

LOWER CARBONIFEROUS CONODONT FAUNAS FROM SOUTH-WEST IRELAND

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ABSTRACT. Lower Carboniferous conodonts have been recovered from the Cork Beds at several localities situated between Cork and Bantry Bay in south-west Ireland. They are all of Tournaisian age. Faunas with siphonodellids and gnathodids suggest comparison with the late Kinderhookian and early Osagean of the U.S.A., and with the upper *Siphonodella crenulata* Zone of Germany. Some small faunas from lower in the Cork Beds succession are tentatively referred to the neighbourhood of the Devonian-Carboniferous boundary.

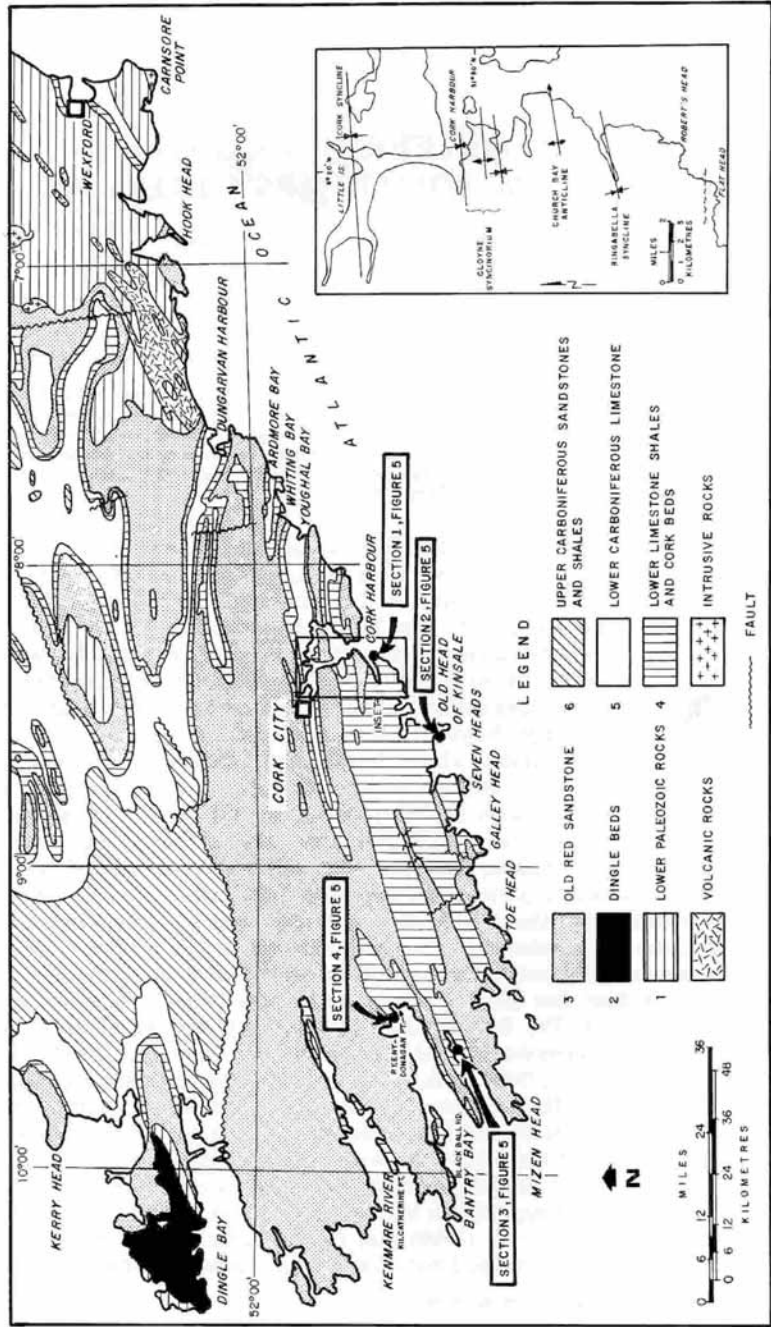
A criticism of Rhodes, Austin, and Druce's work on the Avonian conodonts shows that there is, as yet, no good basis for detailed correlations with the Lower Carboniferous of the Bristol-South Wales region. A previous suggestion that the Cork Beds resemble the Pilton Beds of Devonshire receives support from the new Irish evidence. The Lower Carboniferous portion of the Cork Beds can be shown to be much thicker in south Cork than at Bantry Bay. It can also be shown that this Cork Beds wedge is in general older than the major development of carbonates (including bank-limestone facies) found to the north of the Cork-Kenmare line.

TEXT-FIG. 1 shows the general run of Old Red Sandstone and Lower Carboniferous outcrop in southern Ireland. A line drawn from the Kenmare River to Cork Harbour separates two distinct geological provinces. To the north of the line the Old Red Sandstone is overlain by a relatively thin Lower Limestone Shale unit, which is followed by a thick carbonate succession dominated by shelf and bank limestones. To the south, the red beds referred to the Old Red Sandstone are succeeded by a thick marine sequence which has relatively little carbonate and which is known to range into early Namurian age. Naylor (1966) introduced the name Cork Beds for the succession of rocks that follows above the Old Red Sandstone in this southerly region. Naylor and Jones (1967) used the term 'Cork Facies' for the whole southern facies-complex, contrasting it with the Waulsortian Bank Limestone facies to the north. Naylor *et al.* (1969) attempted correlations of individual rock units distinguished within the Cork Facies, and they reviewed the existing state of information on the age of particular parts of the sequence. Some further palaeontological information (including Matthews's tentative identifications of some small collections of conodonts) was produced by Coe and Selwood (1968). Naylor (1969) has offered an interpretation of facies-relationships across the Cork-Kenmare line.

It has become evident that the Cork Beds are broadly divisible into four gross lithostratigraphical units. The first of these, following above the red and purple strata of the Old Red Sandstone, is a thick arenaceous development, the Old Head Sandstone Group of Naylor (1966). This is overlain by a predominantly argillaceous unit, the Kinsale Group. There follows the relatively calcareous Courtmacsherry Group, and this is overlain by the black goniatitic mudstones of the Lispatrick Group. It should be noted that although thin calcareous lenses are found in the Kinsale Group, the base of the Courtmacsherry Group is clearly marked by the incoming of thick beds of crinoid debris with associated soft calcareous mudstones. It was suggested by Naylor *et al.* (1969) that the character of these broad stratigraphic subdivisions was maintained through to sections in Dunmanus Bay and

[Palaeontology, Vol. 16, Part 2, 1973, pp. 335-380, pls. 35-38.]

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TEXT-FIG. 1. Geological map of south and south-west Ireland to show location of sections studied.

Bantry Bay on the west coast, although the units were given locally based names in these sections. Stratigraphic nomenclature has inadvertently been brought into some confusion on the west coast because of proposals of names made independently by Coe and Selwood (1968), Naylor *et al.* (1969), and Gardiner (1970). It is hoped to unravel these problems in a later paper. The nomenclature of Naylor *et al.* (1969) is used here.

We describe now the results of a study of conodont faunas obtained from several sites in the Cork Beds stratigraphy. The objectives of the work have been, first, to provide for a more precise scheme of correlations within the Cork Beds and, secondly, to suggest how this interesting southern Irish facies-complex may be related to Lower Carboniferous successions of other kinds elsewhere. Naylor undertook the entire task of sampling, and has responsibility here for statements on stratigraphic relationships within the Cork Beds. Matthews, who did most of the work of preparation, takes responsibility for the identifications of conodonts, and for comments on comparisons to be made with conodont faunas described from places outside south-west Ireland.

Most of the samples were collected from four sections through the Courtmacsherry Group or its equivalents (text-fig. 1). These sections are situated, respectively, in the Ringabella Syncline (text-fig. 5, section 1: samples prefixed F and R), on the west coast of the Old Head of Kinsale (text-fig. 5, section 2: samples prefixed OH), in the core of the Dunmanus Bay Syncline (text-fig. 5, section 3: samples prefixed D) and on the northern limb of the Bantry Bay Syncline at Ardnamanagh Point (text-fig. 5, section 4: samples prefixed B). Details of the individual localities are supplied in the Appendix. Some further samples were taken from isolated lenses within the Kinsale Group (see their stratigraphic location in text-fig. 4). A separate study is at present in progress on the Lower Carboniferous rocks of the Ardmore-Whiting Bay area of south-east Ireland (text-fig. 1), described by Smyth (1939), and some mention of relevant results is included here.

The yield of conodonts was in general small. Those sites which proved to be relatively productive were sampled a second time in order to check the first indication of age. In some cases (especially among the higher Ringabella samples) the rock would not readily come apart in 10% acetic acid, although it was often possible to disaggregate rock fragments manually after they had lain for a few weeks in acid and had lost some carbonate from their fabric. Many of the conodonts obtained are deformed, and most specimens carry impacted quartz grains. Some specimens have pyrite overgrowths (especially those from the OH1 sample, a case in which almost the whole of the acid residue sank in tetrabromoethane). In spite of these occasional deficiencies of the specimens, some useful results have been obtained. The following list identifies the most productive cases (the majority of them sampled a second time, in 1971—see suffix '71 here and elsewhere in the text) upon which the scheme of correlations suggested below for the Cork Beds principally depends. Faunal lists for all productive samples are given in the Appendix.

Ringabella:

- F1 *Polygnathus inornatus* (3 specimens), *P. inornatus?* (4), *P. cf. communis* (1), *Pseudopolygnathus dentilineatus* (3), *Ps. multistriatus* (1), *Ps. primus* (1), *Ps. sp.* (1), bar (1). Total 15. Collection number: GSL SAD33.

- F1 '71 *Polygnathus inornatus* (5), *P. sp.* (1), *Pseudopolygnathus dentilineatus* (6), *Siphonodella sp.* (5), *Spathognathodus sp. indet.* (1). Total 18. GSL SAD34.
- R2 *Gnathodus delicatus* (7), *G. semiglaber* (2), *G. sp.* (1), *Spathognathodus crassidentatus* (1), *Sp. stabilis* (2), *Sp. indet.* (1), *Sp. sp.* (9), bars (8). Total 31. GSL SAD22.
- R4 *Gnathodus delicatus* (5), *G. semiglaber* (3), *Polygnathus communis carina* (20), *P. cf. communis* (4), *Spathognathodus stabilis* (5), *Sp. sp.* (1), bars (13). Total 51. GSL SAD24.
- R4a '71 *Gnathodus delicatus* (4), *Polygnathus communis carina* (11), *P. inornatus* (1), *Spathognathodus sp.* (3), *indet.* (1), bars (6). Total 26. GSL SAD25.
- R4b '71 *Gnathodus delicatus* (11), *G. punctatus* (1), *Polygnathus communis communis* (6), *P. communis carina* (9), *P. communis subsp.* (7), *Spathognathodus indet.* (1), *Spathognathodus cf. stabilis* (2), *indet.* (1). Total 38. GSL SAD26.
- Old Head of Kinsale:
- OH1 *Patrognathus variabilis* (1), *Pa. cf. variabilis* (1), *Polygnathus communis communis* (8), *P. cf. communis* (1), *Spathognathodus aculeatus* (4), *Sp. cf. aculeatus* (1), *Sp. anteposicornis* (1), *Sp. stabilis* (11), *Sp. sp.* (2), bars (8). Total 38. GSL SAD47.
- OH1 '71 Bar (1). Total 1. GSL SAD48.
- OH4 *Polygnathus sp. juv.* (1), *Siphonodella isosticha* (3), *S. obsoleta* (2), *Spathognathodus cf. costatus* (1), *Sp. ? sp.* (1), bars (6). Total 14. GSL SAD50.
- OH4 '71 *Siphonodella isosticha* (3), *S. obsoleta* (1), *S. sp. indet.* (1), bars (9). Total 14. GSL SAD41.
- Bantry Bay:
- B8 *Polygnathus symmetricus* (1), *P. sp. indet.* (1), *P. sp.* (3), *Spathognathodus aculeatus/Clydagnathus transition* (2), *Spathognathodus stabilis* (1), *indet.* (1), bars (7). Total 16. GSL SAD43.
- B2 *Gnathodus aff. semiglaber* (1), *Polygnathus symmetricus* (1), *Pseudopolygnathus multistriatus* (1), *Ps. cf. multistriatus* (1), *Siphonodella cooperi* (6), *S. cf. cooperi* (1), *S. cf. S. isosticha* (2), *S. sp.* (17), bar (1). Total 31. GSL SAD36.
- B2 '71 *Elictoagnathus cf. laceratus* (1), *Gnathodus punctatus* (3), *G. aff. semiglaber* (2), *G. sp.* (1), *Polygnathus inornatus* (3), *P. longiposticus* (1), *P. symmetricus* (1), *P. cf. symmetricus* (1), *P. sp.* (4), *Pseudopolygnathus multistriatus* (1), *Siphonodella cooperi* (10), *S. cf. cooperi* (1), *S. isosticha* (5), *S. obsoleta* (3), *S. sp. indet.* (1), *S. sp.* (7), bars (7). Total 52. GSL SAD37.
- Whiting Bay:
- WB2 *Elictoagnathus laceratus* (1), *E. cf. laceratus* (1), *Polygnathus communis communis* (7), *P. inornatus* (5), *P. symmetricus* (4), *P. sp.* (3), *Siphonodella cooperi* (8), *S. spp. juv.* (4), *S. sp.* (4), bars (4). Total 41. GSL SAD57.

It will be recognized that the presence of siphonodellids and gnathodids (and the occasional coincidence of the two) provides a particularly interesting feature of the results. Before embarking on a discussion of whatever relationships within the Cork Beds this new information would suggest, it is useful first to consider the 'external' relations of the Cork Beds and to recognize a frame of reference by which the relative ages of these associations of conodonts might be judged.

CORRELATION WITH REGIONS OUTSIDE IRELAND

The Cork Beds conodonts described here can all be taken to be of Tournaisian age. It is not possible at present to justify this statement by direct reference to the type Tournaisian of Belgium, for although a certain amount of information has been published on the conodonts of the lower (Conil *et al.* 1964; Austin, Conil *et al.* 1970) and of the higher (Conil *et al.* 1969; Groessens 1971) parts of the Belgian Tournaisian, there is, as yet, only relatively meagre information on the middle range, where the siphonodellids give out (in the lowest reaches of Tn 3 according to Groes-

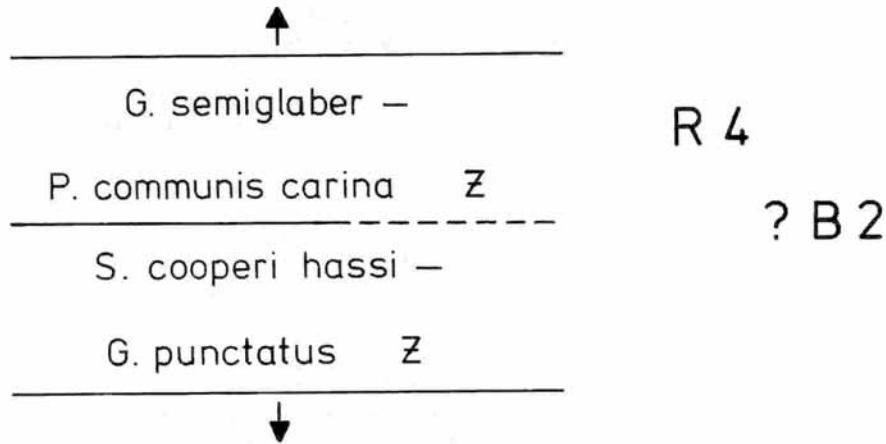
sens) and the first representatives of the main suite of gnathodids emerge. Belgian work, therefore, cannot yet supply precise guidance on the relative ages of the Cork Beds faunas. Nor is German work particularly helpful in the present case. The German succession has yielded good information on the conodont faunas of horizons close to the Devonian-Carboniferous boundary (treated most recently in Ziegler 1969, and Koch *et al.* 1970), and this has made it possible (see Paproth 1964 and later commentators) to recognize an equivalent of the earliest Carboniferous of Germany in Tn 1b of Belgium. Again, it was German evidence (Bischoff 1957; Voges 1959, 1960) which first showed that faunas with siphonodellids are followed in the Lower Carboniferous succession by faunas which have *Scaliognathus anchoralis* and its associates, and it is a representation of this latter association that Groessens (1971) records in the Belgian Tn 3c. However, the thin German stratigraphy supplies relatively little information on siphonodellid-gnathodid associations (i.e. from the carbonate-poor Liegende Alaunschiefer and the lower part of the Horizont vorwiegender Lydite, where the upper part of Voges's *Siphonodella crenulata*-Zone is followed by his *anchoralis*-Zone). One must therefore look elsewhere for guidance on the relative ages of the Cork Beds faunas. It is American evidence that serves this purpose best at the present time. Taking American information together with Groessens's results from Tn 3c, one can establish a sense of the age of the highest Cork Beds conodont faunas, and can proceed from there to make comparisons between southern Ireland and south-west England. The discussion of age-relationships includes also some fairly detailed references to the record of conodonts from the 'Avonian' succession: since much of the earlier information on the age of the Cork Beds has been rendered in terms of Vaughan's coral-brachiopod zonal scheme, one compares the Cork Beds conodont faunas with those reported from the Avon Gorge by Rhodes *et al.* (1969) and hopes to make some test of the consistency of two different lines of information on age.

Correlation with North America

Thompson and Fellows's (1970) work on conodont faunas from the Kinderhook and Osage in south-west Missouri and adjacent parts of Arkansas and Oklahoma has done much to improve our knowledge of the sequence of conodonts in the lower part of the Mississippian. They have been able to show that the rock succession is fuller in the area where they worked than in the upper Mississippi Valley states further to the north. The succession of zones they propose makes reference to certain faunas that were not accounted for in, for example, Collinson, Scott, and Rexroad's (1962) or Rexroad and Scott's (1964) work. It happens that some of the conodonts present in the newly revealed Mississippian zones are found in the Cork Beds faunas also. Cork Beds faunas can be associated with Thompson and Fellows's zones as in text-fig. 2.

