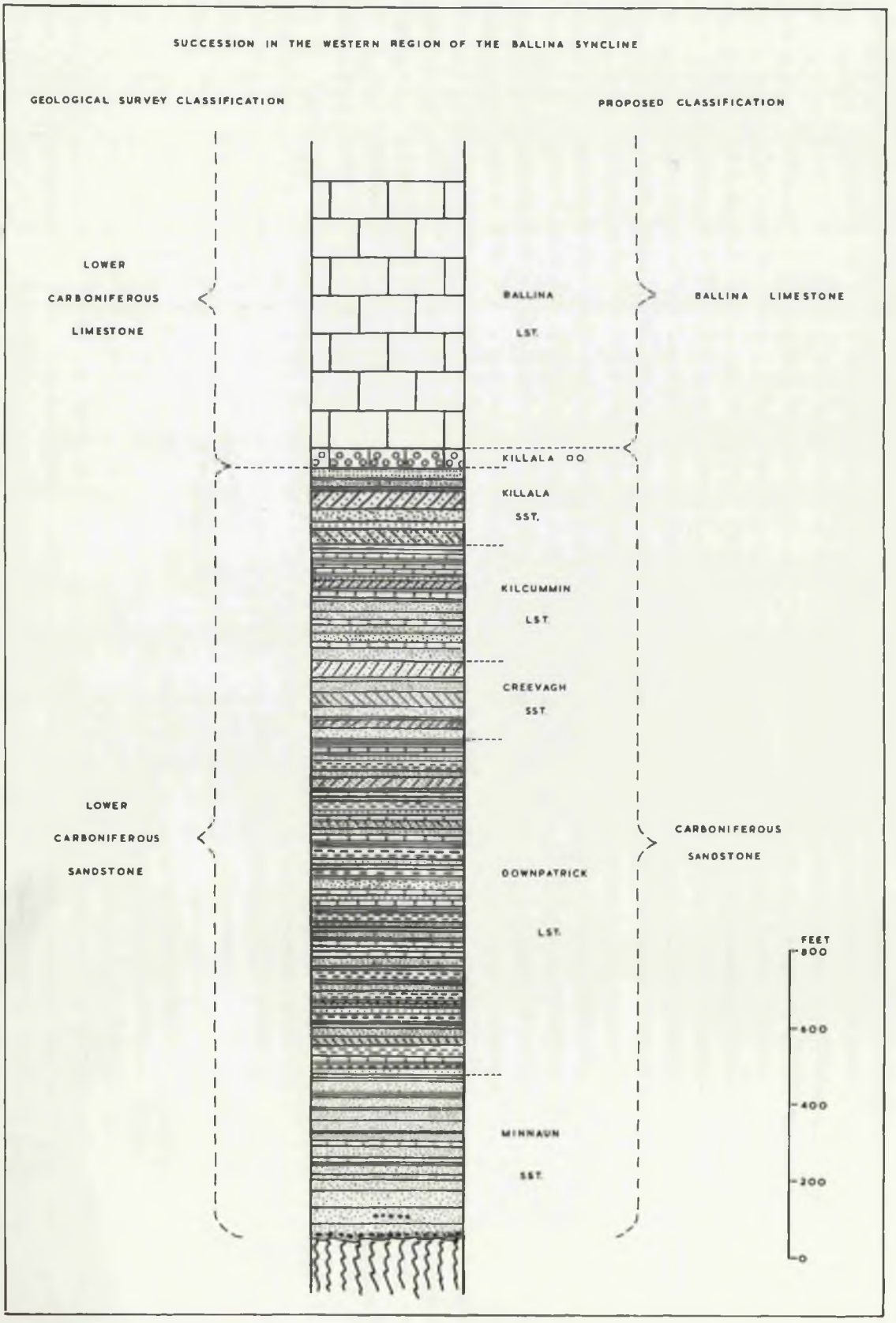
SUCCESSION IN THE WESTERN REGION OF THE BALLINA SYNCLINE
GEOLOGICAL SURVEY CLASSIFICATION
PROPOSED CLASSIFICATION
LOWER CARBONIFEROUS LIMESTONE
BALLINA LST.
BALLINA LIMESTONE
KILLALA OO
KILLALA SST.
KILCUMMIN LST.
CREEVAGH SST.
LOWER CARBONIFEROUS SANDSTONE
CARBONIFEROUS SANDSTONE
DOWNPATRICK LST.
MINNAUN SST.
FEET
800
600
400
200
0

Fig. 3.

Region, in which basal deposits are thin. (See Fig. 2)

(b) Summary of the succession in the Western Region.

The succession is divided into a lower group of dominantly arenaceous sediments and a limestone series as follows: (2) Ballina Limestone.

(1) Carboniferous Sandstone.

(2) Ballina Limestone.

Limestones with argillaceous partings, and sometimes with an irregular nodular bedding. Locally containing chert nodules. Richly fossiliferous, with abundant corals and brachiopods.

(1) Carboniferous Sandstone.

The Carboniferous Sandstone is about 2,000 feet thick in the Western Region, and is subdivided into six parts.

Killala Oolite Up to 50 feet of black oolitic limestone. The rock consists of black ooliths in a lighter coloured matrix; sandy near the base, more calcareous and thicker-bedded above.

Killala Sandstone 200 feet of falsebedded and thinly bedded sandstones, flags, shales, occasional conglomerates, and a few thin beds of limestone.

Kilcummin Limestone 300 feet of bedded sandstones, shales and limestones, becoming less arenaceous near the top. The

limestones and shales contain abundant corals and brachiopods.

Creevagh Sandstone 200 feet of thickly bedded and usually falsebedded fawn sandstone with shales, even-bedded sandstones and limestones. The massive falsebedded sandstones commonly occur in washout channels in the level-bedded series.

Downpatrick Limestone 870 feet of bedded sandstones, shales and limestones without red colouration. The limestones and shales are fossiliferous, containing corals, brachiopods, and gastropods.

Minnaun Sandstone 430 feet of basal conglomerate overlain by quartzites, felspathic sandstones, red and green shales, buff and brown shales, and thin cementstone bands.

(C) Summary of the succession in the Dromore West Region.

The succession is again divisible into a lower arenaceous group (the Carboniferous Sandstone), and an upper limestone group (the Ballina Limestone). The lower part of the Ballina Limestone is dominantly argillaceous, and is referred to as the Donaghintraine Shale, while the upper part is called the Easky Limestone. Thus the Succession can be tabulated:

(2) Ballina Limestone.

Easky Limestone 900 feet of bedded limestones with thin

shale partings, locally cherty, containing a rich fauna of brachiopods and corals.

Donaghintraine Shale 120 feet of alternating thinly bedded dark calcareous shales and argillaceous limestones.

(1) Carboniferous Sandstone The Carboniferous Sandstone of the Dromore West Region is referred to the DROMORE SANDSTONE, which consists of a succession of shales, silts and sandstones with occasional thin limestone horizons, and three or four thick yellow falsebedded sandstones.

(d) Summary of the succession in the South-eastern Region.

(2) Ballina Limestone.

Limestones with thin shale partings, containing a fauna of brachiopods and corals, with oolites, dolomites crinoidal limestones and sometimes sandy limestones in the lower part.

(1) Carboniferous Sandstone.

Conglomerates and sandstones ranging from a few tens of feet to at most a few hundred feet in thickness.

Fig. 4.

Basal Carboniferous Sandstone resting unconformably upon a planed-off surface of Dalradian schists at Fohernadeevaun, near Glenlossera. Fig. 5. was photographed near the middle of the right hand margin of this photograph.

III DETAILED STRATIGRAPHY.

(a) Western Region.

In the Western Region the lower part of the succession, that is, the Carboniferous Sandstone, is more thickly developed and better displayed than elsewhere in the Ballina area. There are long stretches of continuous exposures on the cliffs between Glenlossera, where basal conglomerates are exposed, and the mouth of the Moy River, where the Carboniferous Sandstone is succeeded by Ballina Limestone.

(1) Carboniferous Sandstone.

The relationships of the lowest three subdivisions of the Carboniferous Sandstone are visible in the cliff sections, but near Kilcummin faults and gaps in the succession make difficult the estimation of thicknesses and of the relative age of the Kilcummin Limestone and Killala Sandstone. However on any estimate the total thickness of the Carboniferous Sandstone cannot be less than 1500 feet.

Minnaun Sandstone The Minnaun Sandstone outcrops in four tracts of the Ballina Syncline, all in the Western Region. Elsewhere in the Western Region a considerable area of Minnaun Sandstone is probably concealed by drift and bog.

The succession is best displayed in the Minnaun-Maumakeogh district, in sea cliffs between Glenlossera and

Fig. 5.

Basal conglomerate of the Carboniferous Sandstone filling minor irregularities on the planed-off surface of the Dalradian. The conglomerate is mainly composed of pebbles of schist, quartzite and vein-quartz in a quartzitic matrix.

Fohernadeevaun, near Glenlossera.

Polladarky, and on the shore in the south-west corner of Bunatrahir Bay. Inland, a number of exposures may be seen in stream beds over an outcrop covering about six square miles.

The base of the Carboniferous succession is admirably displayed and is accessible in parts of the cliffs north of Glenlossera, at Fohernadeevaun. The sub-Carboniferous surface dips gently north-westwards, and is well planed, and approximately flat, with only minor irregularities (see Fig. 4 & 5). The minor irregularities are due to the manner of erosion of the Dalradian by dislocation of the rocks along planes of weakness. - this is well illustrated by Fig. 5. These characters suggest that the surface originated as a wave-cut platform.

The irregular surface of the schist is covered by a thin basal conglomerate 0 - 3 feet thick which consists of angular pebbles of metamorphic quartzite, vein-quartz and occasionally schist, usually not exceeding two inches in diameter, but with a few cobbles up to a foot in diameter. The matrix is a quartzitic grit containing a little mica.

The conglomerate is succeeded by massive beds of quartzite interbedded with thin impersistent layers of conglomerate and orange and red sandy shales, which pass upwards into thin-bedded red sandstone and grey and buff-

coloured siltstones and shales. In thin section a red sandstone from this horizon located two hundred yards east of Port Peninsula is seen to be a ferruginous arkose composed of angular grains of quartz and felspar and small mica flakes cemented by a matrix of iron oxide and calcite. Succeeding beds are thick quartzites, red, purple and buff sandstones, and red and mottled red and green shales.

These beds can be reached in the south side of the neck of Port Peninsula and in the cliffs east of Port Peninsula; farther east they are visible in the cliffs, but not accessible.

The middle part of the Minnaun Sandstone is accessible on Minnaun headland. At the base of this section are exposed quartzites of the lower part of the Minnaun Sandstone, and these are succeeded by a thinly bedded series of bright red, pale green, and fawn sandstones and thin shales interbedded with occasional thin beds of conglomerate and cementstone. Thin sections of red sandstone from these beds show them to be arkoses composed of small angular grains of quartz, fresh acid felspar, and muscovite, cemented by iron oxide. The beds are sometimes calcareous, and ripplemarks are common.

At the base of some of the fawn sandstone beds

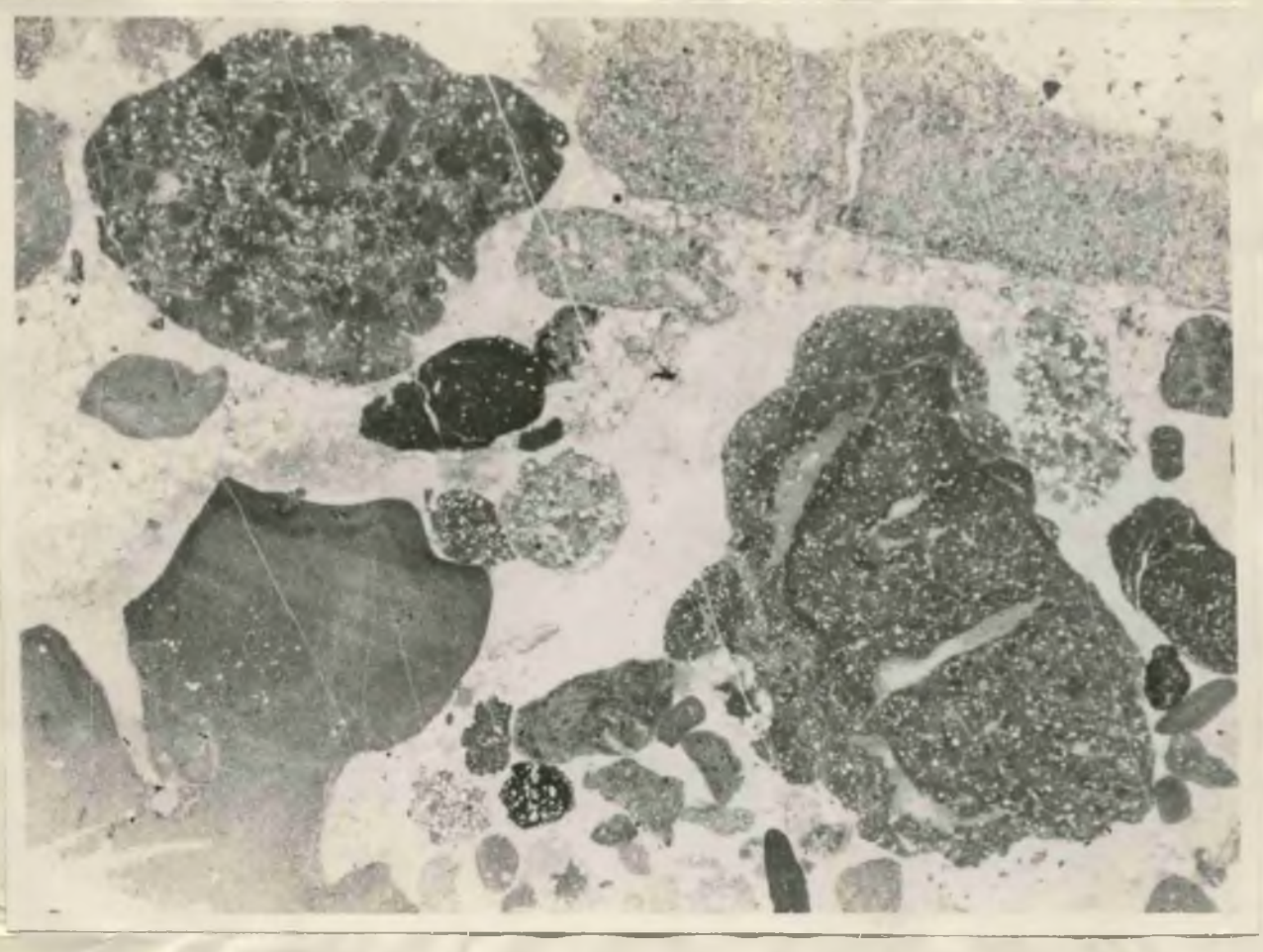

Fig. 6.

Conglomerate from the Minnaun Sandstone. X 6.
This rock is composed of pebbles of limestone (bottom left) and sandy limestone in a matrix of sandy limestone (middle left hand margin) and coarsely crystalline calcite (centre of photograph).

there is sometimes a thin conglomerate (Fig.6). The pebbles in the conglomerate are more or less rounded, or sometimes irregular in shape due to solution, and most of them are composed of sandstone or sandy limestone. The sandstone pebbles are arkoses, with a calcite cement, and the sandy limestones contain grains of quartz, felspar, and pyrites, and sometimes small euhedral quartz crystals. Pebbles of bryozoan limestone, and one of dolomite, have been noted. The matrix of these conglomerates is sandy limestone. The conglomerates pass up into falsebedded arkose. Lithologically the pebbles in the conglomerate closely resemble the sediments of the Minnaun Sandstone, and they are probably the products of contemporaneous erosion. Contributary evidence of the shallowness of the water in which sedimentation was taking place is provided by the cementstones, which commonly exhibit mud-crack patterns. One of these cementstones has yielded some small unidentified gastropods.

The upper part of the Minnaun Sandstone is largly inaccessible in high cliffs. The rocks consist of fawn and purple sandstones, red and greenish sandstones, dull purple and reddish, usually dicey shales, and occasional thin bands of cementstone. This succession is similar to the middle part of the Minnaun Sandstone, except for the

thick shale bands near the top, and the paucity of limestones.

