# POPULATION STUDIES IN THE BALLYSHANNON LIMESTONE, BALLINA LIMESTONE, AND RINN POINT BEDS (VISÉAN) OF N.W. IRELAND

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ABSTRACT. A numerical comparison of the populations of the outcrops formerly ascribed to the Ballyshannon Limestone and its lateral equivalents at Easky, Aughris, Serpent Rock, Streedagh, Kiln Port and Shalwy is presented. The localities define the limits of a subtrapezoidal area some 300 square miles in extent, in which the maximum distance between stations is 33 miles (Easky to Kiln Port) and the minimum 6·5 miles (Kiln Port to Shalwy). The four first named Sligo stations bear close similarities representing coral colonies, thickets, and even local coppices. The last two named Donegal stations have a different fauna which is not as dense and may be argued to represent either a different faunal province or, more probably, a different stratigraphical horizon. Aughrus (Co. Donegal), near the type area of the Ballyshannon Limestone, is alluded to. It shows a distinctive fauna with affinities to the other Donegal stations though proportionally the assemblage is unique.

Stratigraphically the Donegal stations are regarded as belonging to the Ballyshannon Limestone (C<sub>2</sub>S<sub>1</sub>), while the Sligo stations are tentatively ascribed to the Benbulben Shale—Glencar Limestone (S<sub>2</sub>D<sub>1</sub>) transitional

Palaeoecologically all the faunas are regarded as having developed marginally between the dysphotic tropical belt and shallow warm waters of the open shelf. Of the Sligo stations Aughris is regarded as the most seaward facies of a coral biostrome. A niche biota faunal replacement of syringoporids by fasciculate lithostrotiontids, michelininiids by cerioid lithostrotiontids, narrow caniniids by giganteid forms, and davisiellids by linoproductids is postulated

THE Ballyshannon Limestone was first named and described by Oswald (1955, p. 168). He mentions that at Streedagh Point its thickly bedded argillaceous limestones and shales are extremely fossiliferous (p. 170). He continues by quoting Wynne (1864, p. 38) who describes the caniniids as '... like stumps in a cabbage garden, and one is almost disappointed to find that one can not pull them up; some of them are from 18 inches to 2 foot long and 2 to 3 inches in diameter'. Oswald adds that the description is apposite but corals are more numerous than it suggests. He mentions (p. 170) that similar beds are found at Serpent Rock; and cites another conspicuously fossiliferous outcrop between Fairies Bridge and Aughrus (Co. Donegal).

Bowes (unpublished Ph.D. thesis, 1957, p. 52) compares the Ballina Limestone with the Ballyshannon Limestone on lithological and faunal similarities, adding that their outcrops are virtually contiguous. He further describes the prolific faunas of the Ballina Limestone at Easky and Aughris.

George (in George and Oswald 1957, p. 143) places the Rinn Point Beds of Donegal high in the Ballyshannon Limestone, mentioning that they are better exposed in the Largymore syncline than on St. John's peninsula. Both outcrops are regarded as representatives of a mud-zone environment (p. 152). In the highest part of these beds, described in the eastern flank of the Largymore syncline, he draws attention to the very rich coral layers with large caniniids in a profusion comparable with that of Streedagh Point and Serpent Rock in the Lissadell Peninsula (Oswald 1955, p. 170).

To each of the above descriptions a fossil list giving generic and specific details is appended.

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#### **METHOD**

Seven stations have been selected from extensive coastal exposures, chiefly in the intertidal zone, in which the partially silicified fauna is particularly well preserved. These localities are constituent of the previously designated Ballyshannon Limestone outcrop and its lateral equivalents. At each location, excluding Aughrus (Co. Donegal), 100 one-metre quadrants measured with a piece of string anchored by four pebbles were



TEXT-FIG. 1. Outline map of the Sligo-Donegal coast to show the location of the stations from which the population of the Ballyshannon Limestone has been sampled.

sampled. In each quadrant the total fauna, including entire and fragmental forms, above the size of comminuted crinoid debris, was counted. In order to obtain a representative sample bedding planes were studied at each locality.

At Aughrus (Co. Donegal), which is alluded to on account of its proximity to the type area of the Ballyshannon Limestone, it was found impracticable to sample more than 50 one-metre quadrants all of which are derived from the same bedding plane. Thus restricted, with only entire forms counted, no direct correlation may be drawn with this area though its significance is evident.