Three necessary comments on text-fig. 2 are:

1. Systematic practice in this paper is not absolutely consistent with that of Thompson and Fellows. The Cork Beds siphonodellids are identified in accordance with Klapper's (1971) revision of certain of Thompson and Fellows's proposals.
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TEXT-FIG. 2. Two Cork Beds samples related to units in Thompson and Fellows's (1970) zonal scheme for the Kinderhookian-Osagean.

Gnathodids too (especially *Gnathodus punctatus* and *G. delicatus*) are treated slightly differently here. These adjustments are dealt with in the systematic section below.

2. A more substantial departure from the Mississippian arrangement of things is shown by the case of sample B2 (full list above), which has siphonodellids, *Gnathodus punctatus* and *Pseudopolygnathus multistriatus*. According to Thompson and Fellows (1970, table 1) these should not coincide. The possibility of reworking (i.e. 'Kinderhookian' conodonts—the siphonodellids and gnathodids of B2—admixed among 'Osagean' forms—*Ps. multistriatus*) suggests itself. But in that case one would expect to find other conodont species supporting *Ps. multistriatus* in the suggestion of Osagean age. None have been found, neither in the first B2 sample, nor in the second (B2 '71 above). An alternative explanation of this apparent anomaly is possible:

3. Matthews *et al.* (1972) have pointed to certain records of coincidence of *Gnathodus punctatus* and *Polygnathus communis carina*. These suggest the existence of an association of conodonts that is not treated in Thompson and Fellows's (1970) zonal scheme. The chief implication of the suggestion is that Thompson and Fellows have perhaps not yet entirely succeeded in closing the gap which they show to exist in Mississippian sections further north (see fig. 27 of their paper, and also, in their table 1, the decided break of faunal character evident at their Kinderhook-Osage boundary). The suggestion cannot be advanced with any great firmness here, considering the scattered nature of the sampling and the small numbers of the Cork Beds conodonts; but the possibility is indicated in text-fig. 2 by inserting B2, with a query, at the boundary separating the *G. punctatus* subzone from the *G. semiglaber*-*P. communis carinus* (properly: *carina*) Zone in Thompson and Fellows's scheme.

P. communis carina, which is taken to mark a later position in the stratigraphy

than is indicated by the B2 association of forms, is abundantly represented in R4, where it occurs with (among others) *G. semiglaber*. R4 is tentatively allotted to Thompson and Fellows's *G. semiglaber*-*P. communis carina* Zone in text-fig. 2. The qualifications expressed in comment 3 above would apply again here: one should perhaps not regard Thompson and Fellows's definition of the lower limit of the *G. semiglaber*-*P. communis carina* Zone as entirely firm.

The productive samples from the Cork Beds have nowhere supplied any hint of horizons higher than those represented in the Ringabella (R) faunas. No bactrognathids, doliognathids, nor scaliognathids were found, although the presence of *P. communis carina* may be taken to indicate that the Ringabella section ranges up to make a close approach to horizons at which these distinctive forms might appear. Groessens's (1971) results from Belgium would lend some support to this suggestion. He has shown that relatively abundant occurrence of *P. communis carina* precedes fairly closely the emergence (in Tn 3c) of such forms as *Scaliognathus anchoralis*. Given this indication of the age of the highest faunas recovered from the Cork Beds, it is possible to attempt some brief proposals on the way in which the Cork Beds stratigraphy might relate to stratigraphic successions further east in the Variscan fold-belt.

Correlation with south-west England

The higher conodont faunas obtained from the Cork Beds provide a basis for sketching out some relationships with south-west England. At Chudleigh, in south-east Devon, for example, the lower of two conodont faunas described by Matthews (1969*b*) is an approximate equivalent of the WB2, OH4, and B2 faunas described here. The higher Chudleigh fauna described by Matthews (1969*b*) has *Scaliognathus anchoralis* and would therefore appear to be later than anything discovered in the present work. In east Cornwall a detached sheet of Lower Carboniferous rock again has a fauna with *Sc. anchoralis* in a higher, siliceous part of its stratigraphy (Matthews 1969*a*) and a goniatite fauna in a shaly succession below (Matthews 1970). A further occurrence of conodonts in siliceous rocks, at Chillaton, north-east of Tavistock, is approximately of *anchoralis*-Zone age (Matthews *et al.* 1972). A small fauna with a siphonodellid and a gnathodid in association has been found high in the Pilton Beds in north-east Devon (Matthews and Thomas, in preparation) and would seem to be once more an approximate equivalent of the highest Cork Beds faunas. Two interesting points follow from these observations. The first is that siliceous rocks enter the stratigraphy fairly consistently at horizons near the base of the *anchoralis*-Zone. An exceptional case exists at Chudleigh, where silicification is already evident high in the Upper Devonian and continues through the lower part of the Lower Carboniferous (House 1963; Tucker and van Straaten 1970). The implication for the Cork Beds is that the equivalent of the *anchoralis*-Zone might be sought somewhat above the highest conodont faunas so far obtained (e.g. above R4: note the character of the gnathodids and the relative abundance of *Polygnathus communis carina*) in siliceous rocks such as occur in the Lispatrick Group at Minanebridge (Naylor 1969, p. 317). It should, however, be mentioned that at Minanebridge itself the goniatite-lamellibranch fauna reported by Turner (1939, p. 323) would indicate a horizon that is perhaps already slightly higher than the (poorly defined)

upper limit of the *anchoralis*-Zone. The second point is that the increasing amount of evidence of Tournaisian age now available from the Cork Beds does much to reinforce Coe and Selwood's (1968, p. 129) suggestion that the stratigraphic sequence in south-west Ireland has a parallel in the Pilton Beds and immediately succeeding stratigraphy of north Devon.

Correlation with the Lower Carboniferous in 'Avonian' facies

It was noted above that, so far, most of the attempts to set dates on the Cork Beds stratigraphy have depended on the evidence of corals and brachiopods, with the section in the Avon Gorge at Bristol taken as the eventual standard. It should therefore be of some interest to compare the Cork Beds conodont faunas with the zonal units Rhodes *et al.* (1969) proposed on the basis of the conodonts they had collected from the Avon section and from a composite of sections on the North Crop of the South Wales coalfield. Certain of the 'Avonian' conodonts occur again in the Irish faunas. But it is soon clear that the associations of forms found in the Cork Beds do not readily fall into particular positions in Rhodes, Austin, and Druce's scheme of zones. A brief examination of what Rhodes, Austin, and Druce proposed will show that their scheme was not particularly well founded. The following comments refer to that range of the Avonian stratigraphy which has produced individual conodonts of kinds now encountered in the Cork Beds:

1. The lowest Avonian zone, the *Patrognathus variabilis*-*Spathognathodus plumulus plumulus* Assemblage Zone, was recognized in both the Avon Gorge and the North Crop. There was, necessarily, no clear definition of its base. Two subzones were recognized on the North Crop, but these could not be distinguished in the Avon Gorge.
2. Only the Avon Gorge allowed continuous exposure into the rocks allotted to the second zone, the *Siphonodella*-*Polygnathus inornatus* Assemblage Zone. A lower subzone, proposed from the Avon Gorge, was thought to occupy an unexposed interval in the North Crop succession. A higher subzone, proposed from the stratigraphy immediately above the concealed interval on the North Crop, was thought to occupy an unexposed interval in the Avon Gorge. Rhodes *et al.* (1969, p. 39), having suggested this, observed lower on the same page of their paper that that concealed interval in the Avon Gorge probably includes the lower part of their third zone. It should be understood that Rhodes *et al.* (1969, pp. 220-221) recovered only two siphonodellid specimens from the Avon section, from K12 (above the Bryozoa Bed—see Rhodes *et al.* 1969, fig. 59) and K17. A stratigraphic column for the Avon Gorge published by Austin, Conil *et al.* (1971), and said to be based on Rhodes *et al.* (1969), nevertheless shows a range for the genus *Siphonodella* which beings below the Bryozoa Bed.
3. The sequence from the top of the *Siphonodella*-*P. inornatus* Assemblage Zone, through the *Spathognathodus* cf. *robustus*-*Spathognathodus tridentatus* Assemblage Zone and into the *Spathognathodus costatus costatus*-*Gnathodus delicatus* Assemblage Zone, is apparently relatively well represented on the North Crop, although presumably (it is difficult to unravel the evidence from Rhodes *et al.* 1969, figs. 7, 70, and 71) a transfer from one stratigraphic section to another is involved. The

Sp. costatus costatus-*G. delicatus* Assemblage Zone had three subzones valid for the North Crop and two different subzones valid for the Avon Gorge. Neither set of subzones was confirmed in any other section. In the Avon Gorge the *Sp. costatus costatus*-*G. delicatus* Assemblage Zone had no *G. delicatus*. This form, it was reported, first appeared rather higher in the section there—a situation which Rhodes *et al.* (1969, p. 56) interpreted as meaning that the apparently lower North Crop occurrence could be compared with the first North American occurrence of the species in the *Siphonodella quadruplicata*-*S. crenulata* Zone, whereas the apparently higher Avon Gorge occurrence could be compared with the abundant occurrence of the species in what was then called the *S. isosticha*-*S. cooperi* Zone of North America. It should be realized that Rhodes *et al.* (1969, p. 97) had collected, in all, eleven specimens of *G. delicatus*.

4. The *Polygnathus lacinatus* Assemblage Zone, which followed the *Sp. costatus costatus*-*G. delicatus* Assemblage Zone, had no *P. lacinatus* in the Avon Gorge. The three zones following were described from the Avon Gorge (high in the Black Rock Group) only. Apparently there is no stratigraphy of this range of age on the North Crop.

These comments bring attention to certain deficiencies of Rhodes, Austin, and Druce's scheme—to the thinness of their evidence, and to their failure to produce confirmation of the zonal arrangements they proposed. There are cases where proposals based on Avon Gorge evidence could not be confirmed in the North Crop sections, and vice versa. Rhodes *et al.* (1969) mention only one attempt to seek confirmation of the proposals they made for the range of the stratigraphy discussed here. That dealt with sections in Shropshire (Rhodes *et al.* 1969, pp. 25, 48) and some further inconsistencies emerged. Another deficiency of Rhodes, Austin, and Druce's work lies in the fact that they nowhere made allowance for the possibility that conodonts might have been to any extent reworked in the thick Avonian carbonate sequence. They attached a certain amount of significance to upper limits of occurrence, e.g. where they remarked (Rhodes *et al.* 1969, p. 40) that the top of the *Gnathodus simplicatus* assemblage subzone of the *Spathognathodus costatus costatus* Assemblage Zone on the North Crop is marked by the final occurrence of, among others, *Polygnathus communis*—compare Rhodes *et al.* 1969, p. 42, where they remark that the youngest stratigraphic occurrence of *P. communis communis* in the Avon Gorge lies within their *G. antetexanus*-*P. lacinatus* Assemblage Zone. They attached significance also to maximum abundance of particular forms (see an example below) thus again ignoring the risk that sedimentary processes might have had any effect on the observed distribution of conodonts.

Yet another shortcoming of Rhodes, Austin, and Druce's zonal scheme is found in the fact that many of the conodonts involved were given highly idiosyncratic systematic treatment. In the discussion of their scheme above, it has been convenient to retain the generic and specific names they themselves used. The systematic section below will show that in their determinations of genera and species, they departed, in many instances, from opinions generally accepted among conodont workers.

Rhodes, Austin, and Druce's proposals on correlations with the U.S.A. and with

Germany may appear (as in their fig. 12, for example) to be in some cases different from, and in any case more elaborate than, proposals of the kind made for the Cork Beds faunas. Their suggestions involve, here and there, conodonts of kinds now discovered in the Cork Beds, and so it is necessary to examine the essentials of the suggestions they made. They offered a choice between two alternative schemes of correlation with North America. Both schemes were hung on an equation of the Avonian *Polygnathus lacinatus* Assemblage Zone with the *Gnathodus semiglaber*-*Pseudopolygnathus multistriatus* Zone of the Mississippian. The case for this correlation rested on Rhodes, Austin, and Druce's (1969, p. 57) suggestion that gnathodids occur in the Avon Gorge succession in a pattern which could be compared with Rexroad and Scott's (1964) record of a shift of maximum abundance from *G. delicatus* in the *S. isosticha*-*S. cooperi* Zone, to *G. semiglaber* in the *G. semiglaber*-*Ps. multistriatus* Zone and then to *G. antetexanus* in the *Bactrognathus*-*P. communis* Zone. Rhodes, Austin, and Druce claimed to match this with *G. delicatus* at the base of Z_2 (note Rhodes *et al.* 1969, p. 97, where they record that they recovered a total of eleven specimens of this species, and that the range of those found in the Avon Gorge was Z 28-Z 37), with *G. semiglaber* in the upper part of Z_2 (cf. Rhodes *et al.* 1969, p. 106: a total of three specimens, recovered from the range Z 28-Z 30) and with *G. antetexanus*, first appearing in the upper part of Z_2 and ranging into C_1 (cf. Rhodes *et al.* 1969, p. 93: in all ten specimens, Avon Gorge range Z 33-C 9). Nothing of this justifies the suggestion that the Avon Gorge gnathodids show a shift of maximum abundance to be compared with what Rexroad and Scott had observed, nor is there anything to enforce a correlation of the *P. lacinatus* Assemblage Zone (Z 26-Z 32 in the Avon Gorge, according to Rhodes *et al.* 1969, p. 41, i.e. a range which has no *P. lacinatus*; or ZLA 29-ZL 19 on the North Crop, a range which has no *G. semiglaber*) with the *G. semiglaber*-*Ps. multistriatus* Zone of North America. Rhodes, Austin, and Druce's two alternative schemes for correlation with the Mississippian therefore fail at their single common point.

There are numerous shortcomings in Rhodes, Austin, and Druce's (1969) references to the German evidence. Some, such as their mention of 'the Hartz Mountains of the Sauerland' (p. 64 of their paper) should confuse no one. Other references to the German evidence are potentially misleading, and ought to be corrected. For example, their text mentions subdivisions of German zonal units, such as 'basal Cu II α ' (p. 39) as distinct from (i.e. they were correlated with two different Avonian zones) 'Lower Cu II α ' (p. 39), 'Middle and Upper Cu II α ' (p. 40), 'lowest Cu II β - γ ' (p. 41), 'Middle Cu II β - γ ', as well as 'Upper Cu II β - γ ' (p. 42), 'lowest Cu II δ ' (p. 42), and 'the middle and upper part of Cu II δ ' (p. 43). The use of a capital letter in some of these adjectives may be thought to imply that such subdivisions of the zonal units have some established standing. This is not so. In fact the examples quoted above would in every case involve finer distinctions than the Germans themselves have ever attempted. Comments on the ammonoid zones (to which symbols such as cu II α refer), and on the possibility and indeed advisability of rendering conodont dates in ammonoid terms, are available in Matthews (1966, 1970, 1971).

Rhodes, Austin, and Druce's claim to have identified equivalents of the German cu I cannot be substantiated, as Ziegler (1971a) has already pointed out. The claim, which is repeated in Rhodes and Austin (1971), involves reference to a specimen

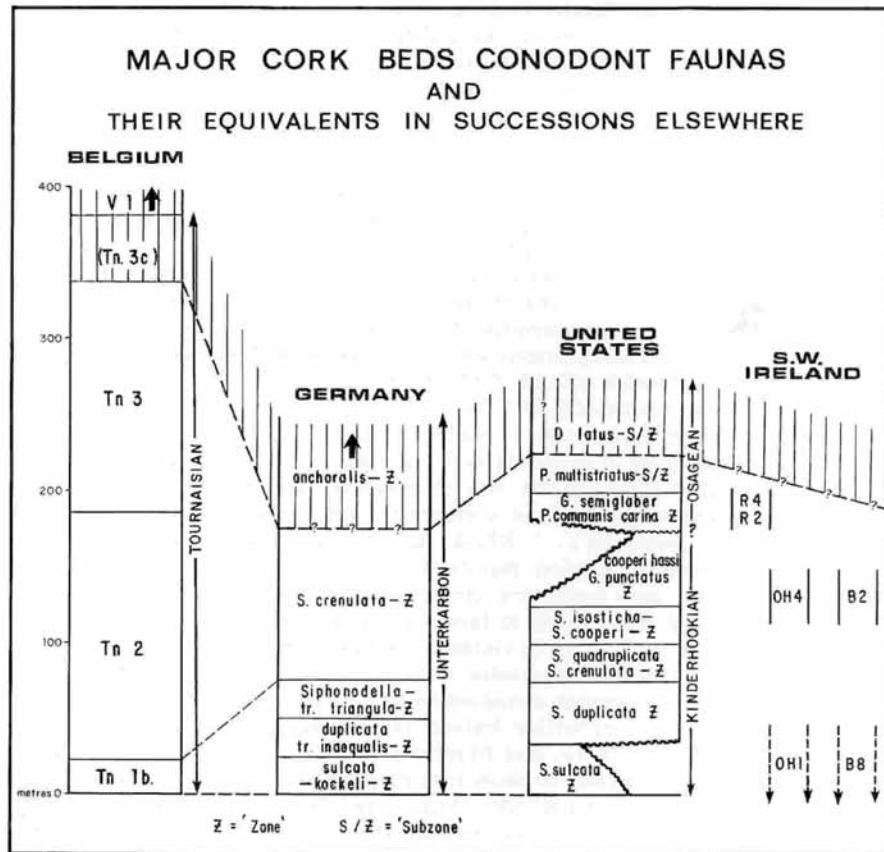
of *Elictognathus*, which Rhodes *et al.* (1969) did not describe nor figure. The genus *Elictognathus*, which is represented in the Irish faunas, need not be thought to specify earliest Carboniferous age (see Voges 1959; Collinson *et al.* 1962; Rexroad and Scott 1964; and later American authors). Rhodes, Austin, and Druce's suggestions on Avonian equivalents of the German *anchoralis*-Zone should also be examined here, for their arguments involved gnathodids of kinds found in the Cork Beds. They twice referred to gnathodids in this connection. On p. 57 of their paper they suggested that 'Ziegler (1960, 1963) has described gnathodids identical to those of the middle *Polygnathus lacinatus* Zone of the Avonian (samples Z 28-Z 30)'. If one refers to Rhodes, Austin, and Druce's systematic treatment of the gnathodids for information on ranges, one finds that only *Gnathodus delicatus* and *G. semiglaber* occur in that range. If one refers to their list of works cited (p. 292 of Rhodes *et al.* 1969) one discovers that 'Ziegler 1960' is a paper on Lower Devonian conodonts. 'Ziegler 1960a' there is a paper in which Ziegler described *G. commutatus homopunctatus* but no other gnathodid. One is left to presume that Rhodes, Austin, and Druce intended to refer to Ziegler's contribution to Kronberg *et al.* (1960) where Ziegler figured a number of gnathodids, *G. delicatus* and *G. semiglaber* among them, found in *anchoralis*-Zone faunas. Ziegler (1963) again figured gnathodids (including *G. delicatus*) from *anchoralis*-Zone faunas and mentioned one specimen of *G. semiglaber* in a faunal list. But he made no extensive descriptive reference to the gnathodids in 1963 since he was awaiting the outcome of American work in progress at that time. In a second reference to the age-significance (in German terms) of their gnathodids, Rhodes *et al.* (1969, p. 60) mentioned that Ziegler had communicated to them his belief that the gnathodid fauna of samples Z 34-Z 38 'is identical to that found in Western Europe in beds equivalent to the *Siphonodella crenulata* Zone . . .'. These two references to comparisons with Germany, taken together, would appear to show that the gnathodids of Z 28-Z 30 are 'identical' to some found in *anchoralis*-Zone faunas, whereas those of Z 34-Z 38 (higher) are 'identical' to gnathodids found in the (earlier) *S. crenulata*-Zone. It might also be noted here that Ziegler's communication, referring to *S. crenulata*-Zone gnathodids, would clash with Rhodes, Austin, and Druce's (1969, p. 57) own observation that the '*anchoralis* fauna of Germany, as at present understood, contains the simultaneous first appearance of several species of *Gnathodus* . . .'. Rhodes and Austin (1971, fig. 4) have repeated this view of the German situation. But Ziegler, in the 1963 paper mentioned above, explicitly denied any such suggestion, citing evidence from Voges (1960), and from Ziegler (in Kronberg *et al.* 1960), in favour of possible earlier, i.e. pre-*anchoralis*-Zone, occurrence of gnathodids in Germany (Ziegler 1963, p. 323).