The uppermost 130 feet or so of the Minnaun Sandstone are exposed in an inlier in the eastern side of Bunatrahir Bay. The lowest beds of the section outcrop on the west side of Portnahally. They are fawn and pinkish calcareous sandstones, and dull red dicey silts. The sandstone at the top of this section is exposed again at Boggagh where it is succeeded by red and fawn sandstones, and red sandy shales; some of the fawn sandstones are conglomeratic at the base. The sandstone at the top of the Boggagh section occurs on the shore again just north of Illancanthal, and downthrown against it are the uppermost ten feet of the Minnaun Sandstone, consisting of grey sandstones and red sandy shales.

A few exposures of Minnaun Sandstone appear in the Altderg River and its tributary. The rocks exposed are fawn, red, or dull red sandstones, red shales, and red sandy shales. A thin section shows a specimen of reddish fawn sandstone to be an arkose composed of angular grains of quartz and acid felspar, most of which is unaltered. Chlorite flakes are plentiful, and the rock is cemented by iron oxide.

A large outcrop of Minnaun Sandstone is exposed

east of Bangor Erris, in the westernmost part of the Ballina Syncline. Basal conglomerate is exposed two miles east of Glenturk Lodge in the western tributary of the Glenturk River. The unconformity cannot be seen, but metamorphic rocks are exposed only a few feet beneath the conglomerate. The basal conglomerate consists of subangular pebbles up to three inches in diameter of white or pink quartz, quartzite, and quartz-schist in a matrix of sandstone. Above the conglomerate are exposed about 200 feet of red and fawn arkoses, red shales, and a conglomerate.

Blocks of basal conglomerate are numerous at the heads of the two other tributaries of the Glenturk River, which rise a quarter of a mile and three quarters of a mile respectively northwest of the exposure of basal conglomerate. Blocks of conglomerate are also numerous in the ground to the north, and may indicate rock in situ there.

Higher beds in the Minnaun Sandstone are exposed in the stream section above the conglomerate, and also in the Muingnakinkee River, and in Glencoe. The beds exposed are mainly arkoses - red, greenish, purple and fawn, with in some localities thin conglomeratic beds resembling the basal conglomerate. Interbedded with the sandstones are fawn, red and green shales.

Generally speaking the Minnaun Sandstone differs from the overlying Downpatrick Limestone in being composed dominantly of sandstones. Many of the sandstones and shales are red; limestones are subordinate, and when they occur, are cementstones, and have yielded fossils (gastropods) only from one bed; whereas the Downpatrick Limestone is a succession of shales, sandstones and limestones, with a rich marine fauna, and red colouration is absent. The transition is quite sharp. At Bunnahowna a red shale of the Minnaun Sandstone occurs only a few feet below a limestone containing brachiopods and Syringopora. No complete section can be measured but in the Minnaun-Maumakeogh district the position of outcrops of the base and top indicates that the Minnaun Sandstone has a thickness of approximately 430 feet, and has a regional north-easterly dip of four degrees.

In Glencoe near Bangor Erris the Minnaun Sandstone dips fifteen degrees north north east near the Nephin Beg Fault, and the dip decreases to three degrees to five degrees and swings to north east within about a mile from the fault. It is estimated that there are probably 300 to 400 feet of Minnaun Sandstone present in this section, and the lowest beds seen are probably close to the base.

Fig. 7.

Doonbristy, a sea stack about 120 feet high close to Downpatrick Head. The rocks forming the stack are typical Downpatrick Limestone sediments, and are a rapidly alternating series of sandstones, silts, shales, sandy limestones and limestones. A large washout channel is plainly visible one-third of the way up the stack. The sandstone half-way up the stack is one of the thick, falsebedded sandstones which occur at several horizons in the Downpatrick Limestone. Immediately below the massive "earthy limestone" bed near the top of the stack is an "earthy limestone" in which falsebedding is visible.

Downpatrick Limestone The Downpatrick Limestone outcrops in a broad belt of country running south-west from Creevagh Head to Bangor Erris. Part of the succession is exposed in the cliffs between Keady and Bunatrahir Bay; the most informative and most complete section is the cliffs between Bunatrahir Bay and Creevagh Head, and the upper part of the series is exposed in Lackan Bay also.

The Downpatrick Limestone is a series of sandstones, siltstones, shales and limestones which are usually thinly bedded and highly varied in character, and individual beds are often conspicuously impersistent.

The sandstones are usually grey, fawn, or brown arkoses. The thickest sandstones are falsebedded fawn arkoses up to twenty feet in thickness which commonly occur in washout channels cut into the thinly bedded sandstone-shale-limestone succession, and when traced out of the washout channel they usually pass laterally into a much thinner and less conspicuous sandstone bed. Some of these thick sandstones have at the base conglomerate containing pebbles of arenaceous limestone and calcareous sandstone. These are probably conglomerates formed from the debris of destroyed penecontemporaneous sediments, and they closely resemble the conglomerates which occur in the Minnaun Sandstone.

Fig. 8.

Polygonal mudcracks in a bed of finegrained limestone.

Downpatrick Limestone, a mile east of Downpatrick Head.

The thinner sandstones are arkoses and calcareous felspathic sandstones; they are not usually falsebedded but are interbedded with silts, shales and limestones. Frequently the bedding planes are marked by oscillation or current ripples. Fig.11 illustrates a ripplemarked sandstone bed which has had the crests of the ripples planed off by penecontemporaneous erosion.

Lithologically there is a continuous transition from these beds to the so-called "earthy limestones" which appear some distance above the base of the succession, and are abundant in the middle and upper parts. The "earthy limestones" are dark blue when fresh, the weathered surfaces being brownish and generally irregular. Thin sections of the rocks show them to be arkoses cemented by varying proportions of calcite and iron oxide. Mica is usually plentiful, and fragments of bryozoa and small bivalves are common. Fucoid markings and annelid casts are generally abundant on the bedding planes.

Thin beds of silt occur abundantly in the lower part of the Downpatrick Limestone, and these are usually brown or grey, frequently calcareous, and often containing small calcareous nodules.

Shales are also abundant, and are brown and dark blue in colour. The brown shales occur mainly near the

Fig. 9.

Shelly limestone from the Downpatrick Limestone. X 14. This rock consists of fragments of shells and bryozoan colonies in a matrix of calcite containing a few angular and subangular quartz and felspar grains.

base of the succession, and are sometimes very closely laminated. The dark blue shales are calcareous, and often strongly falsebedded. They frequently contain abundant brachiopods.

Limestones are sparse in the lower part of the succession, but abundant at higher horizons. Many of the limestones are thin beds up to eighteen inches in thickness composed of dark coloured finegrained limestone which weathern to a cream or pale grey colour. Some of these beds have patterns of polygonal mudcracks, (see Fig. 8.) and some contain obscure vertical tubular markings. At higher horizons the limestones are thicker and purer, and sometimes contain a rich coral-brach fauna.

In the coast section between Bunatrahir Bay and Creevagh Head the uppermost beds of the Minnaun Sandstone are succeeded by a series of thinly bedded grey and fawn sandstones and grey silts and shales and occasional falsebedded calcareous shale, grey limestones, some of which yielded Syringopora and gastropods, and one or two thick falsebedded sandstones which form reefs on the foreshore.

The succession in the cliffs of Downpatrick Head and Doonbristy (see Fig. 7.) consists of a rapidly alternating series of sandstones, siltstones, shales and limestones.

Fig. 10.

Calcareous arkose from the Downpatrick Limestone, S.W. corner of Lackan Bay. X 35.

This rock is composed of about 60% felspar, 20% quartz and 20% calcite, and is one of the more arenaceous of the rocks which are transitional between arkose and limestone.

Fig. 7 illustrates various features characteristic of the Downpatrick Limestone succession. A conspicuous washout channel is infilled with thinly bedded strata. The thick light-coloured falsebedded sandstone in the middle of the stack is one of the well-developed sandstone horizons which commonly (but not in this case) fill washout channels. The impersistent nature of the beds can be seen in various parts of the photograph where beds vary in thickness when traced laterally. The massive bed near the top of the stack is an "earthy limestone" of calcareous composition which has on its upper surface numerous overturned colonies of Syringopora. Below this bed is an "earthy limestone" horizon of more normal aspect, in which falsebedding can be clearly seen. At a horizon slightly higher than the top of Doonbristy stack the uppermost limestone exposed on Downpatrick Head is a grey finegrained limestone, rather purer than most of the limestones in this series, containing a rich fauna of brachiopods and corals.

Above these beds, at Pollnamuck, a mile south-east of Downpatrick Head there is a series of thick sandstones formed in washout channels with rapid lateral variations in thickness.

East of Pollnamuck at a higher horizon a series

Fig. 11.

Sandstone beds with ripple-marks. The crest of each ripple has been planed off by penecontemporaneous erosion. Creevagh Sandstone, a mile south east of Creevagh Head.

resembling that of the Downpatrick Head is continued up to the Creevagh Sandstone which appears in the cliffs half a mile west of Creevagh Head. Of interest in this series is the occurrence of woody material in "earthy limestone", and the occasional development of mudcracks in limestone beds. (The beds illustrated in Fig.8 are in this part of the series.)

West of Creevagh Head the Downpatrick Limestone is exposed for a mile along the eastern cliffs to Lackan Bay, but since the section runs along the strike only the uppermost hundred and fifty feet or so can be seen.

Between Polladarky and Bunatrahir Bay the lowermost three hundred feet of the Downpatrick Limestone is exposed in a coastal section. In Bunatrahir Bay, on the west side, the Minnaun Sandstone is succeeded by fifty feet of fawn and brown sandstones, silts and shales, with interbedded thin limestones which are grey or brown, sometimes weathering white, and including two cornstones near the base. There is a gap at the mouth of the Bellanamina River, and north of this a succession of about one hundred and fifty feet of sandstones and limestones and shales to the north-west corner of Bunatrahir Bay.

Westwards from Bunatrahir Bay these beds are succeeded by sandstones, which may belong to the same

horizon as is met in Pollnamuck (east of Downpatrick Head). The highest beds exposed in the section are the falsebedded sandstones at Bunagaurnan. A similar but less accessible section is found between Bunnahowna near Polladarky, and Bunagaurnan.

Inland there are a number of short sections in the Downpatrick Limestone at Heathfield (three miles east of Ballycastle), and in Ballinglen, Keerglen, and Glencoe.

Apart from these and a few other short sections, the outcrop of the Downpatrick Limestone is largly concealed by drift, and exposures are few and widely scattered.

Creevagh Sandstone The base of the Creevagh Sandstone appears in the top in the cliffs about half a mile west of Creevagh Head, and again about a mile south east of Creevagh Head, so that the Creevagh Sandstone is exposed in cliff sections for about one and a half miles, though most of the cliffs are inaccessible except for a few feet near the top.

Where it can be examined the Creevagh Sandstone is a series about 200 feet thick of thickly bedded and usually falsebedded fawn felspathic sandstones interbedded with shales sandstones and limestones similar to those of the Downpatrick Limestone. The massive falsebedded sandstones are commonly deposited in washout channels in

the even-bedded series.

Inland the sandstones are exposed here and there over their three or four square miles of outcrop between the coast section and the western side of the hill (606 feet) three miles east of Ballycastle. The exposures are nearly all of the same general rock-type, hard falsebedded sandstones eroded into low escarpments. The beds between the resistant sandstones are occasionally exposed in stream sections, and resemble comparable beds seen in the cliff section.

In Ballinglen a sandstone series succeeds the Downpatrick Limestone, and this is probably the Creevagh Sandstone. It appears to be 400 feet thick in the 800 feet hill east of Ballinglen. What is apparently the same sandstone outcrops in Gallowshill and Barnhill, (halfway between Ballycastle and Palmerstown) and probably covers the ground to the south east as far as the fault inferred to run south-westwards through Lackan Bay.

A similar sandstone also outcrops on the hill west of Ballinglen, where it dips north-east and forms an outlier about two square miles in extent; it is at least two hundred feet thick on the hills 573 feet (just above Ballinglen) and 861 feet (above the Keerglen).

It is difficult to be certain that the sandstones

exposed in these various outcrops belong to the same rock group, because much of the inland outcrops are drift covered so that the stratigraphical horizons cannot be determined with accuracy.

Kilcummin Limestone The outcrop of the Kilcummin Limestone is small and occupies only two or three square miles. It is separated from the outcrop of the Creevagh Sandstone by the inferred Lackan Bay Fault, and is bounded on the south by a fault which throws Kilcummin Limestone against Killala Sandstone.

Exposures are found only in the north-eastern and eastern parts of the outcrop. The base of the Kilcummin Limestone is not visible.

The lowest 250 feet exposed consists of false-bedded sandstones and impure limestones, similar in facies to the Downpatrick Limestone. Outcropping at the top of the cliffs on Kilcummin Head is a thick bed of calcareous falsebedded sandstone which forms a conspicuous feature running southwards for a mile. Just above this sandstone is a bed of pure limestone two feet thick which is exposed over a considerable area at Kilcummin Head, and which may be traced in the cliffs to the sea about half a mile south of the head. Above it thirty feet of thick shale beds and limestones are exposed.

The only other exposure which appears to belong to the Kilcummin Limestone is an outcrop of grey crinoidal limestone in Mayo sheet 21 NW, about five and a half miles south of Ballycastle. The exposure consists of sandstones and crinoidal limestones containing Spirifer sp.- a form abundant in the Kilcummin Limestone, but not recorded from the Downpatrick Limestone.

Killala Sandstone The outcrop of the Killala Sandstone lies between the Kilcummin Limestone and the Killala Colite, and is bounded by the inferred Lackan Bay Fault on the west and Killala Bay on the east.

The upper part of the Killala Sandstone is exposed on the coast one and a half miles east of Killala where it consists of fawn and yellow sandstone interbedded with shales, with beds of sandy oolite immediately beneath the Killala Oolite. Farther east at Barnasock Point, (about half a mile ENE of Moyne Abbey) shales and argillaceous limestones are exposed. Other exposures occur on the islands of the Moy Estuary, where brown, orange, yellow, fawn and grey sandstones and some oolitic beds are exposed.

Thin sections of the sandstones show them to be arkoses composed of angular quartz and felspar grains, sometimes with calcareous matrix.

Killala Colite The outcrop of the Killala Oolite is

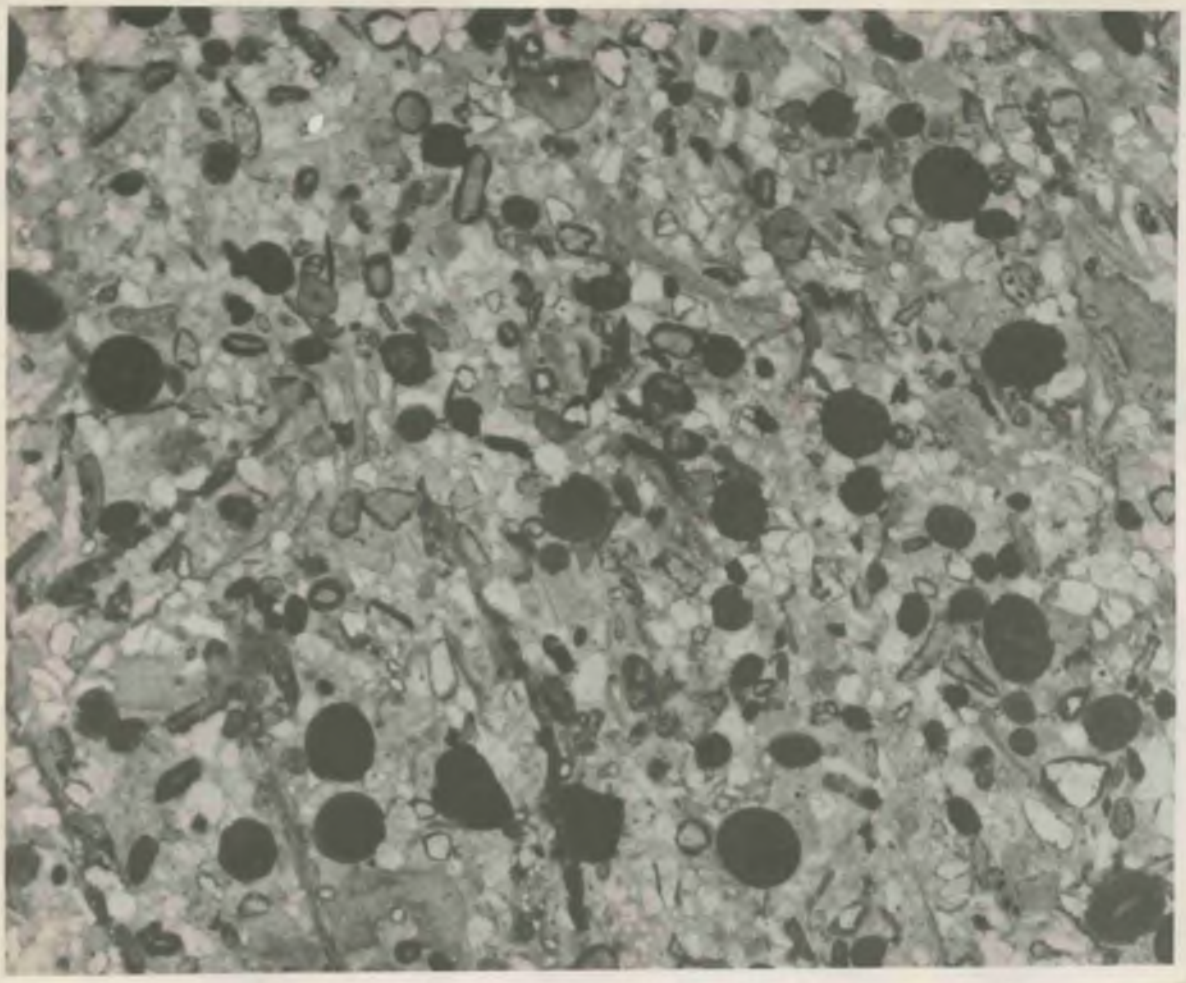

Fig. 12.

