

Late Viséan conodont biostratigraphy and biofacies in the Kingscourt area, Ireland

H.E. Anne SOMERVILLE

Ian D. SOMERVILLE

Department of Geology
University College Dublin

KEY WORDS – Conodonts Biostratigraphy, Biofacies, Carboniferous, Late Viséan, Kingscourt, Ireland.

ABSTRACT – The *Gnathodus bilineatus* and *Lochriea nodosa* zones are recognised in the Kingscourt area, Ireland in both platform and basinal facies. The base of the nodosa Zone is defined by the synchronous first occurrence of *L. nodosa* and *L. mononodosa* in the same bed. Several conodont species (e.g. *Mestognathus bipluti*, *Idioproniodus healdi* and *Kladognathus macrodentata*) are mostly restricted to the Brigantian (upper part of the bilineatus and nodosa zones). The richest and most diverse conodont faunas dominated by species of *Gnathodus* and *Lochriea* are from late Brigantian platform and basinal limestones within the *L. nodosa* Zone (*Gnathodus-Lochriea* Biofacies). Lower yields and diversity are recorded from early Brigantian platform limestones (upper part of the *G. bilineatus* Zone); with the poorest conodont yields in late Asbian platform limestones and mudmounds of the lower *G. bilineatus* Zone. There is a significant rise in the abundance and diversity of conodonts above the Asbian/Brigantian boundary, a change which coincides with changes in foraminiferal assemblages and lithofacies; this indicates probable transgressive environmental influences. A second major increase in conodont abundance and diversity is recognised at the base of the nodosa Zone, in platform and basinal facies. Shallow-water, coarse-grained Asbian platform limestones are dominated by *Syncladognathus geminus* and *Kladognathus tenuis* complexens (*Syncladognathus-Kladognathus* Biofacies), the elements of which are often abraded and fragmented. The best preserved faunas are mostly from the wackestones in the nodosa Zone at Poulmore, which have the best representation of all apparatus components. The late Viséan conodont faunas from Kingscourt are comparable in diversity, abundance and taxa present to those in northern England, North Wales and Poland where cyclothemic sequence limestones occur. The upper beds of Poulmore probably correlate with uppermost Viséan limestones in northern England and Lublin Basin, SE Poland.

RIASSUNTO – [Biostratigrafia a conodonti e biofacies del Viséano superiore nell'area di Kingscourt, Irlanda] – Le biozone a *Gnathodus bilineatus* e *Lochriea nodosa* sono state riconosciute nell'area di Kingscourt, Irlanda, sia in facies di piattaforma, che di bacino. La base della nodosa Zone è definita dalla prima comparsa, sincrona, di *L. nodosa* and *L. mononodosa*. Numerose specie di conodonti (es.: *Mestognathus bipluti*, *Idioproniodus healdi* and *Kladognathus macrodentata*) sono per lo più limitate al Brigantiano (parte alta delle biozone a bilineatus e a nodosa). Le faune a conodonti più abbondanti e più differenziate sono dominate da specie di *Gnathodus* e *Lochriea* e provengono da calcari di piattaforma e di bacino del Brigantiano superiore, corrispondenti alla biozona a nodosa (biofacies a *Gnathodus* e *Lochriea*). Ritrovamenti inferiori sia per abbondanza che per diversità avvengono nei calcari di piattaforma del Brigantiano inf. (parte alta della biozona a *G. bilineatus*), mentre faune ancora più scarse sono rinvenute nei calcari di piattaforma e nei mud-mound della parte inferiore della biozona a *G. bilineatus* (Asbiano sup.). Sopra al limite Asbiano/Brigantiano si verifica un aumento significativo nell'abbondanza e nella diversità dei conodonti; tale variazione coincide con quelle delle associazioni a foraminiferi e delle litofacies e indica probabili variazioni ambientali dovute a una trasgressione marina. Un secondo significativo aumento della abbondanza e della diversità dei conodonti si è verificato alla base della biozona a nodosa, sia in facies di piattaforma, sia bacinale. I calcari grossolani e di acqua bassa delle piattaforme Asbiane sono dominati da *Syncladognathus geminus* e *Kladognathus tenuis* (biofacies a *Syncladognathus-Kladognathus*), i cui elementi sono però spesso danneggiati e frammentati. Le faune meglio conservate provengono soprattutto dai wackestones dell'area di Poulmore (biozona a nodosa, dove tutti i componenti degli apparati sono ben documentati). Le faune a conodonti del Viséano sup. dell'area di Kingscourt sono confrontabili per diversità, abbondanza e composizione con quelle di Inghilterra settentrionale, Nord Galles e Polonia, dove affiorano sequenze cicliche di calcari. Gli strati più giovani di Poulmore, probabilmente, sono equivalenti ai calcari del Viséano terminale del nord dell'Inghilterra e del Bacino di Lublino (SE Polonia).

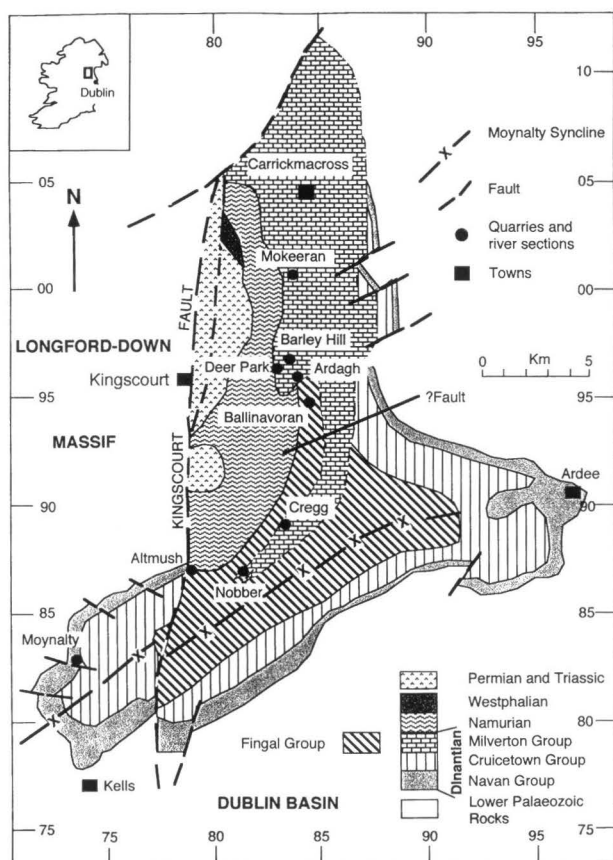
INTRODUCTION

This paper presents data on conodonts from late Viséan (Asbian and Brigantian stages) rocks around Kingscourt in eastern Ireland (Text-fig. 1), an area from which very little conodont data has previously been published. The area has a great variety of depositional environments including shallow-water carbonate platforms, mudmounds and basinal sequences (Strogen *et al.*, 1996; Text-fig. 2). Detailed investigation into the conodont biostratigraphy and biofacies of these rocks involved the collection of over 240 samples of approximately 2 kg weight each at approximately 2 m intervals from 17 measured quarry and river sections.

Processing produced over 40,000 specimens referred to 10 genera and 17 multielement species. The results of the conodont biostratigraphy and biofacies are summarised here with reference to four main stratigraphic sections which yielded nearly 36,000 specimens or 90% of the total number of conodont elements.

GEOLOGICAL SETTING

The Lower Carboniferous (Dinantian) rocks of the Kingscourt area in eastern Ireland form an outlier within the Ordovician and Silurian Lower Palaeozoic



Text-fig. 1 - Geological map of the Kingscourt Outlier showing the lithological groups of the Dinantian and the location of sections sampled for conodonts (adapted from Strogon *et al.*, 1995).

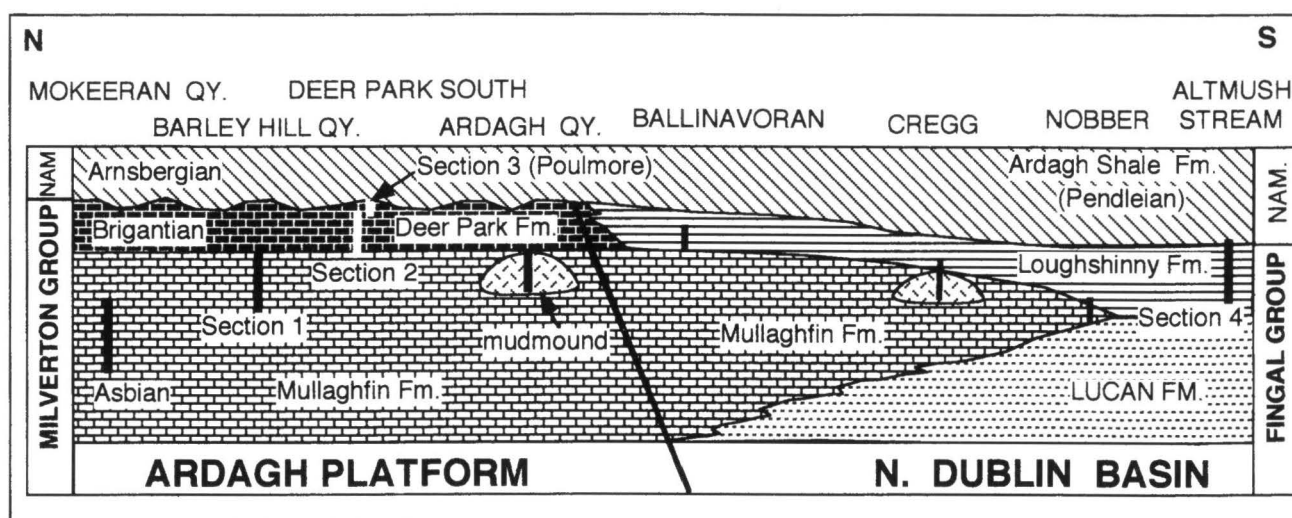
rocks of the Longford-Down Massif. The Dinantian rocks occur mostly within counties Meath and Monaghan. The Kingscourt Outlier, extends 30 km N-S and 25 km E-W and is largely bounded to the west by the major N-S trending Kingscourt Fault (Text-fig. 1). Elsewhere Dinantian strata lie unconformably on Lower Palaeozoic rocks. The Kingscourt Fault forms a hinge fault to a half-graben, preserving younger Upper Carboniferous and Permo-Triassic age rocks (Strogon *et al.*, 1995).

LATE VISÉAN STRATIGRAPHY

The late Viséan succession in the Kingscourt area consists of the Milverton Group, deposited on the Ardagh Platform in the north, and the contemporaneous Fingal Group which accumulated in the Dublin Basin to the south (Text-fig. 2; Strogon *et al.*, 1995). The platform facies of the upper two formations of the Milverton Group which were sampled include the Mullaghfin Formation (Asbian) and Deer Park Formation (Brigantian). The Loughshinny Formation (Brigantian), representing the basinal facies of the Fingal Group was also sampled.

MULLAGHFIN FORMATION

The Mullaghfin Formation forms most of the outcrop of pale, massive and well-bedded platform limestones between Ardagh and Carrickmacross (Text-fig. 1) and is approximately 500 m thick (Strogon *et al.*, 1995). It consists mainly of coarse-grained crinoidal packstones and grainstones, with rare micritic lime-



Text-fig. 2 - Schematic N-S section from the Ardagh Platform to the Dublin Basin showing the approximate stratigraphic intervals of Sections 1-4 (indicated by thick vertical lines) and other sections referred to in the text (see Text-fig. 1 for geographic location of sections).

stones which form pseudobreccias. The formation is also characterised by the development of palaeokarst and palaeosol horizons, as well as small rugose coral colonies. Over 120 m are exposed in Mokeeran Quarry (N 839 994) in the north (Text-fig. 1) and approximately 25 m of the upper part the Mullaghfin Formation is exposed in Barley Hill Quarry (N 827 965) (Section 1; Text-fig. 2). Also near the top of the formation, are massive, pale grey, micritic mudbank limestones which form conspicuous knolls more than 90 m high, as at Ardagh Quarry and Cregg (Text-fig. 2; Strogon *et al.*, 1995; Somerville *et al.*, 1996, 1997).

DEER PARK FORMATION

The Deer Park Formation is a poorly-exposed Brigantian platform sequence, which directly succeeds the Asbian Mullaghfin Formation and crops out NW of Ardagh Quarry (Text-fig. 2). Although the top is erosional (Strogon *et al.*, 1995), it is up to 100 m thick. This formation is composed of a variety of lithofacies including (i) medium grey, thickly-bedded, crinoidal packstones (ii) dark grey to black, cherty, thinly-bedded argillaceous brachiopod wackestones and packstones and (iii) massive, pale grey, crinoidal grainstones and rudstones. The main section sampled for conodonts in the Deer Park Formation is in small scarps south of Deer Park House (Text-fig. 2, Section 2) and at Poulmore Scarp (N 823 959) at the top of the formation (Text-fig. 2; Section 3). The limestones at Poulmore are unconformably overlain by Namurian sandstones of Arnsbergian (E2) age (Jackson, 1955, 1965).

LOUGHSHINNY FORMATION

Basinal facies of the Brigantian Loughshinny Formation are known from outcrops to the south of Ardagh, mainly in river sections. The base of the formation is seen only in the River Dee section NW of Nobber (Text-figs. 1, 2). The thickest section in the Loughshinny Formation (> 60 m thick) is the Altmush Stream section (N 788 871) (Text-fig. 2; Section 4) which consists of well-bedded, fine-grained and coarse-grained limestones, interbedded with shales and thin laminated calcisiltites. The well-bedded limestones are frequently graded, laminated and typically have erosive bases. They contain shale rip-ups, a shallow-water fauna and flora, intraclasts, micritised grains and ooids. These beds have been interpreted as calciturbidites containing much shallow-water, platform-derived material (Strogon *et al.*, 1995). Very coarse-grained crinoidal calcirudites also occur in this formation. The upper contact of the formation is conformable with the succeeding Ardagh Shale Formation of Pendleian (basal Namurian, E1a) age, based on the presence of the zonally diagnostic goniatite *Cravenoceras leion* (Jackson, 1955, 1965).