The conclusion is that Rhodes, Austin, and Druce's paper gives no better guidance on correlation with the German conodont sequence than it does on correlation with the American. Criticisms of further features of Rhodes, Austin, and Druce's work are possible (see Ziegler 1971a; and Matthews and Butler, in press). The remarks made here should be sufficient to show that no purpose is served by attempting to refer the Cork Beds faunas to Rhodes, Austin, and Druce's set of Avonian zones. The comparisons that can be made between the southern Irish and the Bristol-Mendip stratigraphy will be clearer when work now in progress on the conodont faunas of the latter area has been published (Butler, in preparation). For the present,

there is no more to be suggested than that the higher Cork Beds faunas include conodonts which can be compared with specimens recovered from the Black Rock Group by Rhodes, Austin, and Druce—a modest proposal, which is consistent with Turner's (1952) suggestions based on the corals and brachiopods.

These various observations on the relationships of stratigraphic successions that produce conodonts of the kind found in the Cork Beds are brought together in text-fig. 3, to which the following considerations apply:

1. Belgium: if Tn 1b is accepted as an equivalent of the Hangenbergkalk, and the occurrence of *Scaliognathus anchoralis* and *Hindeodella segaformis* reported in Tn 3c by Groessens accepted as an equivalent of the beginning of the *anchoralis*-Zone of Germany, then it is permissible to treat the intervening range (Tn 2a-Tn 3b



TEXT-FIG. 3. Major Cork Beds conodont faunas related to successions in the U.S.A., Germany, and Belgium.

inclusive) of the Belgian succession as an equivalent of the *Siphonodella crenulata*-Zone (defined in Voges 1960, p. 210, as extending from the point of entry of *S. crenulata*, i.e. close above the Hangenbergkalk in Germany, up to the point of entry of *Sc. anchoralis*, *H. segaformis*, and *D. latus*). Belgian thicknesses in text-fig. 3 are taken from Legrand *et al.* (1966).

2. No attempt is made to show the thickness of the German succession to the same scale (see Voges 1960, fig. 2, for an indication of German thicknesses). Lowest Carboniferous zones are shown as in Ziegler (1969).

3. Thicknesses of the American succession can be read from a fence-diagram in Thompson and Fellows (1970, plate 9). The zones shown in text-fig. 3 would occur in some 20–30 m of beds. Thompson and Fellows's figs. 25 and 26 serve as a source of information on breaks in the American succession (left side of the American column in text-fig. 3: Collinson, Scott, and Rexroad's findings; right: Thompson and Fellows's). The interval between Thompson and Fellows's *Pseudopolygnathus multistriatus* subzone and their *D. latus* subzone is taken here as an approximate equivalent of the beginning of the German *anchoralis*-Zone.

4. Some of the Cork Beds faunas are shown on the right of the figure. The placing of OH1 and B8 are by no means certain. For more detailed information on Cork Beds correlations and thicknesses text-fig. 4 should be consulted.

5. Vertical lines indicate the lower part of the *anchoralis*-Zone. None of the Cork Beds conodont faunas are as young as this.

The above discussion provides for the following comments on the ages of the major Cork Beds conodont faunas (see faunal lists on pp. 337 and 338):

OH1: The age of this collection of conodonts involves some rather indirect arguments. The fauna is dominated by spathognathodids, and has *Polygnathus communis communis* and *Patrognathus variabilis*. *Pa. variabilis* is characteristic of Rhodes, Austin, and Druce's lowest Avonian zone, but, as Ziegler (1971) has already pointed out, there was no evidence to justify Rhodes, Austin, and Druce's suggestion that their lowest zone was an equivalent of the earliest Carboniferous of Germany. More recently, Austin, Conil *et al.* (1970) have recovered a fauna (Huy 15/111 in their paper) from Tn 1b in Belgium which includes, notably, several spathognathodids, a patrognathodid, and a specimen of *Siphonodella cooperi*. This fauna, whose evidence is supported by that of spores, gives a clearer indication of very early Carboniferous age. There is a close resemblance between the Huy 15/111 spathognathodids and those of OH1. The resemblance is masked by different use of names (note remarks in the systematic section below, where it will appear that usage here has much in common with, for example, that of Sandberg and Klapper 1967; and note too that the Huy 15/111 conodonts, as identified in Austin, Conil *et al.* (1970), include indices to more than one of Rhodes, Austin, and Druce's Avonian zones), but it exists, and is taken to indicate that OH1 belongs in the neighbourhood of the Devonian/Carboniferous boundary. OH1 was resampled in the hope of obtaining siphonodellids, or protognathodids, which might have provided for a more precise estimate of age. Unfortunately, this is the one case in which the second sampling proved unfruitful. Some support for this estimate of the age of OH1 can

be found in Kuijpers (1972), who refers to palynological evidence of very early Carboniferous age obtained from the lowest part of the Kinsale Group. B8 and the Black Ball Head fauna are tentatively regarded as equivalents of OH1, a suggestion which will be firmer when the range of the clydagnathoid variants of *Spathognathodus aculeatus* is better understood.

B2: In the discussion of American evidence above it was suggested that B2 is an approximate equivalent of the late Kinderhook-early Osage conodont faunas of the U.S.A. *Siphonodella cooperi* is the dominant siphonodellid. The presence of *Pseudopolygnathus multistriatus* is something of an anomaly, in that the American zonal scheme would have it emerge at a higher level. In dealing with relations within the Cork Beds (see text-fig. 4 below), WB2 is treated as an equivalent of B2. OH4 has some similar conodonts, although the specimens are all of relatively small size, and this fauna too is taken to be of much the same age as B2. It is clear that F1 is older than the faunas found higher in the Ringabella succession (R4 for example), but it is difficult to judge its age relative to the B2, OH4, WB2 faunas (note that it includes, again, *Ps. multistriatus*). However, there need be no doubt that it should be interpreted, within the Cork Beds, as representing a horizon distinctly higher than that recorded in OH1.

R4: The R4 fauna has been mentioned above. The presence of abundant *Polygnathus communis carina* is taken to indicate a horizon close below the point at which *Scalio-gnathus anchoralis* and its associates might be expected to emerge.

These suggestions on age are built into the discussion of stratigraphical relationships within the Cork Beds which now follows. References to conodont faunas already reported from southern Ireland have been reserved for this part of the paper.

CORRELATION WITHIN SOUTHERN IRELAND

The four main sections sampled for this study (text-fig. 5) are in the Courtmacsherry Group and its lithological equivalents, at Ringabella, Old Head of Kinsale, Dunmanus, and Bantry (text-fig. 1). Some results are available from the Kinsale Group also.

The new information may be used first to make comments on age-relationships between the Cork Beds and the 'Waulsortian' and associated carbonate rocks found to the north. This more northerly facies includes the 4000 ft (approx. 1300 m) of bank limestone known in the Cork Syncline at Little Island. These limestones are underlain by a thin Lower Limestone Shale succession, and below that there is the Old Red Sandstone. The middle part of the limestone sequence includes the distinctive reddened horizon known as the Cork Red Marble (Nevill 1962). Quarrying provides good access to the stratigraphy at and above the Red Marble horizon, but the lower part of the limestone succession is poorly exposed. Macrofossils from the upper part of the sequence give no exact information on age. Naylor (1969) has reviewed the evidence available and has suggested that Viséan age is probable. Foraminiferids (reported in Naylor 1964, unpublished Ph.D. thesis, University of Dublin) from the upper part of the succession—the lowest sample was taken from a position 50 ft below the Red Marble—again indicate Viséan (S-D₁) age. Austin

(1968) has recorded a Viséan conodont fauna from the Red Marble (it should be noted that his sample was collected 10 miles along strike at Middleton: see Nevill 1962, locality 10). Further to the north in Co. Cork, Hudson and Philcox (1965) were able to distinguish two Lower Carboniferous 'reef' developments. They regarded the lower, a Waulsortian carbonate mud-bank complex, as being of Tournaisian age. It is followed by a thin pyroclastic development, then by well-bedded argillaceous limestones (C_2S_1) and then by the higher reef-complex, of Cracoean character, which was given dates in the range S_2-D_1 . This differentiation between two complexes is not possible at Little Island. It may be that the Cracoean complex here succeeds the Waulsortian bank limestones at some point within the poorly exposed succession lying below the Cork Red Marble. Alternatively, the Waulsortian carbonates may be very thin, and much of the Tournaisian represented in the Lower Limestone Shale facies.

Comparing these northerly successions with that in the Ringabella Syncline, the first point to be considered is the Tournaisian age of the Ringabella Limestone Formation (see especially samples R2, R3, R4). A poor coral fauna from these beds was considered to be of Viséan age by Naylor *et al.* (1969). If the Tournaisian date is now accepted, it would follow that the Ringabella Limestone Formation must predate a considerable part of the thick carbonate succession found to the north. Samples from the base of the bank limestone in the Cloyne Syncline have proved unproductive, and there is no information on whatever might be the correlative of the Ringabella Limestone in the poorly exposed lower part of the stratigraphy at Little Island. But it is clear that the Ringabella conodonts are older than those reported from the Cork Red Marble by Austin (1968). One implication of these suggestions is that much of the thick carbonate succession found at Little Island should correlate with whatever stratigraphy is present along the axis of the Ringabella Syncline in the ground between the coast and the Minanebridge quarries. There is no direct information on the nature of this stratigraphy, nor its age (a possibility discussed above is that it might be to some extent siliceous, and might include the equivalent of the *anchoralis*-Zone), but its thickness can be estimated. It would be reasonable to suggest that this concealed interval is unlikely to contain more than 500 ft (approx. 160 m) of beds. A regional southward thinning is therefore indicated.

The west-coast evidence also suggests southward thinning of the Lower Carboniferous. The northern limit of Cork Beds outcrop is at Kenmare River. North of Kenmare, the Lower Carboniferous includes a Lower Limestone Shale unit and a major thickness of carbonate rocks. There is no published information on the age of the limestones that crop out of the northern limb of the Kenmare Syncline; but somewhat further north, in the Castleisland area at the eastern end of the Dingle Peninsula, Hudson *et al.* (1966) have recognized a lower, Waulsortian (C_1) complex and a higher, Cracoean (S_2-D_1) complex within a Lower Carboniferous succession which totals 4750 ft (approx. 1500 m) in thickness. A similar succession exists in north-west Co. Limerick, where Shepard-Thorn (1963) referred the Waulsortian stratigraphy to the C Zone. Information on conodonts is available here. Austin, Husri, and Conil's (1971) faunas include one from the base of the Waulsortian reef which would appear to be younger than any of the Cork Beds faunas. Hill's (1971) fauna, recovered from 'within the Waulsortian reef bank complex' of this same

general area, has *Scaliognathus anchoralis* and should also be adjudged younger than anything available from the Cork Beds. Comparing these Limerick successions now with that on Bantry Bay, one should first take note of the suggestion that the B8 and B9 faunas are of early Tournaisian age. They come from the northern limb of the Bantry Syncline, where the total thickness of the calcareous succession (which has been regarded as the west-coast equivalent of the Courtmacsherry Group) is unlikely to exceed 800 ft (P. C. Jones, pers. comm.). It is difficult to unravel the structures in the core of the Bantry Syncline, but present opinion is that the succession runs without a break from the Courtmacsherry Group to the goniatite bearing (P-Zone and E-Zone) mudstones on Whiddy Island. The Bantry succession appears then to represent most of the Lower Carboniferous, and is considerably thinner than the Limerick succession.

A second major feature of the results is that they suggest considerable variations of thickness within the Cork Beds themselves. OH4, collected near the base of the Courtmacsherry Group on the Old Head of Kinsale, is regarded as a near correlative of B2 from Bantry Bay. The implication here is that the Kinsale Group, 2500 ft (approximately 750 m) thick at the Old Head of Kinsale, is equivalent to less than 350 ft (approximately 105 m) of the calcareous succession at Bantry Bay. This correlation involves the most surprising result obtained, namely the suggestion that OH1 might be compared with B8 and B9. OH1 comes from the Castle Slate Formation, at the base of the Kinsale Group on the Old Head of Kinsale. B8 and B9 come from near the base of the Reenydonagan Group, which was earlier (Naylor *et al.* 1969) taken to be a Bantry Bay equivalent of the Courtmacsherry Group. The Reenydonagan Group is available again in west Cork, in the Dunmanus section, but samples from there have proved unproductive and, so far, supply no confirmation of the Bantry results. However, P. C. Jones (paper in preparation) finds that there are detailed similarities between the occurrences of the Reenydonagan Group in the Dunmanus and the Bantry successions, and this, together with their close proximity to one another, suggests that they are quite possibly time-equivalent.

The evidence of age in these lowest Bantry samples is weak at present. It may nevertheless be useful to offer it here for consideration along with results emerging from other researches in progress in south-west Ireland. The B8 and B9 conodonts imply that calcareous sediment entered the west-coast succession relatively early. Later in the Tournaisian, sedimentary material of this kind was accumulating both in the west (Bantry) and in the east (Old Head of Kinsale, Ringabella). One possibility is that two separate sub-basins were in existence for a time. Work in progress on the Toe Head to Seven Heads area may help to clarify the picture. Reilly (pers. comm.) finds that in the Glandore area the Kinsale Group is particularly thin, and is overlain directly by beds containing *Posidonia becheri*. There is no calcareous development in the succession, and this appears to be the case at Galley Head also. These preliminary findings may indicate that a positive feature existed in the Glandore-Galley Head area and separated two sub-basins, each of which received calcareous sediment, but it should be recognized that any such proposal will have more weight when further palaeontological work has been done.

Further palaeontological information is needed in the lowest parts of the Cork Beds succession too. References to the early Carboniferous, and to thin Lower

Carboniferous successions, should not obscure the fact that more than 5000 ft (approximately 1500 m) of beds belonging to the Cork Beds lie below sample B9. Two attempts have been made to recover conodonts from this lower part of the succession. In the first case, a limestone sample from Kilcatherine Point was processed. This horizon had been sampled earlier by R. O. Ducharme (then of the University of Reading), who kindly offered his conodonts to Matthews for study (see text-fig. 4, 1966 sample: Columnar Section 8). They include *Polygnathus communis communis*, *Spathognathus cf. aculeatus*, and *Sp. stabilis*, so that fauna is hardly to be distinguished, in terms of age-significance, from OH1. The Kilcatherine Point locality was resampled by Naylor, in the hope of providing for a more precise estimate of age, but no further conodonts were found. The second case involved a sample from the Ardaturrish Group, on the north flank of the Bantry Syncline, but this unfortunately proved unproductive. Possibly palynological work may achieve more in this part of the succession.

Summarizing information available on the Lower Carboniferous part of the Cork Beds, one can suggest first that the succession is distinctly thicker in south Cork than on the west coast. Secondly, it seems to be the case that most of this Cork Beds clastic wedge was already developed before the Waulsortian Bank Limestone and associated carbonates began to accumulate in the area north of the Cork-Kenmare line. The equivalent of the thick Viséan successions found to the north should be sought in the fine-grained upper parts of the Cork Beds, which have a few goniatites, but so far have produced no conodonts. The Cork Beds show a general upward sequence from alluvial, deltaic (Naylor 1966), or tidal (Kuijpers 1971, 1972) sandstones through prodelta siltstones (Kinsale Group) and shallow marine carbonates (Courtmacsherry Group) to restricted basin sediments at the top (Lispatrick Mudstone Group). This sedimentary progression indicates the existence of a gradually deepening basin. Earlier suggestions of a break (P-E zone goniatite-bearing mudstones resting unconformably on Tournaisian) find little support in the evidence now available.

Correlations within the Cork Beds are shown in text-fig. 4.