In the analysis of the fauna a specific identification has not been attempted. The

TABLE 1. Field counts on 100 one-metre quadrants

	EA	EASKY		AUGHRIS		SERPENT		STREE DAGH		KILN PORT		SHAWY	
	a	ь	a	ь	a	b	a	b	a	b	a	b	
SOLITARY CORALS													
caniniids	355	29	323	19	748	82	1050	82	91	8	329	49	
zaphrentids	1		4		3		11		4		5		
clisiophyllids									6	7	28		
COMPOUND CORALS													
lithostrotiontids 1	25	30	31	26	29	144	5	87			1 1		
lithactrationtide '		740		550		861		375					
lith octrotiontide -	11		19	3	25	2	1						
syringoporids, 3									3		58	_	
syringoporids 2						100			16		4		
syringoporids 2 syringoporids 2 syringoporids 3						(	10.50				32		
autoporius	2	7	17	25	47	14	18	75	13		2		
micheliniids			1								30	1	
BRACHIOPODS													
davisiellids			1						580		57		
chonetids	+		_		-				2	_	0.	_	
linoproductoids	521	6			110	24	81	19					
pustulids				10			-	1	2	1			
productids	2	128				49					5	4	
orthotetids	3				19	3	32	5	12	777			
leptaenids					10		4						
spiriferids		1			14		29	7	1				
rhynchonellids									2		1		
brachiopods+			6		28	117	69	174	39	70	3	2	
BRYOZOA									1				
fenestellids	2	22		17		32		23		5	5	1	
trepostomes	3	10		7		51		1					
TRILOBITES						5		2		1			
MOLLUSCS	1												
gastropods <sub>1</sub> gastropods <sub>2</sub> orthocones			2		6		8						
gastropods 2	3		3	i	23						25		
orthocones*					1	1							
ECHINODERMS													
echinoids		1	1	1						27	1		
crinoid debris	GEN	ERAL	LY	PRES	ENT	THR	OUGH	OUT		~			
worm burrows		ERAL		PRES			OUGH					-	

The total population recorded in the field at Easky, Aughris, Serpent Rock, Streedagh, Kiln Port

The total population recorded in the field at Easky, Augilis, Scipent Rock, Streedagh, Rim Forand Shalwy is tabulated.

Column (a) represents entire forms, column (b) fragmental forms.

Lithostrotiontids<sub>1</sub> fasciculate with corallites approximately 5 mm. in diameter.

Lithostrotiontids<sub>2</sub> fasciculate with corallites approximately 12 mm. in diameter.

This lithostrotiontid form was at first mistaken for fragmental material. The figures employed are the results of extrapolation. The majority of coralla were noticed to be composed of fewer than half a dozen corallites, often only two or four. To approximate the fragmental quota 10 per cent was

material involved, though prolific, is somewhat intractably set in a massive matrix which precludes detailed laboratory studies. Specimens are often only partially visible (Plate 41, fig. 2) and sometimes crushed by compaction. Thus brachiopod hinges are often buried or removed by erosion which would not allow for accuracy even at generic level though the profile available is adequate for the family or subfamily level of classification. Likewise it is argued that the selective sampling of corals would add no greater accuracy to this study when it is borne in mind that no less than 6,562 corals have been enumerated.

The faunal lists made available during the last decade by Bowes (1957, pp. 45-48), George and Oswald (1957, pp. 172-4), and Oswald (1955, p. 172) present the generic and specific details which are grouped in the present account. Of these Bowes' is the most localized, specifying Aughris as a collecting locality. Oswald (1955) unfortunately does not localize his material, of which much appears to have been collected from Streedagh Point and Serpent Rock, thus detracting from the significance of the Ballyshannon Limestone fauna quoted.

The Sligo outcrops, mentioned hereafter, consist of relatively thick, irregularly bedded, light grey biomicrite (Folk 1959) with a prolific coral-brachiopod fauna, and occasional thin shale partings. The fauna, which is scattered throughout, is particularly rich along certain planes. There is a tendency for one form to predominate in each stratum notably caniniids (Plate 40, fig. 1), lithostrotiontids (cerioid: Plates 40, figs. 2, 3, or fasciculate: Plate 41, fig. 1), or brachiopods; though a certain amount of mixing is to be found (Plate 41, fig. 2). The Donegal outcrops, by contrast, appear to be less fossiliferous, darker, more regularly bedded, somewhat impure biomicrites with a less silicified fauna.

The location of the stations (Easky, Aughris, Serpent Rock, Streedagh, Kiln Port, Shalwy, and Aughrus (Co. Donegal)) is indicated in text-fig. 1, with the total population as tabulated in the field in Table 1 and text-fig. 2. To simplify interpretation the genera were subsequently subdivided into five groups which seemed to have ecological significance: solitary corals, compound corals, brachiopods, bryozoa, and others which are plotted on histograms to show the varying proportions of entire to fragmental forms as a measure of turbulence.

