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Late Dinantian (Lower Carboniferous) platform carbonate stratigraphy of the Buttevant area North Co. Cork, Ireland

STEPHEN J. GALLAGHER [*] ***AND IAN D. SOMERVILLE***

Geology Department, University College Dublin, Belfield, Dublin 4, Ireland

A thick sequence of late Dinantian (Asbian–Brigantian) carbonates crop out in the Buttevant area, North Co. Cork, Ireland. A mud-mound unit of early Asbian age (the Hazelwood Formation) is the oldest unit described in this work. This formation is partly laterally equivalent to, and is overlain by, over 500 m of bedded platform carbonates which belong to the Ballyclogh and Liscarroll Limestone Formations. Four new lithostratigraphic units are described within the platform carbonates: (i) the early Asbian Cecilstown Member and (ii) the late Asbian Dromdowney Member in the Ballyclogh Limestone Formation; (iii) the Brigantian Templemary Member and (iv) the Coolbane Member in the Liscarroll Limestone Formation.

The Cecilstown Member consists of cherty packstones and wackestones that are inferred to have been deposited below fair-weather wavebase. This unit overlies and is laterally equivalent to the mud-mound build-up facies of the Hazelwood Formation. The Dromdowney Member is typified by cyclic-bedded kamaenid-rich limestones possessing shell bands, capped by palaeokarst surfaces, with alveolar textures below and shales above these surfaces. The carbonates of this unit were deposited at or just below fair-weather wavebase, the top of each cycle culminated in subaerial emergence. The Templemary Member consists of cyclic alternations of subtidal crinoidal limestones capped by subtidal lagoonal crinoid-poor, peloidal limestones possessing coral thickets. Intraclastic cherty packstones and wackestones characterize the Coolbane Member, which is inferred to have been deposited below fair-weather wavebase but above storm wavebase.

The early Asbian Cecilstown Member has a relatively sparse micro- and macrofauna, typified by scattered *Siphonodendron* thickets, archaediscids at *angulatus* stage and common *Vissariotaxis*. Conversely, macro- and microfauna is abundant in the late Asbian Dromdowney Member. Typical late Asbian macrofossils include the coral *Dibunophyllum bipartitum* and the brachiopod *Davidsonina septosa*. The base of the late Asbian (Cf6γ Subzone) is recognized by the first appearance of the foraminifers *Cribrostomum lecompteii*, *Koskinobigenerina* and the alga *Ungdarella*. The Cf6γ Subzone can be subdivided into two biostratigraphic divisions, Cf6γ1 and Cf6γ2, that can be correlated throughout Ireland. Relatively common gigantoproductid brachiopods and the coral *Lonsdaleia duplicata* occur in the Brigantian units. The base of the Brigantian stage (Cf6δ Subzone) is marked by an increase in the abundance of stellate archaediscids, the presence of *Saccamminopsis*-rich horizons, *Loeblichia paraammonoides*, *Howchinia bradyana* and the rarity of *Koninckopora* species.

Changes in facies at the Cecilstown/Dromdowney Member and the Ballyclogh/Liscarroll Formation boundaries coincide closely with the changes in fossil assemblages that correspond to the early/late Asbian and the Asbian/Brigantian boundaries. These facies changes are believed to reflect major changes in relative sea-level on the Irish platforms. The sea-level variations that are inferred to have caused the facies changes at lithostratigraphic boundaries also brought in the new taxa that define biostratigraphic boundaries. Moreover, many of the Dinantian stage boundaries that are defined biostratigraphically in Great Britain, Belgium and the Russian Platform also coincide with major facies boundaries caused by regressive and transgressive episodes. The integration of detailed biostratigraphic analyses with facies studies will lead to better stratigraphic correlations of Dinantian rocks in northwest Europe.

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[*]Correspondence to: S. J. Gallagher, School of Earth Sciences, University of Melbourne, Parkville, Victoria 3052, Australia (current address).