CONODONT BIOFACIES AND BIOSTRATIGRAPHY

SECTION 1: BARLEY HILL QUARRY (ASBIAN PLATFORM FACIES)

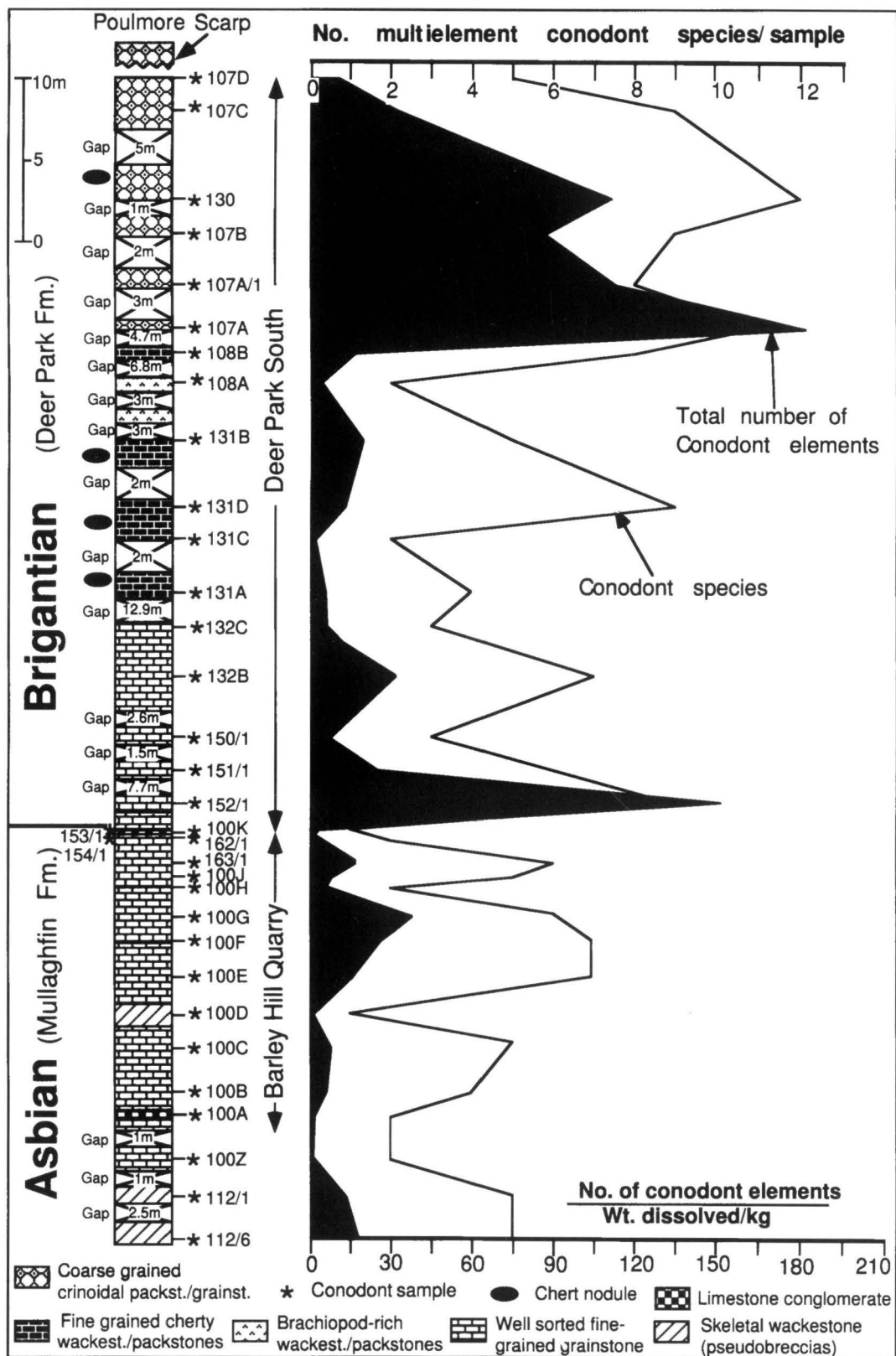
Conodont abundance and diversity

Fifteen samples were collected from Asbian platform limestones of the Mullaghfin Fm. in the 25 m thick Barley Hill Quarry section, which includes the underlying beds below the quarry. The samples yielded 329 conodont elements (Tab. 1), an average of 12.1 elements/kg. The range in the total number of conodont elements is relatively small compared with Sections 2-4, from very low values of 1.3/kg to moderate values of 39/kg (sample 100G). Throughout most of Section 1 the samples yielded <20 elements/kg, but sample 100G forms a conspicuous peak (Text-fig. 3). There is a large variation in the number of species present in the samples, ranging from 1 species in sample 100D to 7 species in samples 100E and 100F (Tab. 1). The average is 4.2 species/sample for the entire section.

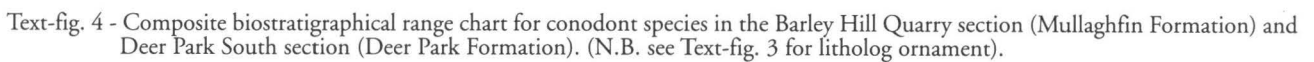
Conodont species present

In total, eleven conodont species are present in the Barley Hill Quarry section (Text-fig. 4). These are listed in the order of their abundance of Pa (platform) (or P) elements, Pb, M and S elements contained in a single sample (Tab. 1), but this listing is problematical. Two of the species *Syncladognathus geminus* and *Kladognathus tenuis/complectens* have a good representation of all the components of their multielement apparatus, and to a lesser extent *Lochriea commutata*, while the gnathodids are represented mainly by their Pa elements only. *K. tenuis/complectens* is represented by at least 8 discrete elements, comprising 2 Pa-Pb, 2 M, 1 Sa, 2 Sb-Sc and possibly 1 Sd element types. In recent reconstructions of the *Kladognathus* apparatus the two species erected have vicariously shared M and S elements and are distinguished only by the *Magnilaterella* (Pa-Pb) elements present. (See Mapes & Rexroad, 1986; Rexroad & Horowitz, 1990; Purnell, 1993; Skompski, 1996), (Pl. 1). However, in this study no evidence emerged (either biostratigraphically or by association) to determine which *Magnilaterella* elements were associated biologically; they are here all considered *K. tenuis/complectens*. *Syncladognathus geminus* is represented by 8 discrete elements, comprising 1 Pa, 1 Pb, and 6 S element types, including a symmetrical Sa element, as in recent reconstructions of *S. geminus* (Rexroad & Varker, 1992; Skompski, 1996), (Plate 1).

When all elements are counted, *Syncladognathus geminus* and *Kladognathus tenuis* are dominant. However, when considering Pa elements only (or Pa equivalent elements in the case of *Kladognathus*),



Text-fig. 3 - Composite lithostratigraphical section of Barley Hill Quarry (Mullaghfin Formation) and Deer Park South (Deer Park Formation) showing variation in conodont abundance (total number of conodont elements/wt. dissolved kg) and diversity (number of species/sample).



Formation	Base	MULLAGHFIN FORMATION														Top	Tot. Els
Sample No. (and lithotype)	112/6 (W)	112/1 (W)	100Z (G)	100A (W)	100B (W)	100C (W/P)	100D (G)	100E (W)	100F (W)	100G (P/G)	100H (G)	100J (W)	1631 (W/P)	1621 (W)	100K (P)		
Multielement species																	
<i>Cavusgnathus naviculus</i> ?	Pa Pb					1						1? 1?			1		3 1
<i>Gnathodus</i> spp.	Pa		1														1
<i>G. bilineatus</i>	Pa	2											1				3
<i>G. girtyi</i>	Pa	4	1					2	4	2		3	3				19
<i>G. homopunctatus</i>	Pa							1	9	16			3?				29
<i>Hindeodus cristula</i>	Pa		1		1			1									3
<i>Kladogn. tenuis/complectens</i>																	
(DE Magnilat. clarkei)	Pa-Pb									1							1
(DE Magnilat. contraria)	Pa-Pb							1?									1
(DE Magnilat. complectens)	Pa-Pb	1?															1
(DE Magnilat. robusta)	Pa-Pb		1														1
(DE Mag. sp.)	Pa-Pb					2											2
(DE Neo. peracutus)	M	1?											2				3
(DE Neo. scitulus)	M		2			1		1									4
(DE Neo. sp.)	M		2		1					3							6
(DE Hib. milleri)	Sa	1						1	1?								3
(DE Lig. tenuis)	Sb-Sc		1							1		1	1				4
(DE Lig. levis)	Sb-Sc			1	1	1						1					4
<i>Kladognathid</i> fragments		3		1	2				4	6		2	1	1			20
<i>Lochreia commutata</i>	Pa Pb M S	2 2	2		1 1 1	1		4	1 1 1 1		1	1			1		12 2 10 3
<i>Mestognathus</i> spp.	Pa					1		1	1?	4							7
<i>M. beckmanni</i>	Pa									1							1
<i>M. bipluti</i>	Pa												1				1
<i>Syncladognathus geminus</i>	Pa Pb S								2		2	1	1	1	1	1	8 2 30
<i>Vogelgnathus</i> spp.	Pa	5	1		2	2?	4	1?	4		2	4	3	1	1		1
Platform (Pa) fragments								2	3	4			1				10
M fragments													1	1	1		3
<i>Hindeodellan</i> fragments		4	3		1	2	3		5	12	14	1	8	10			63
Indet. ramiforms		7	10			2	2	1	5	12	20	4	2	2			67
Total		32	26	2	5	13	16	2	28	53	78	13	21	31	5	4	329
Wt. diss. Kg		1.6	2.0	1.4	1.6	1.0	2.0	1.6	1.9	2.0	2.0	2.0	2.0	2.0	2.0	2.0	27.1
Abundance/Kg		19.4	13	1.4	3.1	6.8	8	1.3	14.7	26.5	39	6.5	10.9	16.5	2.5	2	12.1d
No. multiel. spec/sample		5	5	2	3	4	5	1	7	7	6	2	5	6	3	2	4.2a

Tab. 1 - Numbers of elements of conodont species from samples in the Barley Hill Quarry section (Mullaghfin Formation). The following abbreviations for lithotypes are used here and in Tables 2-4. W=Wackestone, P=Packstone, G=Grainstone, R=Rudstone, D=Dolomite, CS=Calcisiltite, LB=Limestone breccia. Wt. diss. kg = weight dissolved/kilogram.

Gnathodus homopunctatus dominates, followed by *Lochreia commutata* and *G. girtyi*. It is also noteworthy that *Syncladognathus geminus* and *Kladognathus tenuis complectens* are very consistent in their occurrence throughout Section 1, whereas *Gnathodus homopunctatus* occurs in only 4 of the 15 samples with more than 50% of the total number of specimens present in one sample (in 100G). *Gnathodus girtyi* occurs in 7 samples again represented by Pa elements only and *G. bilineatus* is recorded in only 2 samples. *Lochreia commutata* while it is common in its occurrence is sparse in numbers, often recorded by the presence of its M or Pb elements only.

Other species present include: *Cavusgnathus* sp., *Hindeodus cristula*, *Mestognathus* sp., *M. bipluti* (only in sample 163/1) and *Vogelgnathus* sp. All are sparsely represented by Pa elements only.

Biostratigraphically important conodont species

Biostratigraphically important conodont taxa in the Barley Hill Quarry section (Text-fig. 4) include

Gnathodus bilineatus (= *G. bilineatus bilineatus* of other authors), *G. girtyi* (= *G. girtyi girtyi* of other authors) and *G. homopunctatus*, which together with *Mestognathus bipluti*, indicate an horizon within the lower part of the *Gnathodus bilineatus* Zone, of latest Asbian-early Brigantian age (Metcalf, 1981; Varker & Sevastopulo, 1985; Armstrong & Purnell, 1987; Riley, 1993; Perret & Weyant, 1994; Jones & Somerville, 1996; Skompski, 1996).

Conodont biofacies

Syncladognathus geminus occurs as S elements in all lower samples, from samples 112/6 to 100E, but the first Pa element appears only in sample 100E. The dominance of S over Pa elements in samples has been noted from elsewhere (Davies, 1980). According to Austin (1976), Austin & Davies (1984) and Davies *et al.* (1994) this species is indicative of near-shore, high-energy facies in possibly stressful euryhaline environments. However, other possible near-shore species indicators, such as *Cavusgnathus* sp. and

Mestognathus sp., highlighted by the same workers, are sparse at Barley Hill. The common association of *Syncladognathus geminus* and *Kladognathus tenuis/complectens* has permitted the recognition of the *Syncladognathus-Kladognathus* Biofacies, for shallow-water, high-energy, open-marine platform environments.

Gnathodids are present mainly as Pa elements with a notable paucity of associated ramiform elements, particularly in grainstones (Tab. 1). These conodont elements are much abraded throughout the Barley Hill section, suggesting a turbulent depositional environment and much reworking. Perhaps the gnathodid ramiform elements were winnowed out and selectively sorted, leaving only Pa elements? Such low-diversity, low-abundance conodont faunas suggests facies control. Many of the limestone samples are also rich in red and green algae and foraminifers, implying very shallow-water platform sedimentation during the late Asbian (Strogen *et al.* 1995; Adams *et al.*, 1992; Horbury & Adams, 1996). The unusual abundance of conodont elements, particularly *Gnathodus homopunctatus*, in the packstones and grainstones of sample 100G, can not be explained readily by a different microfacies, as most grainstones in the section have a poor yield (Tab. 1). Moreover, sample 100G has abundant indeterminate ramiform elements, more characteristic of wackestones in the section.

SECTION 2: DEER PARK SOUTH (BRIGANTIAN PLATFORM FACIES)

Conodont abundance and diversity

Nineteen samples were collected from the discontinuous outcrop in the >90 m thick Deer Park South section (Section 2). The samples yielded 1644 elements (Tab. 2) with samples averaging 44.7 elements/kg. There is a wide range in the total number of specimens recovered from 2/kg to high values of 181.5/kg. Throughout much of the section samples have low to moderate yields, but at the base of the Deer Park Formation (sample 152/1) and near the top of the section (samples 107A and 130), they have over 100 elements/kg and form conspicuous peaks (Text-fig. 4).