Sandy oolitic limestone. X 14.

The rock is a limestone containing scattered ooliths and fragmentary fossils in a matrix of calcite. The abundant arenaceous material consists of angular and subangular quartz and felspar grains.

Killala Oolite, from an escarpment half a mile SSW of Killala.

restricted to a narrow strip of country extending from the mouth of the Moy River westwards to Palmerstown, and to a few yards in the Dunowen River, five miles south-west of Palmerstown.

The best exposures are on the shore and in the quarry a few hundred yards north of Moyne Abbey, two miles east south east of Killala. Exposures also occur on Bartragh Island and some of the smaller islands of the Moy Estuary, and scattered exposures occur inland as well. Three exposures which are isolated and worth noting are

(1) a quarry half a mile north west of Killala.

(2) " " 400 yards south of Palmerstown Bridge.

(3) Dunowen River, five miles south west of Palmerstown.

There is a complete gradation in rock-type from the arkoses of the Killala Sandstone to almost pure oolitic limestone. (see Figs. 12 & 13). Intermediate rock types are sandstones containing a few ooliths, and sandy oolitic limestones.

In all samples the ooliths are dark, due to minute inclusions of an opaque mineral. Many of the ooliths have cores consisting of angular and subangular grains of quartz, microcline or albite, and sometimes calcite, fragments of shells or bryozoa, crinoid fragments or opaque mineral. In the more calcareous oolites the

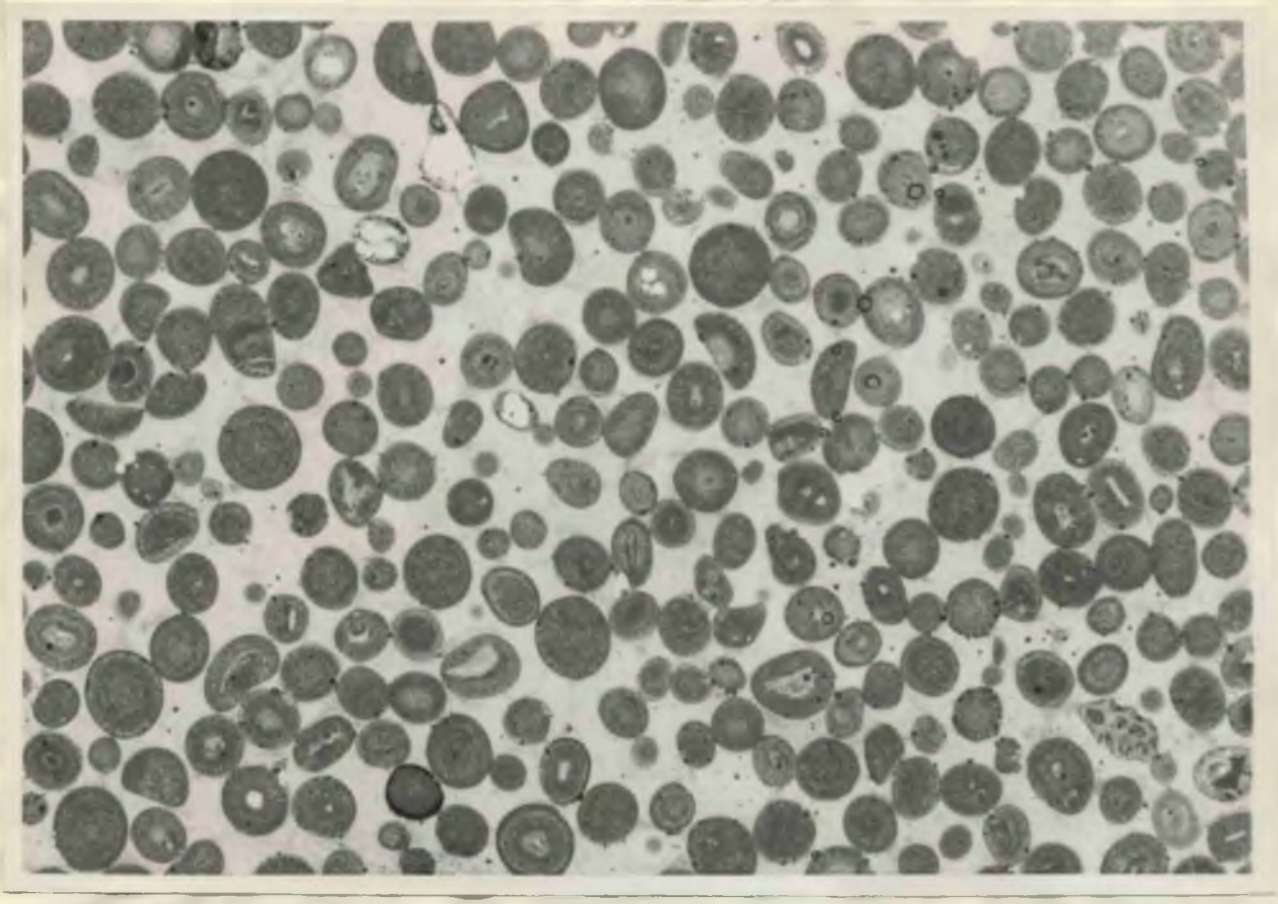

Fig. 13.

Oolitic limestone. X 12.

The ooliths are darker than the matrix owing to the presence of included finely divided opaque material, and are commonly constructed around cores of calcite. Arenaceous cores are rare, and none appear in this photograph (a few patches resembling sand grains are due to holes in the section). The lighter coloured matrix is calcite. Killala Oolite, from the shore, three quarters of a mile east of Killala.

sand grains are small cores within the ooliths, but in the more arenaceous rocks some of the sand and fossil fragments have only a thin oolitic coating.

In the oolitic limestones the matrix consists of anhedral calcite lighter in colour than the ooliths, but still containing numerous opaque inclusions which give a brown colouration to the calcite.

The Killala Oolite occurs at the boundary between the Carboniferous Sandstone and the Ballina Limestone, and it is of interest that a closely similar oolite occurs at the junction of Carboniferous Sandstone and Ballina Limestone at Dromore West, some fifteen miles away (see p. 25).

In the southern part of the Western Region, in the neighbourhood of Keenagh and Lahardaun the base of the Carboniferous succession is not seen, due to the large faults which form the southern boundary of the Carboniferous outcrop; but between the Dalradian rocks and the Ballina Limestone there are in some places outcrops of Carboniferous Sandstone.

These sandstones cannot be correlated in detail with the deposits farther north for they are much thinner, although not so thin as the sandstone at Skreen in the south-eastern region.

Carboniferous Sandstone is exposed near Lahardaun where the beds are pink and white falsebedded arkose and calcareous sandstone. A few miles west of Lahardaun, at Keenagh, Carboniferous Sandstone outcrops in the Deel River between the road bridge and the Dalradian. The beds exposed are fawn, green, and grey sandstones interbedded with shales. Probably 150 feet or more are present in the section.

Near Lahardaun occur the only beds in the Ballina Syncline which are referred to the Old Red Sandstone, and a brief description of them is included here to demonstrate the lithological difference between Carboniferous Sandstone and Old Red Sandstone. The outcrops are situated south-east of Nephin Mountain, in the down-faulted trough which runs from L. Conn to Clew Bay. The beds exposed consist of conglomerates containing well-rounded pebbles of quartzite, quartz, jasper, and schist in a matrix of red sandstone, and falsebedded red sandstone containing pebbles of quartzite, igneous rock, schist, and red grit. The pink quartzite pebbles are well-rounded and noticeably polished. Thin sections of red sandstones show them to be arkoses with felspar grains partially decomposed.

Jasper pebbles, rounded polished quartzite pebbles

and the decomposed condition of the felspar grains are all suggestive of an Old Red Sandstone rather than Carboniferous lithology, and taken together provide good reason for referring these beds to Old Red Sandstone.

(2) Ballina Limestone

In the Western Region the Ballina Limestone occupies an extensive stretch of ground east of the Lackan Bay Fault, and is continuous with the Ballina Limestone of the Easky Syncline.

It is well exposed in the banks of the Moy River, along the escarpment south of Killala, and in a series of river sections near the Lackan Bay Fault. Apart from these localities exposures are sparse.

Near the base the Ballina Limestone is dark in colour, and always with irregular shaly partings between the uneven, nodular limestone beds. There are beds of shale a few feet thick developed here and there, e.g. at Tully Mills, half a mile south of Palmerstown Bridge (Mayo sheet 14 SW).

At almost all levels in the limestone some at least of the fossils are silicified, but there is no chert in the lower beds.

In upward succession the limestone gradually becomes lighter in colour and in general more cherty, and in the central region of the outcrop chert nodules are

locally abundant.

Near the southern margin of the region outcrops of a different facies of limestone occur. These beds include a finegrained recrystallised dolomitic limestone from a stream three quarters of a mile west of Lahardaun. The rock is slightly sandy and contains foraminifera and fragments of larger fossils. Another rock from a quarry half a mile west of Lahardaun is a fossiliferous limestone containing rolled fragments of shelly material and the fragments all have a dark brown peripheral zone due to accretion of calcite containing opaque mineral, but the amount of calcite deposited on the fragments is small, except where algal incrustation has occurred.

Farther west, at a locality some two miles east of Keenagh, crinoidal and dolomitic limestones are exposed.

(b) Dromore West Region.

In this region the base of the Carboniferous succession is not exposed. There are about 200 feet of sandstones and shales exposed in an anticline near Dromore West; belonging to the Carboniferous (Dromore) Sandstone. Above them there are about 1,000 feet of Carboniferous Limestone very well exposed on the coast between Dromore West and Easky, and on Aughris Head. Traced towards the west these limestones are found to be

continuous with the Ballina Limestone.

(1) Dromore Sandstone.

The Carboniferous Sandstone of this region is referred to as the Dromore Sandstone. It outcrops over an area of about two square miles in the axial region of the Dromore West anticline which trends north north east and the axis of which reaches the sea at Portmore about one and a half miles east north east of Dromore West. An almost continuous dip section across the fold is exposed on the coast.

A smaller outcrop of Dromore Sandstone occurs at Dunmoran, on the opposite side of the Easky Syncline.

The beds exposed in the Dromore West anticline are a succession of shales, silts and sandstones, and a few limestones.

The shales are usually dark in colour, and some beds are calcareous. Near the base of the succession they have yielded lamellibranchs, Orthoceras, and Bellerophon, and near the harbour half a mile west of the axis of the Dromore West anticline, some of the shales are remarkably rich in ostracods, including genera such as Cytherella, Cypridina, Rhombina, and Kirkbya.

Most of the silt and sandstone occurs in thin beds alternating with shales, but there are three conspicuous

falsebedded sandstones from ten to thirty feet thick which outcrop on both limbs of the anticline, and form headlands or reefs on the coast.

An argillaceous limestone outcrops on both limbs of the anticline some distance below the uppermost thick sandstone horizon. Limestone also occurs close to the top of the Dromore Sandstone on the western limb of the anticline, including two beds of pisolitic algal limestone and an oolitic limestone. In thin section the algal limestone is seen to be composed of numerous rolled fragments of encrusting and tubular algae, small crinoid ossicles, and fragments of shells. The fragments are coated with a layer of calcareous material which is dark due to the presence of numerous minute opaque inclusions. Sometimes several fragments are cemented together into a small pellet by the dark calcite. The matrix of the rock is finegrained anhedral calcite.

The oolitic limestone consists of four feet of black oolite and oolite sandstones and is lithologically similar to the Killala oolite.

Inland the outcrops strike southwards from the coast to the Ox Mountains Range. The lithology of the Dromore Sandstone is the same as that displayed on the coast, consisting of shales, silts, flaggy and micaceous

sandstones, yellow sandstones, and occasional argillaceous limestones.

The Dunmoran outcrop occurs in an anticline east of the Aughris Syncline. The exposures cover about a quarter of a square mile, and consist of the rocks on the mainland west of Dunmoran Strand, and the rocks of Carrickafadda.

The lowest beds which outcrop on Carrickafadda are bedded limestones with an argillaceous limestone yielding Caninia, productids, zaphrentids, and Chonetes.

The beds on the mainland are some 450 feet thick, and consist of argillaceous limestone and yellow and orange falsebedded and ripplemarked sandstones, some of them micaceous.

(2) Ballina Limestone.

The Ballina Limestone outcrops over the whole of the Dromore West Region, with the exception of the crest of the Dromore West Anticline and the Dunmoran outcrop. The succession is displayed in cliffs in the Aughris Syncline and the Easky Syncline, which lie east and west respectively of the Dromore West Anticline.

In the Dromore West Region the Ballina Limestone is subdivided into Donaghintraine Shale and Easky Limestone.

Donaghintraine Shale The boundary between the Dromore

Sandstone and the Donaghintraine Shale is abrupt in the east, but in the west there are a few feet of oolitic limestone at the junction.

The Donaghintraine Shale is a series of dark calcareous shales and thin argillaceous limestones containing numerous fossils; towards the top the beds become more calcareous, and pass up gradually into the Easky Limestone.

Exposures occur on the shore on both sides of the Dromore West Anticline; inland the beds are usually concealed by drift.

Easky Limestone The Donaghintraine shale passes upwards without a break into the Easky Limestone, and the selection of a boundary is arbitrary. For convenience the boundary is taken to be where the rocks become markedly more resistant to erosion, and form cliffs on the sea front, instead of being exposed only between tide marks.

The Easky Limestone consists of limestones with thin shale partings. The limestones here and elsewhere in the Ballina Limestone outcrop are dark grey finegrained limestones which in thin sections are seen to consist of comminuted shell fragments in a finegrained calcite matrix. The dark colour is due to finely divided opaque mineral of

which some at least is pyritous, occurring in a very fine state of subdivision in oolithic or algal coatings deposited around many of the shell fragments, and less finely divided throughout the matrix.

Successively higher horizons of the Easky Limestone outcrop in the cliffs between Donaghintraine and Easky, and in discontinuous sections in the Easky River.

The lower part of the Easky Limestone contains a rich fauna of brachiopods, but except for zaphrentids, corals are not abundant. Near Carrownabinna higher horizons of the Easky Limestone are exposed in the cliffs, and contain abundant giganteid caniniids and phaceloid Lithostrotion. Higher in the succession, near Easky pier, a cerioid Lithostrotion referred to L. cf. minus is common, and phaceloid Lithostrotion is extremely abundant, large colonies up to three and four feet in diameter resting in position of growth close together on the bedding planes indicating circumstances not far removed from coral reef conditions. Caninia also occurs in large numbers on some of the bedding planes. In the Easky River, above the coral-rich limestones are beds containing chert nodules. Higher beds in the Easky Limestone are exposed between Easky and Clooneen, but these contain neither chert nodules nor Lithostrotion cf. minus, although Caninia

and phaceloid Lithostrotion are common.