Text-fig. 3 which represents the total numerical population shows a distinctly greater density of fragmental forms at Streedagh and Serpent Rock; these are closely followed by Easky in fragmental forms suggesting that these were the more turbulent areas. Kiln Port and Shalwy have a decidedly less dense fragmental population than the Sligo

discounted (a sum to which no statistical significance should be attached). The remaining 90 per cent. was divided by three to produce an approximate 'entire' quota. Thus in subsequent calculations the following numbers are used: Easky 222a 74b, Aughris 166a 55b, Serpent Rock 268a 86b, Streedagh 113a 37b.

Lithostrotiontids3 cerioid forms.

Syringoporids, with corallites approximately 2 mm. in diameter.

Syringoporids<sub>2</sub> with corallites approximately 3 mm. in diameter.

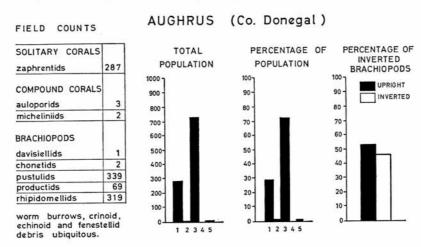
Syringoporids<sub>3</sub> with corallites approximately 4 mm. in diameter.

Brachiopods, unidentified short hinged.

Gastropods<sub>1</sub> fusiform. Gastropods<sub>2</sub> helicoid.

stations and in 'entire' density are also comparatively sparse, indicating an indigenous fauna in less favourable though calm seas.

In text-fig. 4 the total population is expressed in a percentage histogram in which a similarity of distribution in forms is just discernible though less evident than in text-fig. 3. It is also to be noted that most specimens are entire, and of the fragmental fossils brachiopods and compound corals are generally dominant.



TEXT-FIG. 2. The population of Aughrus (Co. Donegal). Field counts record the entire forms counted in 50 one-metre quadrats restricted to one bedding plane. Histogram of the total numerical population showing an anomalously high population which can be related to the selector bias of sampling only one bedding plane. Percentage histogram of total population resembling Kiln Port (text-fig. 5).

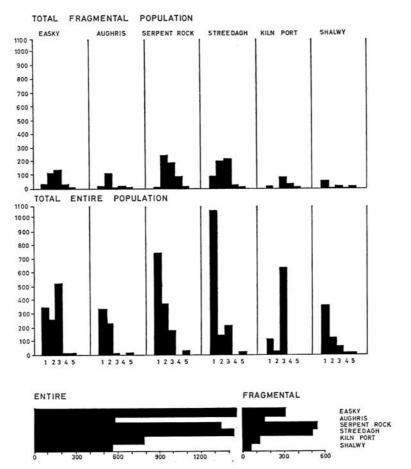
1, solitary corals. 2, compound corals. 3, brachiopods. 4, bryozoa. 5, others.

In text-fig. 5 a similarity in proportions of fragmental population is seen at Easky and Streedagh, while Shalwy and Serpent Rock show similar proportions for entire forms as also seen in text-fig. 4.

In text-fig. 6 the percentage of fragmental material within each group illustrates the abundance of fenestellid debris at Aughris, Serpent Rock, Streedagh, and Kiln Port. Aughris and Serpent Rock show a similar general population reflecting similar conditions of turbulence affecting the area despite initial differences in the faunal proportions seen in text-fig. 4. Shalwy, as in text-fig. 3, appears to have a comparatively small fragmental population in which the chief constituent is gastropods.

Inversion ratios shown in text-figs. 7 and 8 suggest mild turbulence in all areas, as more than 75 per cent. of brachiopods are inverted at all stations; while the corals are dominantly upright. Among the brachiopods no subfamily is present in all areas. In order to approximate similar hydrodynamic properties the larger forms of comparable profile were selected. Of necessity this resulted in the following forms being studied: linoproductids at the four Sligo stations, davisiellids at Kiln Port and Shalwy, and

pustulids at Aughrus (Co. Donegal). The state of preservation did not allow for the determination of whether or not the valves were joined, but since adductor muscles

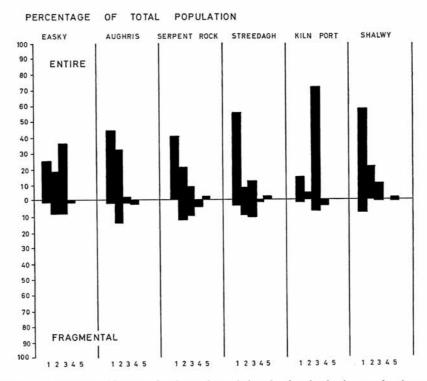


TEXT-FIG. 3. Histograms of the total numerical population, showing the dominance of entire over fragmental forms. On the fragmental population histogram Streedagh, Serpent Rock and Easky, in order of declining importance, show the greatest density. A similarity of proportions for the entire population is to be seen at Shalwy and Serpent Rock.