SYSTEMATIC PALAEOONTOLOGY

The Cork Beds faunas have been deposited in the collections of the Institute of Geological Sciences (Leeds Office). Two-figure numbers prefixed GSL SAD identify 32-cavity microslides. A suffix identifies each cavity.

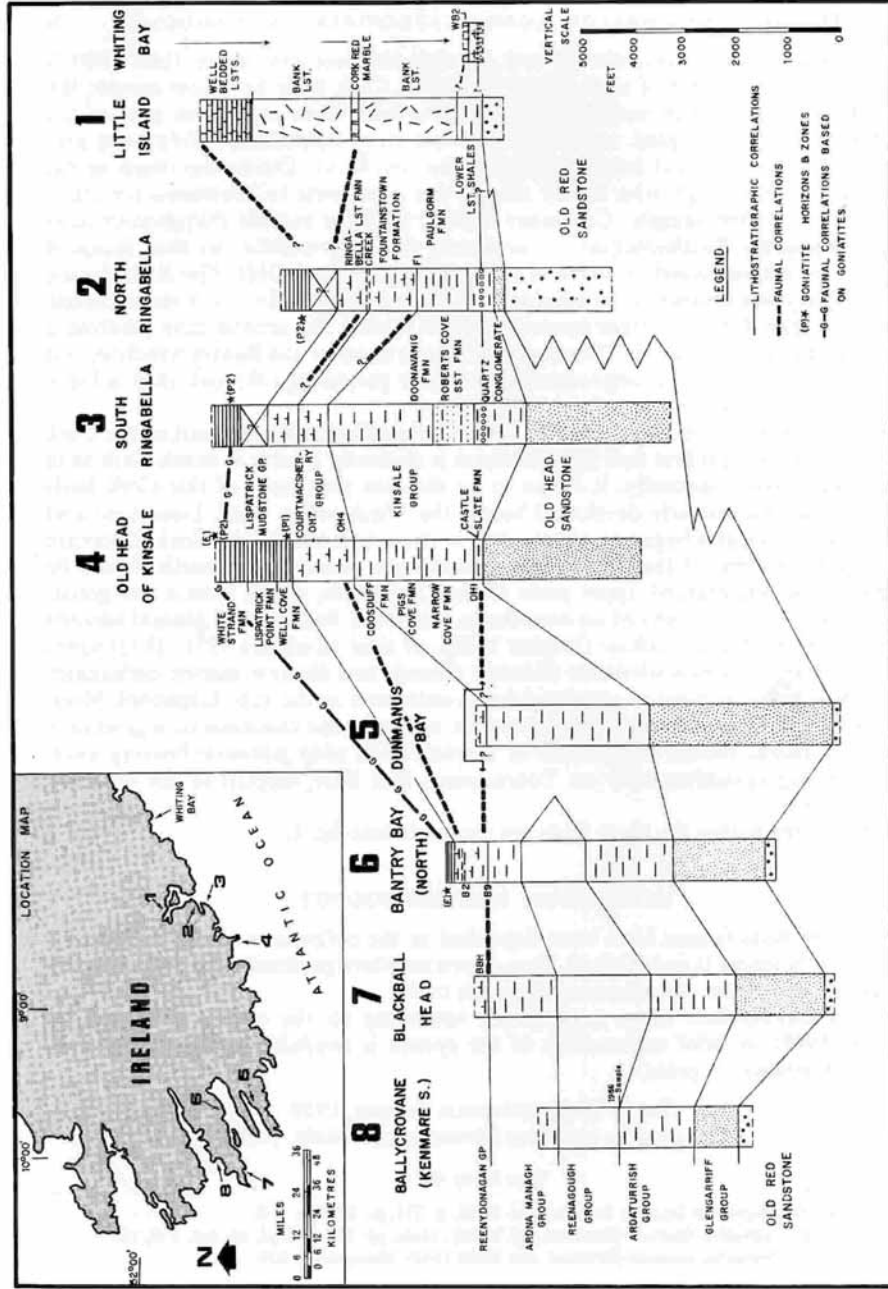
The synonymy lists carry annotations according to the system proposed by Richter (1948). A brief explanation of the system is available in Matthews *et al.* (1972), Matthews (in press).

Genus ELICTOGNATHUS Cooper, 1939

Elictognathus laceratus (Branson and Mehl, 1934)

Plate 37, fig. 19

- *1934 *Solenognathus lacerata* Branson and Mehl, p. 271, pl. 22, figs. 5, 6.
- 1959 *Elictognathus lacerata* (Branson and Mehl); Hass, pp. 386-387, pl. 49, figs. 1-8, 12.
- 1968 *Elictognathus lacerata* (Branson and Mehl 1934); Manzoni, p. 659.



TEXT-FIG. 4. Correlation of eight Cork Beds sections.

- 1969 *Elictognathus laceratus* (Branson and Mehl); Rexroad, pp. 15-17, pl. 1, figs. 15-19.
 1969 *Elictognathus costatus* (E. R. Branson); Rexroad, pp. 14-15, pl. 1, figs. 6-8.
 1969 *Elictognathus tylus* (Cooper); Rexroad, p. 17, pl. 1, fig. 14.
 1969 *Elictognathus lacerata* (Branson and Mehl 1934); Schönlaub, p. 329, pl. 3, fig. 1.
 1970 *Elictognathus laceratus* (Branson and Mehl); Thompson and Fellows, pp. 81-83, pl. 5, figs. 20, 21 (with synonymy).

Material. *E. laceratus* (1), *E. cf. laceratus* (2): 3 specimens from 2 samples. Figured: GSL SAD5717.

Remarks. Thompson and Fellows's (1970) synonymy differs from Klapper's (1966) in only two respects: first, in updating Klapper's list (some further updating is done in the list above) and secondly in placing *Solenognathus fulcrata* Branson and Mehl 1934—and also the *So. fulcra* (*sic*) Branson and Mehl of Cooper 1939—in synonymy with *E. laceratus*. Thompson and Fellows (1970) are consistent with Klapper (1966), and also with Hass (1959), whose example was followed by Voges (1959), in putting *E. costatus* (Branson and Mehl) in synonymy with *E. laceratus*. Straka (1968) and Rexroad (1969) have suggested that the crestal profile of the blade serves to separate these two, and that the separation is stratigraphically useful in that although the two species have much the same stratigraphic range, *E. laceratus* is the more abundant form in the higher part of the range. Because of the small number of specimens available here, and their immature form, it is not possible to follow Straka's and Rexroad's practice. The synonymy list above adjusts Rexroad's findings, treating *E. costatus* as Thompson and Fellows did, and suggesting that Rexroad, who put the relatively elaborate *So. fulcrata* into synonymy with *E. laceratus*, should not have treated *So. tyla* differently.

It may be useful to note here a record of *E. laceratus* in the Caballero Formation of New Mexico (Burton, pers. comm.) and further records of the species given in Klapper (1971, table 1).

Genus GNATHODUS Pander, 1856

Remarks. The literature of the last ten years carries numerous references to the difficult problem of reconciling Voges's (1959) and Collinson, Scott, and Rexroad's (1962) proposals on species of the genus *Gnathodus*. Thompson and Fellows's (1970) work has now made it possible to see that the range of the *anchoralis*-Zone from which Voges obtained the bulk of his *Gnathodus* material is at best only poorly represented in the broken Upper Mississippi Valley sections from which Collinson, Scott, and Rexroad collected their Chouteau, 'Sedalia', Lower Burlington, and Fern Glen gnathodids (Collinson *et al.* 1962, chart 3). There has, as yet, been no comprehensive treatment of the gnathodids (American, European) available from this range of the Lower Carboniferous. Rhodes and Austin's (1971) attempt to supply the need does not suffice. For one thing, it is stratigraphically uninformed. Also, it arbitrarily reassigns specimens described and figured by other authors to particular categories of the genus, some of which are new, and none of which are given adequate definition, neither in respect of their basic characteristics, nor in respect of their range of variation. The effect of this latter shortcoming is that other authors, even if convinced that Rhodes and Austin's phylogenetic proposals were worthwhile, would not find it possible themselves to attempt the identifications Rhodes and Austin recommend.

Gnathodus delicatus Branson and Mehl, 1938

Plate 35, figs. 14-17, 23-26

- *1938 *Gnathodus delicatus* Branson and Mehl, p. 145, pl. 34, figs. 25-27.
 ?1967 *Gnathodus delicatus* Branson and Mehl 1938; Wirth, pp. 209-210, pl. 19, fig. 21 (? = *G. semiglaber*).
 v1972 *Gnathodus delicatus* Branson and Mehl; Matthews, Sadler, and Selwood, pp. 559-560, pl. 110, figs. 5, 7-9 (with synonymy).

Material. 29 specimens (including 1 'cf.' determination) from 5 samples. Figured specimens: GSL SAD22/18, 19, SAD24/6, 14, 15, 16, SAD26/6, 7.

Remarks. The species is interpreted here on the basis described in Matthews *et al.* (1972). It is seen that the parapet on the inner side of the carina tends to be broader in an anterior part of its course. Certain forms are relatively slim, but usually appear to have better-developed ornament (particularly in the posterior parts of the upper surface of the cup) than would be found in *G. cuneiformis* or *G. typicus* (Pl. 35, figs. 17, 26). Some specimens show an arrow-like arrangement of the inner and outer parapet (Pl. 35, figs. 15, 16) but are broader and have more ornament on the anterior part of the outer oral surface than would be found in *G. cuneiformis*.

Gnathodus punctatus (Cooper, 1939)

Plate 35, fig. 11; Plate 36, figs. 7, 8

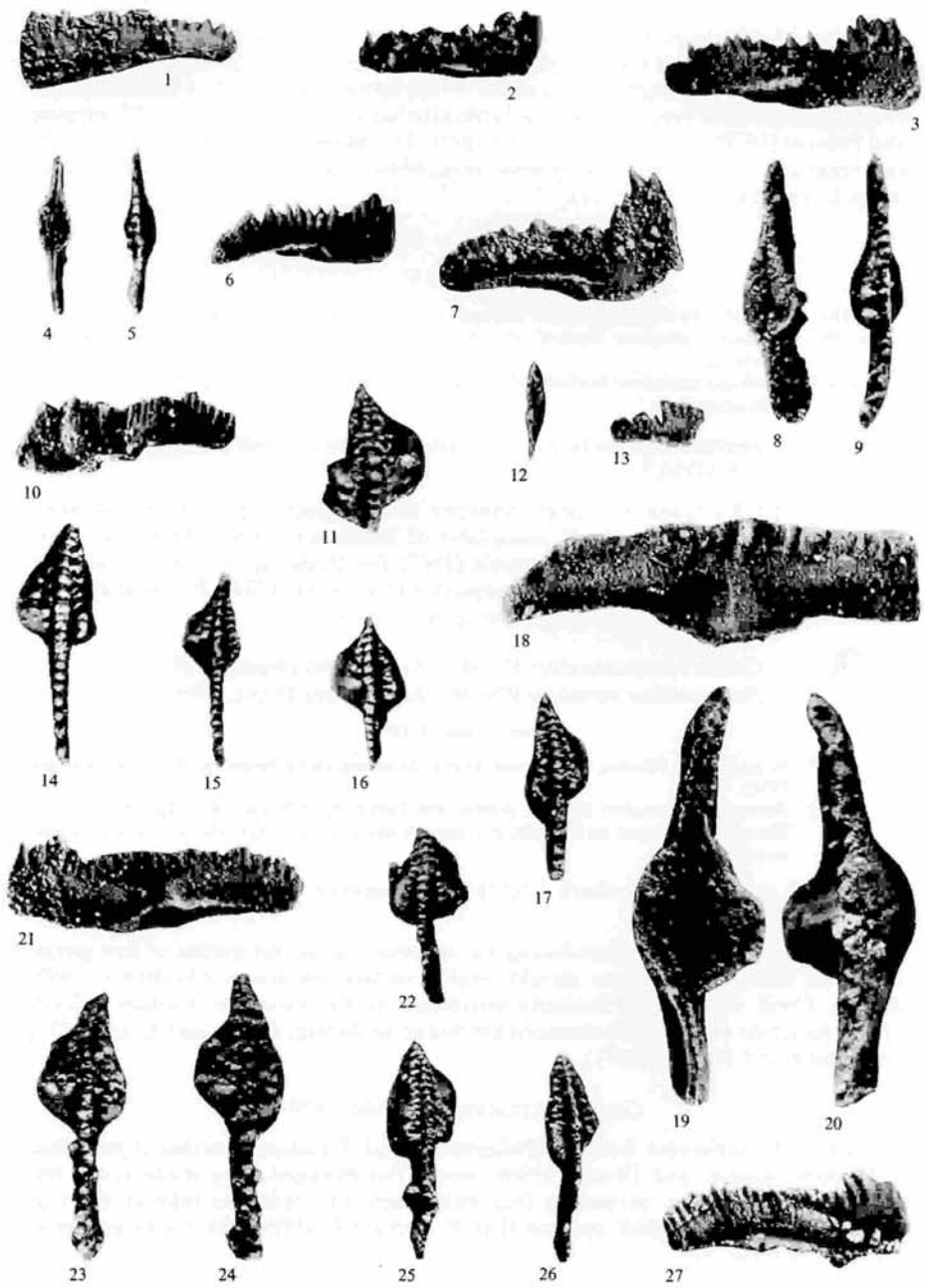
- *1939 *Dryphenotus punctatus* Cooper, p. 386, pl. 41, figs. 42, 43; pl. 42, figs. 10, 11.
 ?1962 *Gnathodus semiglaber* Bischoff 1957; Müller, p. 1388, pl. 1, figs. 1a, b, c.
 v1972 *Gnathodus punctatus* (Cooper 1939); Matthews, Sadler, and Selwood, pp. 560-562, pl. 109, figs. 5, 13; pl. 110, figs. 1-4, 11-15 (with synonymy).

Material. 4 specimens from 2 samples. Figured specimens: GSL SAD26/15, SAD 37/1, 2.

EXPLANATION OF PLATE 35

Specimens dusted with ammonium chloride. All $\times 30$.

- Figs. 1, 10, 21, 27. *Spathognathodus stabilis* (Branson and Mehl). 1, GSL SAD47/2 (OH1). 10, GSL SAD43/20 (B8). 21, GSL SAD22/4 (R2). 27, GSL SAD24/4 (R4).
 Fig. 2. *Spathognathodus anteposicornis* Scott. GSL SAD47/11 (OH1).
 Figs. 3-9. *Spathognathodus aculeatus* (Branson and Mehl). 3, 8, 9. Lateral, aboral, and oral views of GSL SAD47/8 (OH1). 4, 5, 6. Aboral, oral, and lateral views of GSL SAD47/6 (OH1). 7, GSL SAD47/13 (OH1).
 Fig. 11. *Gnathodus punctatus* (Cooper). GSL SAD26/15 (R4b '71).
 Figs. 12, 13. *Patrognathus variabilis* Rhodes, Austin, and Druce. Oral and lateral views of GSL SAD47/15 (OH1).
 Figs. 14-17, 23-26. *Gnathodus delicatus* Branson and Mehl. 14, GSL SAD24/6 (R4). 15, GSL SAD24/14 (R4). 16, GSL SAD24/15 (R4). 17, GSL SAD24/16 (R4). 23, GSL SAD26/7 (R4b '71). 24, GSL SAD26/6 (R4b '71). 25, GSL SAD22/18 (R2). 26, GSL SAD22/19 (R2).
 Figs. 18-20. *Spathognathodus* sp. Lateral, aboral, and oral views of GSL SAD26/11 (R4b '71).
 Fig. 22. *Gnathodus semiglaber* Bischoff. GSL SAD24/5 (R4).



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Remarks. Matthews *et al.* (1972) have referred to *G. punctatus* specimens which have on the inner side of their upper surface a short curved parapet arranged convex to the carina. They recognized a variant of the species (variant 2: Matthews *et al.* 1972, p. 561) which would include a form attributed to *G. delicatus* by Thompson and Fellows (1970). A further variant recognized by Matthews *et al.* (1972: variant 3), and regarded by them as showing some resemblance to *G. semiglaber*, occurs again in the Cork Beds (Pl. 35, fig. 11).

Gnathodus semiglaber Bischoff, 1957

Plate 35, fig. 22

- v*1957 *Gnathodus bilineatus semiglaber* Bischoff, p. 22, pl. 3, figs. 1-10, 12-14.
 ?non 1962 *Gnathodus semiglaber* Bischoff 1957; Müller, p. 1388, pl. 1, figs. 1a, b, c (? = *G. punctatus*; see above).
 v1972 *Gnathodus semiglaber* Bischoff 1957; Matthews, Sadler, and Selwood, p. 562, pl. 110, fig. 10 (with synonymy).

Material. 14 specimens (including 3 'aff.' determinations) from 5 samples. Figured specimen: GSL SAD24/5.

Remarks. The R4 fauna has clear examples of this species. B2 contains slimmer forms which resemble the *G. aff. semiglaber* of Matthews (1969b). Matthews there suggested a resemblance to Thompson's (1967) *Gnathodus* sp. C, which was later referred to *Gnathodus* n. sp. B by Thompson and Fellows (1970). Rexroad's (1969) *Gnathodus* n. sp. includes forms that are again comparable.

Genus PATROGNATHUS Rhodes, Austin, and Druce, 1969

Patrognathus variabilis Rhodes, Austin, and Druce, 1969

Plate 35, figs. 12, 13

- 1967 N. gen. n. sp. Rhodes, Austin, and Druce; Sandberg and Klapper, p. B 52 (*vide* Klapper 1971).
 v*1969 *Patrognathus variabilis* Rhodes, Austin, and Druce, pp. 179-180, pl. 2, figs. 8-11. (N.B.: The specimen shown on figs. 10a, b, c appears again on pl. 1, figs. 15b, a, c of Rhodes and Austin 1971.)

Material. 2 specimens (of which 1 'cf.') from 1 sample. Figured specimens: GSL SAD47/15.

Remarks. Klapper (1971), introducing *Pa. andersoni*, a second species of this genus, suggested that *Pa. andersoni* should receive certain specimens (Anderson 1969; Austin, Conil *et al.* 1970) formerly attributed to *Pa. variabilis*. Further records of *Pa. variabilis* (without illustration) are found in Austin, Husri, and Conil (1971) and Austin and Rhodes (1971).