There is great variation in the number of species present in the samples, from 1 species at the base (sample 154/1) to 12 species near the top (sample 130) (Text-fig. 4; tab. 2). The average is 6.4 species/sample for the entire section (excluding samples 154/1 and 153/1, which belong to the top of the Mullaghfin Formation). Samples which contain the highest number of specimens, also have the greatest diversity; however, in sample 131D a prominent peak occurs with a low yield.

Conodont species present

Seventeen conodont species were recovered from Deer Park South (Text-fig. 4); the section is dominated by species of *Gnathodus* and *Lochriea*, together with *Syncladognathus geminus* and *Kladognathus tenuis/complectens*. *Gnathodus girtyi* is the most abundant species (Tab. 2) and is present in 12 of the 19 samples, with the greatest number of Pa specimens being present in sample 107A/1. *Gnathodus homopunctatus* is present in 12 samples, mostly in small numbers, with the highest yields in samples 107A-107B. *Kladognathus tenuis/complectens* is present in 11 of the 19 samples, with the greatest yields in samples 152/1 and 107A. *Syncladognathus geminus* is present in 13 samples and is most abundant in samples 152/1 and 130. *Lochriea commutata* occurs in 12 samples, mainly in small numbers, except in samples 130 and 107A. *Gnathodus bilineatus* is present in 9 samples, but is generally present in small numbers in all samples. *Lochriea mononodosa* and *L. nodosa* occur together in several samples from the top of the section, all with very low numbers.

Other species present in small numbers include: *Hindeodus cristula*, *Hindeodontoides spiculus*, *Mestognathus* sp., *M. bipluti* (sample 131D), *M. beckmanni* (sample 107B), and *Cavusgnathus naviculus?* (samples 131B and 130). *Vogelgnathus campbelli* is present as Pa elements in 3 samples, mostly in small numbers, except for an unusually high number in sample 130, the highest recorded for any sample from the Kingscourt area. *Kladognathus macrodentata* was recovered in this section from samples 108A and 108B and is regarded as an element of a separate species of *Kladognathus* (see Rexroad & Merrill, 1996 for further discussion). The only other species present is *Idioproniodus healdi* which was recovered from 7 samples, mostly from the upper part of the section. *I. healdi* is represented by 7 elements including, 1 Pa, 1 Pb, 1 M, 1 Sa, and 3 Sb-Sc elements (see Stone & Geraghty, 1994; Purnell & von Bitter, 1996) (Pl. 1).

Biostratigraphically important conodont species

Biostratigraphically important conodont taxa in the Deer Park South section include *Mestognathus bipluti*, *Kladognathus macrodentata*, *Gnathodus bilineatus*, and *G. homopunctatus* (in the lower part), and *Lochriea nodosa* and *L. mononodosa* (both first appearing together in sample 107A). Thus the section extends from the lower part of the *Gnathodus bilineatus* Zone, of latest Asbian-early Brigantian age to the *L. nodosa* Zone, of middle to late Brigantian age (Text-fig. 4), (Metcalf, 1981; Varker & Sevastopulo, 1985; Armstrong & Purnell, 1987; Riley, 1993; Perret, 1993; Perret & Weyant, 1994; Alekseev *et al.*, 1996; Skompski, 1996). The youngest Brigantian conodont

Formation		DEER PARK FORMATION																			Top	
Sample No. (and lithotype)		154/ 1 (G)	153/ 1 (W/P)	152/ 1 (W)	151/ 1 (P)	150/ 1 (G)	132 B (W/P)	132 C (P)	131 A (P/G)	131 C (W/P)	131 D (W)	131 B (G)	108 A (W)	108 B (W)	107 A (P)	107 A1 (P)	107 B (P)	130 (P)	107 C (P)	107 D (P)	Tot. Els	
Multielement species																						
Cavusgnathus naviculus?	Pa Pb M			1					3		4 1	3						3			14 1 1	
Gnathodus spp.	Pa Pb M Sa Sb Sc Sd		2	2	2	1	2				5				4?	1 1	1			1	14 7 2 3 2 3 1	
G. bilineatus	Pa			8	1		3	1							4		5	12	7	2	43	
G. girtyi	Pa			13	4		10				2	1		4	41	57	32	16	5	10	195	
G. homopunctatus	Pa Pb			4	3	1	3				1		1	2	50 6	42 1	28	9	7		151 7	
Hindeodontoides spiculus	Pa										1							1			2	
Hindeodus cristula	Pa								1		1?			1				8			11	
Idiopriodontus healdi																						
(DE Lonch. ponderosa)	?						1?														1	
(DE Prion. clarki)	?															1					1	
(DE Neo. conjunctus)	M						1?											1			3	
(DE Hib. subacodus)	Sa																		1		1	
(DE Meta. bidentata)	?						1										1				2	
(DE Lon. lexingtonensis)	?							3										1			6	
(DE Lig. typa)	Sc frags							2 1									1 6	2 2	2		8 13	
Kladogn. tenuis/complectens																						
(DE Magnilat. clarkei)	Pa-Pb						1?							1							1	
(DE Magnilat. complectens)	Pa-Pb			2																	3	
(DE Magnilat. contraria)	Pa-Pb														2						3	
(DE Magnilat. robusta)	Pa-Pb			7											1?	1?		1		1	11	
(DE Magnilat. sp.)	Pa-Pb								1			1									2	
(DE Neo. peracutus)	M			5										1	2						8	
(DE Neo. scitulus)	M			2							1						1			1	5	
(DE Neo. sp.)	M			7																	8	
(DE Hib. milleri)	Sa			3													1				4	
(DE Lig. tenuis)	Sb-Sc			1										1	2	2			1		7	
(DE Lig. levis)	Sb-Sc			1							2	1			1						6	
(DE Klad. macrodentata)	?Sb-Sc												2?		1						3	
Kladognathid fragments			3	5	7		3		1	1?	1	1		11	5	1		7			46	
Lochriea spp.	Pa																3				3	
L. commutata	Pa Pb M Sa S			3 2 1 2	4 1		4 1	1						1	10 5 6	3 4 4	5 1	12 2 3	2 1	2	2	47 13 20 1 11
Lochriea nodosa	Pa				1										4	3		1			14	
Lochriea mononodosa	Pa														5	1	3	4	1		14	
Mestognathus spp.	Pa			6							1	1							2		10	
M. beckmanni	Pa																1				1	
M. bipluti	Pa										1				1?						2	
Syncladognathus geminus	Pa Pb S			10 1 39		3	1?			1								9			24 1 76	
Vogelgnathus spp.	Pa	5			1?						1				1	1		16		1	3	
Vogelgnathus campbelli	Pa S		4											3		1?		40 10			47 10	
Platform (Pa) fragments			1	7	3	1	1					4			40	23	18	16	12	1	127	
Pb fragments											1	1					4	1			7	
M fragments				4												4		1			9	
Alate (Sa) fragments							1					1?									2	
Hindeodellian fragments			2	13	5		6	3			2		2		75	35	56	20	12	1	232	
Indet. ramiforms		1	1	134	13	7	11	1	6	1	5	15	4	3	80	25	10	43	8		368	
Total		6	9	289	48	15	53	12	13	4	28	39	9	32	363	227	174	239	63	21	1644	
Wt. diss. Kg		1,9	1,9	1,9	1,9	2,0	1,8	1,9	1,8	2,0	2,0	1,9	2,0	2,0	2,0	2,0	2,0	2,0	2,0	1,8	36,8	
Abundance/Kg		3,2	4,8	152	25,3	7,5	29,4	6,3	7,2	2	14	20,5	4,5	16	181,5	113,5	87	119,5	31,5	11,7	44,7a	
No. multiel. spec./sample		1	2	9	6	3	7	3	4	2	9	5	2	8	11	8	9	12	9	5	6(a)	

Tab. 2 - Numbers of elements of conodont species from samples in the Deer Park South section [Mullaghfin Formation (samples 154/1 and 153/1) and Deer Park Formation].

zone in Britain, the *G. girtyi collinsoni* Zone of Rhodes *et al.*, (1969) and Varker & Sevastopulo, (1985), is not distinguished in Kingscourt, although occasionally, some specimens of *G. girtyi* recovered in the late Brigantian closely resemble the subspecies *collinsoni*.

The *L. nodosa* Zone (as used in Austin *et al.*, 1970; Metcalfe, 1981; Austin & Davies, 1984; Perret & Weyant, 1994; Alekseev *et al.*, 1996; Skompski, 1996) is recognised in preference to the *L. mononodosa* Zone (as used in Varker & Sevastopulo, 1985). *Kladognathus*

macrodentata occurs at the top of the *bilineatus* Zone; however, in Poulmore Scarp and Altmush Stream it is found only in the succeeding *nodosa* Zone (see below).

Conodont biofacies

Samples 154/1 and 153/1 from the base of the Deer Park South section have low conodont diversity and low abundance. These samples are from massive, fine-grained grainstones (sample 154/1) or intraclastic wackestone/packstone beds (sample 153/1) which can be correlated with the same beds at the top of Barley Hill Quarry (Text-fig. 3). Both sections expose the uppermost Mullaghfin Formation which has a paucity of conodonts in the Kingscourt area. These beds are locally rich in calcareous algae such as *Koninckopora* as well as foraminifers (Strogen *et al.*, 1995), and represent very shallow-water, offshore shelf environments. The basal beds of the succeeding Deer Park Formation (sample 152/1) mark an abrupt change in facies to wackestones and coarser grained crinoidal grainstones with abundant and diverse conodont faunas, and an absence of *Koninckopora*.

The overlying strata (samples 132B-C) are mostly peloidal intraclastic packstones with low numbers of conodont elements and average diversity. These beds are locally rich in the green alga *Nanopora anglica*. In the middle of the section (samples 131A-B) the limestones are mainly dark grey, fine-grained cherty wackestones and packstones with very low conodont yields and below average diversity (except for sample 131D). These samples have very sparse gnathodids and lochreids. The brachiopod-rich wackestone bed (sample 108A) similarly has a very low yield and diversity, with complete absence of *Gnathodus girtyi* and *Lochriea commutata*, but with rare *Kladognathus macrodentata*.

The incoming of thickly-bedded, well-sorted, coarse-grained crinoidal packstones and grainstones near the top of the Deer Park South section (samples 107A-D) coincides with a dramatic rise in the abundance and diversity of conodonts, reaching a peak in samples 107A and 130 (see also the succeeding Poulmore Scarp section described below). These samples include platform and ramiform elements of *Gnathodus* and *Lochriea*, together with ramiform elements of *Kladognathus tenuis/complectens* and *Idioproniodus healdi*.

Summary

There are 2 prominent diversity and abundance peaks in the Deer Park South section, peaks that coincide with major facies changes. The first peak near the base of the section (sample 152/1) marks the boundary between the Mullaghfin and Deer Park formations, a boundary which is clearly recognisable by a colour change in the limestones, bed thickness

and grain size, as well as changes in the other microfossil groups such as foraminifers and calcareous algae, notably *Koninckopora*. The formation boundary also coincides with the Asbian/Brigantian stage boundary in the Kingscourt area (Strogen *et al.*, 1995). Similar lithofacies and microfossil changes at the Asbian/Brigantian stage boundary were noted by Somerville & Strank, (1984) in North Wales and northern England.

The second major peak in conodont diversity and abundance near the top of the section coincides with another abrupt change in lithofacies, from dark grey, fine-grained, thinly-bedded cherty limestones, to pale grey, coarse-grained, thickly-bedded crinoidal-rich limestones (sample 107A). This boundary coincides with the base of the *L. nodosa* Zone. These rapid changes in facies may be related to relative sea-level changes (shallowing or deepening events), and/or changes in the rate of sedimentation.

The cherty wackestone/packstone interval in the middle of the Deer Park Formation (samples 131A-108A) containing local concentrations of brachiopods, an impoverished conodont fauna and an almost complete absence of species of *Gnathodus*, *Lochriea* and *Idioproniodus*, suggests stressful, low-energy, near-shore environments (Davies *et al.*, 1994). Similar gigantoproductid-rich limestones with low conodont yields are recorded from the late Viséan Yoredale Group cyclothems in the north of England (Davies, 1980; Armstrong & Purnell, 1987; Davies *et al.*, 1994).

SECTION 3: POULMORE SCARP (BRIGANTIAN PLATFORM FACIES)

Conodont abundance and diversity

Twenty samples were collected from Poulmore Scarp, a 11 m thick section at the top of the Deer Park Formation (Text-fig. 5). Every bed was sampled and in some cases several samples were taken from the same bed, in order to detect any variation in the number of conodont specimens from bottom to top within individual beds, and between successive beds. Poulmore Scarp is by far the most productive section sampled anywhere in Ireland, with 28,528 elements recovered from the 20 samples (averaging 726 elements/kg). There is a great range in the total number of conodont elements recovered per sample from relatively low values of 42/kg in sample PH6 to exceptionally high abundance of 3174/kg in sample PH15 (Tab. 3; text-fig. 5). In the middle of the section many samples have yielded over 1000 elements/kg.