1, solitary corals. 2, compound corals. 3, brachiopods. 4, bryozoa. 5, others.

contract on death it is unlikely that this would be of great significance. In relation to the shell profile the brachiopods are described as upright when the pedicle valve is convex downwards on the bedding plane. Aughrus (Co. Donegal) would appear to be unique

in this study (text-fig. 7). The significance of the data would seem to be related to the number of sturdy spines for anchorage present. These are well developed only in the pustulids, while the linoproductids and davisiellids are unattached forms more susceptible to current traction. Of the compound corals the cerioid lithostrotiontid with the



TEXT-FIG. 4. Percentage histogram for the total population showing the dominance of entire over fragmental forms. In comparison to the data expressed in fig. 2 the significance of given forms is accentuated.

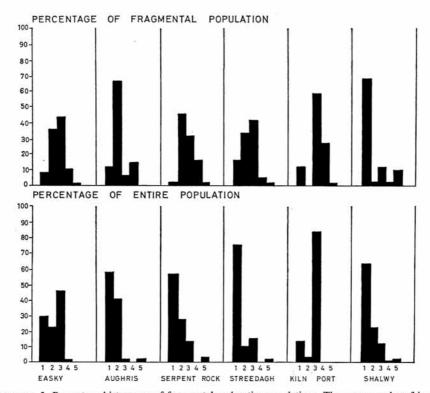
1, solitary corals. 2, compound corals. 3, brachiopods. 4, bryozoa. 5, others.

wider apical angle and generally more massive corallum is more stable than the fasciculate lithostrotiontid. Similarly the syringoporids of Shalwy are seen to be comparable with the fasciculate lithostrotiontids as a measure of stability.

The proportion of geniculate to straight caniniids shown in text-fig. 9 suggests that attachment of these forms to a soft lime substratum would not be sufficient to support the giganteid forms, which, while sinking, would tend to grow upwards towards the light. Three horizons are given for comparison at Streedagh (text-fig. 9) showing a uniformity which is not seen in the coral inversion ratios (text-fig. 8) for the same

area. The relationship between the straight and geniculate caniniids would appear to have no direct correlation with the size of the corallum or the species present.

The details of the Aughrus (Co. Donegal) (text-fig. 2) fauna show closest similarity with those of Kiln Port (text-fig. 3). Though the faunal list makes a striking contrast



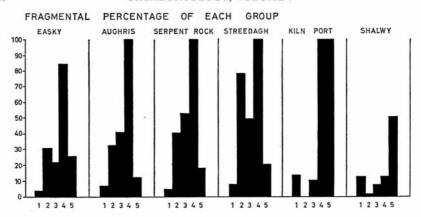
TEXT-FIG. 5. Percentage histograms of fragmental and entire populations. The reverse order of importance of fragmental material is to be seen at Serpent Rock and Streedagh, and of entire material at Streedagh and Kiln Port. Similar distribution for entire material is seen at Serpent Rock and Shalwy.

1, solitary corals. 2, compound corals. 3, brachiopods. 4, bryozoa. 5, others.

this can, in part, be attributed to the selector bias involved in sampling only one bedding plane. Caniniids and syringoporids, though not abundant, are to be found at this locality. Likewise euomphallids and *Conocardium*, which are not listed, also occur at the Donegal stations, though the latter is absent from the Sligo stations.

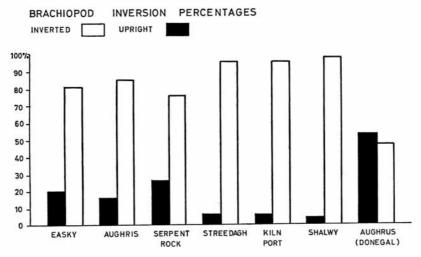
To attempt current analysis, orientations of crinoid stems from localities near the stations were recorded as well as umbonal orientations in inverted productoid

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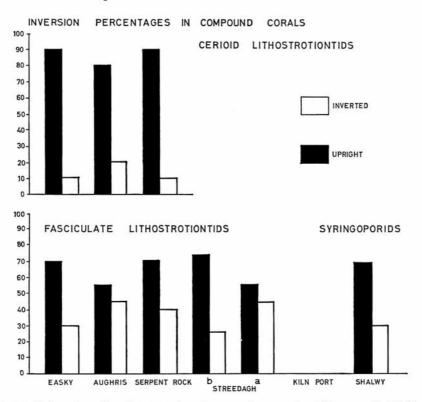
TEXT-FIG. 6. Percentage histogram of fragmental material expressed in terms of each group. A notable abundance of fragmental bryozoan material is to be seen at all stations except Shalwy. Aughris and Serpent Rock show similar population distributions.