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1. INTRODUCTION

The Carboniferous sequence in the Buttevant area crops out discontinuously in an area of approximately 450 km^2 just north of Mallow, Co. Cork, Ireland (Figure 1). Here over 1500 m of Lower Carboniferous rocks conformably overlie Old Red Sandstone clastic sediments. Hudson and Philcox (1965) were the first to allocate formation names to the Dinantian stratigraphy of the Buttevant area; the Courceyan part of the Buttevant stratigraphy was further subdivided by Wilbur and Carter (1986). This predominantly carbonate sequence ranges in age from Courceyan to Brigantian and can be subdivided into several lithostratigraphic units (Hudson and Philcox 1965; Wilbur and Carter 1986; Clipstone 1992). Hudson and Philcox (1965) describe three units in the late Dinantian part of the succession in this region: the Cracoean Reef Complex of S_2 (Holkerian) age; the Ballyclogh Limestone Formation, of D_1 (Asbian) age; succeeded by the D_2 (Brigantian) Liscarroll Limestone Formation. Namurian rocks are inferred to unconformably overlie the late Dinantian carbonate succession in the area (Philcox 1961).

Complex faulted anticlines and synclines occur in the area (Philcox 1964). The largest of these is the ENE trending Kilmaclenine Anticline (Figure 1), which occurs south of Buttevant. This structure is cut by NW–NE trending subvertical faults and by ENE trending thrusts on the northern flank of the Kilmaclenine Anticline (Figure 1). These faults determine the outcrop pattern of the late Dinantian rocks just west of Buttevant. Here carbonates of Brigantian age are thrust upon Asbian carbonates, causing local bedding reversal and steepening of dips. To the north of the Kilmaclenine Anticline Namurian sediments outcrop in the core of a complex synclinorium. Still further north the late Dinantian sequence is well exposed in a small faulted anticline around Liscarroll.

Sedimentological and palaeontological data are used to revise both the local lithostratigraphy and the regional biostratigraphic framework. The newly defined lithostratigraphic units can be correlated across large parts of western and southern Ireland, to the Burren area of County Clare and the Callan area of Counties Tipperary and Kilkenny.

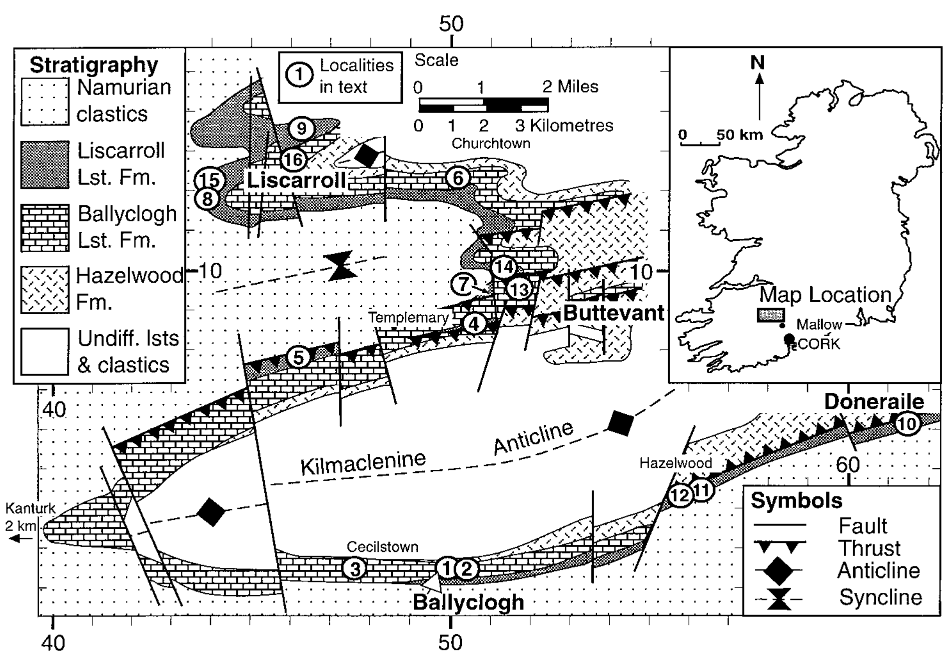

Figure 1. A simplified geological map of the Buttevant region (adapted from Hudson and Philcox 1965) showing the distribution of the late Dinantian (Asbian–Brigantian) units together with Namurian clastic rocks. Also shown are important structural features and the localities (1–16) referred to in the text (see Appendix for precise location). The Irish National Grid (R) is indicated