Upward in the Poulmore section there is an increase in species diversity, from a low value of 6 species near the base, to the highest value of 11-13 species (samples PH9, 16 and 17) all from Bed 7 (Text-fig. 5); the average is 9 species per sample (Tab. 3). Interestingly,

Formation		DEER PARK FORMATION																				Top	
Sample No. (and lithotype) (height above the base) (m)		PH 1 0,25m (G)	PH 12 0,75 (G)	PH 6 1,25 (W/P)	PH 7 2,0 (P)	PH 2 3,0 (P/G)	PH 13 3,1 (P)	PH 8 3,8 (W/P)	PH 14 4,3 (P/G)	PH 20 4,8 (P/G)	PH 15 5,05 (P)	PH 3 5,6 (G)	PH 9 6,8 (G)	PH 16 7,4 (G)	PH 17 7,8 (G)	PH 10 8,0 (P)	PH 4 8,6 (W/P)	PH 18 8,9 (G)	PH 11 9,1 (P/R)	PH 5 9,9 (P/G)	PH 19 10,8 (W/P)	Tot. Els	
Multielement species																							
Cavusgnathus naviculus?	Pa	3	6										1		11	1	1					23	
	Pb	1	2									2		2	2	1						8	
	M	1	1												2							4	
	S	4	6										4		3							17	
Cavusgnathus naviculus	Pa											2										2	
Cavusgnathus unicornis	Pa	1	1									1?		7								10	
Gnathodus spp.	Pa		2				11			2	62			13	3			30		6		130	
	Pb	3			2			98		12	84	31	38	10	2	3	11	3	9	49	22	377	
	M	2					3	34	25	6	16	2	28	5	3	2	4		2	17	7	156	
	Sa							12				1	6	1		2	1		2	2	2	33	
	Sb			2	1	2		25	3	5	10	13	1	2	2	5		1	22	10		104	
	Sc			1		2	4	29	24	5	20	1	14	3	3	4	3	2	2	22	6	145	
	Sd				1			30	4	11	4		5	2	1	2	4		2	12	3	85	
	Pa			4	9	8	552	209	405	34	1725	462	33	17	19	6	153	324	60	61	126	4203	
G. girtyi	Pa	77	70	1	12	17	268	192	1335	148	1311	598	1367	283	226	1	10	90	23	325	193	6547	
Hindeodus cristula	Pa	7											13	9	2			1				32	
	Pb													1	1							2	
	M	2											4	1	1							8	
	S												10	3								13	
Idioproniodus healdi																							
(DE Lonch. ponderosa)		?				1	15	2	12	2	23	5	8	3	3	2	3	3	1	10	4	97	
(DE Prion. clarki)		?		1	1		9	11	8	2	18	6	10		2		2	3		6	3	82	
(DE Neo. conjunctus)		M					5	4	7	2	12	9	7	2	1		1	2		7	2	61	
(DE Hib. subacodus)		Sa					7	3	16	2	22	10	4	1	1	1	4	2	2	1	4	80	
(DE Meta. bidentata)		?					9	3	9	1	21	8	15	1			1	1		3		72	
(DE Lon. leixingtonensis)		?			1	1	13	7	21		25	19	20	8	1	2	1	6		7	7	139	
(DE Lig. typa)		Sc		1			25	15	44	7	69	33	14	2			6	5		12	11	244	
frags		2			2	3	26	3	41	3	51	89	40	7	8	3	6	7		7		298	
Kladogn. tenuis/complectens																							
(DE Magnilat. clarkei)		Pa-Pb	1					1	1		3	1								1		9	
(DE Magnilat. complectens)		Pa-Pb	2	7					2	1	1			4	2			1	1		2	23	
(DE Magnilat. contraria)		Pa-Pb											4				2				17	23	
(DE Magnilat. robusta)		Pa-Pb		6								1	1							2		11	
(DE Magnilat. sp.)		Pa-Pb				1	1				1				2							5	
(DE Neo. peracutus)		M	5	1			5	30	21	7	36	27	12	1	5	8	9	2	3	10	16	198	
(DE Neo. scitulus)		M	1		1	1			3		7		2		2		2		1		6	26	
(DE Neo. sp.)		M	4		1						1			5								11	
(DE Hib. milleri)		Sa	1			1		2	1	2	1		1	2?		1		3	1	1		6	23
(DE Lig. tenuis)		Sb-Sc	3	6			1	1	1		2	4		2	2					2	2	26	
(DE Lig. levis)		Sb-Sc	1				2		3		4	4		5	2						3	24	
(DE Klad. macrodentata)		?	2					18	2?	3	8					9	7	1?	4	6	13	76	
(DE Lig. sp.)		?					12	1	2	8						11	10			6	7	57	
Kladognathid fragments			34	34	2	8	11	3	226	24	11	82	6	33	34	6	61	28	7	19	97	828	
Lochriea spp.																							
L. commutata		Pa			2		5	58	2	59		5		3	3			7	5	5	3	157	
Lochriea mononodosa	Pa	29	6	3	19	19	214	154	581	58	316	133	23	22	10	5	15	30	6	71	43	1757	
	Pb			5	10	7	11	75	187	8	77	9	3	21	4	1	7	5	2	24	19	475	
	M	7	1	9	22	17	56	97	489	28	177	35	16	16	13	6	31	16	4	71	38	1149	
	Sa				1			12			2	9		1	4		3			5		37	
	S			2	2	5	14	57	122	12	55	1	4	17	3	3	8	1	1	27	10	344	
Lochriea mononodosa		Pa		1	9	10	33	12	165	26	156	227	11	8	4	2	5	38	14	19	22	762	
Lochriea nodosa		Pa		1	3	3	22		29	6	78	62	5	4	4	4	45	12	8	9	12	307	
L. mononodosa/nodosa		Pa								2								15			5	22	
Mestognathus spp.		Pa									11			4								15	
M. bipluti	Pb										10											10	
	M										3											3	
	S										14											14	
	Pa										2											2	
Syncladognathus geminus		Pa	16	3		1	1		1		2	3	7	6	7		2	1	1			51	
Vogelgnathus spp.	Pb	1						1			1	2	2	1			2					10	
	S	14	12			1	1	3	7		13	11	29	12	12		19	3			7	144	
	Pa							5?			3?		7				1				1	17	
Vogelgnathus campbelli		S											3?				1					13	
Pa		2							2		1			9?	22	5		1?		3		36	
Platform (Pa) fragments			14	4	1		5	124	68	283	29	438	232	128	72	33		14	41	15	39	35	1575
Pb fragments				1	2		1	136	11	152		100	7	30	10	12	2	6	8	4	7	31	520
M fragments			6	4				15	1	6	2	37	8		13	5	2	5	3				107
Alate (Sa) fragments			3	2				8	12	25		37	1	4	1	1		12	6				112
Hindeodellian fragments			25	4	11	63	57	270	518	1209	139	696	87	585	141	112	40	71	50	35	245	166	4524
Indet. ramiforms			31	22	7	5	15	130	118	380	41	442	53	280	137	67	26	63	39	6	87	94	2053
Total			305	212	55	177	186	2000	2110	5710	622	6368	2189	2861	939	625	215	588	767	234	1298	1068	28528
Wt. diss. Kg			2,0	2,0	1,3	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	39,3	
Abundance/Kg			152	106	42,3	89	93	1000	1055	2855	311	3189	1099	1431	469	312	108	294	384	117	649	534	726a
No. multiel. spec./sample			9	6	6	8	8	8	9	10	8	11	8	13	11	12	8	11	11	9	9	10	9,2(a)
Bed number			1		2	3		4		5		6		7		8		9		10			

Tab. 3 - Numbers of elements of conodont species from samples from the top of the Deer Park Formation in the Poulmore Scarp section.

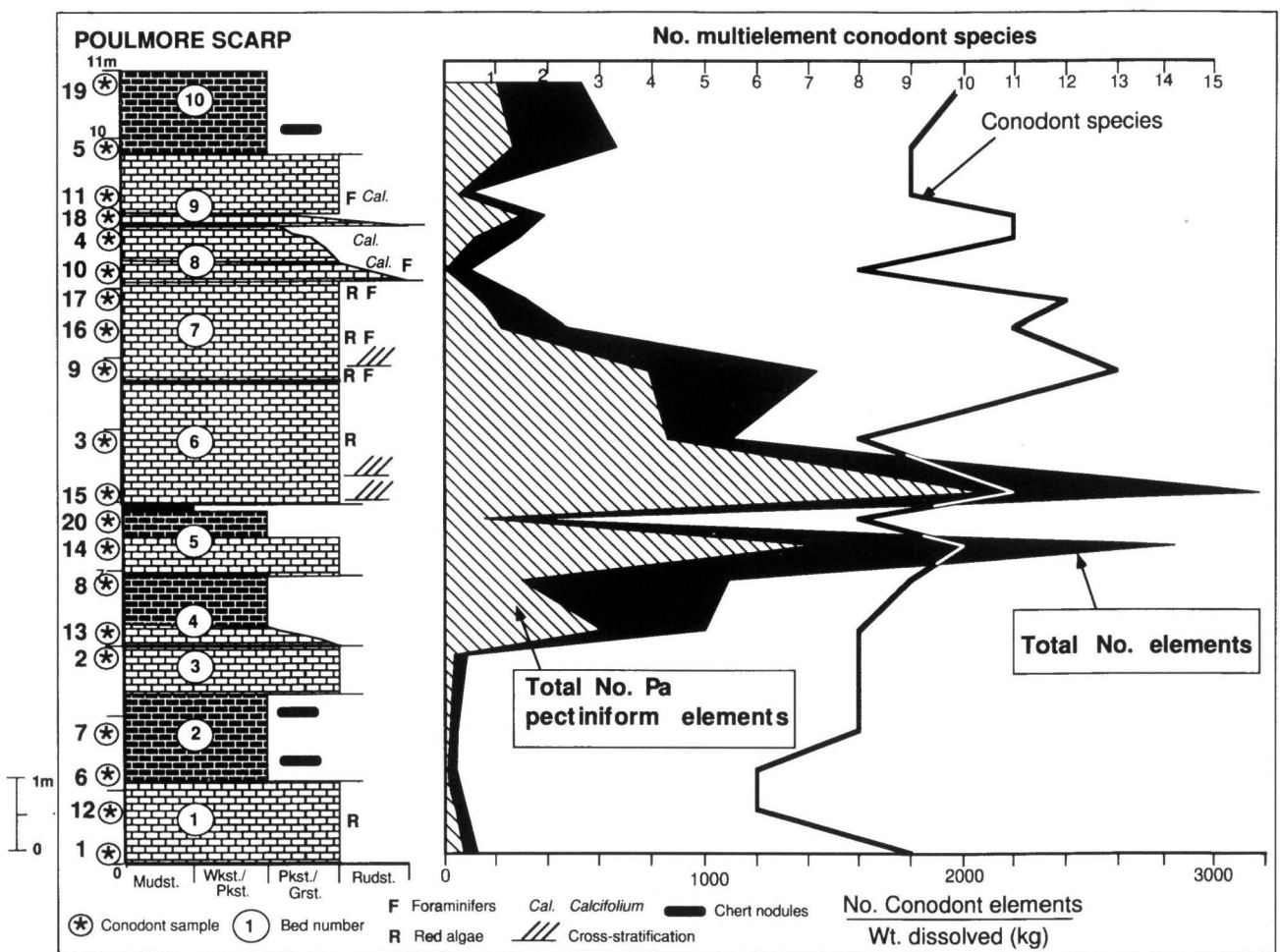
the samples from Bed 7 have not yielded the highest number of specimens. Also, several beds record higher species diversity at the base, compared to the middle or top of the same bed.

Conodont species present

The most abundant conodont in the Poulmore section is *Gnathodus girtyi* which is present in every sample and is particularly abundant in samples PH3, 9, 14 and 15 (Tab. 3). *Gnathodus bilineatus* is also very abundant and is present in every sample, except the lowest three samples. It is most abundant in sample PH15. This species shows notable variations within individual beds, e.g. in Bed 4, where there is a marked decrease (>60%), from the base to the top of the same bed, in the number of Pa elements. Similarly in Bed 5, a >80% decrease (from the middle to the top of the bed). *Lochriea commutata* is present in all samples. It has a great variation in abundance, but has the highest

yields in samples PH14 and PH15. *L. mononodosa* and *L. nodosa* occur together in most samples (except in samples PH1 and PH12). Large numbers of specimens of both species are recorded in samples PH14, PH15 and PH3, but in almost every sample, *L. nodosa* is subordinate in number to *L. mononodosa*, except in sample PH4.

Other species in the Poulmore section occur usually in smaller numbers. They include: *Syncladognathus geminus* in 16 of the 20 samples, *Cavusgnathus* sp. in 6 samples, *Hindeodus cristula* only in 5 samples, *Mestognathus bipluti* from only sample PH15. *Vogelgnathus* sp., is recorded in 10 samples (as *V. campbelli* in 7 samples), mainly in small numbers, but locally rich as in sample PH16. *Idioproniodus healdi* present in all 20 samples, is variable in number, with high values in several samples (samples PH3, 13, 14 and 15; Table 3). The genus *Kladognathus* is represented by two species *K. tenuis/compectens* and *K. macrodentata*. *K. tenuis/compectens* occurs in moderate to large numbers



Text-fig. 5 - Lithostratigraphical section of Poulmore Scarp (top of the Deer Park Formation) showing variation in conodont abundance (total number of conodont elements/wt. dissolved kg), total number of Pa elements/wt. dissolved kg), and diversity (number of species/sample).

in all samples. *K. macrodentata* is present in 13 samples and is most abundant in sample PH8.

Pectiniform/ramiform element ratios and species composition

The range in the number of pectiniform (Pa platform) elements (both assigned species and fragments of Pa blades and platforms combined) in the samples is very large, from a very low value of 7/kg (sample PH6) to a very high value of 2130/kg (sample PH15) (Text-fig. 5). Most samples with high values in the total number of Pa elements have large numbers of ramiform elements/kg, especially those in the middle of the section (samples PH13, 14, 15-9) (Tab. 3). In the majority of samples the Pa elements represent between 40-65% of the total. However, in two samples (PH18 and PH3) they exceed 75%, with a consequent under-representation of ramiform elements. Conversely, in samples PH7, 8, 10 and 5-19, ramiform elements form 60-75% of the total.

Analysis of the conodont species composition from the Poulmore section (Tab. 3) shows that in 15 of 20 samples the five most abundant species containing Pa elements are *Gnathodus girtyi*, *G. bilineatus*, *Lochriea commutata*, *L. mononodosa* and *L. nodosa*. They represent over 90% of all conodont species containing Pa elements. The other species, belonging to the genera *Mestognathus*, *Cavusgnathus*, *Hindeodus*, *Syncladognathus* and *Vogelgnathus*, generally account for less than 10% (of the conodont species containing Pa elements), except in sample PH1, where they exceed 35%.

Conodont biofacies

The samples with the highest yields (samples PH14, 15, 3 and 9) are in thickly-bedded, well-washed, medium to coarse-grained, crinoidal packstones and grainstones. These samples, with an exceptionally high average of 1-3000 elements/kg, also have high diversity ranging from 8-12 species. Most of these samples, particularly those which show cross-stratification such as samples PH15, PH9 and PH3, or from the base of beds, have the poorest preserved conodont elements, (especially the ramiform elements, which are frequently broken, and perhaps over-represented). Moreover, in some samples (e.g. PH9) a single species such as *Gnathodus girtyi* may dominate the population. These features suggest turbulent sedimentation and hydraulic action in shoals was responsible for selective removal of the lighter, less robust ramiform elements, concentrating the pectiniform elements.