East of the Dromore West Anticline the Easky Limestone is exposed in the Aughris Syncline - a lower part with abundant Caninia and phaceloid Lithostrotion, followed by cherty beds with Caninia and both phaceloid and cerioid Lithostrotion.

Higher beds in the Aughris Syncline are very poorly exposed.

(c) South-eastern Region.

The South-eastern Region comprises that part of the Ballina area which lies close to the Ox Mountains Range. In this narrow belt of ground there are numerous outcrops of Carboniferous Sandstone and a facies of the Ballina Limestone resembling that developed in the southern-most parts of the Western Region.

The succession is subdivided as follows:

(2) Ballina Limestone.

(1) Carboniferous Sandstone.

(1) Carboniferous Sandstone.

The thickness of the Carboniferous Sandstone cannot be accurately estimated, but it is believed to be at most only a few hundred feet, since its outcrop is everywhere narrow. The Carboniferous Sandstone consists of conglomerates and sandstones, and is not sub-

divided. Exposures occur in three widely separated parts of the South-eastern Region, at Knockmore, Skreen, and near Ballysadare.

At Knockmore, near L. Conn, conglomerates are exposed close to outcrops of metamorphic rocks of the Ox Mountains Range. The conglomerates contain angular fragments of quartz and quartzite and rounded fragments of schist, locally up to eight inches diameter, in a grit or sandstone matrix which is usually fawn, but is red and micaceous half a mile south-east of Knockmore.

One locality worthy of mention lies a quarter of a mile east of Ballymore Lough, where a very coarse conglomerate, containing boulders of schist and quartz up to three feet in diameter in a gritty matrix, outcrops about thirty yards from metamorphic rocks.

At Skreen the basal sandstone is exposed only in the Doonflin River. Half a mile upstream from Doonflin school a few feet of micaceous quartz-grit, micaceous shale and sandstone are visible in the Doonflin River. Thin sections of a conglomerate and a sandstone show that the former contains small pebbles of quartzite, and the sandy material in both is mainly quartz, with subordinate mica and a little felspar. In the river there are also numerous blocks of coarse quartz conglomerate

indicating the proximity of the Carboniferous base and strongly suggesting that the boundary between metamorphic and Carboniferous rocks is an unconformity and not a fault.

Farther upstream on the east bank of the river the approximate position of the base of the Carboniferous can be plotted from outcrops and topography. There is no evidence of any considerable development of arenaceous rocks, but the base of the Carboniferous is nowhere exposed.

The thickness of the Basal Carboniferous in the Skreen district cannot be measured directly, but in the Doonflin River half a mile above Doonflin school, sandstones are exposed in the river bed about a hundred yards downstream from the road bridge, and limestones about thirty feet above them. The Carboniferous - Dalradian boundary probably crosses the river at about the position of the road bridge, and the Carboniferous Sandstone is thus about fifty feet thick.

At Ballysadare the presence of the Carboniferous Sandstone is indicated by exposures of sandstone close to the Ox Mountains Fault, a mile south-west of Ballysadare, but no extensive sections are exposed.

(2) Ballina Limestone.

Two limestone facies occur in this region. Arenaceous dolomitic and crinoidal limestones usually form

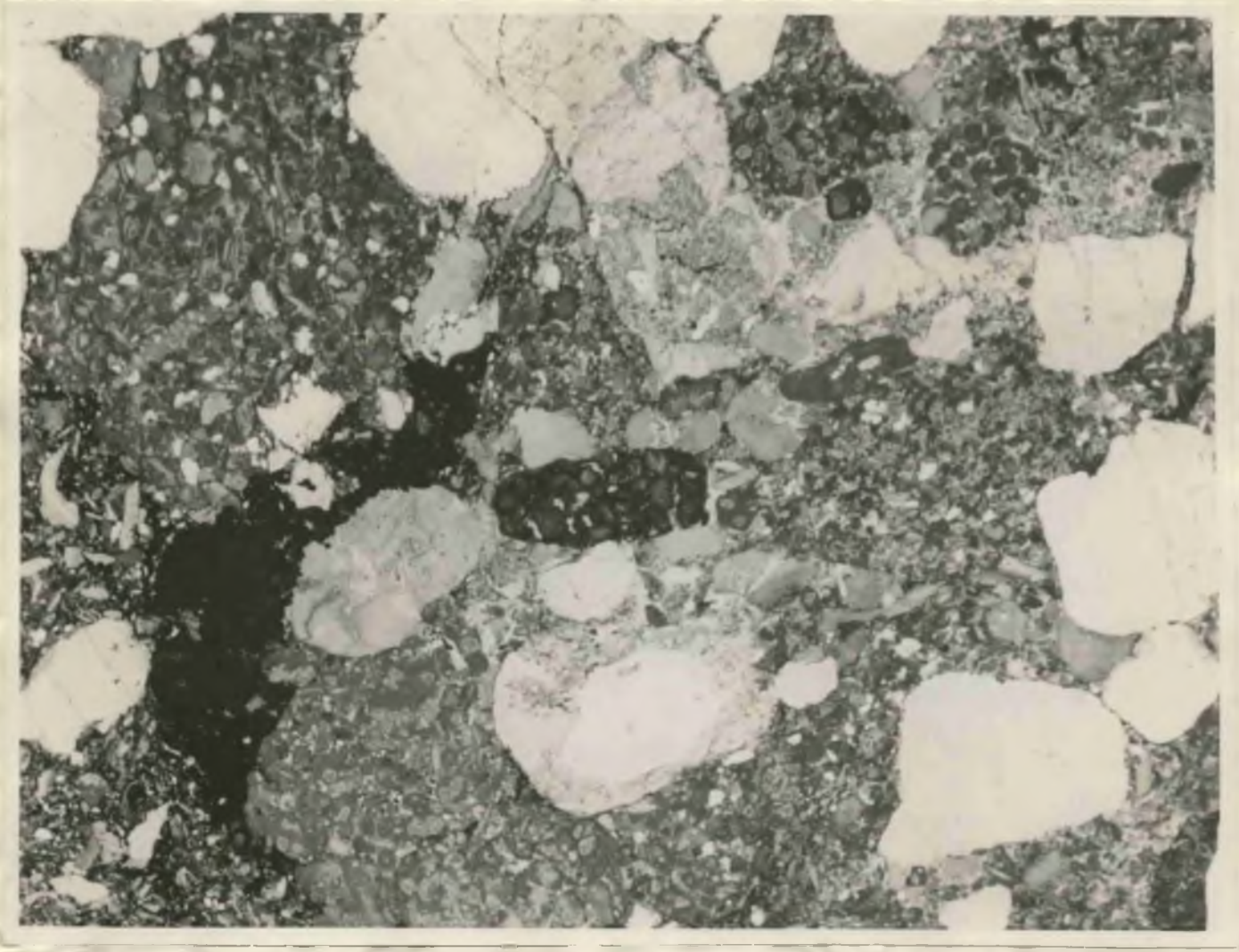

Fig. 14.

Conglomeratic oolitic limestone. X 7.

Fragments of quartzite, strained quartz, felspar, and oolitic limestone are embedded in a matrix of slightly sandy oolitic limestone. Ballina Limestone from the shore, half a mile NE of Toberpatrick.

the lower part of the succession, and are overlain by limestones with shale partings.

At Knockmore near the Ox Mountains Fault dolomitic limestones are exposed. Thin sections show these limestones to be composed of a mosaic of anhedral dolomite, with a few euhedral crystals, and occasional crinoid ossicles and patches of calcite.

At greater distances from the Ox Mountains Fault there are scattered exposures of typical Ballina Limestone - that is, bedded limestone, sometimes cherty, usually containing a coral fauna rich in Lithostrotion and Caninia.

Near Derkmore the best exposures are those in the strike section extending from the eastern end of Dunmoran Strand to Derkmore. The lowest beds occur near the middle of the section, west of Carrowloughan Lough, and consist of beds of quartz-pebbly oolitic limestone interbedded with normal limestone. These quartz-pebbly oolitic limestones contain large subangular grains up to three sixteenths of an inch in diameter of strained quartz, quartz-schist, and perthites and some fragments of oolitic limestone.

The oolitic limestone consists of closely packed ooliths and a few quartz grains with an interstitial filling of finegrained calcite. The ooliths are brown in

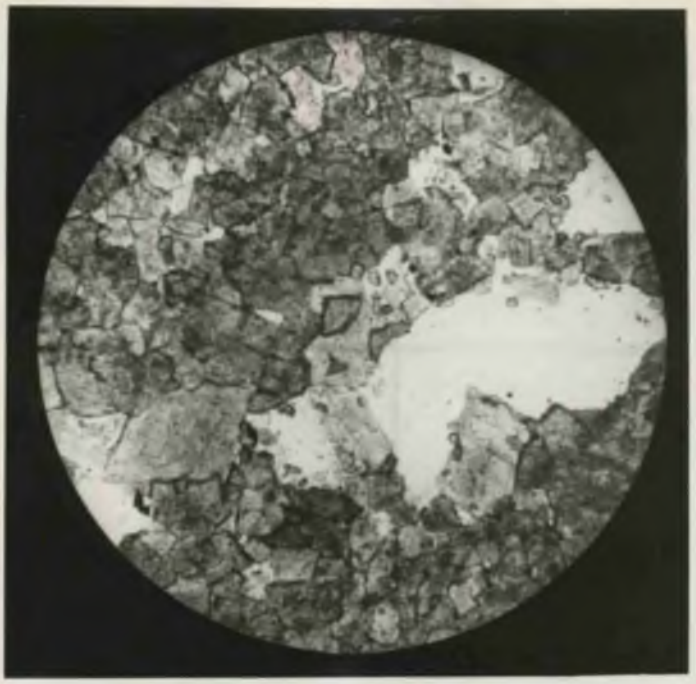

Fig. 15.

Dolomitic limestone. X 35.

Idiomorphic crystals of dolomite can be seen near the hole in the section. Ballina Limestone, from the shore near Derkmore.

colour, and often have cores of calcite. A specimen of limestone from Toberpatrick consists of angular fragments of shells in a calcareous matrix with much opaque material.

Beds which probably belong to a similar horizon to those just described occur near Derkmore, where the Red Hill - Derkmore anticlinal axis reaches the sea; at this locality dolomitic beds are interbedded with limestones. Thin sections of the dolomitic beds show that they are composed mainly of a mosaic of anhedral dolomite. The rock contains a few grains of calcite and recrystallised crinoid ossicles, and a very little sandy material. The dolomite crystals are euhedral where they replace calcite or fill cavities.

Above the lowest sandy and dolomitic beds, there occurs about one hundred feet of bedded limestones without chert, containing brachiopods and corals.

Higher beds are exposed in the westermost part of the section, adjacent to Dunmoran Strand, and both north and south of Derkmore Point. These beds are cherty bedded limestones containing abundant brachiopods, zaphrentids, Michelinia, clisiophyllids, and giganteid Caninia.

Inland there is no continuous section exposed, but it is evident that lower beds outcrop near the axis of the

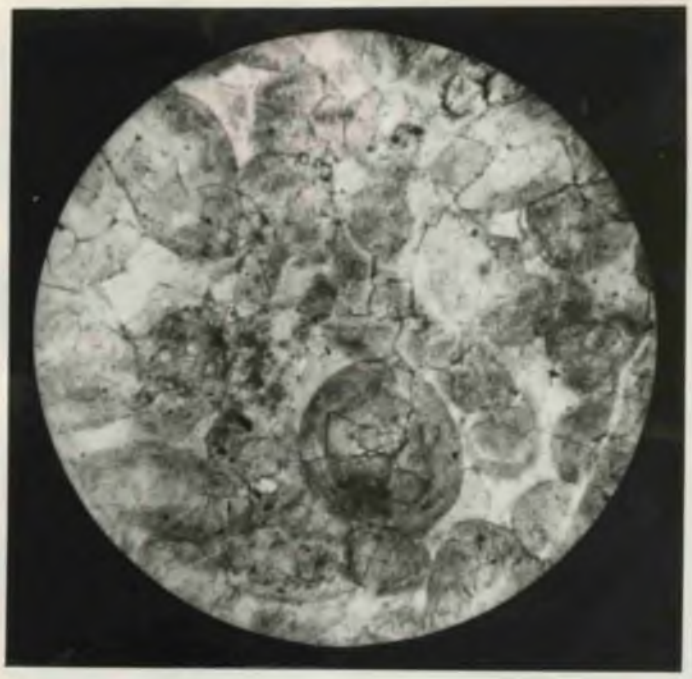

Fig. 16.

Recrystallised oolitic limestone. X 35.
The photograph shows the shapes of the ooliths defined by the minute opaque inclusions which they contained, and the outlines of the present calcite crystals crossing the positions of the ooliths.
Ballina Limestone from Ballysadare.

Red Hill - Derkmore Anticline, and higher beds to north and south. A point of interest is the occurrence of arkose near Caltragh, one and a half miles south of Derkmore, in the midst of the limestone succession.

Near Skreen the Ballina Limestone outcrops at Red Hill and in the anticline north east of Red Hill. At Red Hill the base of the limestone is not exposed, but at several localities in the east side of the Doonflin River valley there are exposures of beds which must be near the base. Beds closest to the base are quartz-conglomerate in a limestone matrix, and quartz-pebbly limestone beds are common in the lower part of the succession. Most of the limestones in the lowest two hundred and fifty feet of the succession are crinoidal dolomites, and there are also thin beds of grit, conglomerates, and quartz-pebbly limestones. Clisiophyllum and Syringopora occur in this lower part.

The limestone beds forming the upper part of Red Hill are cherty and dolomitic, and contain Clisiophyllum, Syringopora, Lithostrotion, Michelinia, and productids.

Many of the exposures of the lower beds of the Ballina Limestone near Ballysadare are arenaceous or dolomitic. Below the rapids of the Ballysadare River are micaceous limestone and falsebedded shale; in the Ballysa-

Fig. 17.

Recrystallised sandy oolitic limestone, from Ballysadare. X 10. When the boundaries of the calcite crystals are visible they are seen to pass through the ooliths as in Fig. 15. The sandy material consists of quartz, quartzite and felspar.

dare lead mines the Index Bed is a recrystallised and dolomitised arenaceous falsebedded oolite. Non-arenaceous dolomites also occur in the lead mines.

Higher beds in the Ballina Limestone are mainly crinoidal limestones and limestones with chert nodules and a fauna of brachiopods, Caninia, Syringopora and Clisiophyllum.

IV FAUNAL LISTS.

The columns are numbered as follows:

(1) Downpatrick Sandstone.

(2) Dromore Sandstone.

(3) Kilcummin Limestone.

(4) Ballina Limestone. (West of Dromore West.)