1, solitary corals. 2, compound corals. 3, brachiopods. 4, bryozoa. 5, others.



TEXT-FIG. 7. Inversion ratios of productoid brachiopods (linoproductids at Easky, Aughris, Serpent Rock and Streedagh; davisiellids at Kiln Port and Shalwy; pustulids at Aughrus (Co. Donegal)) expressed in terms of percentage histograms. A dominance of inverted forms is to be noted at all stations except Aughrus (Co. Donegal).

brachiopods, and the orientation of geniculate caniniids. The results are variable and inconclusive but never suggest transport from the south, thus generally supporting the palaeogeographical reconstruction presented by George (1958). This pattern is one which might be expected in an area with such a uniform population density and lack of evidence of channeling.



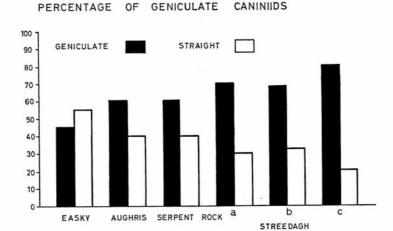
TEXT-FIG. 8. Inversion ratios of compound corals expressed as percentage histograms. Cerioid lithostrotiontids shown for Easky, Aughris, and Serpent Rock are dominantly upright. Fasciculate lithostrotiontids at Easky, Aughris, Serpent Rock and two horizons at Streedagh, and syringoporids of Shalwy show a less pronounced dominance of upright forms.

#### ENVIRONMENT

The fauna outlined above may be described in terms of Hill's (1948, p. 121) three coral associations. She showed these to have different morphological characters which varied according to the environment. Thus by analogy with present day faunas she reaches the conclusions tabulated (Table 2).

In text-fig. 10 the populations of this account are plotted on a triangular diagram

whose apices represent Hill's coral associations. This diagram supports her statement that solitary *Rugosa* with dissepiments are found associated with the compound *Rugosa*, but rarely with the *Cyathaxonia* fauna. In generalized terms the total fauna may be ascribed to her intermediate fauna of solitary *Rugosa*. However, when the beds are studied more closely, it would appear that there are alternations of the compound and



TEXT-FIG. 9. Ratio of straight to geniculate caniniids expressed in terms of a percentage histogram for Easky, Aughris, Serpent Rock, and three horizons at Streedagh. At all stations except Easky geniculate forms are dominant, notably at Streedagh.

solitary Rugosa faunas within a few feet as illustrated in text-fig. 11, and Plates 40 and 41.

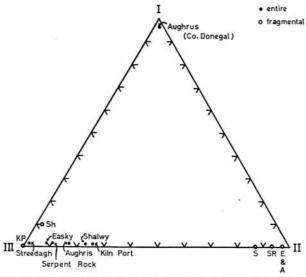
TABLE 2. Hill's (1948) three coral associations tabulated to show the relationship between the faunal characteristics and the modern analogy and environment.

FAUNAL CHARACTERISTICS	MODERN ANALOGY AND ENVIRONMENT						
I <u>Cyathaxonia</u> Fauna small, solitary, non-dissepimented forms.	small, solitary, corals cold, deep or murky sea.						
II Compound Rugosa & Chaetetida.	reef corals. warm, shallow, pellucid sea						
III Solitary <u>Rugosa</u> with dissepiments (chiefly caninids & clisiophyllids.)	intermediate between I & II.						

The palaeoecological conclusions quoted by Wells (in 1957, p. 774) have, until recently, been accepted widely for the limitation of rugosan habitats. Thus by analogy to present day, non-surface, essentially lagoonal reef corals he states that the ecological

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niche has the following parameters: (1) a maximum depth of about 50 metres; (2) well within the pellucid zone; (3) annual minimum temperature of 16–21° C; (4) well oxygenated, gently circulating waters; (5) on a substratum clear or relatively free from rapid sedimentation, but not necessarily in clear non-turbid waters.



TEXT-FIG. 10. The coral populations of Easky, Aughris, Serpent Rock, Streedagh, Kiln Port, Shalwy, and Aughrus (Co. Donegal) are expressed in terms of Hill's three coral associations showing that the entire forms belong to the solitary *Rugosa* association.

- I. Cyathaxonia fauna: small, solitary, non-dissepimented forms.
- II. Compound Rugosa and Chaetetida.
- III. Solitary Rugosa with dissepiments (chiefly caniniids and clisiophyllids).