Genus POLYGNATHUS Hinde, 1879

Remarks. The difference between *Polygnathus* and *Pseudopolygnathus* is not clear in Rhodes, Austin, and Druce's (1969) work. For example, they made much reference to *P. lacinatus*, proposing four subspecies, but failed to take account of Rexroad and Scott's (1964) opinion that *P. lacinata* Huddle 1934 is a synonym of

Ps. fusiformis Branson and Mehl 1934. This view is confirmed by Thompson and Fellows (1970) and in part, by Rexroad (1969), who refers only the specimen shown in fig. 3 of Huddle (1934, pl. 8)—i.e. the only one of Huddle's specimens whose basal cavity is figured—to *Ps. fusiformis*. *P. lacinata* Huddle of Cooper (1939, pl. 40, figs. 3, 4), which Rhodes, Austin, and Druce included in their *P. lacinatus lacinatus* synonymy, had already been referred to *Ps. marginata* Branson and Mehl 1934 by Klapper, an opinion confirmed by Rexroad (1969) and Thompson and Fellows (1970). Rhodes, Austin, and Druce's (1969) treatment of *P. longiposticus* Branson and Mehl also deserves attention here. On p. 210 of their paper they dealt with *Ps. cf. longiposticus* Branson and Mehl (*sic*). The sole item in their synonymy list was *P. longipostica* Branson and Mehl 1934. On p. 212 they remarked that 'the Avonian *P. multistriatus* pseudopolygnathids gave rise to *P. cf. longiposticus*'. Rhodes, Austin, and Druce's (1969) *Ps. nodomarginatus* (E. R. Branson) is again an example of a case in which *Pseudopolygnathus* and *Polygnathus* are confused. Other authors have been consistent in referring this species to *Polygnathus*. The only pseudopolygnathid in Rhodes, Austin, and Druce's synonymy list for this species is *Ps. brevimarginata* E. R. Branson 1934, which appears again in their synonymy list for *Ps. dentilineata*, with the same plate and figure reference but a different page reference. The page reference under *nodomarginatus* is the correct one, but it is the attribution to *dentilineatus* that matches other authors' opinions (e.g. Voges 1959; Klapper 1966). Rhodes, Austin, and Druce's synonymy list for '*Pseudopolygnathus nodomarginatus*' (p. 212 of their paper) also includes *P. cf. flabella* of Voges (1959, p. 290, pl. 34, figs. 8-11). One finds that the synonymy list for Rhodes, Austin, and Druce's own *P. bischoffi* (p. 184 of their paper) includes *P. cf. flabella* of Voges (1959, pl. 34, fig. 11 only).

It is possible to identify a worthwhile systematic problem among these confusions. Certain polygnathid conodonts have relatively large basal cavities whose lips extend some way toward the posterior end. Klapper (1966) recognized such a case in *P. delicatula*. A similar condition appears to exist in Thompson's (1967) *P. mehli* (which resembles *P. delicatula*, as Thompson noted, and may be an immature form of that species). The question is whether these polygnathoid conodonts that have relatively robustly featured, attenuate basal cavities should be excluded from *Polygnathus*. If this were to be done, it would not necessarily follow that they should be placed in *Pseudopolygnathus*, a genus whose basal cavity normally gives a clear indication of asymmetry and is relatively well developed in the lateral sense. Any attempt to produce such a reinterpretation of the polygnathoid conodonts might take account of the fact that *Siphonodella* is distinguished from *Polygnathus* on the evidence of basal features (Klapper 1966), and might also touch on the problem of the status of those late pseudopolygnathids (e.g. *Ps. triangulus pinnatus*) whose basal cavity is relatively small (see Ziegler 1963, footnote on p. 324).

Polygnathus communis Branson and Mehl, 1934

Polygnathus communis communis Branson and Mehl, 1934

Material. 49 specimens (including 14 *P. cf. communis*) from 5 samples.

Polygnathus communis carina Hass, 1959

Plate 37, figs. 2-5, 10

- *1959 *Polygnathus communis* Branson and Mehl *carina* Hass n. var., Hass, p. 391, pl. 47, figs. 8, 9.
 v1972 *Polygnathus communis carina* Hass; Matthews, Sadler, and Selwood, pp. 563-564, pl. 111, figs. 6, 7, 13 (with synonymy).

Material. 43 specimens from 4 samples. Figured specimens: GSL SAD24/2, 7, 8, SAD26/21.

Remarks. Matthews *et al.* (1972) have remarked that *carina* is the proper form of the subspecies name. The form '*carinus*' is unnecessary and the form '*carinatus*' (as given in Austin and Rhodes 1971, p. 194, and in Austin, Husri, and Conil 1971, p. 187; *P. communis carinatus* Hass) is wrong.

Details of ornament are seen to vary in specimens attributed to this subspecies. Matthews *et al.* (1972) refer to one variant which has up to three ridges on the anterior part of the platform on the inner side. That arrangement has been found again here (Pl. 37, fig. 5). Another variant (Pl. 37, fig. 10) has a longitudinal row of fine nodes on the inner platform surface. A similar form, but with larger nodes, is noted in Matthews *et al.* (1972).

Polygnathus flabellus Branson and Mehl, 1938

Plate 37, figs. 16, 24

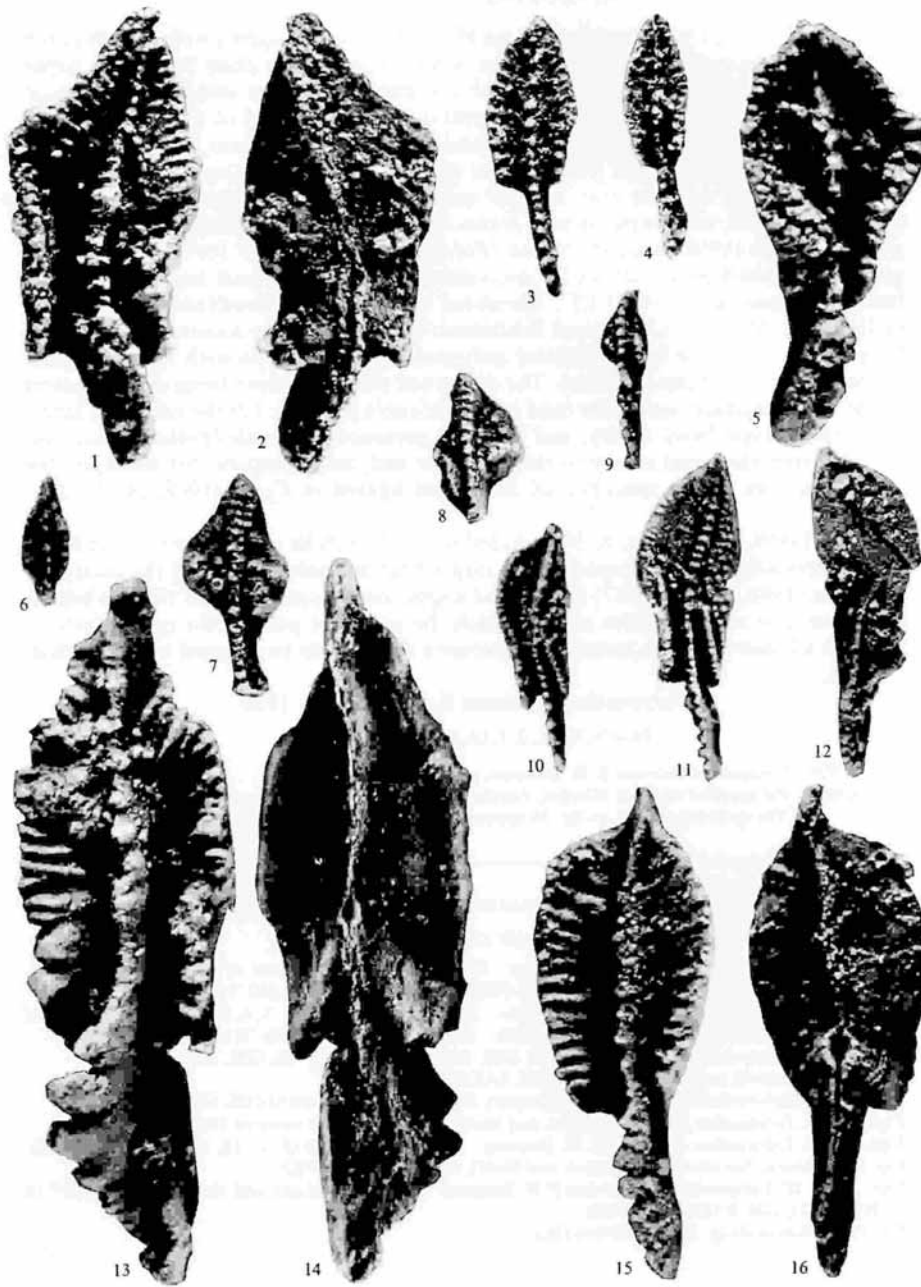
- *1939 *Polygnathus flabella* Branson and Mehl, p. 147, pl. 34, fig. 48.
 non 1939 *Polygnathus flabellum* Branson and Mehl; Cooper, p. 400, pl. 39, figs. 13, 14 (= *P. symmetricus*, *vide* Klapper 1966).
 v?1959 *Polygnathus cf. flabella* Branson and Mehl; Voges, p. 290, pl. 34, figs. 8-11.
 1968 *Polygnathus flabella* (Branson and Mehl 1938); Manzoni, p. 667, pl. 62, fig. 16 only (fig. 17 = ?).
 ?1968 *Polygnathus inornata*; Manzoni, pl. 61, figs. 6, 9.
 ?1968 *Siphonodella cf. sulcata*; Manzoni, pl. 61, fig. 10 only.
 1969 *Polygnathus flabella* Branson and Mehl 1938; Schönlaub, pp. 333-334, pl. 2, fig. 25.
 ?1969 *Siphonodella sulcata* (Huddle 1934); Schönlaub, pl. 2, figs. 16, 17 (figured as an 'adult example'; 'juvenile forms' on figs. 18-20 = ?).

Material. 2 specimens from 2 samples. Figured specimen: GSL SAD27/20.

EXPLANATION OF PLATE 36

Specimens dusted with ammonium chloride. All $\times 30$.

- Figs. 1, 2, 5, 15, 16. *Polygnathus inornatus* E. R. Branson. 1, 2, Oral and aboral views of GSL SAD37/23 (B2 '71). 5, GSL SAD37/20 (B2 '71). 15, 16, Oral and aboral views of GSL SAD37/21 (B2 '71).
 Figs. 3, 4. *Polygnathus symmetricus* E. R. Branson. 3, GSL SAD36/10 (B2). 4, GSL SAD37/19 (B2 '71).
 Fig. 6. *Polygnathus* sp. GSL SAD37/32 (B2 '71).
 Figs. 7, 8. *Gnathodus punctatus* (Cooper). 7, GSL SAD37/1 (B2 '71). 8, GSL SAD37/2 (B2 '71).
 Fig. 9. *Gnathodus* aff. *semiglaber* Bischoff. GSL SAD36/20 (B2).
 Figs. 10-12. *Siphonodella cooperi* Hass. 10, GSL SAD37/3 (B2 '71). 11, 12, Oral and aboral views of GSL SAD36/4 (B2).
 Figs. 13, 14. *Polygnathus longiposticus* Branson and Mehl. Oral and aboral views of GSL SAD37/24 (B2 '71).



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Remarks. The large specimen figured on Pl. 37, figs. 16, 24, agrees well with Branson and Mehl's holotype (which, it might be noted, is figured on plate 34 of their paper along with the conodonts among which it occurred at Branson and Mehl's Danville locality). The posterior end of the platform is better preserved in the present specimen (and seen to be broadly rounded), and the blade is complete. The convex outward lateral margins of the platform are slightly upturned as they converge at the relatively narrow anterior end, but the general appearance of the platform is one of broad flatness, as compared with forms referred to either of the two *P. inornatus* groups. Voges (1959) used the name '*Polygnathus cf. flabella*' for one of the two groups of ribbed polygnathids he encountered in his Sauerland faunas, the other being '*Polygnathus inornata* s.l.'. He noted a superficial resemblance to siphonodellid form. Manzoni (1968) and Schönlaub (1969) were also aware of this resemblance, but appear to have confused polygnathids of this type with siphonodellids of the type of *S. sulcata* (Huddle). The difference should be clear from the characters of the aboral surface: note here (and in Schönlaub's pl. 2, fig. 17) the relatively large, polygnathid-type basal cavity, and also the presence of a well-developed keel extending from the basal cavity to the posterior end, and compare, for example, the aboral features of the specimen of *S. sulcata* figured in Canis (1968, pl. 72, figs. 22, 23).

Voges (1959, pl. 34, figs. 8, 9) included in *P. cf. flabella* one variant which has a pair of specially well-developed radial ridges near the anterior end of the platform. Manzoni (1968, pl. 62, fig. 17) has figured a specimen whose platform ribs are breaking down into runs of nodes and in which the posterior part of the carina fails. It is not at all clear that this interesting specimen deserves to be referred to *P. flabellus*.

Polygnathus inornatus E. R. Branson, 1934

Plate 36, figs. 1, 2, 5, 15, 16; Plate 37, figs. 17, 18

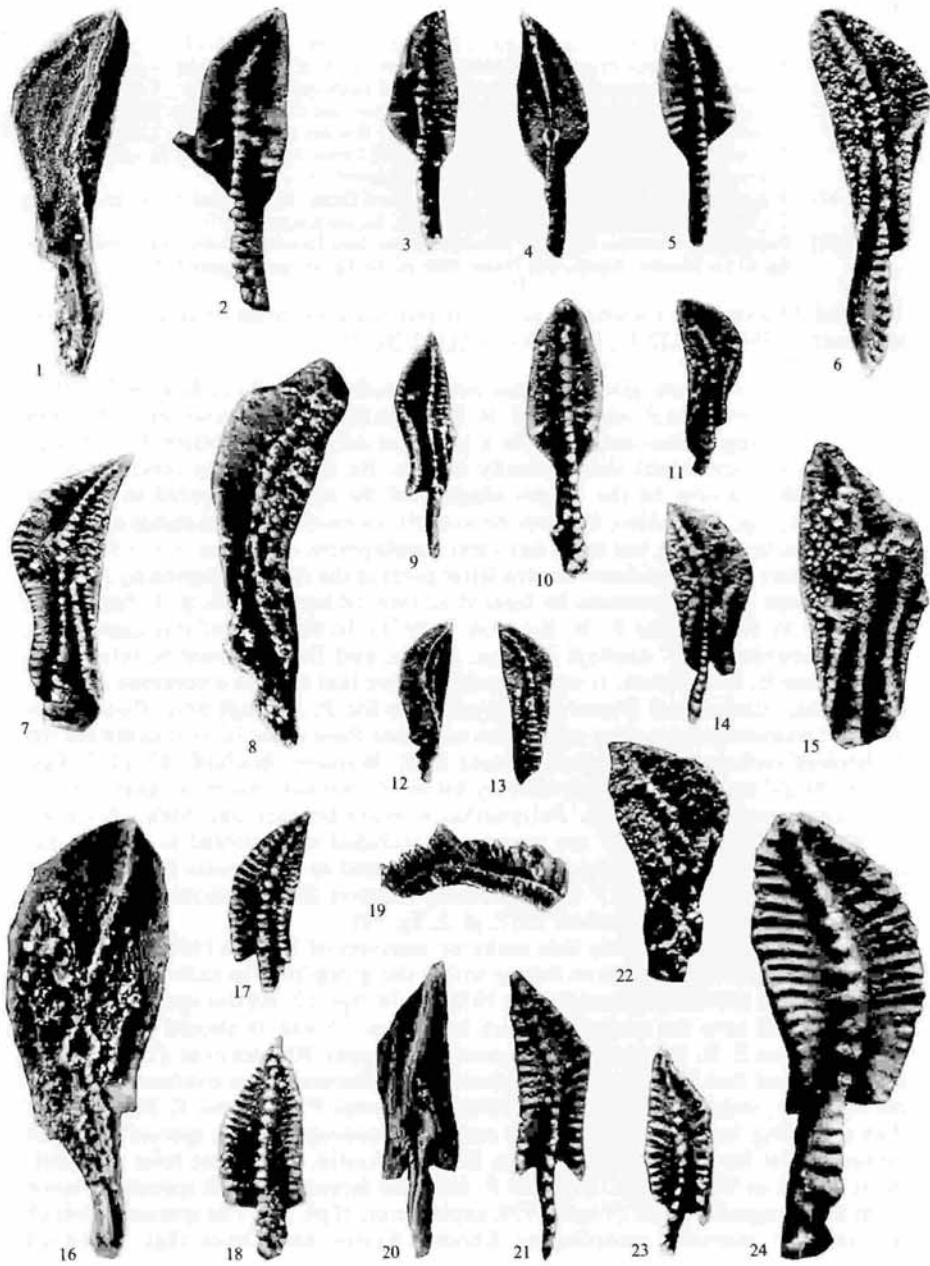
*1934 *Polygnathus inornata* E. R. Branson, p. 309, pl. 25, figs. 8, 26.

v1969 *Polygnathus bischoffi* Rhodes, Austin, and Druce, pp. 184-185, pl. 13, figs. 7a-11c. (N.B.: The specimen shown on fig. 10 appears again on pl. 2, fig. 13 of Rhodes and Austin 1971.)

EXPLANATION OF PLATE 37

Specimens dusted with ammonium chloride. All $\times 30$.