(5) " " (Aughris)

(6) " " (Skreen)

	1	2	3	4	5	6
Aulopora sp.					X	
Michelinia megastoma.(Phillips)	X					X
Michelinia cf. tenuisepta (Phillips)					X	
Michelinia sp.			X	X		
Syringopora sp.	X	X			X	X
Claviphyllum sp.			X			
Rotiphyllum rushianum (Vaughan)						X
Triplophyllites cf enniskilleni M.E.& H.				X.		X
Zaphrentids.	X	X	X	X	X	X

	1	2	3	4	5	6
Caninia benburbensis Lewis				X	X	
Caninia cf benburbensis Lewis				X	X	
Caninia cf cylin drica (Scouler)				X	X	
Caninia sp.		X	X	X	X	X
Diphyphyllum cf. lateseptatum (M'Coy)				X	?	
Diphyphyllum cf.smithi Hill				X	?	
Diphyphyllum sp.				X		
Lithostrotion cf. affine (Martin)	X					
Lithostrotion cf. martini M.E.& H.	X			X	X	X
Lithostrotion cf. minus (M'Coy)				X	X	
Lithostrotion cf. pauciradiale (M'Coy)				X	X	X
Lithostrotion sp.	X			X	X	
Carcinophyllum sp.		X				X
Clisiophyllum sp.					X	X
? Hettonia sp.						X
Koninckophyllum cf echinatum (Thomson)						X
Palaeosmilia murchisoni M.E.& H.			X		X	X
? Thysanophyllum sp.	X					

	1	2	3	4	5	6
Rhipidomella michelini (L'eveille)auct			X	X	X	X
Leptaena cf analoga (Phill.)				X		X
Orthotetids			X	X	X	X
Buxtonia sp.					X	
Chonetes sp (papilionaceous)			X		X	X
Chonetes sp.		X	X	X	X	X
Daviesiella destinezi (Vaughan)				X	X	X
Dictyoclostus spp.				X	X	
Echinoconchus elegans (M'Coy)			X		X	
Echinoconchus cf elegans (M'Coy)			X		X	
Echinoconchus sp.		X	X	X	X	
Krotovia spinulosa (Martin)				X		
? Krotovia sp.				X		
Linoproductus cf. hemisphaericus (Sow)				X		
Linoproductus spp.	X			X	X	X
Marginifera sp.						X
Productina sp.						X
Productus sp.				X		
Productids	X	X				

	1	2	3	4	5	6
Pustula pyxidiformis (de Kon)			X	X		X
Pustula sp.		X	X	X	X	
Cleiothyridina glabristria (Phillips) auct	X		X			
Cleiothyridina royssii (Leveille) auct			X			
Cleiothyridina sp.						X
'Composita' gregaria (M'Coy)	X				X	
Spirifer cf. crassus (M'Coy)		X	X			
Spirifer cf. konincki Douglas.			X			
Spirifer striatus (Martin) auct			X			X
Spirifer spp.						X
Spiriferellina octoplicata (Sow) auct			X	X		X
Spiriferellina cf perplicata North			X	X		X
? Syringothyris sp.					X	
Tylothyris cf subconica (Martin)						X
Tylothyris sp.				X		X
Camarotoechia sp.	X					
Griffithides cf seminiferus (Phill.)				X		
Phillipsia sp.				X		X

	1	2	3	4	5	6
Bellerophon spp.	X	X				X
Euomphalus sp.			X	X	X	
Gastropods	X	X	X	X	X	X
Fish teeth	X	X				
Lamellibranchs	X	X				
Orthoceratid		X				
Ostracods	X	X				
Plant fragments	X	X				

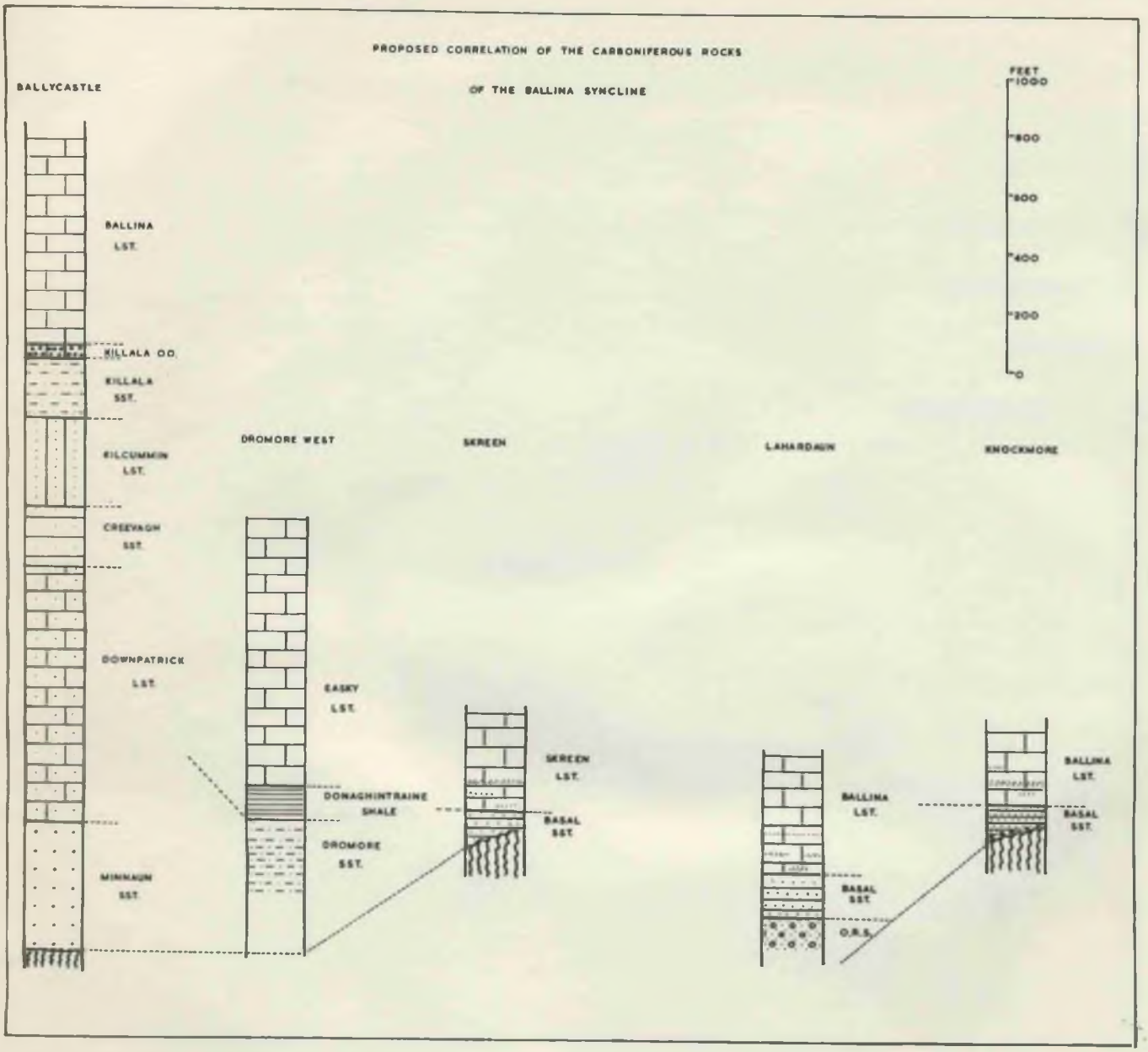
PROPOSED CORRELATION OF THE CARBONIFEROUS ROCKS
OF THE BALLINA SYNCLINE
BALLYCASTLE
FEET
1000
800
600
400
200
0
BALLINA LST.
KILLALA OO.
KILLALA SST.
KILCUMMIN LST.
CREEVAGH SST.
DOWNPATRICK LST.
MINNAUN SST.
DROMORE WEST
EASKY LST.
DONAGHINTRAINE SHALE
DROMORE SST.
SKREEN
SKREEN LST.
BASAL SST.
LAHARDAUN
BALLINA LST.
BASAL SST.
O.R.S.
KNOCKMORE
BALLINA LST.
BASAL SST.

Fig. 18.

V CORRELATION.

Although the rocks in the Ballina Syncline belong to a single and apparently uninterrupted succession in one basin there is considerable variation of lithology and thickness as the sediments are traced laterally. Those variations are most clearly evident when an attempt is made to effect a correlation. The correlation which is adopted here is illustrated in Fig. 18.

The Minnaun Sandstone, Downpatrick Limestone and Creevagh Sandstone do not outcrop east of Ballina, and there is as yet insufficient evidence to enable tneir lateral equivalents, if any exist, to be identified east of Ballina.

The top of the Kilcummin Limestone resembles Ballina Limestone lithologically: if the upper part of the Kilcummin Limestone is in fact equivalent to part of the Ballina Limestone, the succession in the Western Region is such that the Killala Oolite and Kilcummin Sandstone are equivalent to the lower part of the Kilcummin Limestone and part of the Creevagh Sandstone; in this case the thickness of the Carboniferous Sandstone is only 1850 feet and not 2050 feet (see alternative interpretations of succession in figs. 3 and 19). The wide separation of the outcrop of the Kilcummin Limestone from that of the

ALTERNATIVE INTERPRETATIONS OF THE SUCCESSION IN THE WESTERN REGION

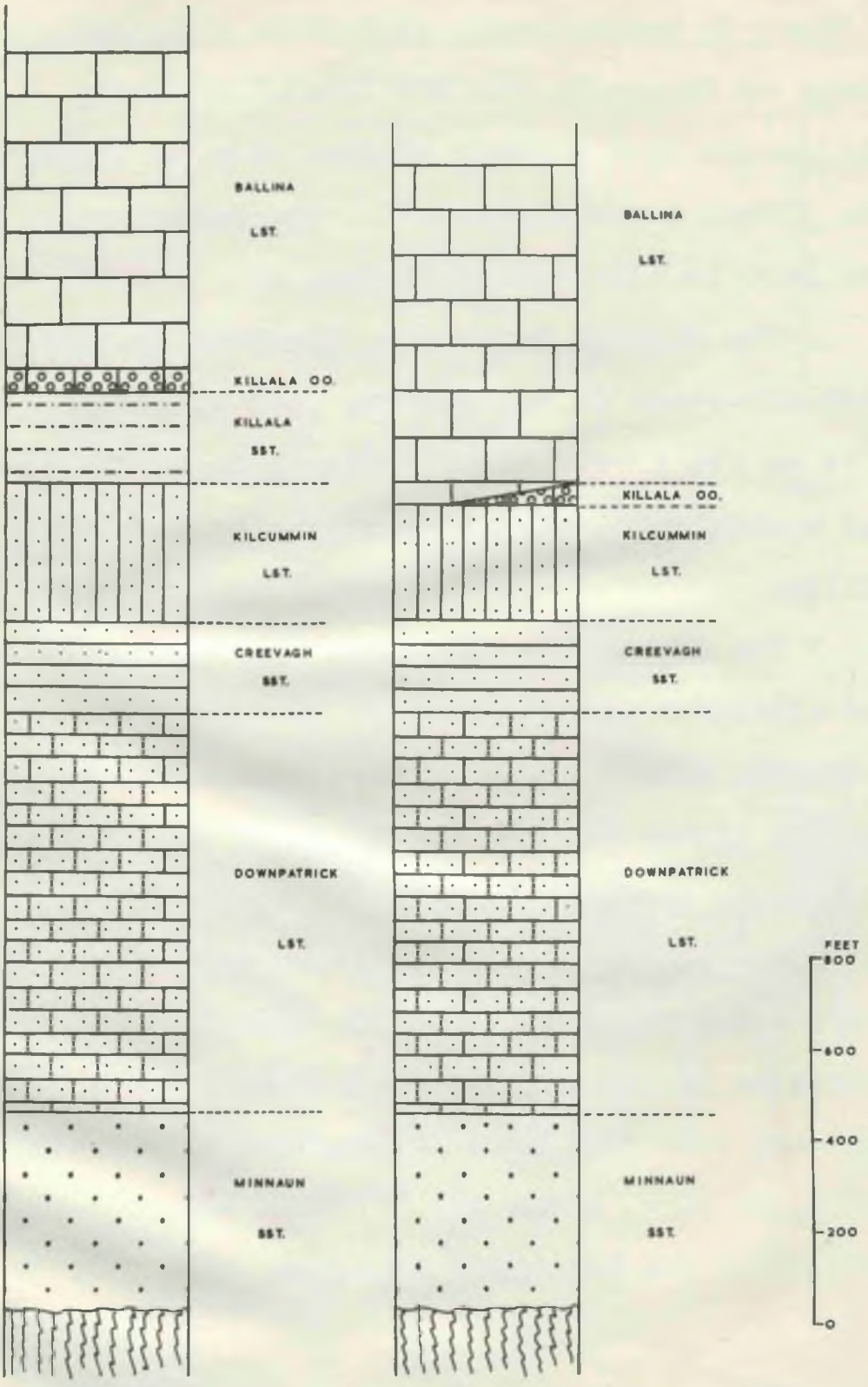

Fig. 19.

Ballina Limestone however, and the inconclusive nature of the faunal evidence, make either correlation uncertain.

Correlation of the lower part of the succession in the West with that of Dromore West is uncertain. The great thickness of arenaceous sediments of the West may be in part represented by Ballina Limestone at Dromore West, and in part overlapped. The uncertainty is due to the absence of exposures of Carboniferous Sandstone between the Moy River and Dromore West.

The limestones of Ballina, Easky and Aughris are in part equivalent at least; the Easky and Ballina limestones are continuous, and the Easky and Aughris limestones occur at about the same level in the Dromore West succession.

The limestones at Derkmore, Skreen and Ballysadare are probably facies variants of the Ballina Limestone since they contain a fauna closely resembling that of the Ballina Limestone, and appear to be laterally continuous with the Ballina Limestone.

At most places close to the Ox Mountains Fault where there are outcrops of Carboniferous strata, the deposits nearest the fault are conglomerates, sandstones, oolites, and dolomitic limestones. It has not been possible to estimate the thickness of these beds except

at Skreen, nor has any accurate estimation of their age been made but they may well be no more than local basal beds forming a uniform but diachronous facies.

ZONAL AGE.

The determination of the age of the rocks of the Ballina Syncline in terms of "standard" zones is not easy. The Ballina faunas do not correspond closely with those of the English South-western Province. Nevertheless a broad comparison can be made, and the evidence available indicates that the rocks of the Ballina Syncline are probably all of Lower Visean age.

The age of the Minnaun Sandstone cannot be determined from its fauna as nothing has been found except a few poorly preserved gastropods and ostracods, but its location immediately beneath and its stratigraphic continuity with the Downpatrick Limestone suggest an early Visean age.

'Composita' cf. gregaria is abundant throughout the Downpatrick Limestone. Lithostrotion occurs occasionally in the upper part, and the remainder of the fauna, which consists of such forms as Michelinia, Syringopora, zaphrentids, Cleiothyridina, Camarotoechia, and Linoproductus, may indicate an Upper Caninia zone age.

The Ballina Limestone contains abundant

Lithostrotion, and other common forms are Caninia, zaphrentids, Syringopora, Michelinia, productids, athyrids, and spiriferids. No typical D zone forms have been recorded from the Ballina Limestone fauna, and the Ballina Limestone can also be referred to the Upper Caninia zone.

Comparison with neighbouring areas.

Oswald (1955 p. 167) found in the Sligo Syncline a succession beginning with Ballyshannon Limestone upon a thin basal series, and he referred the lower part of this succession to C_2S_1. This agrees with the succession in the eastern part of the Ballina area, since the Ballina Limestone is lithologically and faunally similar to the Ballyshannon Limestone and virtually continuous with it.

Higher beds described by Oswald in the Sligo Syncline have not been preserved in the Ballina Syncline.

In the Omagh Syncline Simpson (1955) referred the basal Carboniferous sandstones (1000 - 5500 feet in thickness) to Tournaisian, and the Pettigo Limestone Group to C_2S_1. The fauna of the Pettigo Limestone Group closely resembles that of Ballina Limestone, which is referred here to C_2S_1. Higher beds (the Clonelly Sandstone Group) which Simpson referred to S_2 are not represented in the Ballina Syncline.

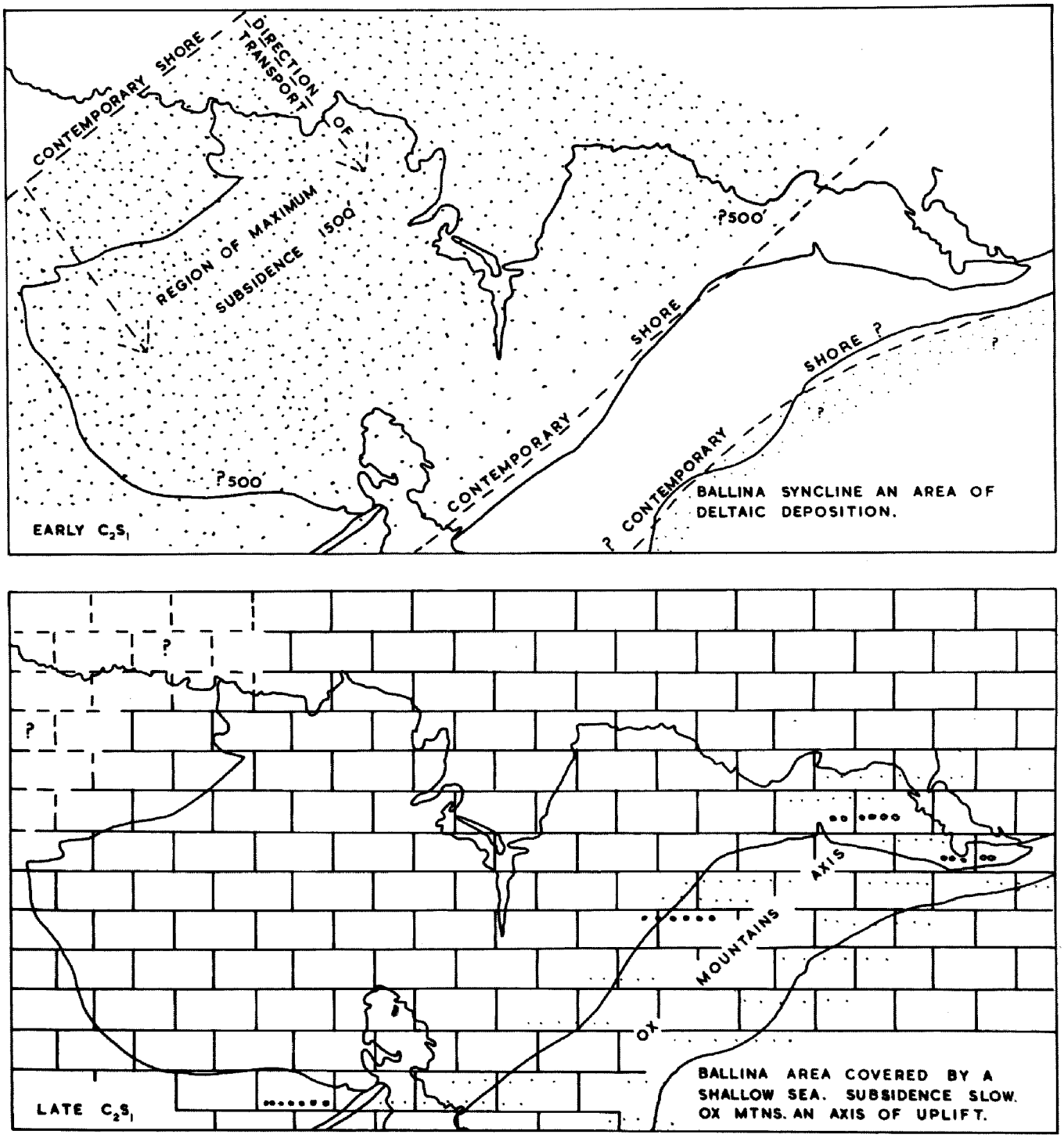

Fig. 20.