Teichert (1958, p. 1064), however, reminds us of Dons's (1933) and Shott's (1926) works in giving an account of cold deep water coral banks which are alive today off the coast of Norway. Thus he divides the modern scleractinian corals into two major ecological groups: the first of these, the Hermatypic, are dependent on the symbiotic flagellates, the zooxanthellae, and consequently restricted to an annual minimum water temperature of  $18.5^{\circ}$  C, and 300 ft. depth. Teichert's second group of Ahermatypic scleractinian corals are not dependent on zooxanthellae, and therefore are not restricted to the pellucid zones. These Hermatypic conditions would appear to be similar to those outlined by Wells (op. cit.). The degree of tolerance of the Ahermatypic group is wide, members having been recorded at depths of up to 20,000 feet, and temperatures as low as  $-1.1^{\circ}$  C, though the majority occur at depths of 600–900 ft.

Teichert (1958, p. 1075) concludes that the best measure of depth is the presence of calcareous algae which are not found below 150 ft. From comparison with the

environments and biota tabulated (p. 1076) it would appear that the fauna described herein probably belongs to Teichert's category number 1. In this few species of frame building coelenterates with rich invertebrate association and absence of calcareous algae are recorded. This category is found in deep and cool waters, shelf or bay environments, within the temperature range of the dysphotic zone of the tropical belt to the polar regions. This contrasts with his category number 4, in which a rich assemblage of frame building coelenterates, in association with a rich invertebrate fauna, with the addition of abundant calcareous algae, is attributed to shallow warm waters in open shelf to near shore environments of the tropical belt. Calcareous algae are not obvious in the Irish coral limestone populations described here, though their presence has been noted elsewhere in the succession both above and below this horizon. This would suggest that the environment was probably marginal to the tropical dysphotic belt.

The development of conspicuously fossiliferous bedding planes alternating with less fossiliferous bands has been attributed by Broadhurst (1964, pp. 866 and 867) to the rate of sedimentation and the associated amount of bottom turbulence in the non-marine Coal Measures. On this view each fossiliferous plane represents a phase of restricted sedimentation. Teichert (1958, p. 1073) states that bioherms may show signs of sudden extinction, in which the destruction of the coral frame results from the attack of boring organisms, yet evidence of wave destruction is absent. He continues by saying that though this might be regarded as evidence of subsidence and consequent 'drowning' of the reef, it might equally well result from the elevation of the sea floor above the level of tolerance of the corals. In these beds there is evidence of extensive burrowing in both horizontal and vertical directions. From the infill of the burrows it is apparent that there was a variation in the nature of the sediment supplied. There is also abundant evidence of auloporids encrusting brachiopods, caniniids, and even occasional syringoporids, not infrequently in the position of growth, at Shalwy, Kiln Port, and Easky. This might be interpreted as a sign of a decline in sedimentational rate.

The fasciculate lithostrotiontid associations may chiefly be described as thickets, though occasionally there is evidence of coppice (Plate 41, fig. 1) development (Squires 1964, pp. 904-6). An unusual relationship is seen in one place at Serpent Rock where caniniids have been observed penetrating a fasciculate lithostrotiontid colony (Plate 41, fig. 3); this appears to be a commensal association. A similar relationship between two

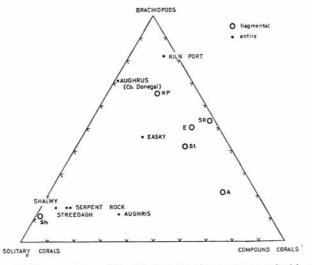
lithostrotiontids is seen high in the succession at Streedagh (text-fig. 11).

The cerioid lithostrotiontids, by contrast, seem to have an unsociable habit, commonly occurring on separate bedding planes from the other faunas where there is a distinct paucity of other fossils save trace fossils. The individuals thus appear as well separated colonies (Plate 40, figs. 2 and 3) in bioturbated biomicrites. An exception to this rule is seen near Easky pier where the coral brachiopod fauna is notably mixed, containing lithostrotiontids (fasciculate and cerioid), pustulids, chonetids, productids, and even rare caniniids which would suggest that the fauna may in part be transported.

The population is summarized in terms of the dominant ecologically significant groups in text-fig. 12. In entire population close similarities are seen at Shalwy, Streedagh, Serpent Rock characterized by a dominance of solitary corals, and few compound corals and brachiopods, indicating calm well aerated shallow seas. Aughris and Easky have fewer solitary corals but have more compound corals and brachiopods respectively, suggesting that more stable forms were tolerant of a somewhat greater turbulence. Kiln

TEXT-FIG. 11. Diagrammatic representation of the lithology of the coral limestone horizon within the Ballyshannon Limestone of Streedagh to illustrate the rapid alternation of Hill's coral associations.