All of the large, robust *Cavusgnathus* and *Mestognathus* Pa elements were recorded only from coarse-grained limestones in beds 1, and 6-8, often from the base of beds, where the samples have the largest grain size (e.g. samples PH15 and 9). These beds were deposited above fair-weather wave-base in

shallow water, in probably less than 10 m deep turbulent conditions. Austin (1976), von Bitter (1976), von Bitter *et al.* (1986), Davies *et al.* (1994) and Krumhardt *et al.* (1996) suggested that *Cavusgnathus* and *Mestognathus* probably inhabited near-shore restricted environments. Interestingly, 5 of the 7 samples containing *Vogelgnathus campbelli* are from the base of beds. This species shows similar characteristics in late Viséan rocks in northern Spain (van den Boogaard, 1992).

Several samples (PH 5, 7, 8, and 19) are from fine-grained wackestones and packstones at the top of individual beds; they were probably sedimented under quiet-water lagoonal conditions, in the lee of shoals, with little turbulence and sorting. These samples have high proportions of ramiform elements and excellent preservation, especially in samples PH5 and PH8.

A distinctive facies present near the top of the Poulmore section in samples PH4, 10 and 11 (Text-fig. 5) has some of the lowest conodont yields, but with an average number of species. These limestones are mainly poorly-sorted, intraclastic, crinoidal packstones, with a diverse fauna and flora; the latter include the codiacean green alga *Calcifolium okense*, and foraminifers, but are characterised by fragmented bioclasts.

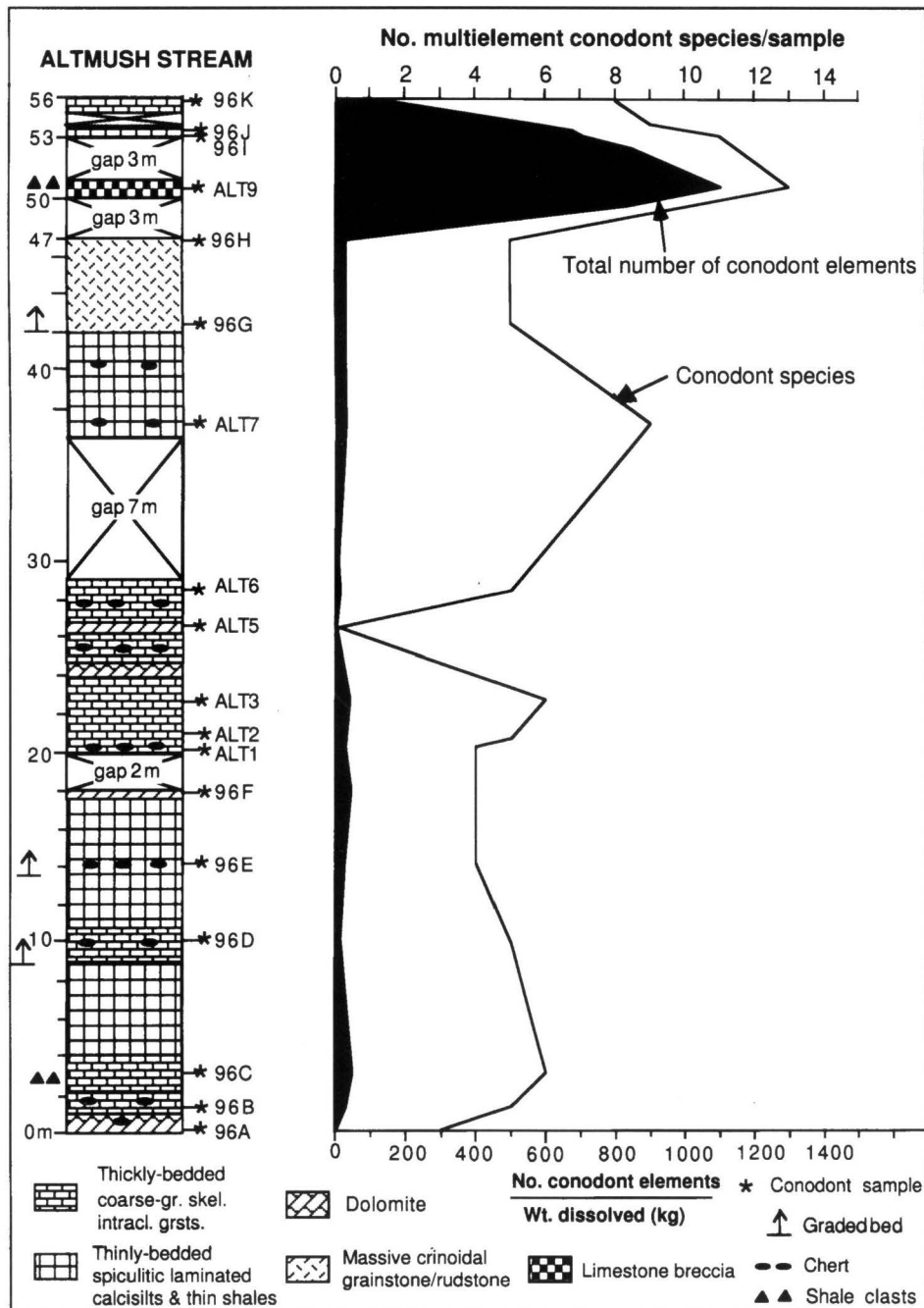
Summary of Brigantian platform facies

Brigantian platform rocks of the lower part of the Deer Park Fm., have higher conodont yields (averaging 44 elements/kg) and diversity (averaging 6 species/sample) than those from the underlying Asbian platform limestones of the Mullaghfin Formation (averaging 12 elements/kg and 4 species/sample, respectively). The yields are highest in thin-bedded, fine-grained limestones in which *Gnathodus girtyi* is dominant, followed by approximately equal numbers of *G. homopunctatus*, *G. bilineatus* and *Lochriea commutata*. The faunas are similar to those of the Mullaghfin Fm, but additionally, *Mestognathus bipluti*, *Vogelgnathus campbelli*, *Idioprioniodus bealdi* and *Kladognathus macrodentata* are present. The upper beds of the Deer Park Fm. yielded *Lochriea mononodosa*, and *L. nodosa* from the *nodosa* Zone (Text-fig. 4), but *G. homopunctatus* is not recorded from the youngest beds of the *nodosa* Zone in the Poulmore section.

Samples from the upper Deer Park Formation at Poulmore (all within the *nodosa* Zone) have exceptionally high yields (averaging 726 elements/kg) and high diversity (averaging 9 species/sample) but were not expected to yield many conodonts, especially gnathodids, because of the predominant coarse-grained, crinoidal-rich limestone shoal facies. However, similar extraordinarily high yields (>2000 elements/kg) and very high diversity (6-8 genera) were recorded from high-energy packstones in Upper Carboniferous (Pennsylvanian) rocks from Utah and Colorado (Driesel

et al., 1984) and interpreted as shallow-water nearshore conodont biofacies. These high-energy shoal deposits in near-shore settings usually have a paucity of conodont elements (although sample 152/1 from near the base of the Deer Park Formation had high yields from this lithofacies) and are commonly fragmented (Davies, 1980; Austin, 1987). Local sedimentological factors apparently transported and concentrated exceptionally large numbers of

conodont elements, particularly the more robust pectiniform elements; their abundance is only comparable in rocks belonging to the basinal facies, within the *nodosa* Zone (see below). Some wackestones from Poulmore also have high yields with similar diversity to the grainstones; their faunas are much better preserved and more likely to be representative of the population before transport and mixing.



Text-fig. 6 - Lithostratigraphical section of Altmush Stream (Loughshinny Formation) showing variation in conodont abundance (total number of conodont elements/wt. dissolved kg), and diversity (number of species/sample).

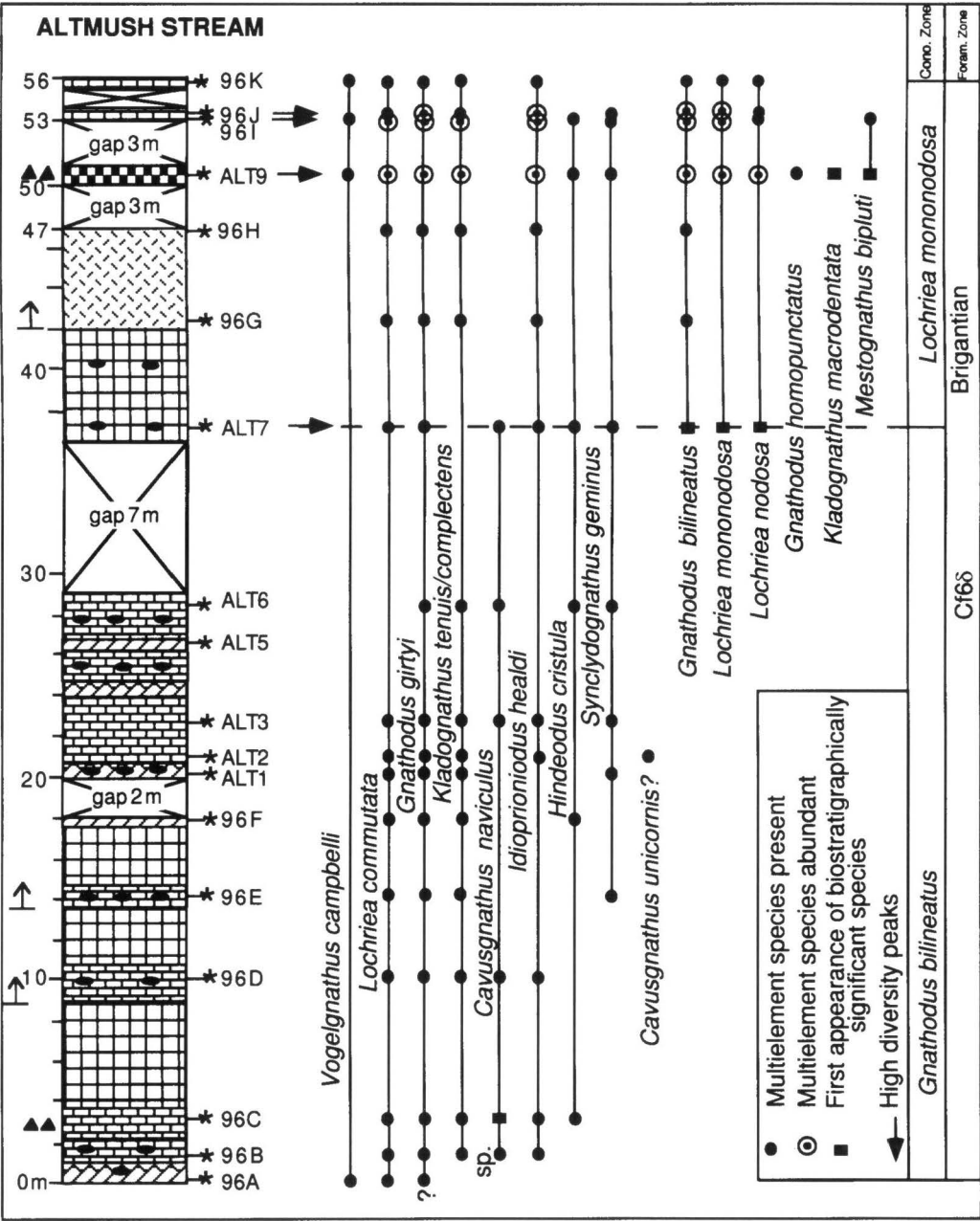
SECTION 4: ALTMUSH STREAM (BRIGANTIAN BASINAL FACIES

Conodont abundance and diversity

Basinal Brigantian limestones of the Loughshinny Formation from Altmush Stream yielded similar conodont assemblages to those of the Deer Park Fm, particularly the upper part. Eighteen samples (96A-K;

ALT 1-9) were collected from the discontinuous outcrop of the 56 m thick Altmush Stream section (Text-figs. 1, 2, 6). The Altmush Stream is the second most productive section in Kingscourt, after Poulmore, with 5,431 specimens or an average of 170.3 elements/kg.

The range in the total number of conodont elements is very high, from *relatively* low values of between 6.7-46.3 elements/kg, to very high values of



Text-fig. 7 - Biostratigraphical range chart for conodont species in the Altmush Stream section (Brigantian Loughshinny Formation) (N.B. see Text-fig. 6 for litholog ornament).

1113/kg (sample ALT9). The stratigraphically highest four samples (ALT9 to 96K) have an average of over 650 elements/kg and form a conspicuous peak (Text-fig. 6). The species diversity in most of the section is variable (3-8 species) (Text-fig. 7; tab. 4), but from sample ALT9 to the top of the section four samples have values ranging from 8-13 species (highest in sample ALT9). The average for the entire section is 6 species per sample. Two samples from

lower in the section (samples 96C and ALT7) have high diversity peaks, but have much lower total number of specimens (Text-fig. 6).