Palaeogeography of the Ballina area during early Visean times.

VI PALAEOGEOGRAPHY.

In the North-western part of the Ballina Syncline the lowest beds of the Carboniferous Sandstone are conglomerates and quartzites. Succeeding sediments of the Minnaun Sandstone are "red beds" in that they include a proportion of conspicuous dull red sandstones and shales. That they were deposited in a marine environment is indicated by the occurrence of marine gastropods in one of the limestones, but the presence of mudcracks on bedding planes shows that the sea must have been shallow and impersistent. The sandstones are arkoses, and the abundance and freshness of felspar indicate rapid accumulation of sediments, since the felspar must have been swiftly transported, and soon buried beyond reach of reworking. These characters suggest the inclusion of the Minnaun Sandstone as an early phase of development of the large delta in which the Downpatrick Limestone Series was formed.

The sediments of the Downpatrick Limestone are arkoses, siltstones, shales and limestones. The freshness and abundance of felspar grains indicate that the beds accumulated rapidly and the presence of mud-cracks in some of the limestones shows that they accumulated in shallow water. Further evidence of shallow water

conditions is provided by penecontemporaneous conglomerates and ripplemarks with planed-off crests (Fig.9). The sediments are commonly falsebedded, and some of the thick sandstones were laid down in washout channels cut in slightly older sediments. Conspicuous in thin sections are the angular habit and lack of sorting of arenaceous grains in the sediments.

Taken together these characters suggest a deltaic environment of sedimentation, and the occasional occurrence of woody material in the sediments tends to support this view.

The succession includes a considerable proportion of calcareous beds and limestones, and shales, limestones and calcareous sandstones yielded a marine fauna; the delta therefore must have been normally covered, or part covered by the sea.

At Keenagh and Dromore West the base of the Carboniferous Sandstone is not visible. The beds exposed have most of the characters and lithology of the deltaic facies in the north-west, but the succession is much thinner; and it is suggested that the Carboniferous Sandstone of Keenagh and Dromore West may have been deposited in the same delta as the Carboniferous Sandstone in the north-west, but farther from the source of terrigenous material.

In the south-eastern region the Carboniferous Sandstone consists of a thin series of conglomerate and sandstones. These are basal beds which are certainly in part at least of local derivation, but some of them may have been laid down as part of the Carboniferous Sandstone delta.

The deltaic facies of the Carboniferous Sandstone is thus thickest in the north-west, thinner at Keenagh and Dromore West, and very much attenuated in the south-east. This distribution suggests that the source of sediments lay to the north-west. This is in agreement with the evidence of direction obtained from falsebedding in the Creevagh Sandstone, although as yet data from falsebedding are not adequate to produce an unequivocal result.

The Ballina Limestone outcrops over much of the Ballina area; the abundance of unbroken brachiopod shells, and bryozoan and coral skeletons indicates deposition in relatively quiet environment, beyond the reach of destructive wave action, but in water still sufficiently shallow for the growth of corals and bryozoa, which are typically associated with well-aerated, wave-disturbed water.

At numerous places in the southern and eastern parts of the Ballina Syncline there occurs a limestone facies conspicuously different from the normal Ballina

Limestone. The rocks are arenaceous, oolitic, shelly, crinoidal and dolomitic limestones.

Much of the dolomitic limestone is probably the result of metasomatism associated with the large faults which form the south-eastern boundary of the Ballina area, but the lithology of the other beds suggests that they have been deposited under different conditions from those obtaining where the typical Ballina Limestone facies was deposited. The falsebedded oolitic limestones, crinoidal limestones, and limestones containing rounded pebbles of quartz and quartz-schist all have the characters of sediments which have been thoroughly worked by wave and current action before their final burial, and this is here attributed to slowness of subsidence and sedimentation in the south-eastern region during at least the earlier part of Ballina Limestone times. The anticlinal structure of the Ox Mountains suggests that these beds were deposited across a contemporary axis of relative uplift.

Analogy with the ground to the north-east supports this interpretation, for Oswald (1955 p.181) has demonstrated that near Lurganboy (Co. Leitrim) the Carboniferous succession thins towards the Ox Mountains from north-west and south-east, and that the Ox Mountains range is thus on the site of a Visean axis of uplift.

Both the Ballina Syncline and the Donegal Syncline were areas of deposition during Visean times; the truncated ends of the north-western and south-eastern boundaries of the Carboniferous outcrops, and the facies belts of the Carboniferous rocks, are aligned across Donegal Bay in such a manner as to suggest that the two areas are remnants of a single basin of deposition which stretched from Donegal south-westwards past Ballina.

The north-western shore has been shown by George and Oswald (1956) to have occurred a short distance west and north of the region of maximum sedimentation in Donegal, and from there it probably ran south-westwards and was located a few miles north-west of the present Carboniferous outcrop in Mayo. In early C_2S_1 times the deltaic facies may well have been continuous from Mayo to Donegal, flanking the shore. South-east of the deltaic belt lay a region in which Ballina-Ballyshannon Limestone was deposited, and south-east of this again a belt where the influence of the Ox Mountains (and L.Derg) anticlines caused the development of a littoral facies.

Thus the north-western shore, the axis of the basin and the Ox Mountains axis of uplift all trend north-east and south-west, so that it is probable that the origin and development of this Visean sedimentary basin was

controlled in large measure by the caledonoid structure of the basement due to the operation of Visean movements on the old structural lines.

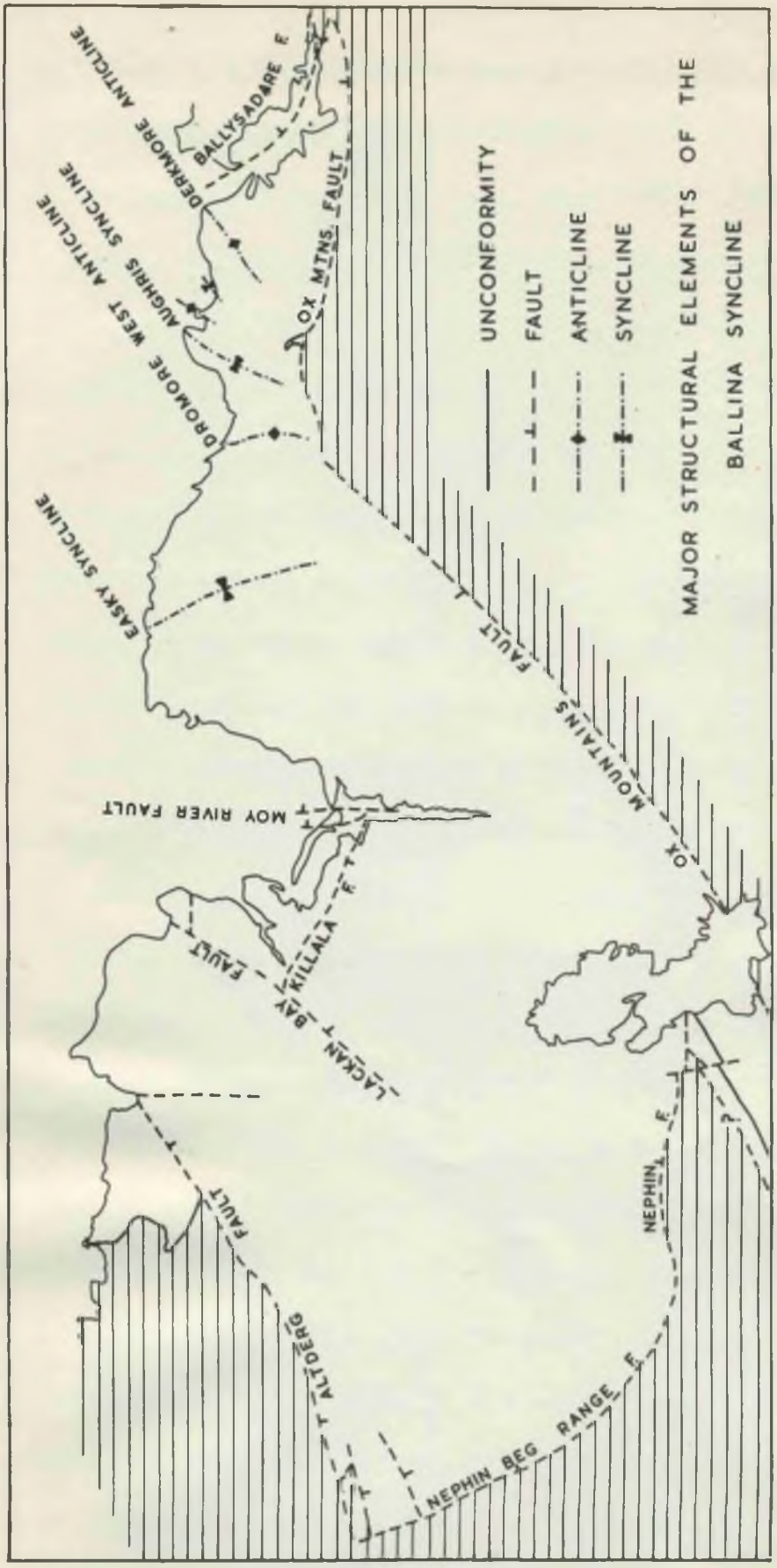

Fig. 21.

Major structural elements of the Ballina Syncline.

VII STRUCTURE.

The metamorphic rocks underlying the Carboniferous sediments of the Ballina Syncline had a caledonoid structural pattern impressed upon them during the Caledonian Orogeny, and it is not surprising that later sediments have adopted a structural pattern which in the main conforms with that of the indurated rocks beneath.

The caledonoid influence on the structure of the Ballina Syncline is shown by the general distribution of outcrops and by the dominant north-east and south-west trend of folds and faults. The Altderg Fault, Lackan Bay Fault, parts of the Ox Mountains Fault, the Derkmore Anticline and the Aughris Syncline all have a caledonoid trend.

There is also a strong suggestion of contemporary caledonoid influence during Visean times which is noticed when palaegeographical reconstruction is attempted.

The Western part of the Ballina Syncline.

There are several faults in the western part which are conspicuous on the maps, and for which field evidence is plentiful. The faults which are included in this category may be briefly noted.

The most obvious are those forming the boundary of the Ballina Syncline, where the Carboniferous rocks are

downthrown against Dalradian. They are all faults of large throw, and exposures in Carboniferous rocks close to the faults usually show beds dipping 15 to 30 degrees away from the faults. None of the fault planes is is exposed. The most westerly is the Nephin Beg Range Fault, which runs north north west past Bangor Erris. Forming the southern boundary of the area from L. Conn westwards to Keenagh is the Nephin fault, which strikes east-west. Anomalous southerly dips close to this fault near Keenagh indicate that movement of this fault was not a single simple downthrow. A third large fault runs from near Glenturk Lodge towards Bunatrahir Bay, and forms the north west boundary of the Ballina area from Glenturk to Altderg. A few miles north-east of Altderg this fault throws down the base of the Minnaun Sandstone against a high horizon in the Downpatrick Limestone, so that the throw is of the order of a thousand feet.

Other large faults whose presence is obvious are the Ballinglen Fault, the Killala Fault, and the Moy River Fault.

The only important fault for which evidence is poor is the Lackan Bay Fault. This is inferred to run south-westwards through Lackan Bay, where it is difficult to correlate the beds on opposite sides of the bay, past

Palmerstown where the escarpment of the Ballina Limestone vanishes and the boundary between Ballina Limestone and Carboniferous Sandstone turns southwestwards.

Another fault of less importance, probably runs east-west through Palmerstown Bridge and Castlereagh. At Palmerstown the Ballina Limestone has in general a northward dip. Thus the truncation of the outcrop of the Ballina Limestone along the east - west line, and the occurrence of Carboniferous Sandstone north of this line is probably due to faulting.

Near Bangor Erris the distribution of outcrops indicates the occurrence of a number of faults running parallel to the Altderg Fault.

It is noticeable that the faults on the map are confined to well-exposed areas. Where exposures are poor, evidence of faulting may be absent, which does not mean that no faults exist. In some places there is evidence suggesting the occurrence of faults, but not sufficient to permit marking faults on a map. Such a locality is found between Ballycastle and Lacken Bay, where the outcrops are confusing but there is little evidence of the positions and directions of faults.

Folding in the western part of the Ballina Syncline is slight and dips rarely exceed ten degrees

except near faults. The distribution of outcrops so that the older rocks occur in the north west and the younger rocks in the south east is due to step faulting rather than regional dip.

Region East of Ballina.

In this region folding is considerably stronger than in the west, and there are fewer faults.

The largest fault is the Ox Mountains Fault which forms the southern boundary of the Ballina Syncline from Lough Conn to Ballysadare. This fault can be traced north eastwards to within two or three miles of Dromore West, where it turns abruptly eastwards, and runs to Ballysadare.

An interesting example of the occurrence of Caledonian, Visean, and post Visean movements on a single structural line is to be found in the history of the Ox Mountains Fault where it runs north-eastwards from L. Conn towards the sea. Its direction shows it to be most probably an old Caledonoid structure, while the facies change in Ballina Limestone on approaching it indicates Visean movements. The present Ox Mountains Fault separates Visean from Dalradian, and is due to post Visean movement during which the Visean rocks locally incurred steep dips due to drag, and were locally shattered and

dolomitised. It is of interest that the Visean structure and the post-Visean fault part company where the Ox Mountains Range changes direction near Dromore West. The Visean line of movement as defined by its associated facies change continues in a north-easterly direction, while the post-Visean fault turns east, and as a result there is preserved in the Skreen - Ballysadare area rocks of sandy-oolitic facies which farther south have been mostly removed by erosion and are found only where they have been faulted down close to the Ox Mountains Range.

The only other large fault forms the northern boundary which separates the Ballina area from the Sligo Syncline. This fault or system of faults can be mapped near Ballysadare, and its continuation westwards is proved by the absence of the Knocknarea succession south of Ballysadare Bay.

The most conspicuous folds in the area are the Aughris Basin, and the Dromore West Anticline. The Aughris Basin is notable because it is the tightest fold in the Ballina Syncline. The beds within this structure attain dips up to fifty degrees in the eastern flank, and fifteen degrees to forty five degrees in the western. The Dromore West Anticline is a gentler fold, and its dips

are in general five degrees to ten degrees. It is notable because it has a north-south axial trend, as has also the contiguous Easky Syncline. The reason for this anomaly is unknown, but may well be connected with the change of direction of the Ox Mountains Fault, since this lies close to the two axes. It seems likely that these folds developed along north-south axes because the large salient of the Ox Mountains a few miles to the south has interfered with the movements and prevented the formation of Caledonoid structures such as occur elsewhere.