Port and Aughrus (Co. Donegal) are anomalous in showing a marked preponderance of brachiopods over all other forms. The fragmental populations at Easky, Streedagh and Serpent Rock have marked similarity with a decrease in the number of solitary



TEXT-FIG. 12. The population of the Ballyshannon Limestone summarized in terms of the three dominant ecologically significant groups: brachiopods, compound corals and solitary corals. A close similarity is seen between the entire forms of Shalwy, Aughris, Streedagh, and Serpent Rock, while a secondary, less conspicuous group is formed by Easky, Kiln Port, and Aughrus (Co. Donegal). Of the fragmental population Streedagh, Easky, and Serpent Rock are particularly similar, with Kiln Port and Aughris showing a certain amount of similarity while Shalwy remains anomalous.

#### EXPLANATION OF PLATE 40

Fig. 1. Portion of a bedding plane at Streedagh showing prolific partially silicified caniniids with variable degree of geniculation, set in a biomicrite matrix. Scale: hammer measures 13 inches.

Fig. 2. Bedding plane at Serpent Rock showing well spaced cerioid lithostrotiontid colonies appearing as lighter coloured patches in the jointed biomicrite matrix. Scale: hammer 13 inches long.

Fig. 3. Close-up of a cerioid lithostrotiontid colony in situ with horizontal burrow to the left of it, from the same bedding plane as fig. 2 at Serpent Rock. Scale: coin measures one inch in diameter.

#### EXPLANATION OF PLATE 41

Fig. 1. Fasciculate lithostrotiontid coppice showing fragmental lithostrotiontid corallites in the lower portion of the stratum from which one large upright fasciculate lithostrotiontid corallum protrudes. Scale: hammer measures 13 inches.

Fig. 2. Mixed caniniid, fasciculate lithostrotiontids 1 & 2 and brachiopod fauna, worn smooth by wave action; illustrating the impracticability of detailed identification of many intractable forms. Scale: half the magnification of fig. 1.

Fig. 3. Apparently commensal association of caniniids and lithostrotiontid thicket at Serpent Rock. Scale: coin measures one inch in diameter. corals present, possibly indicating that the solitary corals are more resistant on account of their thicker skeletons. Aughris likewise shows a proportional decrease in solitary corals. Kiln Port is once more anomalous in showing an increase in the number of both compound and solitary corals present. This may represent a fauna which has been transported further from the source of coralline material. It may be suggested that Streedagh, Serpent Rock, and Shalwy represent solitary coral biostromes in quiet seas while Aughris was on the rougher seaward side sustaining a greater proportion of hydrodynamically more stable forms. Kiln Port may represent more muddy seas with a vagrant benthonic fauna of brachiopods which developed on the landward side of the coral biostrome where a more restricted circulation would not favour coral growth.

Easky, Serpent Rock, and Streedagh may thus be regarded as an inshore, and Aughris a further seaward facies of a coral biostrome. These conclusions support the palaeogeography postulated by George (1958).

#### CONCLUSIONS

Variations in environment are clearly not the sole factor since there are faunal differences between the Donegal stations and those of Sligo. Thus in general the Donegal fauna consists of syringoporids, micheliniids, a relatively narrow caniniid and davisiellids which are replaced by fasciculate and cerioid lithostrotiontids, giganteid caniniids and linoproductids in Sligo. It is not yet known whether these represent niche biotas of different faunal provinces or whether they are at different horizons, though the latter is suspected. In Sligo the former association can be traced low in the succession. Additional support for the latter argument has been reached independently on gross lithological grounds by W. F. Hubbard and D. J. R. Sheridan (personal communication) and on detailed foraminiferal studies by R. W. L. Oldroyd (personal communication). However, until further detailed macropalaeontological and micropalaeontological dating elucidates this problem, it could be argued that this faunal replacement results from the diachronous northward migration of faunas.

It would appear highly probable that the Sligo outcrops are of approximately the same age but of a different age to the Donegal outcrops. In support of this hypothesis the dating of the underlying Carrowmoran Sandstone found in the ground between Easky and Aughris is crucial. The Carrowmoran Sandstone has been shown by the author (1966, in press) to correlate with the Mullaghmore Sandstone of Sligo, to which an age between S2-D1 has been ascribed by Oswald (1955, pp. 173, 174, and 180) on the basis of lithological comparison and ostracod dating. Furthermore the Ballyshannon Limestone of the coastal regions of Sligo from which these population studies are derived is shown to contrast strongly with that of the type area, yet it resembles higher stratigraphical horizons only six miles away. In the type area about Ballyshannon the Ballyshannon Limestone consists of massive crinoidal biomicrites, biosparites, and oomicrites containing mainly fragmental or transported fossils among which cerioid lithostrotiontids are not recorded. The lowest record of cerioid lithostrotiontids outside Oswald's (1955) area is in S2 beds of Garwood (1913, p. 547). The second lithological comparison concerns Oswald's (1955) transitional Benbulben Shale-Glencar Limestone (S2D1) exposed on the south-western flanks of Benbulben Mountain, where four recognizable units, one of which is the coral-brachiopod limestone mentioned, can be