- Figs. 1, 6, 7, 9, 14. *Siphonodella cooperi* Hass. 1, 6, Aboral and oral views of GSL SAD57/6 (WB2). 7, GSL SAD57/3 (WB2). 9, GSL SAD57/4 (WB2). 14, GSL SAD37/6 (B2 '71).
 Figs. 2-5, 10. *Polygnathus communis carina* Hass. 2, GSL SAD24/8 (R4). 3, 4, Oral and aboral views of GSL SAD24/2 (R4). 5, GSL SAD 24/7 (R4). 10, GSL SAD26/21 (R4b '71).
 Figs. 8, 15. *Siphonodella cf. cooperi* Hass. 8, GSL SAD 37/4 (B2 '71). 15, GSL SAD36/5 (B2).
 Fig. 11. *Siphonodella isosticha* (Cooper). GSL SAD37/25 (B2 '71).
 Figs. 12, 13. *Siphonodella cf. S. isosticha* (Cooper). Aboral and oral views of GSL SAD36/3 (B2).
 Figs. 16, 24. *Polygnathus flabellus* Branson and Mehl. Aboral and oral views of GSL SAD27/20 (R6).
 Figs. 17, 18. *Polygnathus inornatus* E. R. Branson. 17, GSL SAD33/6 (F1). 18, GSL SAD27/11 (R6).
 Fig. 19. *Elictognathus laceratus* (Branson and Mehl). GSL SAD57/7 (WB2).
 Figs. 20, 21, 23. *Polygnathus symmetricus* E. R. Branson. 20, 21, Aboral and oral views of GSL SAD57/18 (WB2). 23, GSL SAD57/20 (WB2).
 Fig. 22. *Siphonodella* sp. GSL SAD36/6 (B2).



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- . 1969 *Polygnathus inornatus* E. R. Branson; Rexroad, p. 34, pl. 5, figs. 13-15.
 1969 *Polygnathus lobatus* Branson and Mehl; Rexroad, p. 35, pl. 5, figs. 16-18.
 1971 *Polygnathus inornatus* Branson; Klapper, pp. 6-7 (with synonymy).
 ?1971 *Polygnathus inornatus* E. R. Branson; Austin, Husri, and Conil, pl. 1, figs. 12a, b.
 1971 *Polygnathus lobatus lobatus* Branson and Mehl; Rhodes and Austin, pl. 1, fig. 8. (N.B.:
 The same figure appears in Rhodes, Austin, and Druce 1969, pl. 9, fig. 8a, and has been
 referred to *P. inornatus* E. R. Branson by Klapper 1971.)
 1971 *Polygnathus inornatus vexatus* Rhodes, Austin, and Druce; Rhodes and Austin, pl. 1, fig. 10
 (= Rhodes, Austin, and Druce 1969, pl. 10, fig. 3a, see Klapper 1971).
 1971 *Polygnathus inornatus rostratus* Rhodes, Austin, and Druce; Rhodes and Austin, pl. 1,
 fig. 13 (= Rhodes, Austin, and Druce 1969, pl. 10, fig. 9b, see Klapper 1971).

Material. 35 specimens (of which 4 are 'cf.' determinations) from 10 samples. Figured specimens: GSL SAD27/11, SAD33/6, SAD37/20, 21, 23.

Remarks. The treatment given to these polygnathids here follows Klapper's (1971) paper, which separates *P. inornatus* E. R. Branson from *P. inornatus* sensu Branson and Mehl. Klapper does not yet offer a proposal on the name which *P. inornatus* sensu Branson and Mehl should finally receive. He unfortunately omits to point out what should now be the proper identity of the specimen figured in Klapper (1966, pl. 1, figs. 7, 8). Also, he gives no explicit instruction on the status of a form which has a bent carina but lacks any clear development of a sinus in the posterior margin. There is some guidance on this latter point in the treatment given by Klapper (1971) to one of the specimens he figured in 1966 (Klapper 1966, p. 1, figs. 9, 10, attributed to *P. inornatus* E. R. Branson in 1971). In the light of this example, it seems probable that *P. bischoffi* Rhodes, Austin, and Druce should be referred to *P. inornatus* E. R. Branson. It was remarked above that there is a common element in Rhodes, Austin, and Druce's synonymy lists for *P. bischoffi* and '*Pseudopolygnathus*' *nodomarginatus*. One might also note that these authors' synonymy list for *P. bischoffi* includes '*Polygnathus inornata* E. R. Branson; Bischoff: 42, pl. 2, figs. 17, 18, 20, 21' and that in their synonymy list for *P. inornatus inornatus* Branson and Mehl (*sic*), specimens listed as '*Polygnathus inornata* Branson and Mehl; Bischoff: 42, pl. 2, figs. 17, 18, 20, 21' are specifically excluded and referred to *P. lacinatus lacinatus*. Bischoff's specimens (described and figured as *P. inornata* E. R. Branson 1934) should probably go to *P. inornatus* E. R. Branson. So, too, should his *P. lobata* Branson and Mehl 1934 (Bischoff 1957, pl. 2, fig. 19).

Klapper's (1971) synonymy lists make no mention of Voges's (1959) specimens. Voges, who treated *P. lobata* as falling within the group that he called *P. inornatus* E. R. Branson 1934 s.l., figured (Voges 1959, pl. 34, figs. 12-20) five specimens under this name. All save the specimen shown in his figs. 15 and 16 should probably go to *P. inornatus* E. R. Branson as interpreted by Klapper. Rhodes *et al.* (1969, p. 188) have remarked that 'German workers, describing collections from condensed sequences of strata, included *P. lacinatus* within the species *P. inornatus* E. R. Branson, thus extending both the stratigraphic range and concept of that species'. In their synonymy list for *P. lacinatus lacinatus*, Rhodes, Austin, and Druce refer the specimens shown in Voges's figs. 17-20 to *P. lacinatus lacinatus*. These specimens come from the Hangenbergkalk (Voges 1959, explanation of pl. 34). The specimens which remain in *P. inornatus* according to Rhodes, Austin, and Druce (figs. 12-16 on

Voges's pl. 34) include one (fig. 12) which comes from the Erdbacherkalk equivalent at Borkewehr.

The specimen shown on Pl. 36, figs. 15, 16, is relatively straight, hinting at *P. inornatus* sensu Branson and Mehl, and has an attenuate posterior end, hinting at *P. longiposticus*, but is included here because of the sinus in the posterior part of its outer margin. Müller's (1962a) *Pseudopolygnathus?* cf. *P. triangula* Voges, which Klapper (1966) referred to *P. inornatus*, is comparable in many respects.

Polygnathus longiposticus Branson and Mehl, 1934

Plate 36, figs. 13, 14

- *1934 *Polygnathus longipostica* Branson and Mehl, p. 294, pl. 24, figs. 8-11, 13.
- 1969 *Polygnathus longiposticus* Branson and Mehl; Rexroad, pp. 35-36, pl. 5, figs. 11, 12.
- 1969 *Polygnathus* cf. *P. longiposticus* Branson and Mehl 1934; Druce, pp. 100-101, pl. 21, figs. 4a, b only (fig. 5 = ?).
- ?1969 *Polygnathus toxophorus* Cooper, 1939; Druce, pp. 105-106, pl. 25, figs. 4a, b, 7a-9c.
- 1970 *Polygnathus longiposticus* Branson and Mehl; Thompson and Fellows, pp. 95-96, pl. 4, figs. 4, 16, 19 (with synonymy).
- ?1971 *Pseudopolygnathus longiposticus* Branson and Mehl; Austin, Husri, and Conil, pl. 1, fig. 10 (lateral view only).

Material. 1 specimen, GSL SAD37/24, figured.

Remarks. A particularly large specimen (Pl. 36, figs. 13, 14; length 3.5 mm) has all of the oral characteristics of the species, including the relatively poor development of carinal nodes near mid length (as observed by Klapper 1966). The blade has the character seen in the holotype. On the aboral surface, however, the basal cavity is small. The sample which produced this large conodont (B2 '71) produced also the large specimens of *P. inornatus* E. R. Branson illustrated on Pl. 36. These four conodonts vary in terms of the amount of marginal upturn developed at the anterior end of the platform, of the shape developed at the posterior end, and of the approach to straightness of the carina. However, there is a sense of common character in their ribbing (arranged everywhere at right angles to the margin, and fading toward the carina), and they may be more closely related to one another than the use of two different specific names would suggest. Klapper (1966) has some remarks on forms which mediate between *P. longiposticus* and *P. inornatus* (presumably *P. inornatus* in the sense of Branson and Mehl, since *P. longiposticus* has a relatively straight blade-carina arrangement) and he has observed, too, that *P. longiposticus* itself mediates between *P. inornatus* and *P. symmetricus*. An occurrence of *P. symmetricus* in the B2 fauna is noted below.

Reference has been made above to the question of the generic status of the specimens described as *Pseudopolygnathus* cf. *P. longiposticus* Branson and Mehl by Rhodes, Austin, and Druce. The question of their specific status also arises. They are omitted from the synonymy list here because the writer (S. C. M.) is not satisfied that the specimens figured by Rhodes, Austin, and Druce deserve to be included in this species. They would in most cases seem to have more in common with *P. nodomarginatus*. One specimen (Rhodes *et al.* 1969, pl. 30, fig. 11) resembles the holotype of their *Ps. postinodosus* (Rhodes *et al.* 1969, pl. 6, figs. 6a-c).

Polygnathus symmetricus E. R. Branson, 1934

Plate 36, figs. 3, 4; Plate 37, figs. 20, 21, 23

- *1934 *Polygnathus symmetricus* E. R. Branson, p. 310, pl. 25, fig. 11.
 v. 1969 *Polygnathus lacinatus asymmetricus* Rhodes, Austin, and Druce, pp. 188-189, pl. 11, figs. 1a-3c only (figs. 4a-c = ?).
 1969 *Polygnathus symmetricus* E. R. Branson 1934; Schönlaub, p. 337, pl. 1, fig. 27; pl. 2, fig. 23.
 1969 *Polygnathus anidus* Cooper, 1939; Druce, pp. 91-92, pl. 22, figs. 1a-4c.
 1970 *Polygnathus symmetricus* Branson; Thompson and Fellows, p. 97, pl. 4, figs. 17-18 (with synonymy).
 1970 *Polygnathus symmetricus* E. R. Branson; Austin, Conil, Rhodes, and Streeel, pl. 1, figs. 20a, b, 21a, b.
 ?1971 *Polygnathus* cf. *symmetricus* Branson; Philip and Jackson, pp. 70-71, pl. 5, figs. 17-18.

Material. 10 (1 'cf.') specimens from 6 samples. Figured specimens: GSL SAD36/10, SAD37/19, SAD57/18, 20.

Remarks. Klapper (1966) and Thompson and Fellows (1970) have commented on the similarities this species shows to *P. inornatus* and *P. longiposticus*. Thompson and Fellows's (1970) diagnosis and description mentions that maximum width of this narrow conodont is to be found in the posterior half of the platform. This involves a departure from what is typical of Branson's species. The character of the holotype is well represented by the specimen shown in Klapper (1966, pl. 6, figs. 1, 5). The features specified by Thompson and Fellows are evident in the specimen shown in Klapper (1966, pl. 4, figs. 7, 8). The specimens referred to *P. anidus* by Druce appear to be of this latter type. Rhodes, Austin, and Druce's (1969) *P. lacinatus asymmetricus* has the same character. It seems possible that this relatively slim *P. symmetricus* variant might be simply an immature form (relatively large basal cavity, relatively poorly developed marginal upturn at the anterior end of the platform) of the *P. inornatus* type of polygnathid.

Philip and Jackson (1971), like Bischoff (1957), have suggested that *P. symmetricus* might be represented in the late Devonian.

GENUS PSEUDOPOLYGNATHUS Branson and Mehl, 1934

Remarks. Some attention was given above to the problem of the *Polygnathus-Pseudopolygnathus* distinction. Identification of pseudopolygnathid species also involves problems. Klapper's (1966) procedure is followed here. It is not entirely satisfactory in that it depends to some extent on the width of the basal cavity relative to that of the platform, a ratio which may vary during ontogeny. His procedure is nevertheless clearly preferable to that of Rhodes *et al.* (1969), which relies heavily on numbers of nodes and ridges, and which, as Ziegler (1971a) has observed, attempts too many and too fine distinctions. A number of internal inconsistencies can be discovered in Rhodes, Austin, and Druce's treatment of the pseudopolygnathid species, and could serve to illustrate the essential impracticability of their proposals. Given the present state of pseudopolygnathid systematics, and the low numbers of specimens available as a basis for judgement here, it seems best to make only a brief record of the species found, with no suggestions on synonymies.

Pseudopolygnathus dentilineatus E. R. Branson, 1934

Plate 38, figs. 14, 15

Material. 15 specimens from 6 samples. Figured specimen: GSL SAD34/5.*Remarks.* The species has an Upper Devonian range (recent information in Ziegler 1971b and Klapper *et al.* 1971), and possibly continues as high as the *anchoralis*-Zone (Ziegler 1963). In the Cork Beds faunas the highest occurrence appears to be in F1; but many of these relatively high records may involve immature representatives of other species of the genus.*Pseudopolygnathus multistriatus* Mehl and Thomas, 1947

Plate 38, figs. 12, 13, 16-18, 20

Material. 7 specimens (2 'cf.') from 6 samples. Figured specimens: GSL SAD3/11, SAD36/9, SAD37/8; 'cf.' specimens figured SAD27/5, SAD36/18.*Remarks.* Specimens of *Ps. multistriatus* have relatively small basal cavities. All save one of the conodonts referred to this species here have ribs which maintain their character toward the carina. The exception is the individual figured on Pl. 38, figs. 16-18. This has marginal nodes which are in many cases linked to the carina by low fine ridges. It also has a relatively narrow, more elongate, basal cavity. It resembles in some respects *Ps. lanceolata* Hass, a species which most authors place in synonymy with *Ps. multistriatus*.*Pseudopolygnathus primus* Branson and Mehl, 1934

Plate 38, figs. 5, 6, 21-23

Material. 2 specimens from 2 samples. Figured specimens: GSL SAD33/12, SAD44/20.*Remarks.* Specimens referred to *Ps. primus* here have a less wide basal cavity than is found in *Ps. dentilineatus* and have ridges rather than marginal nodes on the upper surface. *Ps. multistriatus* also has ridges, but has a smaller basal cavity again. The specimen figured on Pl. 38, figs. 5, 6, has a relatively small basal cavity, but is referred to *Ps. primus* because of its relatively broad platform. None of the Cork Beds pseudopolygnathids show any hint of a transition to *Ps. triangulus*.

Genus SIPHONODELLA Branson and Mehl, 1944

Remarks. Klapper's (1971) proposals on the systematics of this genus are accepted here.*Siphonodella cooperi* Hass, 1959

Plate 36, figs. 10-12; Plate 37, figs. 1, 6, 7, 9, 11, 14

*1959 *Siphonodella cooperi* Hass, pp. 392-393, pl. 48, figs. 35, 36.1971 *Siphonodella cooperi* Hass; Klapper, p. 10, pl. 1, figs. 13-15, 21; pl. 2, figs. 1-3 (with synonymy).

Material. 26 specimens (2 'cf.') from 3 samples. Figured specimens: GSL SAD36/4, SAD37/3, 6, SAD57/3, 4, 6; 'cf.' specimens figured: SAD36/5, SAD37/4.

Siphonodella isosticha (Cooper, 1939)

Plate 37, fig. 11

- *1939 *Siphonognathus isosticha* Cooper, p. 409, pl. 41, figs. 9, 10 (refigured in Klapper 1971, pl. 1, fig. 16).
- v1971 *Siphonodella isosticha* (Cooper); Rhodes and Austin, pl. 1, fig. 6 (= pl. 12, figs. 11a, b of Rhodes, Austin, and Druce 1969).
- 1971 *Siphonodella isosticha* (Cooper); Klapper, p. 10, pl. 1, fig. 16 (with synonymy).

Material. 11 specimens from 3 samples. Figured specimen: GSL SAD37/25.

Siphonodella cf. *S. isosticha* (Cooper)

Plate 37, figs. 12, 13

- 1971 *Siphonodella* cf. *S. isosticha* (Cooper); Klapper, p. 12, pl. 1, figs. 17-20 (with synonymy).

Material. 2 specimens from 1 sample. Figured specimen: GSL SAD36/3.

Remarks. Klapper (1971) applies this name to certain specimens which would formerly have been referred to *S. isosticha*. Their longer outer rostral ridge terminates on the platform rather than at its outer margin.