West of Aughris folding is gentle. The Dunmoran Syncline and Derkmore Anticline are mappable because they are fairly well exposed, but farther east exposures are poor and the pattern of folding is not clearly displayed.

Pneumatolysis in the Ballina Syncline appears to be related to the faults. Silicification occurs near the Ballinglen Fault, and dolomitisation at numerous places close to the Ox Mountains Fault and the Nephin Fault. The silver lead and zinc mines near Ballysadare are located close to faults. The deposits at present being worked occur a short distance south of the Ballysadare Fault, and old workings some two miles west south west are close to the Ox Mountains Fault.

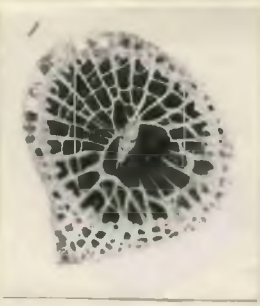

Fig. 22.

Lithostrotion pauciradiale from the Ballina Limestone, one mile north of Rosserk. X 4·5.

Fig. 23.

Diphyphyllum sp. from the Ballina Limestone. Lough Conn. X 3·5.

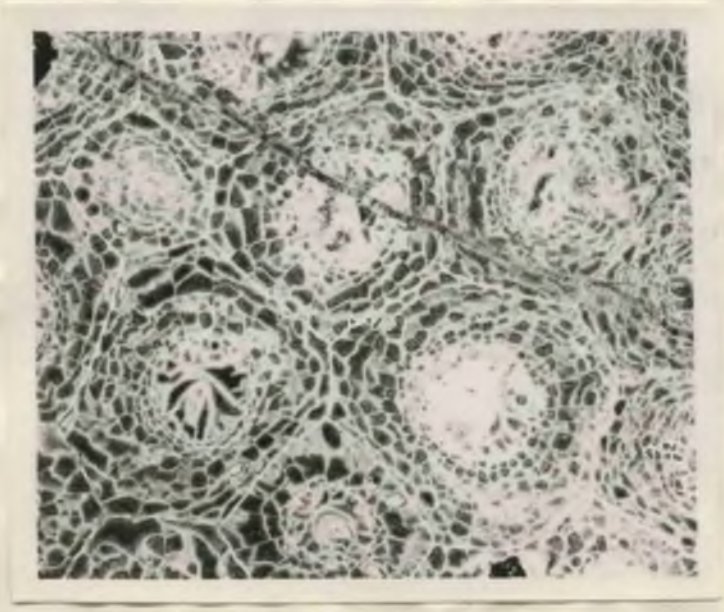

Fig. 24.

Lithostrotion cf. minus from the Ballina Limestone, two miles north of Enniscrone. X 3.

VIII PALAEONTOLOGICAL NOTES.

Lithostrotion pauciradiale (M'Coy).

Fig. 22.

Referred to this species are small phaceloid Lithostrotion, 4 to 8 mm. in diameter with 18 to 27 major septa, several of which usually extend to the columella on the upper surfaces of tabulae. Minor septa extend into the tabularium, and most commonly are about half as long as the major septa. There is a single ring of dissepiments in the smaller specimens, and two or three rings in larger ones.

Lithostrotion cf. martini M.E.& H.

Forms resembling L. martini are common in the Ballina Limestone. They have diameters of 7 to 11 mm. and 27 to 34 major septa. The major septa usually extend about half-way to the columella, and sometimes reach the columella. The counter septum is usually longer than the others, and is often continuous with the columella. The cardinal septum is usually withdrawn into the weakly defined cardinal fossula. Minor septa extend a short distance into the tabularium.

There appears to be no clear-cut distinction between L. pauciradiale and L. cf. martini, and transitional forms occur which it is difficult to classify. L. cf. martini may also be continuous with the diphymorph species which has been referred to Diphyphyllum cf. lateseptatum.

Lithostrotion cf. minus (M'Coy)

Fig. 24.

In the forms referred to this species the major septa extend to or nearly to the columella which is lenticular in cross section or in small corallites, styliform. The minor septa extend about one half or two thirds of the radius, and the dissepimentarium extends about half way to the centre of the corallite. The corallites range in size from 5 to 9 mm. and have 15 to 21 major septa.

"Composita" cf. gregaria (M'Coy).

Fig. 25.

This species externally resembles Composita, but it has a well-developed median septum in the dorsal valve. The median septum extends from the floor of the dorsal valve to a divided hinge plate for the posterior 5 mm. of its length, and then loses height rapidly until it is only a low median ridge.

From the point where the median septum separates from the hinge plate, each half of the hinge plate is produced anteriorly into a rod about 5 mm. long. In none of the specimens examined is there evidence of spiralia, suggesting that this form may well prove to be a smooth species of rhynchonellid.

a

b

c

d

Fig. 25.

"Composita" gregaria, from the Downpatrick Limestone, one mile east of Downpatrick Head.

a and b : photographs of a small specimen.

c : interior of a dorsal valve showing hinge plate and median septum.

d : cellulose peel of a specimen taken 4.4 mm. from the umbo, showing dorsal median septum and divided hinge plate, the anterior ends of the ventral dental plates, and the deep muscle scar in the ventral valve. Approx. X 3.

Tylothyris cf. subconica (Martin)

Fig. 26.

The proportions of the cardinal area suggest that this form should be referred to T. subconica rather than T. laminosa.

Phillipsia sp.

Fig. 27.

This form resembles P. gemmulifera (Phillips), but the eyes are nearly twice as long and reach the neck furrow. Another conspicuous difference is the ornament of the axial lobe of the pygidium, each segment having about ten small tubercles on its posterior edge, instead of four.

Fig. 26.

Tylothyris cf. subconica. Ballina Limestone, Toberpatrick. X 3.

Fig. 27.

Phillipsia sp. Ballina Limestone, West side of Aughris Head. X 3.