Conodont species present

Fifteen species, dominated by species of *Gnathodus* and *Lochriea* (Text-fig. 7), are present in the Altmush Stream section. The most abundant species is

Formation		LOUGHSHINNY FORMATION																			Top	
Sample No. (and lithotype)		96A 1 (DG)	96B 2 (G)	96C 3 (G)	96D 4 (G)	96E 5 (R)	96F 6 (DG)	ALT1 7 (CS)	ALT2 8 (G)	ALT3 9 (G)	ALT5 11 (D)	ALT6 12 (G)	ALT7 13 (G)	96G 14 (G)	96H 16 (G)	ALT9 17 (LB)	96I 18 (P)	96J 19 (G)	96K 20 (W)	Tot. Els		
Multielement species																						
Cavusgnathus spp.	Pa		7	1						1										9		
	Pb			2						1										3		
	M									1										1		
	S		1	4																5		
C. naviculus	Pa			2	1					2		1	1							7		
C. unicornis	Pa								2?											2		
Gnathodus spp.	Pa									1										79		
	Pb	1		1	1	1	2			2?				2?	1	37	21	19		63		
	M															29	14	6	4	20		
	Sa															18	2			33		
	Sb					1		1								2	3			6		
	Sc															3				5		
	Sd															7	2			9		
	Pa															31	2			33		
G. bilineatus	Pa												7	12	6	168	115	505	31	844		
G. girtyi	Pa		22	32	7	10	29	12	34	36		10	24	27	21	188	276	262	35	1025		
G. homopunctatus	Pa															6				6		
Hindeodus cristula	Pa			1			1					1?	1				1?			5		
	Pb						1?									1				2		
	M											1				1?	1?			3		
	S			1			1													2		
Ildioproniodus healdi																						
(DE Lonch. ponderosa)	?			1?					1							3	1	2		8		
(DE Prion. clarki)	?			1												1	1	1		4		
(DE Neo. conjunctus)	M			1											1?	1	2	4	1	10		
(DE Hib. subacodus)	Sa								1							6	5	7		19		
(DE Meta. bidentata)	?														1	8			1	10		
(DE Lon. lexictonensis)	?			1						1						15	7	3	1	28		
(DE Lig. typa)	Sc		1	1				1								20	10	6	1	40		
	frags		1	1	2								2	3	1	13	11	13	7	54		
Kladogn. tenuis/complectens	Pa-Pb							1												1		
(DE Magnilat. robusta)	Pa-Pb								1										1?	3		
(DE Magnilat. clarki)	Pa-Pb								1			3					1			4		
(DE Magnilat. complectens)	Pa-Pb			1																1		
(DE Mag. sp.)	Pa-Pb																			1		
(DE Neo. peracutus)	M		2											1	1	21	9	3	4	43		
(DE Neo. scitulus)	M			1												1	1			3		
(DE Neo. sp.)	M									1							6		1	8		
(DE Hib. milleri)	Sa		1	1												1				3		
(DE Lig. tenuis)	Sb-Sc			1				1		1?		1				4	4	1		13		
(DE Lig. levis)	Sb-Sc		1	1			1	1		2		2				2		2		12		
(DE Klad. macrodentata)	?Sb-Sc															6				6		
Kladognathid fragments			2	5	1	3	6	3	3							107	26	10	5	171		
Lochriea spp.	Pa																17	8		25		
L. commutata	Pa	1	4	1	1	2	1	5	2	4			2			111	76	35	5	249		
	Pb															82	38	3	1	124		
	M			1	1	1	2	2	1	3				1	1	168	77	8		266		
	Sa																			2		
	S																74	21		97		
Lochriea mononodosa	Pa												2			59	72	48	4	185		
Lochriea nodosa	Pa												1		1	65	23	17	2	109		
L. mononodosa/nodosa	Pa															6	7			13		
Mestognathus spp.	Pa															1	1	6		8		
	S															3?		20		23		
M. beckmanni	Pa																					
M. bipluti	Pa																	10		10		
Syncladognathus geminus	Pa					2		2		1		1?				2				3		
	S												1			1	1?	1?		9		
Vogelgnathus campbelli	Pa	1														1	1		1	4		
	S															1				1		
Platform (Pa) fragments		1	5	14	5	1	6	5	7	8		1	11	6	4	174	194	207	15	664		
Pb fragments				2										1		10	3			16		
Hindeodellian fragments		2		3	1	13	14	11	8	9		6	7	3		425	193	38	45	778		
Indet. ramiforms		3	9	7	2	4	8	1	2	7		3	3	7	8	127	54	25	4	274		
Total		9	58	88	22	40	72	46	62	83	0	30	63	63	45	2003	1300	1269	179	5431		
Wt. diss. Kg		1.5	1.9	1.9	1.3	1.5	1.6	1.6	2.0	2.0	1.6	1.9	1.9	2.0	2.0	1.8	1.9	1.9	1.6	31.9		
Abundance/Kg		6	30	46.8	16.9	26.7	45	28.8	31	41.5	0	15.8	33.2	31.5	22.5	1113	684	668	111.2	170.3		
No. multiel. spec./sample		3	5	6	5	4	4	4	5	6	0	5	9	5	5	13	11	9	8	6(av)		

Tab. 4 - Numbers of elements of conodont species from samples from the Loughshinny Formation in the Altmush Stream section.

Gnathodus girtyi present in 16 of 18 samples, with the greatest number of specimens in samples 96I, 96J and ALT9 (Tab. 4). *Gnathodus bilineatus* is also abundant, but is present in only 7 samples, all from the upper part of the section (ALT7-96K), with the highest yields in samples 96J and ALT9. *Lochriea commutata* occurs in 14 samples, with the largest number of Pa elements in samples ALT9 and 96I. *Gnathodus homopunctatus* was only recovered in small numbers from sample ALT9. Other species of *Lochriea* represented include *L. mononodosa* and *L. nodosa*, both of which are present in the upper four samples (ALT9 to 96K) and ALT7. Large numbers of specimens of both species are recorded in samples ALT9, 96I and 96J.

Other species present in Altmush Stream section include *Kladognathus tenuis/complectens* and *Idiopriodontus healdi*. *K. tenuis/complectens* is present in 15 samples, usually in small numbers, except in sample ALT9, which has >50% of the total number of specimens. *Idiopriodontus healdi* is present in 12 samples, most of which have low yields, except for samples ALT9, 96I-96J (Tab. 4). The other 8 species occur in small numbers and include *Cavusgnathus naviculus* (in 4 samples) and *C. unicornis?* (sample ALT2). (All cavusgnathids were recovered from the lower part of the section). In contrast, *Mestognathus* as *M. bipluti* is present only in the upper part of the section (sample 96J). *Synchyrognathus geminus* is present in 8 samples, *Hindeodus cristula* occurs only in five, and *Vogelgnathus campbelli* only in 4 samples.

Biostratigraphically important conodont species

Biostratigraphically important conodont taxa at Altmush Stream (Text-fig. 7) include in the upper section the lowest co-occurrence of *Lochriea nodosa* and *L. mononodosa* in sample ALT7 which define the base of the *L. nodosa* Zone. A rich fauna in sample ALT9 within the *nodosa* Zone includes *Mestognathus bipluti*, *Gnathodus bilineatus*, and the only records of *Gnathodus homopunctatus* and *Kladognathus macrodentata*. Interestingly, *Gnathodus bilineatus* is not recorded from the *bilineatus* Zone in this section.

The unusually rich conodont concentration in the youngest samples occurs close to the Brigantian/Namurian boundary in Altmush Stream, as the basal Namurian zonal goniatite *Cravenoceras leion* is present near the base of the succeeding Altmush Shale Formation (Jackson, 1965).

Conodont biofacies

The samples with the highest yields (samples 96I-K) near the top of the section are in mainly thickly-bedded, medium to coarse-grained, intraclastic-skeletal packstones and grainstones, or limestone breccia (sample ALT9). The conodont faunas are dominated by species of *Gnathodus* and *Lochriea*, referred to here

as the *Gnathodus-Lochriea* Biofacies. However, similar limestones in the lower section (samples 96A-F) have generally low yields (Tab. 4). Some of these samples, from the base of graded limestones (samples 96D, 96E), may have suffered loss from the redistribution of elements during accumulation of the beds. Samples with very low yields, are in calcisiltites (e.g. sample ALT1) or cherty/dolomitic limestones (e.g. samples 96A, 96D).

The unusually high conodont abundance and diversity in sample ALT9 may be partially explained by the facies, a polymict limestone breccia, this lithology suggests reworking of older rocks and probable concentration of conodont elements from the adjacent contemporaneous platforms. However, the sample not only has large numbers of Pa elements, but also has abundant Pb, M and S elements of *Gnathodus* and *Lochriea*, as well as of *Kladognathus* and *Idiopriodontus*. These might not be expected to survive transport and abrasion together with the more robust platform elements which would be preferentially concentrated.

The massive, coarse-grained and graded crinoidal unit near the top of the section (samples 96G and 96H) shows a distinct uniformity of microfacies and fauna. The conodont yield is poor and diversity is low in both samples, although *Gnathodus girtyi* Pa elements are present in similar numbers, as in stratigraphically older samples. This facies, occurring in the *L. nodosa* Zone, is comparable with the coarse crinoidal grainstones at the top of the Deer Park South and in Poulmore Scarp sections within the same zone, and probably represents a transported platform fauna.

Summary

The samples from Altmush Stream were expected to have high conodont yields because of the predominantly deeper-water basinal facies and the known association of species of *Gnathodus* and *Lochriea* in deeper-water, open-marine facies (Austin, 1976; Davies, 1980; Austin, 1987). However, conodonts are only abundant in the upper section, within the *L. nodosa* Zone. Not only is there great abundance, but also large diversity of conodonts with up to 13 species present in samples.

COMPARISON WITH OTHER LATE VISÉAN SECTIONS IN EUROPE

CONODONT BIOSTRATIGRAPHY

Higgins (1975, 1981) regarded late Viséan and early Namurian conodont faunas of Europe to be a continuation of faunas characterised by the genera *Gnathodus* and *Lochriea* established in basinal environments in mid-Viséan time. This evolutionary sequence is recognised from Ireland to the Donets Basin

and in the Pyrenean region of France (Perret & Weyant, 1994) and the Cantabrian Mountains of Spain (Boogaard, 1992; Belka & Lehmann, 1998). The faunas are mostly from deeper-water basinal and pelagic platform facies, but comparable shallow-water faunas are known from Ireland, England (Yorkshire), Scotland, and Poland from the late Viséan and early Namurian (Pendleian-Arnsbergian, E1 and E2) (Higgins, 1981; Skompski, 1996; Skompski *et al.*, 1995).

Three species of *Lochriea* occur in late Viséan rocks of northern Europe; *Lochriea commutata*, the unornamented, long-ranging species, and the ornamented species *L. nodosa* and *L. mononodosa* which originate in the Brigantian (P1) and all extend up to E2b (Arnsbergian) or Serpukhovian (Higgins, 1981; Skompski *et al.*, 1995). In addition two new species of *Lochriea* (*L. senckenbergica*, *L. zieglerei*) first appear at the Viséan/Namurian boundary or early Namurian (Nemirovskaya *et al.*, 1994; Skompski *et al.*, 1995; Skompski, 1996). *Lochriea nodosa* is the eponymous taxon defining the *L. nodosa* Zone which succeeds the *Gnathodus bilineatus* Zone; both zones are recognised all over the world (Perret & Weyant, 1994). *Lochriea nodosa*, in particular, is recognised worldwide in both shallow- (Rexroad & Horowitz, 1990; Armstrong & Purnell, 1987) and deep-water biofacies (Higgins & Wagner-Gentis, 1982). Furthermore, in many sections in Britain and Poland, as well as in Ireland *Lochriea mononodosa* and *L. nodosa* appear simultaneously (Davies, 1980; Metcalfe, 1981; Armstrong & Purnell, 1987; Skompski *et al.*, 1995). It is significant that at Kingscourt both *L. mononodosa* and *L. nodosa* appear together for the first time in the platform facies of Deer Park South section (sample 107A) and in the basinal facies in Altmush Stream (sample ALT7). In both sections this co-occurrence coincides with a major increase in conodont diversity and abundance.

In Ireland as in Poland (Skompski *et al.*, 1995; Skompski, 1996) the *L. nodosa* Zone is characterised by an abundance of *Gnathodus bilineatus*, *G. girtyi*, *Lochriea mononodosa*, *L. nodosa*, associated with *Kladognathus tenuis/complectens*, *K. macrodentata*, *Syncladognathus geminus*, *Mestognathus bipluti*, *Cavusgnathus unicornis*, *C. naviculus* and rare *Gnathodus homopunctatus*. A similar diverse assemblage was recorded from Brigantian rocks of the north crop, South Wales (Rhodes *et al.*, 1969; Austin & Davies, 1984), North Wales (Aldridge *et al.*, 1968; Reynolds, 1970), the Yoredale Group of northern England, especially from the Gayle Limestone (Davies, 1980; Davies *et al.*, 1994), and in the NW and W of Ireland (Austin, 1974; Austin & Husri, 1974; Austin *et al.*, 1970). *M. bipluti* is first reported from the *nodosa* Zone in Britain, Belgium, Poland and the Pyrenees (Varker & Sevastopulo, 1985; Groessens, 1974; Belka, 1983; Skompski *et al.*, 1989; Marks & Wensink, 1970; Perret & Weyant, 1994), but at Kingscourt it occurs earlier, in the *bilineatus* Zone, near the Asbian/

Brigantian boundary; it is therefore of local biostratigraphical significance (Jones & Somerville, 1996). However, *M. bipluti* has also been reported from the *bilineatus* Zone in the Cantabrian Mountains (Park, 1983).

CONODONT BIOFACIES

Shallow-water platform faunas

Limestones of the Asbian Mullaghfin Formation from Barley Hill Quarry and from a thicker sequence in Mokeeran Quarry to the north (Text-figs. 1, 2), contain a mainly sparse conodont fauna dominated by *Syncladognathus geminus*, *Kladognathus tenuis/complectens* (*Syncladognathus-Kladognathus* Biofacies) with cavusgnathids, rare *Gnathodus girtyi* and *Lochriea commutata*, but with local concentrations of *Gnathodus homopunctatus*. Moreover, several samples from rocks of this age from the Kingscourt area were barren. Similar low-diversity faunas occur in the Yoredale Group of northern England (Varker, 1968; Higgins & Varker, 1982; Rexroad & Varker, 1992) and South Wales (Rhodes *et al.*, 1969; Austin & Davies, 1984), and are typical of Asbian shallow-water, partially-restricted platform environments.

Many of the thickly-bedded, pale limestones of the Mullaghfin Formation contain abundant foraminifers, red and green algae (including *Koninckopora*), and display palaeokarsts and palaeosols. This is a very shallow-water facies which was occasionally exposed subaerially. Such environments were presumably unfavourable for the conodont animal. This late Asbian interval showing a paucity or absence of conodonts is recognised in bedded platform limestones and mudmounds in Ardagh Quarry (N 835 955) (Somerville *et al.*, 1996, 1997). Indeed, these massive mudmounds at Ardagh Quarry have the poorest conodont yields of any known depositional environment in the Kingscourt area.