Siphonodella obsoleta Hass, 1959

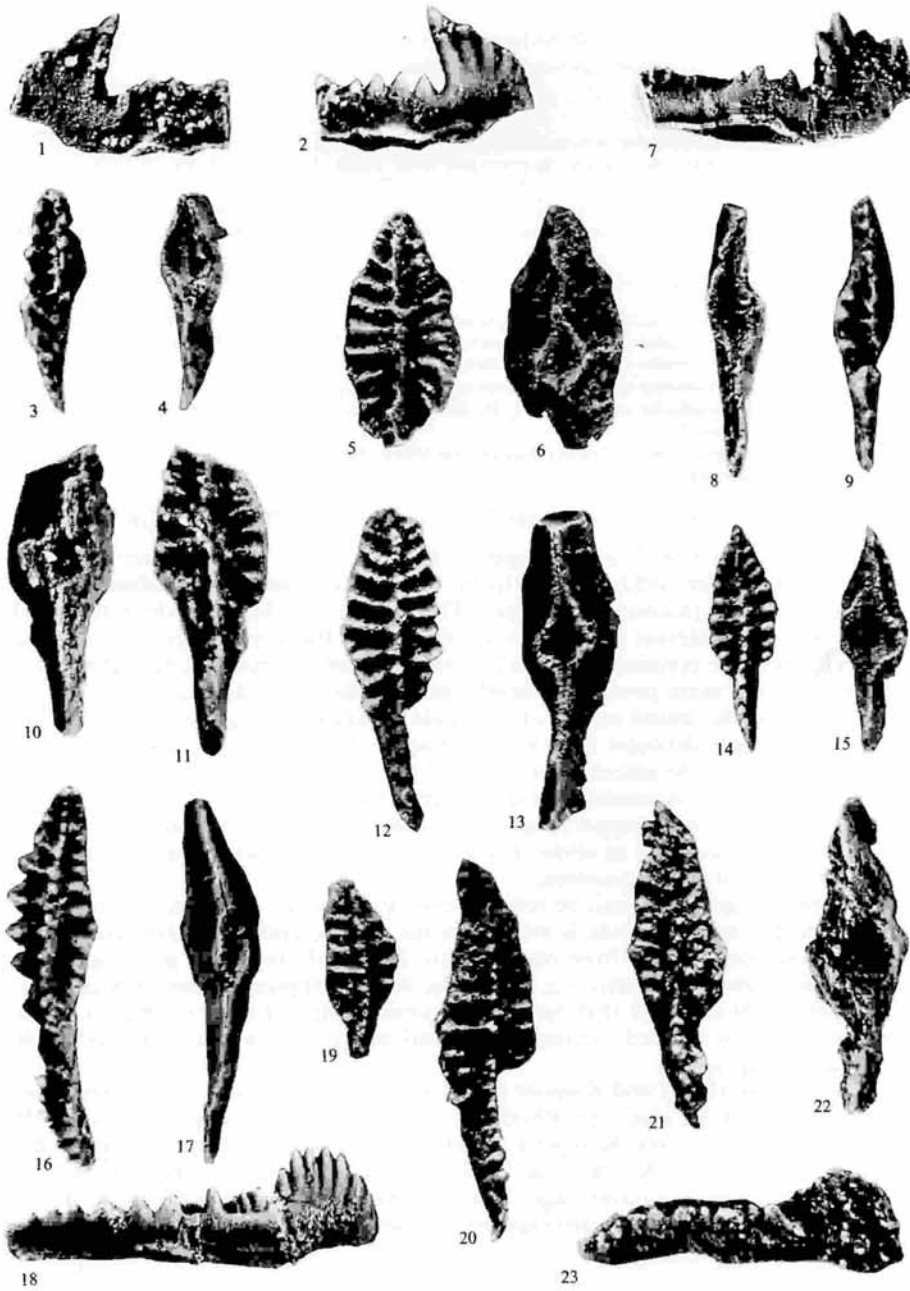
- *1959 *Siphonodella obsoleta* Hass, pp. 392-393, pl. 47, figs. 1, 2.
- v1969 *Siphonodella obsoleta* Hass 1959; Matthews (1969a), pp. 273-274, pl. 46, fig. 1.
- 1971 *Siphonodella obsoleta* Hass; Klapper, p. 12, pl. 1, fig. 25 (with synonymy).
- v1972 *Siphonodella obsoleta* Hass 1959; Matthews, Sadler, and Selwood, p. 565, pl. 111, figs. 4, 5.

Material. 6 specimens from 3 samples.

EXPLANATION OF PLATE 38

Specimens dusted with ammonium chloride. All $\times 30$.

- Figs. 1-4, 7-9. *Spathognathodus aculeatus*-*Clydagnathus* transition. 1-4, Left and right lateral, oral, and aboral views of GSL SAD46/12 (BBH). 7-9, Right lateral, aboral, and oral views of GSL SAD43/22 (B8).
- Figs. 5, 6, 21-23. *Pseudopolygnathus primus* Branson and Mehl. 5, 6, Oral and aboral views of GSL SAD33/12 (F1). 21-23, Oral, aboral, and right lateral views of GSL SAD44/20 (B9).
- Figs. 10, 11, 19. *Pseudopolygnathus* cf. *multistriatus* Mehl and Thomas. 10, 11, Aboral and oral views of GSL SAD36/18 (B2). 19, GSL SAD27/5 (R6).
- Figs. 12, 13, 16-18, 20. *Pseudopolygnathus multistriatus* Mehl and Thomas. 12, 13, Oral and aboral views of GSL SAD33/11 (F1). 16-18, Oral, aboral, and right lateral views of GSL SAD37/8 (B2 '71). 20, GSL SAD36/19 (B2).
- Figs. 14, 15. *Pseudopolygnathus dentilineatus* E. R. Branson. Oral and aboral views of GSL SAD34/5 (F2 '71).



MATTHEWS and NAYLOR, Carboniferous conodonts

Genus SPATHOGNATHODUS Branson and Mehl, 1941
Spathognathodus aculeatus (Branson and Mehl, 1934)

Plate 35, figs. 3-9

- *1934 *Spathodus aculeatus* Branson and Mehl, pp. 186-187, pl. 17, figs. 11, 14.
- 1962 *Spathognathodus aculeatus* Branson and Mehl; Ziegler 1962, pp. 105-106, pl. 13, figs. 27-36 (with synonymy).
- 1962 *Spathodus* (*Bispathodus*) *aculeatus* (Branson and Mehl); Müller (1962a), p. 114.
- 1966 *Spathognathodus aculeatus* (Branson and Mehl) 1934; Klapper, p. 24, pl. 6, figs. 16-17 (with further synonymy).
- v. 1969 *Spathognathodus tridentatus* (E. R. Branson); Rhodes, Austin, and Druce, p. 237, pl. 3, figs. 9a-12c.
- 1969 *Spathognathodus* cf. *S. aculeatus* (Branson and Mehl 1934); Druce, p. 124, pl. 27, figs. 5a-c.
- ?1969 *Spathognathodus cyrius nodus* n. subsp., Druce, pp. 129-130, pl. 28, figs. 6a-c, text-fig. 27.
- . 1969 *Spathognathodus sculderus* n. sp., Druce, p. 135, pl. 43, figs. 1a-5.
- 1969 *Spathognathodus aculeatus* (Branson and Mehl 1934); Schönlaub, p. 347, pl. 3, fig. 17.
- 1970 *Spathognathodus tridentatus* (E. R. Branson); Conil, Austin, Rhodes, and Streeel, pl. 1, figs. 3, 6a, b.
- 1971 *Spathognathodus aculeatus* (Branson and Mehl); Philip and Jackson, pp. 72-73, figs. 12, 20 (with recent synonymy).

Material. 5 specimens from 1 sample. Figured specimens: GSL SAD47/6, 8, 13.

Remarks. Ziegler (1962) and Klapper (1966) have given detailed descriptions of this species. Ziegler (1962) referred to the presence of one to three, often four, or rarely five lateral (accessory) denticles. They arise from the area where the basal cavity has its maximum lateral extent, often reach the same height as the blade denticles and are occasionally bound to these by weak ridges. At all ontogenetic stages they are more powerfully developed than the blade denticles. Ziegler also observed that the crestal profile of the blade becomes lower posteriorly, and that the highest blade denticles arise either abruptly or gradually out of the series of blade denticles in the anteriormost parts of the conodont. Klapper's (1966) treatment of the species is consistent with Ziegler's (1962) in most essentials, but points out that most of his (Klapper's) specimens have three to five lateral denticles and some may have as many as seven. The series of lateral denticles in no case reaches the posterior end of the conodont.

The present specimens can be referred confidently to *Sp. aculeatus*. The variable profile of the anterior blade is evident in the figures, and the number of lateral denticles is found to vary from one to seven. The basal cavity is in some cases (i.e. in relatively small specimens, e.g. Pl. 35, fig. 4) long-elliptical rather than circular. Klapper (1966) observed that *Sp. anteposicornis* Scott is a case in which a single lateral denticle is situated anterior to the basal cavity. Such a specimen is available here (Pl. 35, fig. 4).

Both Ziegler (1962) and Klapper (1966) regard *Sp. tridentatus* (E. R. Branson) as a synonym of *Sp. aculeatus*. Rhodes *et al.* (1969) appear to have taken too little account of Ziegler's and Klapper's opinions on this matter. Their synonymy list for *Sp. tridentatus* (see Rhodes *et al.* 1969, p. 237) contains no entry dated later than 1961. Their suggestion (same page) that *Sp. aculeatus* has a more expanded (laterally) basal cavity than *Sp. tridentatus* does not seem to be borne out by the evidence

of their own and others' published figures. Philip and Jackson (1971) have already pointed out that there was no basis for Rhodes, Austin, and Druce's (1969, p. 236) querying of Ziegler's (1961) (*sic*) and other authors' identifications of German examples of *Sp. aculeatus*.

Rhodes *et al.* (1969) have proposed a species, *Sp. plumulus*, which is characterized by a plume-like blade, whose crestal profile descends rapidly from maximum height seen in the posteriormost denticle of the series. In other respects it bears comparison with *Sp. aculeatus* (whose variable blade profile was mentioned by Ziegler 1962—see above) although Rhodes *et al.* (1969) specify that the lateral nodes are developed on the outer side only, whereas Ziegler (1962) noted that the lateral denticles of *Sp. aculeatus* may appear on either the inner or the outer side. The present material, like Klapper's of 1966, shows inner side development only. The holotype of *Sp. plumulus plumulus* has denticles on its inner side (Rhodes *et al.* 1969, pl. 1, fig. 1*b*) and thus fails to match the terms of Rhodes, Austin, and Druce's diagnosis of the species. Rhodes, Austin, and Druce also proposed the subspecies *Sp. plumulus nodosus*, which has one or more nodes developed on the inner side. Two specimens in the present collection resemble the forms Rhodes, Austin, and Druce attributed to *Sp. plumulus*. In view of the confused state of the definition of that species, and in view of the fact that one of the specimens here (Pl. 38, figs. 7–9) does not exactly match the form of the blade specified for *Sp. plumulus* (the holotype of *Sp. plumulus nodosus* may also fail to do this) the two are figured as *Sp. aculeatus*–*Clydagnathus* transitions. One (Pl. 38, figs. 7–9) shows continuity from the blade into the relatively short run of accessory denticles. The other (Pl. 38, figs. 1–4) has a more plumose blade and appears to make a closer approach to *Clydagnathus*. Again, the blade runs into the series of accessory denticles, which are more numerous here, and which are each bound to the relatively featureless carina by a low ridge. The inner side (i.e. left side as seen in oral view, posterior end down) has a single peg-like denticle. Druce (1969, pl. 30, figs. 1*a*–2*c*: *Spathognathodus* cf. *S. plumulus*) has figured a specimen which bears some resemblance to the two discussed here. Beinert *et al.* (1971) have described *Clydagnathus? ormistoni* from the Upper Devonian, and remark that the generic assignment is tentative because of the lack of a complete lineage linking their conodont to early Carboniferous clydagnathids.

The majority of recorded occurrences of *Sp. aculeatus* are from the Upper Devonian. Lower Carboniferous records can be found in Sandberg and Klapper (1967) and in Canis (1968).

Spathognathodus crassidentatus (Branson and Mehl 1934)

- *1934 *Spathodus crassidentatus* Branson and Mehl, p. 276, pl. 22, fig. 17.
- 1966 *Spathognathodus crassidentatus* (Branson and Mehl), 1934; Klapper, p. 23, pl. 5, figs. 15–17 (with synonymy).
- ?1969 *Spathognathodus crassidentatus* (Branson and Mehl); Rhodes, Austin, and Druce, pp. 227–228, pl. 3, figs. 1–4 (fig. 2*a* repeated in 1971).
- 1969 *Spathognathodus crassidentatus* (Branson and Mehl, 1934); Druce, pp. 127–128, pl. 27, figs. 2*a*–3*b*.
- 1969 *Spathognathodus crassidentatus* (Branson and Mehl); Rexroad, p. 46, pls. 6, 7, 8.
- 1970 *Spathognathodus crassidentatus* (Branson and Mehl); Thompson and Fellows, pp. 111–112, pl. 7, figs. 8, 14.

- 1970 *Spathognathodus crassidentatus* (Branson and Mehl); Austin, Conil, Rhodes, and Streeb, pl. 1, fig. 4.
 1971 *Spathognathodus crassidentatus* (Branson and Mehl); Philip and Jackson, p. 73, pl. 6, fig. 1.

Material. 1 specimen.

Remarks. Klapper's (1966) revision of the species restricts *Sp. crassidentatus* to forms which have two distinctly well-developed anterior denticles. Rhodes, Austin, and Druce's (1969) representatives of this species would, therefore, not match entirely the specifications given by Klapper. Philip and Jackson (1971) have observed that their own specimens agree with paucidentate forms of *Sp. crassidentatus* rather than with forms of the kind illustrated by Rhodes *et al.* (see further remarks under *Sp. stabilis*, below).

Spathognathodus sp. indet.

Plate 35, figs. 18-20

Material. 4 specimens from 4 samples. Figured specimen: GSL SAD26/11.

Spathognathodus stabilis (Branson and Mehl, 1934)

Plate 35, figs. 1, 10, 21, 27

- *1934 *Spathodus stabilis* Branson and Mehl, pp. 188-189, pl. 17, fig. 20.
 1962 *Spathognathodus stabilis* (Branson and Mehl); Ziegler, pp. 112-114, pl. 13, figs. 1-10 (with synonymy).
 1966 *Spathognathodus stabilis* (Branson and Mehl); Klapper, p. 23, pl. 5, figs. 6, 7 (with further synonymy).
 ?1968 *Spathognathodus* cf. *S. stabilis* (Branson and Mehl, 1934); Straka, pp. 49-50, pl. 6, fig. 3.
 1968 *Spathognathodus macer* (Branson and Mehl); Canis, p. 553, pl. 74, fig. 32.
 1968 *Spathognathodus stabilis* (Branson and Mehl, 1934); Schulze, p. 228, pl. 20, fig. 19.
 ?1969 *Spathognathodus stabilis* (Branson and Mehl); Anderson, p. 925, pl. 109, figs. 2, 5, 8, 19.
 1969 *Spathognathodus macer* (Branson and Mehl); Rexroad, pp. 47-48, pl. 6, figs. 9-11.
 v. 1969 *Spathognathodus coaptus* (Branson and Mehl); Rhodes, Austin, and Druce, pp. 224-225, pl. 7, figs. 9a-11c.
 v. 1969 *Spathognathodus elongatus* (Branson and Mehl); Rhodes, Austin, and Druce, pp. 228-229, pl. 7, figs. 1a-5b.
 v. 1969 *Spathognathodus pulcher* (Branson and Mehl); Rhodes, Austin, and Druce, p. 231, pl. 4, figs. 9a-11c.
 v. 1969 *Spathognathodus* cf. *cyrius* (Cooper); Rhodes, Austin, and Druce, pp. 234-235, pl. 7, figs. 12a-14c.
 . 1969 *Spathognathodus cyrius cyrius* (Cooper, 1939); Druce, p. 129, pl. 28, figs. 4a-5c.
 . 1969 *Spathognathodus quintidentatus* Thomas, 1949; Druce, p. 132, pl. 31, figs. 2a, b.
 1969 *Spathognathodus stabilis* (Branson and Mehl, 1934); Druce, p. 136, pl. 31, figs. 6a, b.
 1969 *Spathognathodus stabilis* (Branson and Mehl, 1934); Schönlaub, p. 349, pl. 3, figs. 14, 15.
 1970 *Spathognathodus stabilis* (Branson and Mehl); Thompson and Fellows, p. 113, pl. 4, figs. 1-3.
 v. 1972 *Spathognathodus* cf. *stabilis* (Branson and Mehl); Matthews, Sadler, and Selwood, pp. 565-566, pl. 109, fig. 11.

Material. 22 specimens from 6 samples. Figured specimens: GSL SAD22/4, SAD24/4, SAD43/20, SAD47/2.

Remarks. Rhodes *et al.* (1969) and Druce (1969) failed to take note of Klapper's (1966) revision of *Sp. crassidentatus*. One consequence of Klapper's proposal is

that many forms earlier attributed to *Sp. crassidentatus* are now switched to *Sp. stabilis*. Klapper's (1966) synonymy list for *Sp. stabilis* includes species—*Sp. elongatus*, *Sp. pulcher*—which Rhodes *et al.* (1969) continued to treat as having independent standing. *Sp. cf. cyrius*, which Rhodes *et al.* (1969) regarded as distinct from *Sp. crassidentatus* because of the large number of its denticles, would not be excluded for that reason from *Sp. stabilis*. Rhodes, Austin, and Druce's synonymy lists for *Sp. crassidentatus* and *Sp. coaptus* have numerous items in common, which becomes reasonable if they are regarded as close to (their *Sp. crassidentatus*—see remarks above) or synonymous with (their *Sp. coaptus*) *Sp. stabilis*.

Ziegler (1962) has supplied a detailed description of *Sp. stabilis*. The species ranges from the Upper Devonian into the Lower Carboniferous (as high as the *anchoralis*-Zone) and it has been regarded as the root from which protognathoid form was derived (Ziegler 1969; Collinson *et al.* 1971).

Canis (1968) and Thompson and Fellows (1970) propose that the name *Sp. stabilis* be reserved for forms whose basal cavity extends to the posterior end. They would refer forms whose basal cavity is confined to the middle third of the conodont to *Sp. macer*. Thompson and Fellows's figures (cf. their pl. 4, fig. 3, with their pl. 4, fig. 7) do not seem to justify this view.

Spathognathus cf. costatus (E. R. Branson, 1934)

Material. 3 specimens from 3 samples.

Remarks. These conodonts are identified here in keeping with Voges's (1959) practice. Ziegler (1971a) has emphatically rejected Rhodes, Austin, and Druce's (1969) view of such forms.

Acknowledgements. During the initial stages of this work, Naylor held a Post-doctoral Research Fellowship at the University of Birmingham. That financial support is gratefully acknowledged. Thanks are due to several individuals: to P. C. Jones and E. B. Selwood, who contributed material for study; to Jones and T. P. Reilly, who discussed some aspects of the results with Naylor; to M. Butler, who discussed the conodonts with Matthews; and to M. Mitchell for his comments on the two brachiopods. Thanks are due also to E. W. Seavill, who did the photographic work included in the paper.