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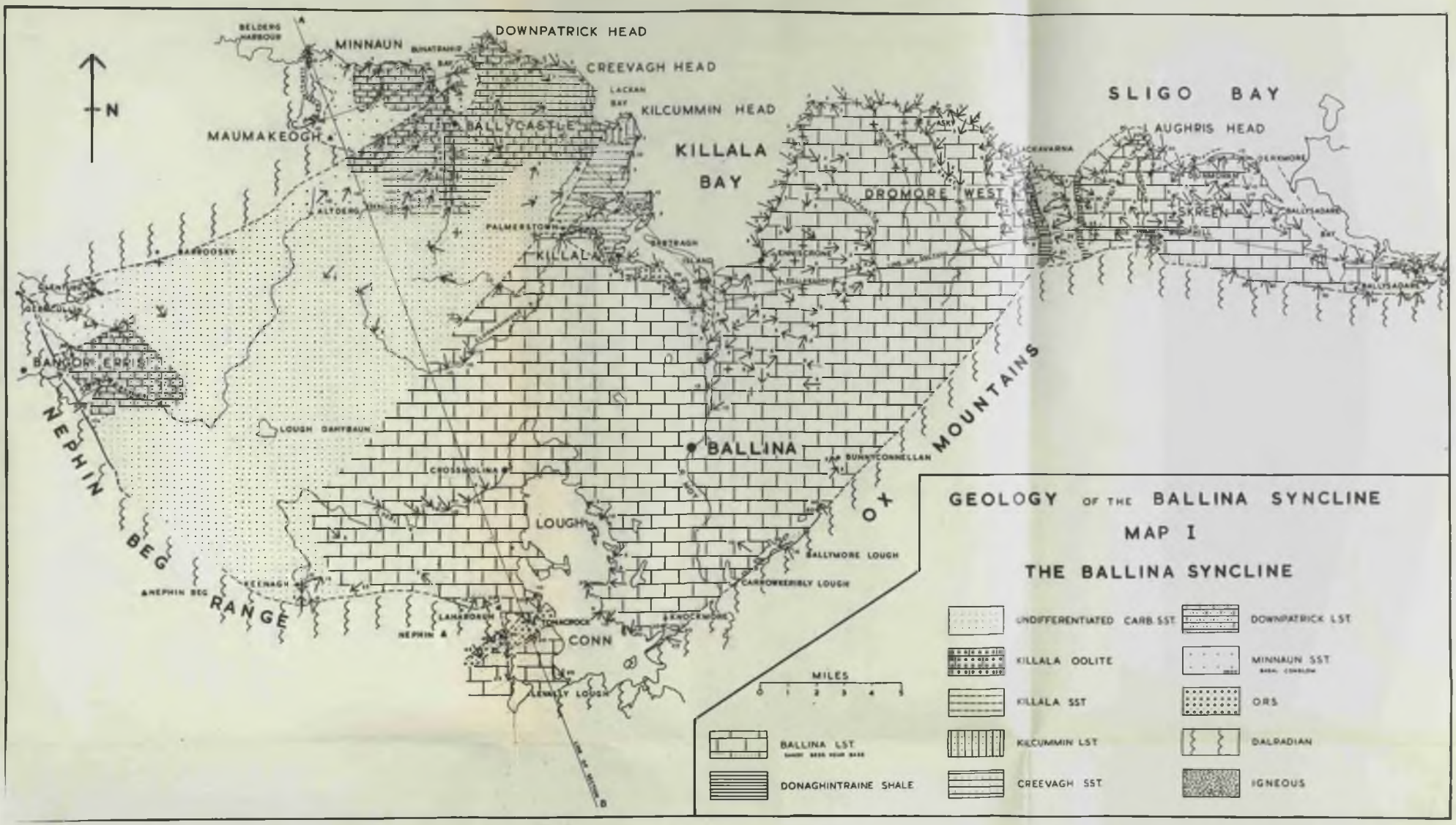
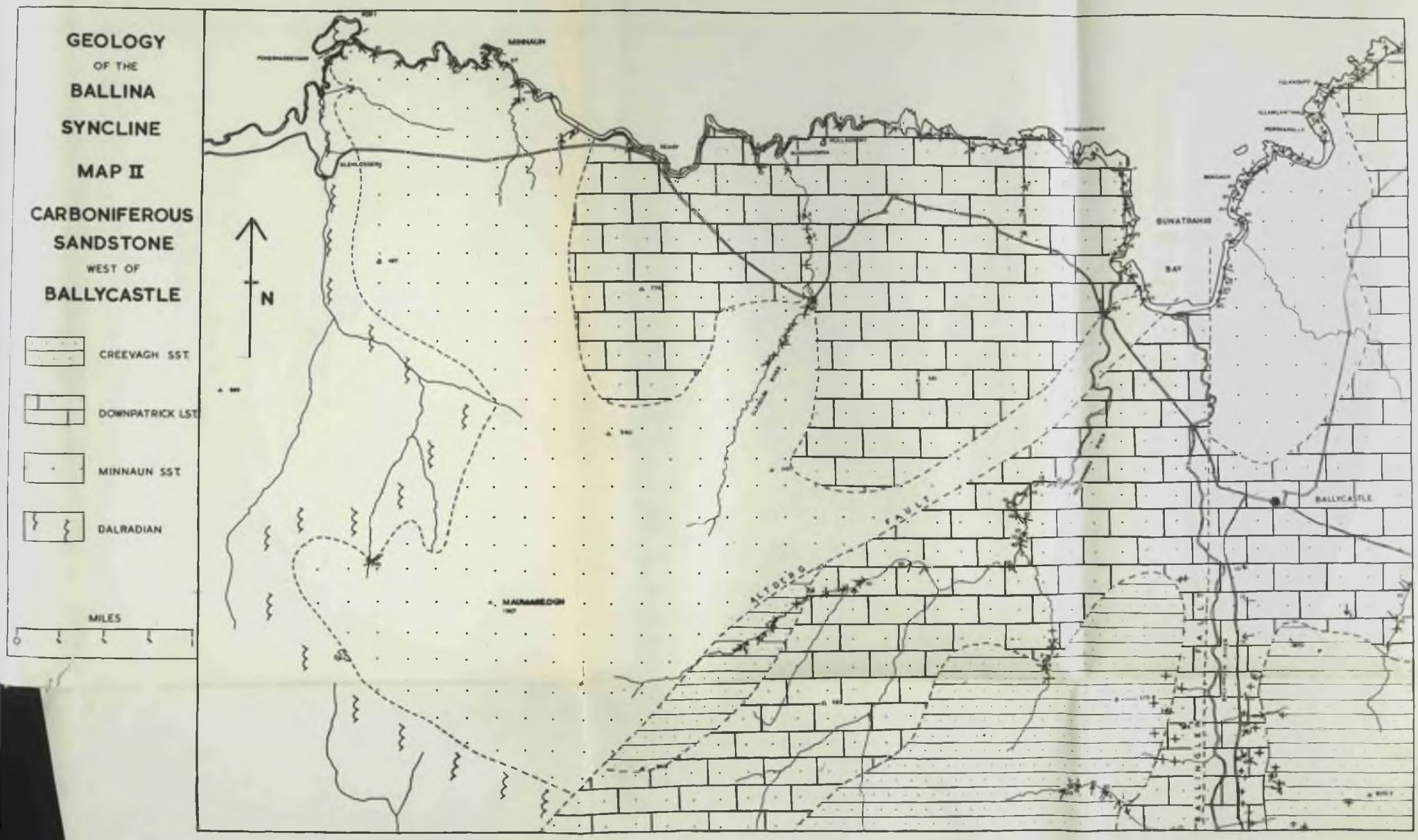
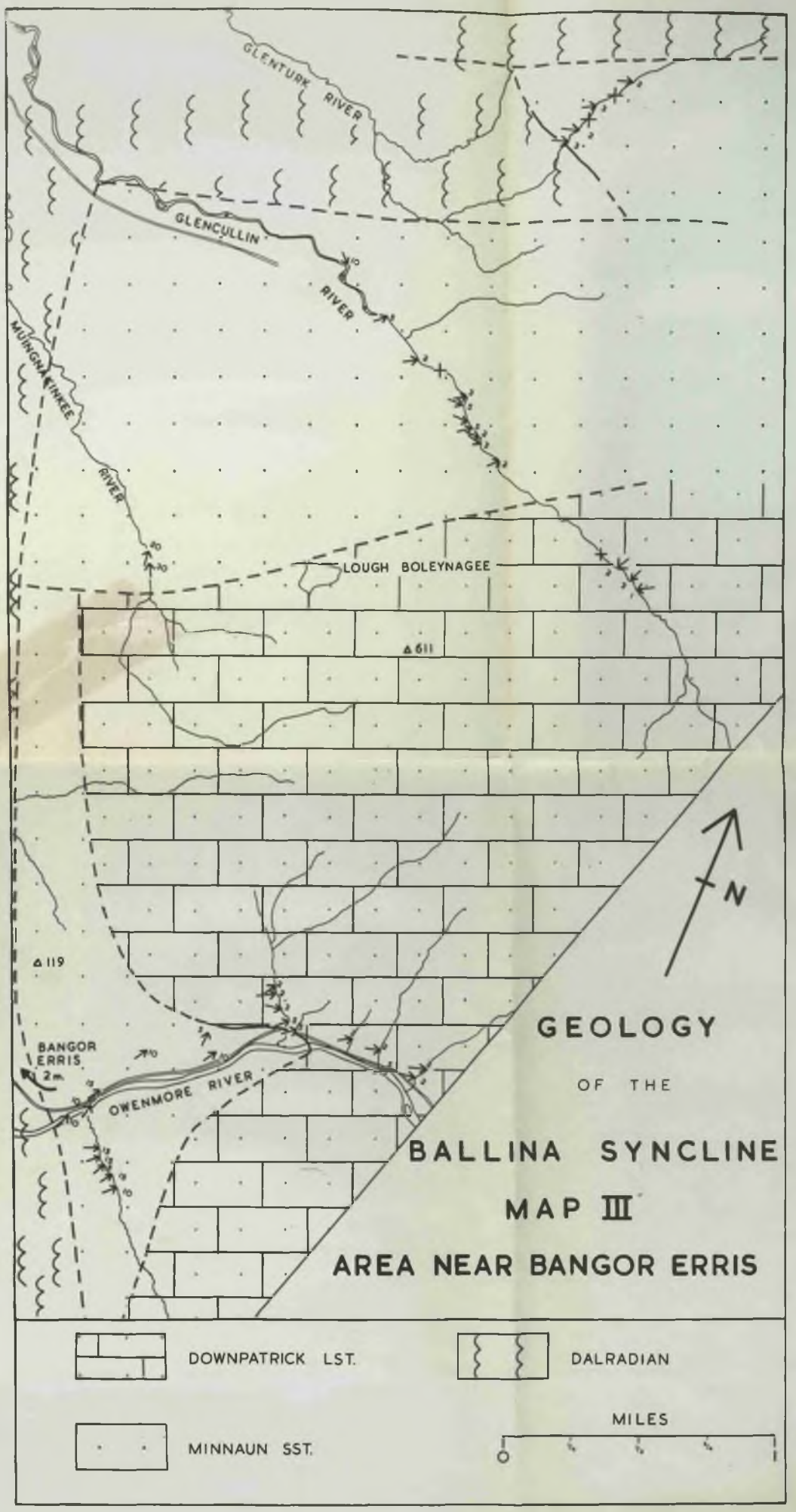
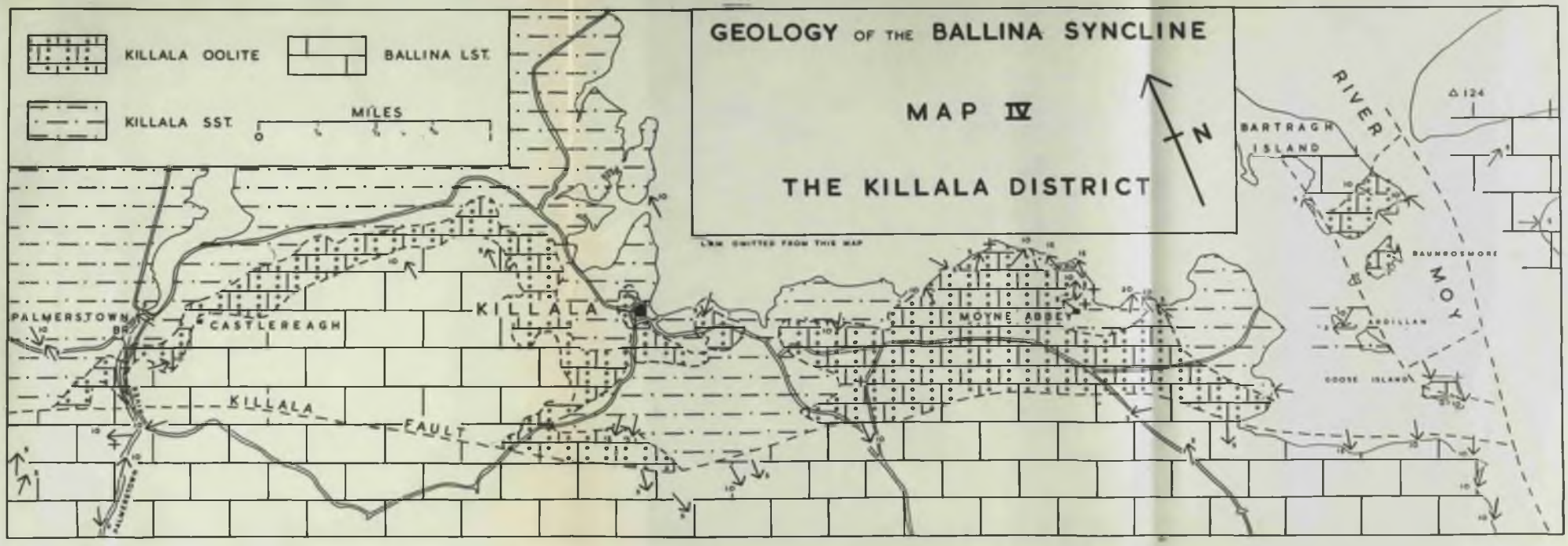
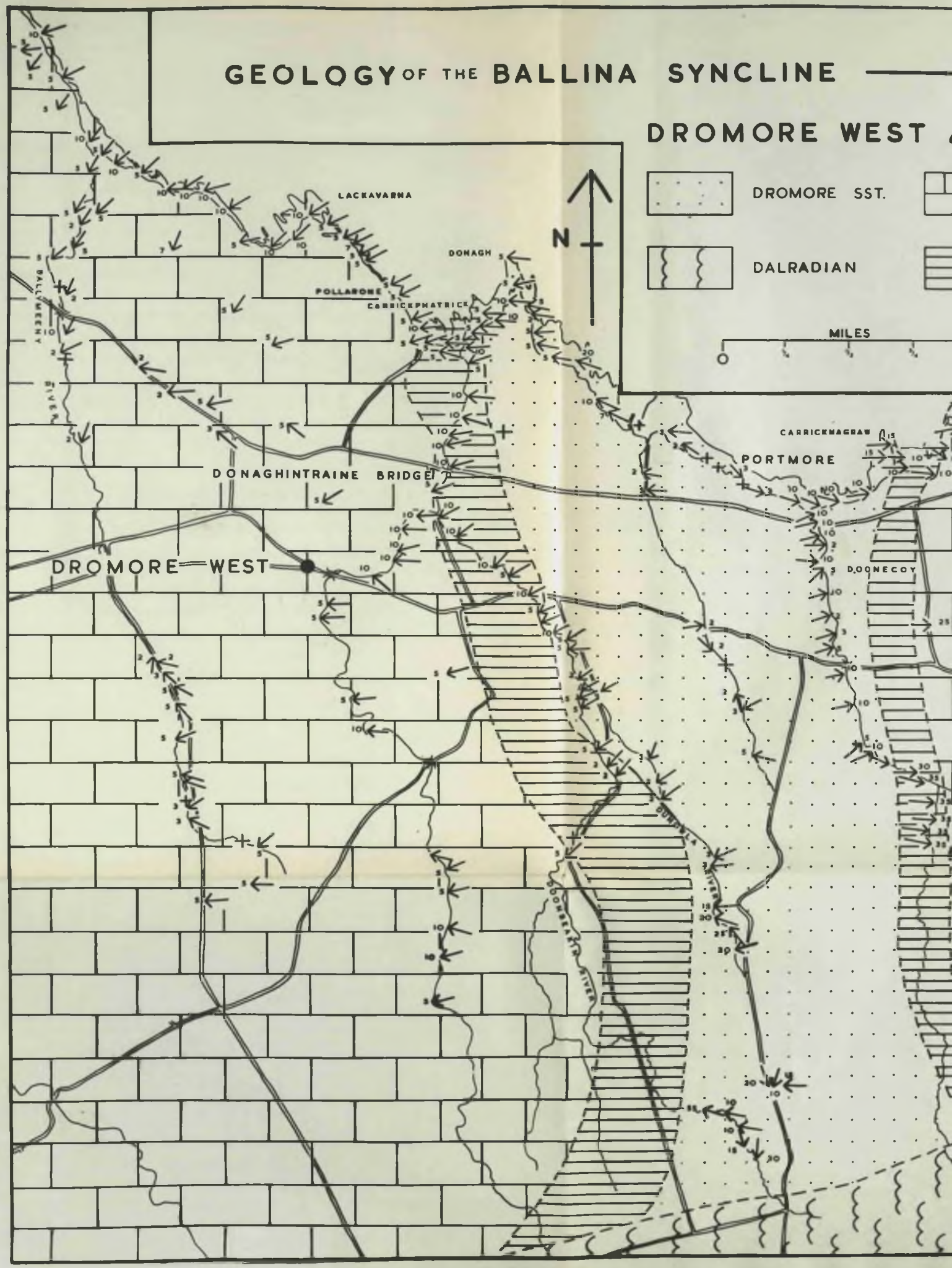
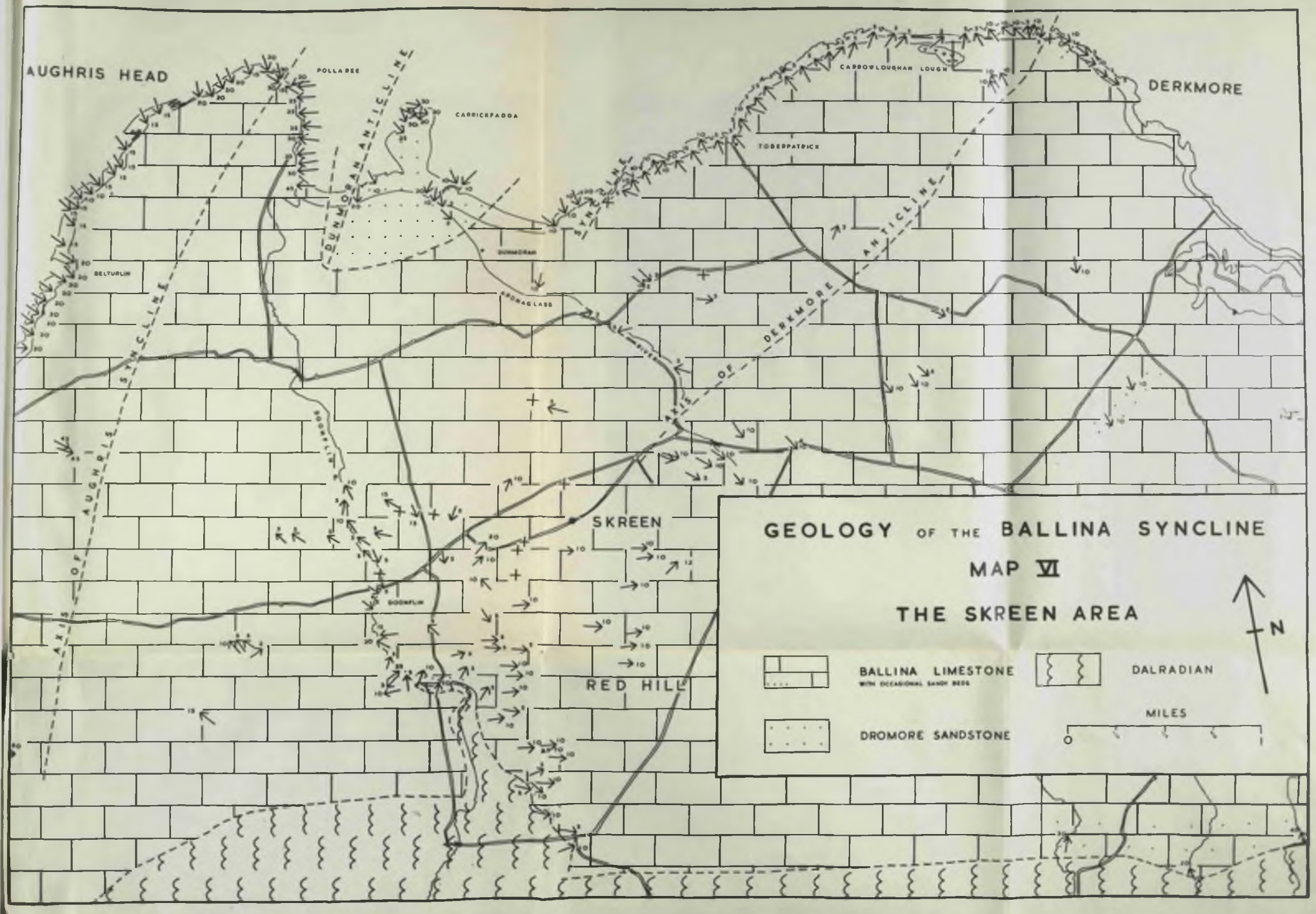

N
DOWNPATRICK HEAD
MINNAUN
CREEVAGH HEAD
KILCUMMIN HEAD
BALLYCASTLE
MAUMAKEOGH
KILLALA BAY
SLIGO BAY
AUGHRIS HEAD
DROMORE WEST
SKREEN
KILLALA
BALLINA
BANGOR ERRIS
NEPHIN BEG RANGE
NEPHIN BEG
LOUGH CONN
BALLYMORE LOUGH
CARROWKEERIBLY LOUGH
MOUNTAINS
OX
GEOLOGY OF THE BALLINA SYNCLINE
MAP I
THE BALLINA SYNCLINE
MILES
0 1 2 3 4 5
UNDIFFERENTIATED CARB. SST
KILLALA OOLITE
KILLALA SST
KILCUMMIN LST
CREEVAGH SST
BALLINA LST
DONAGHINTRAINE SHALE
DOWNPATRICK LST
MINNAUN SST
ORS
DALRADIAN
IGNEOUS

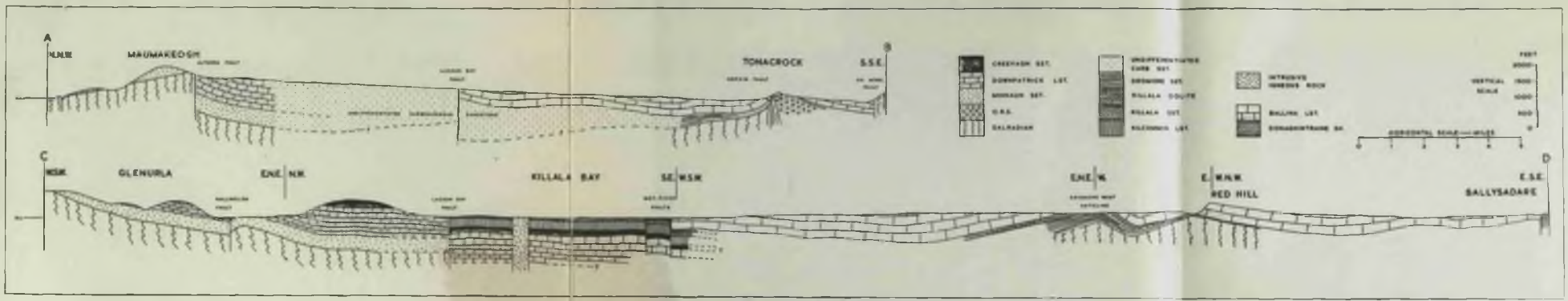

GEOLOGY
OF THE
BALLINA
SYNCLINE
MAP II
CARBONIFEROUS
SANDSTONE
WEST OF
BALLYCASTLE
CREEVAGH SST.
DOWNPATRICK LST.
MINNAUN SST.
DALRADIAN
MILES
N
MINNAUN
BUNATRAHIR
BAY
BALLYCASTLE
FAULT
ALTDOO
MAUMEEDOGH


GLENTURK RIVER
GLENCULLIN
RIVER
MUINGNA KINKEE
RIVER
LOUGH BOLEYNAGEE
△611
△119
BANGOR ERRIS
2m
OWENMORE RIVER
N
GEOLOGY
OF THE
BALLINA SYNCLINE
MAP III
AREA NEAR BANGOR ERRIS
DOWNPATRICK LST.
DALRADIAN
MINNAUN SST.
MILES


KILLALA OOLITE
BALLINA LST.
KILLALA SST.
MILES
0
GEOLOGY OF THE BALLINA SYNCLINE
MAP IV
THE KILLALA DISTRICT
N
L&M OMITTED FROM THIS MAP
RIVER
MOY
BARTRAGH ISLAND
△124
BAUMROSMORE
ROSILLAN
GOOSE ISLAND
MOYNE ABBEY
KILLALA
PALMERSTOWN
CASTLEREAGH
KILLALA FAULT


GEOLOGY OF THE BALLINA SYNCLINE
DROMORE WEST
DROMORE SST.
DALRADIAN
MILES
N
LACKAVARNA
DONAGH
POLLABONE
CARRICKPHATRICK
BALLYMEENY
RIVER
DONAGHINTRAINE BRIDGE
DROMORE WEST
CARRICKMAGRAW
PORTMORE
DOONECOY
DUNNEALA
DONNEALA RIVER


AUGHRIS HEAD
POLLADEE
CARRICKPADDA
DUNMORAN ANTICLINE
SYNCLINE
CARROWLOUGHAN LOUGH
DERKMORE
TOBERPATRICK
ANTICLINE
DERKMORE
SYNCLINE
BELTURLIN
DUNMORAN
BROHAGLASS
AXIS OF AUGHRIS SYNCLINE
SKREEN
DOONFLIN
RED HILL
GEOLOGY OF THE BALLINA SYNCLINE
MAP VI
THE SKREEN AREA
N
BALLINA LIMESTONE
WITH OCCASIONAL SANDY BEDS
DALRADIAN
DROMORE SANDSTONE
MILES
0
1


A
MAUMAKEOGH
TONACROCK
S.S.E.
B
C
GLENURLA
KILLALA BAY
D
RED HILL
E.S.E.
BALLYSADARE