The conodont fauna from the platform limestones of the Brigantian Deer Park Formation is abundant and diverse and has more in common with the deeper water *Gnathodus-Lochriea* Biofacies of basinal environments. Gnathodids are the dominant and most abundant forms, particularly *G. girtyi* and *G. bilineatus*, together with *Lochriea commutata* and locally abundant *L. mononodosa* and *L. nodosa*. In addition *Kladognathus tenuis/complectens* and *Idioprioniodus healdi* form a significant part of the fauna, as in the Yoredale limestones, with less common *Syncladognathus geminus*, cavusgnathids and mestognathids (Varker 1967, 1968, 1993). These platform limestones with a rich benthic fauna of crinoids, brachiopods, and calcareous algae (including *Nanopora*) are characteristic of shallow-water, high-energy platform environments similar to those in the Yoredale Group of northern England and

SE Poland (Varker, 1968; Davies, 1980; Davies *et al.*, 1994; Varker *in* Skompski *et al.*, 1995; Skompski, 1986, 1996).

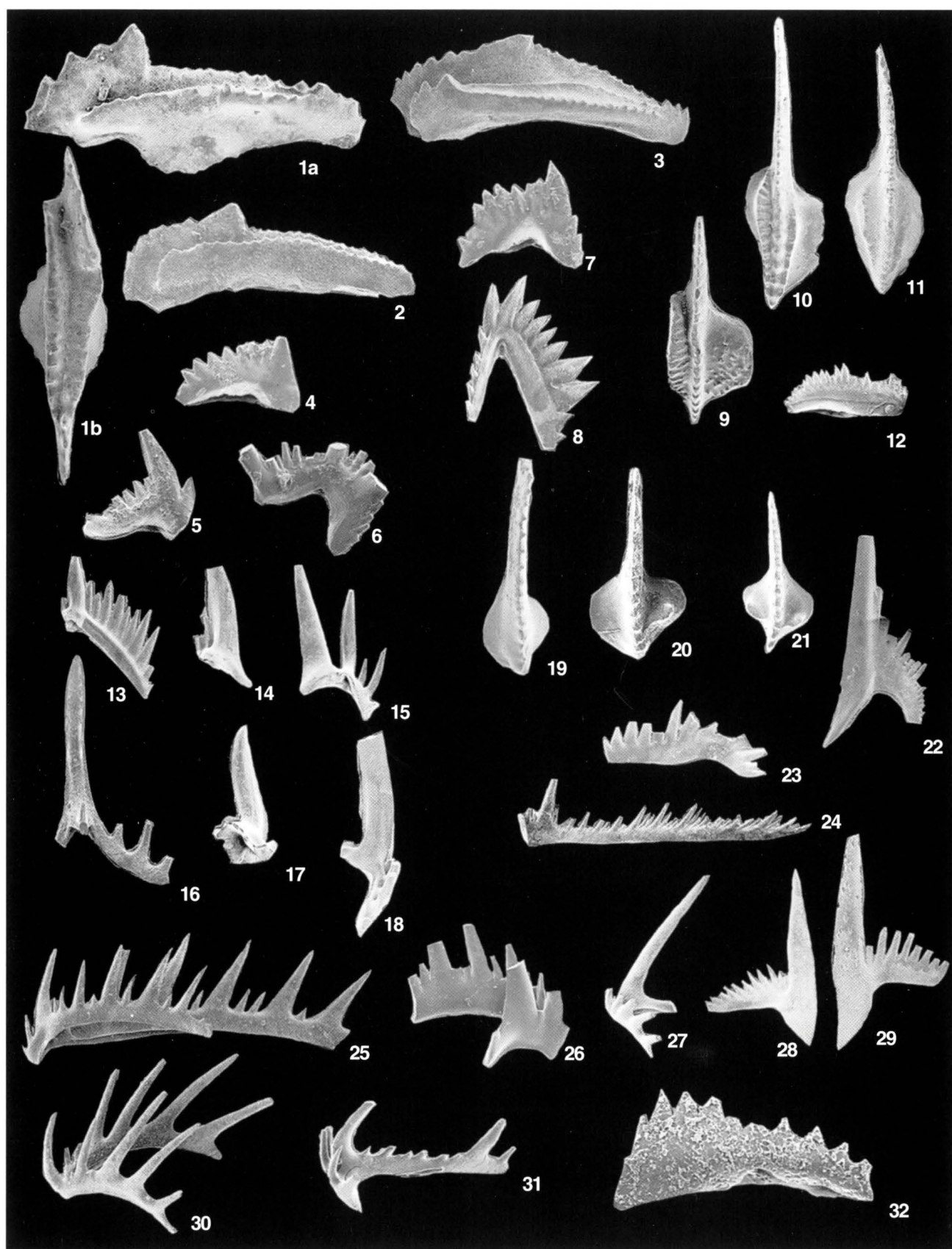
The *nodosa* Zone of the upper Deer Park Formation at Poulmore Scarp has exceptionally rich and diverse faunas; however, many samples are ramiform element deficient; and pectiniform elements may constitute over 80% of the total number of elements. This suggests some form of winnowing during sediment transport, activity of predators or selective preservation

(diagenetic?) control (see Davies *et al.* (1994). Similar shallow-water facies with comparable ecological constraints occur in limestone beds within uppermost Viséan cyclothemic sequences in northern England (Three Yard limestone to the Great = Main limestone) (Johnson & Nudds, 1996; Skompski, 1996) and in boreholes from the Lublin Basin of SE Poland (Skompski, 1996). In all three areas the late Brigantian limestones are rich in foraminifers and calcareous algae, including species of *Calcifolium*.

EXPLANATION OF PLATE 1

All specimens illustrated (SEM photographs) refer to National Museum of Ireland, Dublin collections (NMI). Specimens in figs. 1, 3, 9-10, 19-22, 26 were collected from Altmush Stream section (Loughshinny Fm.); specimens in figs. 2, 4-6, 7-8, 12-18, 23-25, 27-31 were obtained from Poulmore Scarp (Deer Park Fm.), Specimens in figs. 11, 32 came from the Deer Park South section (Deer Park Fm.).

- Fig. 1 - *Cavusgnathus naviculus* (Hinde).
a) inner lateral view, Pa element (x 40), specimen number F23001/1, Sample ALT6.; 1b) upper view, Pa element (x 40)
- Fig. 2 - *Cavusgnathus unicornis* (Youngquist & Miller).
Inner lateral view, Pa element (x 40), specimen number F230011/1, Sample PH1
- Fig. 3 - *Mestognathus bipluti* Higgins.
Inner lateral view, Pa element (x 40), specimen number F23002/1, Sample 96J.
- Figs. 4-6 - *Hindeodus cristula* (Youngquist & Miller).
4) lateral view, Pa element (x 65), specimen number F23003/1, Sample PH16;
5) lateral view, Pb element (x 65), specimen number F23003/2, Sample PH16;
6) lateral view, S element (x 65), specimen number F23003/3, Sample PH16.
- Figs. 7-8 - *Synclydogmathus geminus* (Rexroad & Varker).
7) lateral view, Pa element (x 65), specimen number F23004/1, Sample PH9;
8) lateral view, S element (x 80), specimen number F23004/2, Sample PH9.
- Fig. 9 - *Gnathodus bilineatus* (Roundy).
Upper view, Pa element (x 40), specimen number F23006/1, Sample ALT9.
- Fig. 10 - *Gnathodus girtyi* (Hass).
Upper view, Pa element (x 40), specimen number F23006/2, Sample ALT9.
- Fig. 11 - *Gnathodus homopunctatus* Ziegler.
Upper view, Pa element (x 65), specimen number F23007/1, Sample 107C.
- Fig. 12 - *Vogelgnathus campbelli* (Rexroad).
Lateral view, Pa element (x 65), specimen number F23003/4, Sample PH16
- Figs. 13-18 - *Idioproniodus healdi* (Roundy).
13) lateral view, (x 35), specimen number F23008/1, Sample PH3.;
14) lateral view, M element (x 35), specimen number F23008/2, Sample PH3;
15) lateral view, (x 40), specimen number F23008/3, Sample PH3;
16) posterior view, Sa element (x 40), specimen number F23009/1, Sample PH19;
17) lateral view, (x 30), specimen number F23008/5, Sample PH3;
18) lateral view, Sc element (x 30), specimen number F23008/6, Sample PH3.
- Fig. 19 - *Lochriea commutata* (Branson & Mehl).
Upper view, Pa element (x 65), specimen number F23006/3, Sample ALT9.
- Fig. 20 - *Lochriea mononodosa* (Rhodes, Austin & Druce).
Upper view, Pa element (x 65), specimen number F23006/4, Sample ALT9.
- Fig. 21 - *Lochriea nodosa* (Bischoff).
Upper view, Pa element (x 65), specimen number F23006/5, Sample ALT9.
- Figs. 22-24 - *Lochriea* sp.
22) lateral view, M element (x 40), specimen number F23006/6, Sample ALT9;
23) lateral view, Pb element (x 40), specimen number F23009/2, Sample PH19;
24) lateral view, S element (x 40), specimen number F23009/3, Sample PH19.
- Fig. 25 - *Kladognathus macrodentata*? (Higgins).
Lateral view, Pa/Pb? element (x 80), specimen number F23010/1, Sample PH8.
- Fig. 26 - *Kladognathus macrodentata* (Higgins).
Lateral view, Pa/Pb? element (x 80), specimen number F23006/7, Sample ALT9.
- Figs. 27-31 - *Kladognathus tenuis/complectens* (Branson & Mehl), emend. Rexroad
27) lateral view, Sc element (x 30), specimen number F23009/4, Sample PH19;
28) lateral view, M element (x 35), specimen number F23009/5, Sample PH19;
29) lateral view, M element (x40), specimen number F23010/2, Sample PH8;
30) lateral view, Pa/Pb element (x 65), specimen number F23009/6, Sample PH19;
31) posterior view, Sa element (x 110), specimen number F23010/3, Sample PH8.
- Fig. 32 - *Hindeodontoides spiculus* (Youngquist & Miller).
Lateral view, Pa element (x 110), specimen number F23005/1, Sample 131D.



Deeper-water, basinal faunas

The conodont faunas of the Altmush Stream section are dominated by abundant *Gnathodus bilineatus*, *G. girtyi*, *Lochriea commutata*, *L. nodosa*, *L. mononodosa* and rare specimens of *Cavusgnathus* and *Mestognathus* (*Gnathodus-Lochriea* Biofacies). Faunal diversity is as high as that of the coeval shelf faunas and the faunas have much in common. Notably, *Syncladognathus* is rare in the basin facies as in the platform facies of the Deer Park Fm. *G. homopunctatus* is extremely rare in the upper part of the *nodosa* Zone in Altmush Stream, but is absent in Poulmore. Factors controlling the distribution of conodonts in both basin and platform depositional settings were probably numerous and interrelated. However, the most important were likely water depth, food availability, and the energy of the environment. Similar conclusions were reached by Davies (1980), Austin & Davies (1984) and Davies *et al.* (1994).

CONCLUSIONS

1. The *Gnathodus bilineatus* and *Lochriea nodosa* zones are recognised in the Kingscourt area in platform and basinal facies. The base of the *nodosa* Zone is defined by the synchronous first occurrence of *L. nodosa* and *L. mononodosa* in the same bed, in both the Deer Park and Loughshinny formations. Several species (e.g. *Mestognathus bipluti*, *Idioproniodus healdi* and *Kladognathus macrodentata*) are virtually restricted to the upper part of the *bilineatus* and the *nodosa* zones of the Brigantian and may be of local biostratigraphical use.
2. The richest conodont faunas were obtained within the *L. nodosa* Zone from late Brigantian platform and basinal limestones. Moderately rich and diverse faunas occur in the upper *G. bilineatus* Zone in early Brigantian platform limestones. The poorest conodont yields were from the *G. bilineatus* Zone (lower part) and the underlying *L. commutata* Zone in Asbian platform limestones and mudmounds.
3. There is a significant rise in the abundance and diversity of conodonts above the Asbian/Brigantian boundary, at the base of the Deer Park Formation. This coincides with changes in lithofacies and foraminiferal assemblages, indicating probable environmental influences associated with transgressive deepening events across the Ardagh Platform. A second major increase in conodont abundance and diversity is recognised at the base of the *nodosa* Zone in platform (Deer Park Fm.) and basinal (Loughshinny Fm.) facies.
4. Slightly deeper-water, fine-grained Brigantian platform limestones contain better preserved conodonts than do shallower-water, coarser-grained Asbian platform limestones. The latter are often

dominated by the *Syncladognathus-Kladognathus* Biofacies, the elements of which are often abraded and fragmented. The best preserved faunas are mostly from wackestones in the *Gnathodus-Lochriea* Biofacies within the *nodosa* Zone at Poulmore. These faunas also have the best representation of all apparatus components.

5. Exceptionally rich and diverse conodont faunas from the top of the Deer Park Formation may be explained in part by local sedimentological factors, resulting in the concentration of elements, particularly Pa elements, in high-energy shallow-water shoal deposits. Similar deposits are known from the Pennsylvanian in the USA.
6. The late Viséan conodont faunas from Kingscourt are comparable in diversity, abundance and by the presence of biostratigraphically important taxa, to those in northern England, North Wales and Poland where limestones occur in cyclothemic sequences. The upper beds at Poulmore, in particular, may be correlated with uppermost Viséan limestones in northern England (Three Yard Limestone to Main Limestone) and Lublin Basin, Poland (Unit A3, Huczwa Fm.).

ACKNOWLEDGEMENTS

We would like to thank the two anonymous referees who offered many useful suggestions and helped us to make substantial improvements to the manuscript.