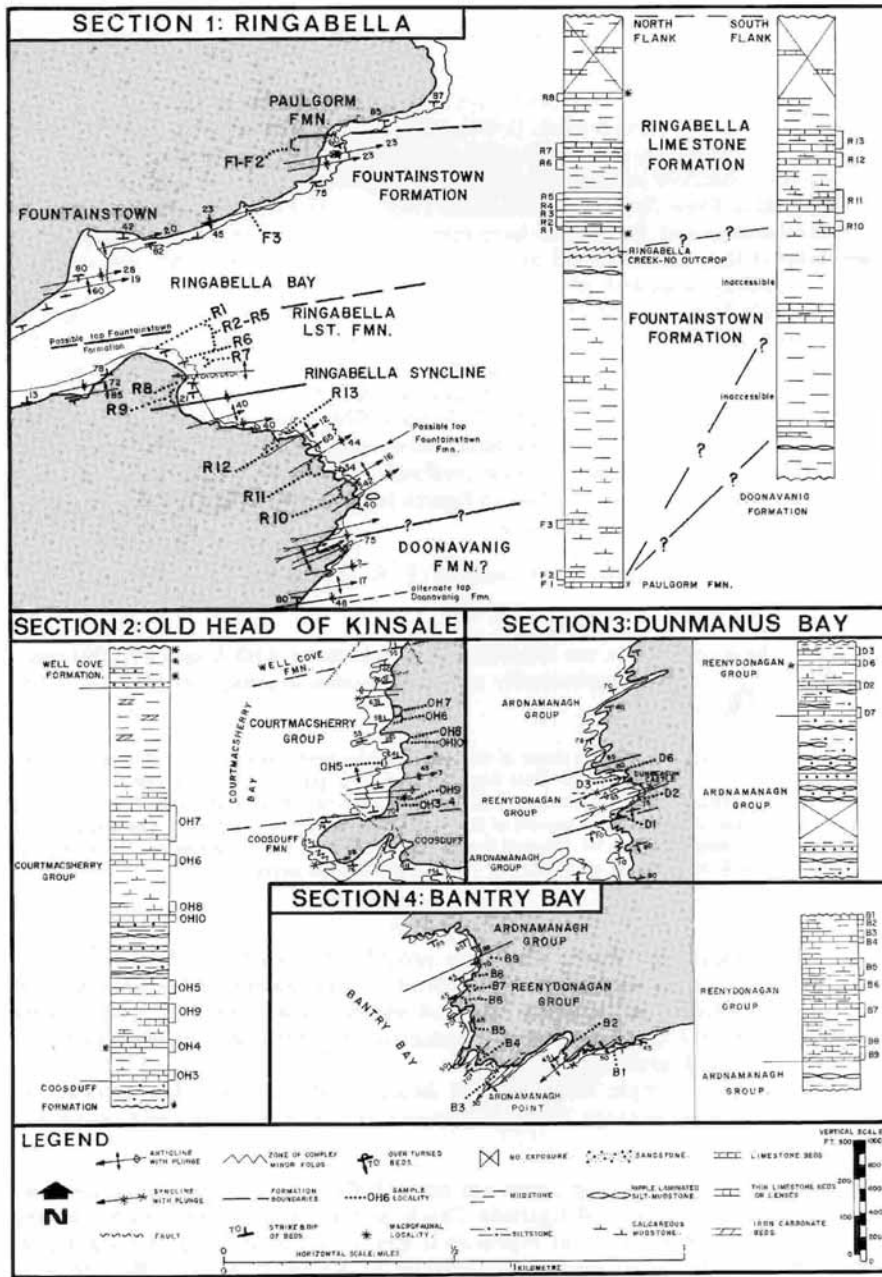
APPENDIX

The Courtmacsherry Group, which has provided the majority of the conodonts described here, consists typically of calcareous or non-calcareous mudstones interbedded with crinoid-rich limestone beds and lenses. Initial conodont samples were bulked from several limestone lenses. Productive or otherwise interesting horizons were resampled with greater precision.

Text-fig. 5 gives sample locations and details of the stratigraphic sequence in each of the four main sections. The main sections may be briefly described as follows:

Ringabella Syncline

The Courtmacsherry Group crops out on each flank of the Ringabella Syncline. Exposure is interrupted at Ringabella Creek and Fountainstown beach. On the south limb of the major syncline exposure is almost continuous, but the lower part of the succession is almost inaccessible because of the height of the cliffs. The base



TEXT-FIG. 5. Location of sampling-points in the four major sections studied.

of the Courtmacsherry Group (Fountainstown Formation plus Ringabella Limestone Formation) has been taken at a siliceous limestone bed with corals (Naylor *et al.* 1969) and this interpretation of the boundary is used in text-fig. 5. More recent examination of the high cliff section southward from this marker has revealed a further limestone (at the southern limit of the map in text-fig. 5) and the base of the group should probably be taken at this lower limestone. The laminated calcareous mudstones immediately to the north strongly resemble those attributed to the Fountainstown Formation on the north limb of the fold and are probably their equivalent. The possibility of a representation of the Fountainstown Formation on this south flank of the fold was not recognized in Naylor *et al.* (1969). The laminated beds are overlain by a sequence of calcareous and non-calcareous mudstones which include beds and lenses of crinoidal debris. A sequence of irregularly bedded limestones (R12 and R13) to the south of the synclinal axis is very similar to the limestones at Ringabella Point to the north. The highest beds seen are calcareous grey mudstones.

The succession on the north limb of the Ringabella Syncline has been described by Naylor (1969). The Fountainstown Formation as defined in that paper is 840 ft (approximately 250 m) thick. The well-exposed upper bedding plane of a bioclastic limestone with rolled fossils and phosphatic pebbles was taken to define the base of the formation. This limestone has corals of Tournaisian aspect and is the site of sample F1. The Fountainstown Formation consists of calcareous and non-calcareous mudstone with a delicate lamination. Near the base there is some crinoid debris (F2). Naylor (1969) referred the formation to the Kinsale Group, but because of the calcareous material present it would be more reasonable to regard it as the lowest formation of the Courtmacsherry Group. Ringabella Creek obscures the Fountainstown Formation-Ringabella Limestone Formation contact. The covered stratigraphic interval may be only a small one because of the amount of repetition produced by small folds hereabouts. The Ringabella Limestone Formation is excellently exposed on Ringabella Point, where some 350 ft of beds are seen. Dark grey, non-calcareous pyritic mudstones at the base of the sequence have goniatites (including some which Dr. W. H. C. Ramsbottom proposes to refer to a new species of the genus *Kazakhstania*, and which he will describe elsewhere). The succession above has calcareous and non-calcareous mudstones, with inter-bedded bioclastic limestones which contribute approximately 40% of the total thickness. Many of the limestones (R1 to R8 are representative samples) contain simple corals and black phosphatic pebbles. Their bases cut down into the sediment below. Limestones become less abundant in the upper part of the exposed section. R9 was bulked from lenses poorly exposed on the north flank of the syncline. The sample ranges through much of the succession from R8 up toward the presumed position of the main synclinal axis.

Text-fig. 5 shows different thicknesses on the north and south limbs of the Ringabella Syncline. Three considerations to be borne in mind are:

1. The base of the Courtmacsherry Group should perhaps be placed rather lower in the southern sequence, as mentioned above.
2. Complex folding makes it difficult to effect exact correlation.

3. Exposure is poor in the axial zone of the Ringabella Syncline and the position of the main synclinal axis itself is not precisely known.

Old Head of Kinsale (west side)

The type-locality of the Courtmacsherry Group (1116 ft—approximately 330 m—thick: Naylor 1966) is here. There are many minor folds and faults in the section on the west side of the headland, and these make it difficult to estimate thickness. The upper part of the sequence is especially affected by these difficulties. A number of units can be recognized in the Courtmacsherry Group. They are, in upward sequence:

Unit 1. 273 ft thick. The abrupt entry of calcareous beds clearly identifies the base of the group on the north side of Ringalursky Point. Crinoidal debris in beds and lenses is inserted into a calcareous and non-calcareous grey nodular mudstone succession. Samples OH3–OH5 were collected from this unit.

Unit 2. 118 ft thick. A non-calcareous unit consisting of siltstones with fine sand cross laminae and rare thin shale-flake breccias.

Unit 3. 385 ft thick. Interbedded calcareous and non-calcareous mudstones with fewer thick limestone beds than in Unit 1, although parallel-sided and lensing laminae of crinoidal debris are still available.

Unit 4. 340 ft thick. Dark-grey mudstones containing rhombs of ferroan dolomite form the uppermost part of the group. The iron carbonate in places forms 20% of the rock. It occurs as rhombs in the groundmass or as occasional large concretions but never as discrete beds. The top of the Courtmacsherry Group is taken at the base of an unusual 7-ft-thick fine sandstone.

The overlying Lispatrick Mudstone Group contains a P-Zone lamellibranch-goniatite fauna near its base. Pyritic black mudstones are interbedded with evenly bedded fine sandstone and ferroan dolomite beds. There is also an intercalation of crinoidal limestones. These have been sampled, but no conodonts have been obtained.

It is difficult to associate the units of the Old Head succession with any in the Ringabella succession. The Old Head sequence has nothing that compares with the parallel-laminated, partly calcareous Fountainstown succession. F1, according to the conodont faunas, might be an equivalent of OH4, but fuller evidence is desirable before reaching any firm conclusion. On the other hand, it is already clear that the faunas of Unit 1 at the Old Head (see OH4) are older than those of the Ringabella Limestone Formation (see R2 to R4).

Dunmanus Bay (Dunbeacon Castle)

The samples from this sequence have produced only a single conodont. It may be useful to provide for any resampling (for conodonts or any other fossils) by making a record here of the character of the stratigraphy. Over 200–250 ft (60–75 m) of beds are available in the tightly folded axial part of the Dunmanus Bay Syncline. On each flank of the fold there are four units to be recognized:

Unit 1. 80–90 ft thick. Limestone beds and lenses usually 1–2 ft thick, interbedded with cleaved non-calcareous or slightly calcareous mudstones. The base of the unit is taken at the first bed of limestone (9 in thick) in the sequence. The underlying beds

of the Kinsale Group are massive ripple-banded non-calcareous siltstones with common horizontal burrows. Unit 1 becomes more calcareous upwards, with perhaps 30% of the sequence in the middle of the unit consisting of thin brown decalcified limestone beds and lenses, whilst the uppermost 8 ft are decalcified limestone.

Unit 2. 30 ft (may be 45 ft on north flank). Dark-grey brittle cleaved mudstones, rarely nodular. The uppermost 10 ft of this unit contains very thin (less than 3 in) bands and lenses of brown carbonate.

Unit 3. Approximately 35 ft. Non-calcareous and calcareous brittle grey mudstones with interbeds (40%) of evenly bedded brown decalcified limestones and possibly ferroan dolomite. Thin, grey carbonate stringers are also present. Sections through isolate corals are sometimes seen on joint surfaces. The uppermost bed of the unit is a 1-ft-thick bed of ferroan carbonate.

Unit 4. ?50 ft, top not seen. The grey non-calcareous mudstones of the previous unit grade upwards into the pyritic, black, highly organic massive mudstones of Unit 4. Concretions and bands of pyrite are common throughout and occasional large non-calcareous bullions also occur.

The Dunmanus sequence is less calcareous than at Bantry. P. C. Jones (pers. comm. and paper in preparation) recognizes four units similar to these discussed above in the Reenydonagan Group of the Bantry Syncline. The calcareous basal beds of this group at Ardnamanagh Point on the north flank of the Bantry Syncline, described below, constitute the lowest member of Jones's sequence. Whether they are equivalent to Unit 1, or Units 1 to 3 of the Dunmanus sequence is not yet known. However, the Ardnamanagh Beds are lithologically similar to Unit 1 at Dunmanus and the latter may be an attenuated and less calcareous equivalent. Certainly, no pyritic shales (Unit 4) occur at Ardnamanagh Point itself, although they are known in the core of the Bantry Syncline (Coe and Selwood 1968; P. C. Jones, pers. comm.).

Bantry Bay (Ardnamanagh Point)

The stratigraphy of the Cork Beds on the north flank of the Bantry Bay Syncline has been outlined by Naylor *et al.* (1969). Calcareous strata of the Reenydonagan Group are well exposed on Ardnamanagh Point (text-fig. 5). A coastal section, with complex folding and faulting, at the head of the bay in the neighbourhood of Reenydonagan Point exposes higher beds of the group (text-fig. 1). Since these will be described by P. C. Jones (in preparation), no attempt has been made to sample or map from this portion of the coastline. The thickness of the Reenydonagan Group shown in text-fig. 4 for the Bantry section is based on work by P. C. Jones and is included with his kind permission.

The base of the Reenydonagan Group in the Ardnamanagh section is clearly defined. Ripple-laminated non-calcareous siltstones on Ardnamanagh beach are abruptly succeeded southwards (up sequence) by crinoidal limestones set in calcareous and non-calcareous mudstones. The limestones (2 in to 1 ft thick) increase in number upwards and constitute up to 20% of the sequence. Channelled bases can be seen on some beds. For the remainder of the Ardnamanagh section non-calcareous medium-grey mudstone is dominant and contains variable amounts of

limestone. Light-grey limestone occurs as thin lenses of comminuted crinoid debris, in thin (1-ft) beds or occasionally as massive beds (more than 50% of the succession in places). There is severe folding on Ardnamanagh Point itself and correlation through these folds is difficult. The stratigraphic thickness shown on the section (text-fig. 5) should be regarded as a maximum figure: the upper part of the section may be too expanded. However, the Ardnamanagh sequence is strikingly calcareous and quite unlike any underlying part of the Cork Beds. The limestones are characteristically of variable thickness and often exhibit downcutting relationships at their bases and some internal cross bedding.

Text-fig. 5 shows all horizons sampled in the four major sections. These should be put on record in order to provide for any resampling or for any attempt to integrate, say, palynological studies with this conodont work. Only the productive samples are treated in the faunal lists that follow.

Faunal lists

- R1 *Gnathodus delicatus* (1), *G. delicatus* juv.? (1), *Polygnathus communis communis* (8). Total 10. GSL SAD21.
- R2 (GSL SAD22): see list on p. 338, above.
- R3 *Gnathodus semiglaber* (6), *G.* sp. (1), *Polygnathus communis communis* (2), *P. communis carina* (3), *Spathognathodus stabilis* (1), *Sp.* cf. *costatus* (1), *Sp.* sp. (2), bars (7). Total 23. GSL SAD23.
- R4 (GSL SAD24), R4a '71 (GSL SAD25), R4b '71 (GSL SAD26): see lists on p. 338, above.
- R6 *Polygnathus communis communis* (3), *P. flabellus* (1), *P. symmetricus* (1), *P.* sp. (4), *Pseudopolygnathus dentilineatus* (1), *Ps. multistriatus* (1), *Ps.* cf. *multistriatus* (1), *Ps.* sp. (1), *Siphonodella* sp. (1), indet. (2). Total 16. GSL SAD27.
- R7 *Polygnathus symmetricus* (1), *P.* sp. (2). Total 3. GSL SAD28.
- R8 *Polygnathus* sp. (1). Total 1. GSL SAD29.
- R9 *Polygnathus inornatus* (6), *P.* sp. (1), *Pseudopolygnathus dentilineatus* (1), *Ps. multistriatus* (1). Total 9. GSL SAD30.
- R11 *Polygnathus* sp. (3), *Pseudopolygnathus* sp. (1). Total 4. GSL SAD31.
- R13 *Polygnathus* cf. *inornatus* (3), *P.* sp. (1), *Ps. dentilineatus* (1). Total 5. GSL SAD32.
- F1 (GSL SAD33), F1 '71 (GSL SAD34): see lists on pp. 337, 338, above.
- B1 *Polygnathus* cf. *communis* (1). Total 1. GSL SAD35.
- B2 (GSL SAD36), B2 '71 (GSL SAD37): see lists on p. 338, above.
- B3 *Polygnathus communis communis* (1). Total 1. GSL SAD38.
- B4 *Polygnathus flabellus* (1), *P. inornatus* (1), *Siphonodella* sp. (2). Total 4. GSL SAD39.
- B5 *Polygnathus inornatus* (2), *Siphonodella* sp. (1). Total 3. GSL SAD40.
- B6 *Polygnathus inornatus* (2), *P.?* sp. (2), *Pseudopolygnathus multistriatus* (1), bar (1). Total 6. GSL SAD41.
- B7 *Polygnathus symmetricus* (1), *Pseudopolygnathus?* sp. (1), *Spathognathodus* cf. *costatus* (1), indet. (1), bars (2). Total 6. GSL SAD42.
- B8 (GSL SAD43): see list on p. 338, above.
- B9 *Polygnathus symmetricus* (1), *Pseudopolygnathus dentilineatus* (3), *Ps. primus* (1), bars (3). Total 8. GSL SAD44.
- BBH *Spathognathodus aculeatus*/*Clydagnathus* transition (1), gen. et sp. indet. (2). Total 3. GSL SAD46. (Sampled by E. B. Selwood—location: V 60/40 intersection on Bantry sheet, at a point 1 mile west of Black Ball Head.)
- OH1 (GSL SAD47), OH1 '71 (GSL SAD48), OH4 (GSL SAD50), OH4 '71. (GSL SAD51): see lists on p. 338, above. (Note that OH1 and OH1 '71, which are not located on text-fig. 5, were taken from the middle of the Castle Slate Formation at the northern end of Holeopen Bay West—see Naylor 1966, pl. 21.)
- D6 Bar (1). Total 1. GSL SAD54.
- WB2 (GSL SAD57): see list on p. 338, above.

Many of the samples produced small (< mesh no. 10) specimens of molluscs, brachiopods, ostracodes (internal casts), echinoderms (plates and spines of echinoids and, more frequently, crinoid ossicles), and fish denticles. These have been retained in the collections, but are not treated in the lists. This explains the omission of, for example, GSL SAD49 (i.e. sample OH3) from the sequence of collection-numbers in the faunal lists above.

In one case (sample R3), two partially silicified brachiopods were recovered from the acid residue before sieving. Both specimens have been deposited in the collections of the Institute of Geological Sciences, Leeds. Mr. Murray Mitchell has kindly provided the following identifications and comments:

LZA 522 *Antiquatonia molarum* Turner.

LZA 523 Orthotetoid, juv., encrusted with a bryozoan identified as cf. *Fistulipora*.

The holotype of *A. molarum* is from the *Productus globosus* Band of Fawcett Mill, Ravenstonedale. The horizon of this band is currently correlated with low Viséan (very low) but the full range of the species is not known as the *P. globosus* Band is underlain by algal beds with very little macrofauna.

The evidence of the conodonts in R3 would suggest that in southern Ireland, at least, *A. molarum* was extant during the late Tournaisian.

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Revised manuscript received 30 September 1972.