correlated with similar units at Streedagh and Serpent Rock. Similarly material of comparable lithology to the type section of the Ballyshannon Limestone has been recorded on bore-hole cores which penetrate the basement to the south of the outcrops herein described. Thus it would appear that the Sligo outcrops under discussion are referable to Oswald's (1955) Benbulben Shale-Glencar Limestone (S<sub>2</sub>D<sub>1</sub>).

Reference to the faunal lists of Bowes (1957), George and Oswald (1957) and Oswald (1955) shows that the following corals are not present in the south-eastern flank of the Donegal syncline but are to be found in Sligo. At Aughris: Caninia benburbensis Lewis and Lithostrotion pauciradiale (McCoy). In Oswald's (1955) Ballyshannon Limestone list derived from the total outcrop: Zaphrentis (Hapsiphyllum) konincki (Edwards and Haime), Lithostrotion affine Fleming, Lithostrotion martini Edwards and Haime, and Lithostrotion portlocki (Bronn). To the south of this area Caldwell (1959, pp. 168, 180) does not record these species below the Ballymore Beds which he correlates with the Benbulben Shale.

In contrast to the situation in Sligo the Donegal outcrops are known to be relatively close to the base of the Carboniferous succession and do not contain cerioid lithostrotiontids, even fasciculate lithostrotiontids being extremely scarce.

Environmentally it would appear that the Sligo fauna represents a similar ecological niche to that of Donegal; having developed marginally between the dysphotic tropical belt and shallow warm waters of the open shelf. The Sligo fauna is not present in the Donegal assemblage, yet occasionally Donegal members are still present in the Sligo fauna indicating that the dominant incoming fauna had not entirely excluded the earlier forms. It is suggested that there is a general replacement of syringoporids by fasciculate lithostrotiontids, narrow by giganteid caniniids, and davisiellids by linoproductids. Each of these pairs, being analogous forms, would appear to occupy the same ecological niche. The greater density and diversity of the Sligo fauna would suggest the attainment of more favourable conditions during the later Viséan, by which time the Carboniferous marine transgression had become established.

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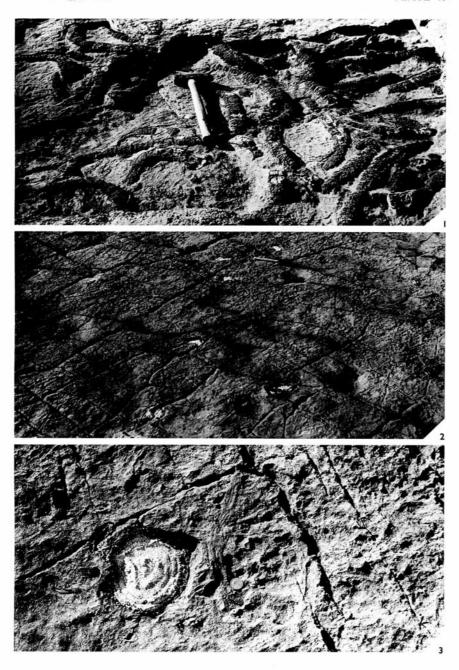
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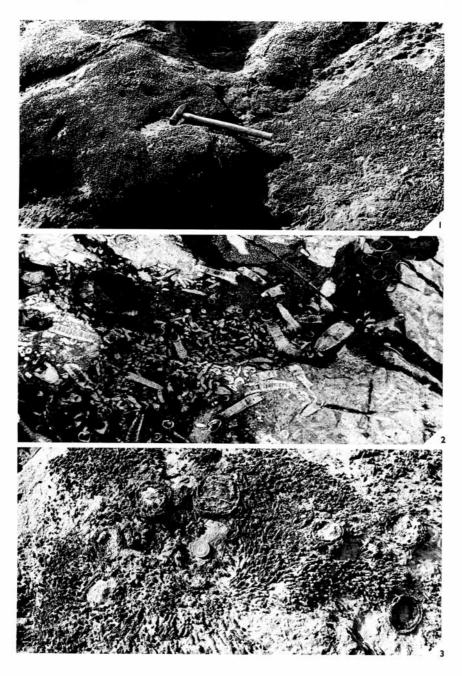
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