REFERENCES

- ADAMS, A.E., HORBURY, A.D. & RAMSAY, A.T.S., 1992, Significance of palaeoberesellids (Chlorophyta) in Dinantian sedimentation, U.K.: *Lethaia*, 25: 375-382.
- ALEKSEEV, A.S., KONONOVA, L.I. & NIKISHIN, A.M., 1996, The Devonian and Carboniferous of the Moscow Syncline (Russian Platform). *Stratigraphy and sea-level changes: Tectonophysics*: 268: 149-168.
- ALDRIDGE, R.J., AUSTIN, R.L. & HUSRI, S., 1968, Viséan conodonts from north Wales and Ireland: *Nature*, 219: 255-258.
- ARMSTRONG, H.A. & PURNELL, M.A., 1987, Dinantian conodont biostratigraphy of the Northumberland Trough: *Journal of Micropalaeontology*, 6 (2): 97-112, 3 pls.
- AUSTIN, R.L., 1974, The biostratigraphic distribution of conodonts in Great Britain and the Republic of Ireland. In Bouckaert, J. & Streel, M. (eds.) *International Symposium on Belgian Micropalaeontological Limits, from Emsian to Viséan*, Namur, 1974: Geological Survey of Belgium, 3: 1-17.
- AUSTIN, R.L., 1976, Evidence from Great Britain and Ireland concerning West European Dinantian conodont palaeoecology: *Special Paper of the Geological Society of Canada*, 15: 201-224.
- AUSTIN, R.L., 1987, Conodonts of the Arundian (Dinantian) stratotype boundary beds from Dyfed, South Wales. In Hart, M. (ed.) *Micropalaeontology of carbonate environments: British Micropalaeontology Society Series*, Ellis Horwood Ltd., Chichester: 238-255, 4 pls.
- AUSTIN, R.L., CONIL, R. & HUSRI, S., 1970, Correlation and age of the Dinantian rocks north and south of the Shannon,

- Ireland: Congrès Colloques Université Liège, 55: 179-192, 2 pls.
- AUSTIN, R.L. & DAVIES, R.B., 1984, Problems of recognition and implications of Dinantian conodont biofacies in the British Isles. In Clarke, D.L. (ed.), *Conodont Biofacies and Provincialism*: Geological Society of America, Special Paper, 196: 195-229, 3 pls.
- AUSTIN, R.L. & HUSRI, S., 1974, Dinantian conodont faunas of County Clare, County Limerick and County Leitrim. In Bouckaert, J. & Streel, M. (eds.) *International Symposium on Belgian Micropaleontological Limits, from Emsian to Viséan*, Namur, 1974: Geological Survey of Belgium, 3: 18-69, 15 pls.
- BELKA, Z., 1983, Evolution of the Lower Carboniferous conodont genus *Mestognathus*: *Acta Geologica Polonica*, 33: 73-84, 2 pls.
- BELKA, Z. & LEHMANN, J., 1998, Late Viséan/early Namurian conodont succession from the Esla area of the Cantabrian Mountains, Spain: *Acta Geologica Polonica*, 48: 31-41, 4 pls.
- BOOGAARD, M. VAN DEN, 1992, The recurrence of *Vogelgnathus campbelli*-dominated conodont faunas in the Viséan and early Namurian of the Cantabrian Mts. (Spain): a reflection of sea-level fluctuations?: *Scripta Geologica*, 99: 1-33, 3 pls.
- DAVIES, R.B., 1980, Conodont distributions in some British Dinantian shelf sediments: the Gayle Limestone (Brigantian) of North Yorkshire and selected sections (Courceyan-Brigantian) in the South Wales-Mendip area: Unpublished Ph.D. thesis, University of Southampton: 319 pp.
- DAVIES, R.B., AUSTIN, R.L. & MOORE, D., 1994, Environmental controls of Brigantian conodont-distribution: evidence from the Gayle Limestone of the Yoredale Group in Northern England: *Annales de la Société Géologique de Belgique*, 116 (2): 221-241.
- DRIESE, S.G., CARR, T.R. & CLARK, D.L., 1984, Quantitative analysis of Pennsylvanian shallow-water conodont biofacies, Utah and Colorado. In Clarke, D.L. (ed.), *Conodont Biofacies and Provincialism*: Geological Society of America, Special Paper, 196: 233-250, 1 pl.
- HIGGINS, A.C., 1975, Conodont zonation of the late Viséan-early Westphalian strata of the south and central Pennines of northern England: *British Geological Survey Bulletin*, 53: 1-90, 18 pls.
- HIGGINS, A.C., 1981, The distribution of conodonts in relation to the palaeogeography of late Viséan-Namurian time. In Neale, J.W. & Brasier, M.D. (eds.), *Microfossils from Recent and Fossil Shelf Seas*: British Micropaleontological Society Series, Ellis Horwood, Chichester: 37-51.
- HIGGINS, A.C. & VARKER, W.J., 1982, Lower Carboniferous conodont faunas from Ravenstonedale, Cumbria: *Palaeontology*, 25(1): 145-166, 2 pls.
- HIGGINS, A.C. & WAGNER-GENTIS, C.H.T., 1982, Conodonts, goniatites and biostratigraphy of the earlier Carboniferous from the Cantabrian Mountains, Spain: *Palaeontology*, 25(2): 313-350, 3 pls.
- HORBURY, A.D. & ADAMS, A.E., 1996, Microfacies association in Asbian carbonates: an example from the Asbian Urswick Limestone Formation of the southern Lake District, northern England. In Strogon, P., Somerville, I.D. & Jones, G.L. (eds.), *Recent advances in Lower Carboniferous Geology*: Geological Society of London, Special Publication, 107: 221-237.
- JACKSON, J.S., 1955, The Carboniferous succession of the Kingscourt Outlier with Notes on the Permo-Trias: Unpublished Ph. D. thesis, University of Dublin: 245 pp.
- JACKSON, J.S., 1965, The Upper Carboniferous (Namurian and Westphalian) of Kingscourt, Ireland: *Proceedings of the Royal Dublin Society*, 2A: 131-152.
- JOHNSON, G.A.L. & NUDDS, J.R., 1996, Carboniferous biostratigraphy of the Rookhope Borehole: *Transactions of the Royal Society of Edinburgh Earth Sciences*, 86: 181-226.
- JONES, G.L. & SOMERVILLE, I.D., 1996, Irish Dinantian biostratigraphy: practical application, In Strogon, P., Somerville, I.D. & Jones, G.L. (eds.), *Recent advances in Lower Carboniferous Geology*: Geological Society of London, Special Publication, 107: 371-385.
- KRUMHARDT, A.P., HARRIS, A.G. & WATTS, K., 1996, Lithostratigraphy, microlithofacies and conodont biostratigraphy and biofacies of the Wahoo Limestone (Carboniferous), Eastern Sadlerochit Mountains, Northeast Brooks Range, Alaska: United States Geological Survey Professional Paper, 1568: 1-70, 4 pls.
- MAPES, R.H. & REXROAD, C.B., 1986, Conodonts from the Imo Formation (Upper Chesterian), North-central Arkansas: *Geologica et Paleontologica*, 20: 113-123.
- MARKS, P. & WENSINK, H., 1970, Conodonts and the age of the "Griotte" Limestone Formation in the upper Aragon Valley (Huesca, Spain) I and II: *Proceedings Koninkl Nederlands Akadademie Wetenschappen*, B73 (3): 238-275.
- METCALFE, I., 1981, Conodont zonation and correlation of the Dinantian and early Namurian strata of the Craven Lowlands of northern England: Institute of Geological Sciences Report, 80/10: 1-70, 19 pls.
- NEMIROVSKAYA, T.I., PERRET, M-F. & MEISCHNER, D., 1994, *Lochriea zieglerei* and *Lochriea senckenbergica* - new conodont species from the latest Viséan and Serpukhovian in Europe: *Courier Forschungsinstitut Senckenberg*, 168: 311-317, 2 pls.
- PARK, S.I., 1983, Zonenfolge, Phylogenie und Taxonomie Karbonischer Conodonten zwischen Tournai und Westfal (Westeuropa): Inaugural Dissertation zur Erlangung der Würde eines Doktors der naturwissenschaften, Marburg: 187 pp., 5 pls.
- PERRET, M-F., 1993, *Recherches Micropaleontologiques et biostratigraphiques (Conodontes - Foraminifères) dans le Carbonifère Pyrénéen*: Unpublished Ph.D. thesis, Université Paul Sabatier, Toulouse: 597 pp.
- PERRET, M-F. & WEYANT, M., 1994, Les biozones à conodontes du Carbonifère des Pyrénées. Comparaisons avec d'autres régions du globe: *Geobios*, 27 (6): 689-715.
- PURNELL, M.A., 1993, The *Kladognathus* apparatus (Conodonta, Carboniferous): homologies with Ozarkodinids, and the Prioniodinid bauplan: *Journal of Paleontology*, 67 (5): 875-882.
- PURNELL, M.A., & VON BITTER, P.H., 1996, Bedding-plane assemblages of *Idioprioniodus*, element locations, and the Bauplan of prioniodinid conodonts: Sixth International Conodont Symposium (ECOS VI), Abstracts. Warszawa 1996: 48.
- REXROAD, C.B. & HOROWITZ, A.S., 1990, Conodont paleoecology and multielement associations of the Beaver Bend Limestone (Chesterian) in Indiana: *Courier Forschungsinstitut Senckenberg*, 118: 493-537, 3 pls.
- REXROAD, C.B. & MERRILL, G.K., 1996, Conodonts from the Reelsville Limestone (Chesterian, Lower Carboniferous) in Indiana and adjacent Kentucky: *Geologica et Palaeontologica*, 30: 225-238.
- REXROAD, C.B. & VARKER, W.J., 1992, The new Mississippian conodont genus *Synchydogathus*: *Journal of Paleontology*, 66 (1): 165-170, 3 pls.
- REYNOLDS, M.J., 1970, A Lower Carboniferous conodont fauna from Flintshire, North Wales: *Bulletin of the Geological Survey of Great Britain*, 32: 1-19, 5 pls.
- RHODES, F.H.T., AUSTIN, R.L. & DRUCE, E.C., 1969, British Avonian (Carboniferous) conodont faunas and their value in local and intercontinental correlation: *Bulletin of the British Museum (Natural History) Geology Supplement*, 5: 4-313, 31 pls.
- RILEY, N.J., 1993, Dinantian (Lower Carboniferous) biostratigraphy and chronostratigraphy in the British Isles: *Journal of the Geological Society, London*, 150: 427-446.
- SKOMPSKI, S., 1986, Upper Viséan calcareous algae from the Lublin Coal Basin: *Acta Geologica Polonica*, 36 (1-2): 151-185.
- SKOMPSKI, S., 1996, Stratigraphic position and facies significance of the limestone bands in the subsurface Carboniferous

- succession of the Lublin Upland: *Acta Geologica Polonica*, 46 (3-4): 171-268, 28 pls.
- SKOMPSKI, S., CONIL, R., LALOUX, M. & LYS, M., 1989, Etude micropaléontologique des calcaires du Viséen terminal et du Namurien dans le bassin Carbonifère de Lublin à l'est de la Pologne: *Bulletin de la Société Belge de Géologie*, 98 (3-4): 353-369.
- SKOMPSKI, S., ALEKSEEV, A. MEISCHNER, D., NEMIROVSKAYA, T., PERRET, M-F. & VARKER, W.J., 1995, Conodont distribution across the Viséan/Namurian boundary: *Courier Forschungs-institut Senckenberg*, 188: 177-209, 4 pls.
- SOMERVILLE, I.D., & STRANK, A.R.E., 1984, The recognition of the Asbian/Brigantian boundary fauna and marker horizons in the Dinantian of North Wales: *Geological Journal*, 19: 227-237.
- SOMERVILLE, I.D., STROGEN, P., JONES, G.LI. & SOMERVILLE, H.E.A., 1996, Late Viséan buildups at Kingscourt, Ireland. *In* Strogon, P., Somerville, I.D. & Jones, G.LI. (eds.), *Recent advances in Lower Carboniferous Geology*: Geological Society of London, Special Publication, 107: 127-144.
- SOMERVILLE, I.D., STROGEN, P., & SOMERVILLE, H.E.A., 1997, Upper Viséan platform carbonates and buildups in the Kingscourt Outlier, Ireland: *Proceedings of the XIII International Congress on the Carboniferous and Permian*, 28th August-2nd September 1995 Krakow, Poland. Part 2: 143-152.
- STONE, J.J. & GERAGHTY, D.A., 1994, A predictive template for the apparatus architecture of the Carboniferous conodont *Idioproniodus*: *Lethaia*, 27: 139-142.
- STROGEN, P., SOMERVILLE, I.D., PICKARD, N. & JONES, G.LI., 1995, Lower Carboniferous (Dinantian) stratigraphy and structure in the Kingscourt Outlier, Ireland: *Geological Journal*, 30: 1-23.
- STROGEN, P., SOMERVILLE, I.D., PICKARD, N. & JONES, G.LI. & FLEMING, M., 1996, Controls on ramp, platform and basinal sedimentation in the Dinantian of the Dublin Basin and Shannon Trough, Ireland. *In* Strogon, P., Somerville, I.D. & Jones, G. LI. (eds.), *Recent advances in Lower Carboniferous Geology*: Geological Society of London, Special Publication, 107: 263-279.
- VARKER, W.J., 1967, Conodonts of the genus *Apatognathus* Branson and Mehl from the Yoredale Series of the north of England: *Palaeontology*, 10(1): 124-141, 2 pls.
- VARKER, W.J., 1968, Conodont distribution in Yoredale limestones (D2-E1) of the north of England: *Transactions of the Leeds Geological Association*, 7 (5): 275-290.
- VARKER, W.J., 1994, Multielement conodont faunas from the proposed Mid-Carboniferous boundary stratotype locality at Stonehead Beck, Cowling, North Yorkshire, England: *Annales de la Société Géologique de Belgique*, 116 (2) (1993): 301-321.
- VARKER, W.J. & SEVASTOPULO, G. D., 1985, The Carboniferous System: Part 1 - Conodonts of the Dinantian Subsystem from Great Britain and Ireland. *In* Higgins, A.C. & Austin, R.L. (eds), *A Stratigraphical index of conodonts*: 167-209. 6 pls.; Ellis Horwood, Chichester
- VON BITTER, P.H., 1976, Paleoeecology and distribution of Windsor Group (Viséan-?Early Namurian) conodonts, Port Hood Island, Nova Scotia, Canada: *Geological Association of Canada, Special Paper* 15: 225-241.
- VON BITTER, P. H., SANDBERG, C.A & ORCHARD, M.J., 1986, Phylogeny, speciation and palaeoecology of the Early Carboniferous (Mississippian) conodont genus *Mestognathus*: *Royal Ontario Museum, Life Sciences Contributions*, 143: 1-115, 29 pls.

(manuscript received December 9, 1998
accepted June 11, 1999)

H.E. Anne SOMERVILLE

Ian D. SOMERVILLE

Department of Geology, University College Dublin
Belfield, Dublin 4, Ireland
e-mail address: idsomer@macollamh.ucd.ie