2. LITHOSTRATIGRAPHY

The stratigraphic framework erected by Hudson and Philcox (1965) is here modified and four new lithostratigraphic members are proposed (Figure 2).

2a. The Hazelwood Formation (Sleeman and McConnell 1995) (thickness up to 265 m)

The Cracoean Reef Complex mapped in the Buttevant area was first described by Hudson and Philcox (1965). Campbell (1988) and Clipstone (1992) informally mapped this unit as the Hazelwood Formation. Subsequently, this formation has been formally defined by Sleeman and McConnell (1995) for Map Sheet 22 (East Cork–Waterford) by the Geological Survey of Ireland. The type section occurs in scattered old quarries beside Hazelwood House (Irish Grid Ref. R556 045) between Mallow and Buttevant (Figure 1). The formation consists of poorly bedded to unbedded pale grey to cream 'crinoidal grainstones and packstones, skeletal calcilutites, mottled and poorly fossiliferous calcilutites and pale grey calcilutites with sparry masses associated with bryozoan fronds and brachiopods' (Sleeman and McConnell 1995).

The Hazelwood Formation is thickest to the East of Ballyclogh near Doneraile (Figure 1) and thins gradually westwards (Figure 2), until it eventually disappears 2–3 km west of Ballyclogh. Complex faulting complicates the distribution of this unit near Buttevant. The macrofauna recorded by Hudson and Philcox (1965) from their 'Cracoean Upper Reef Complex' suggested that this mud-mound build-up complex was Holkerian (S_2) in age. New biostratigraphic data based on a study of foraminifera, conodonts and calcareous algae (Clipstone 1992) has subsequently revealed an Asbian age for the Hazelwood Formation (see below).

Mudbank and inter-bank facies of the Hazelwood Formation
Clipstone (1992) identified the following facies that typify the micritic mudbank and inter-bank limestones of the Hazelwood Formation:

1. bryozoan frond and biomicrite facies typical of mud-bank core facies;
2. peloidal facies of the inter-bank facies with locally abundant chert bands and nodules;
3. thinly bedded discontinuous crinoidal beds or lenses;
4. wackestone inter-bank facies, pale to medium grey in colour; this facies is lighter and less bioclastic than the wackestone facies of the Cecilstown Member.

2b. The Ballyclogh Limestone Formation (emended)

The Ballyclogh Limestone is typified by well-bedded limestones with cherty horizons in its lower part and faunal horizons in its upper part. The type section of this 250 m thick unit occurs near the village of Ballyclogh (Figure 1). The unit was originally defined by Hudson and Philcox (1965). They included in this unit those beds that occur above the Upper Reef Complex and below the Liscarroll Limestone. However, west of Ballyclogh (Figure 1) Hudson and Philcox noted the absence of the Liscarroll Formation (attributed to erosion) and the Ballyclogh Limestone Formation is overlain unconformably by the Namurian. The Ballyclogh Limestone Formation is exposed discontinuously on the flanks of the Kilmaclenine Anticline. The most continuous section of this unit occurs in a stream north of Ballyclogh town (Ballyclogh Stream type section, locality 1, Figure 1) where approximately 190 m of the formation have been logged (Figures 3 and 4). Elsewhere the upper part of the formation crops out 1–2 km east of Kanturk (R381 031), near Templemary, 4 km west of Buttevant (near locality 4, Figure 1) and around Liscarroll.

The lithological differences between the lower and upper part of the formation described by Hudson and Philcox (1965), and emphasized in this study, allow the recognition of two members (Figure 2): the Cecilstown Member and the overlying Dromdowney Member.

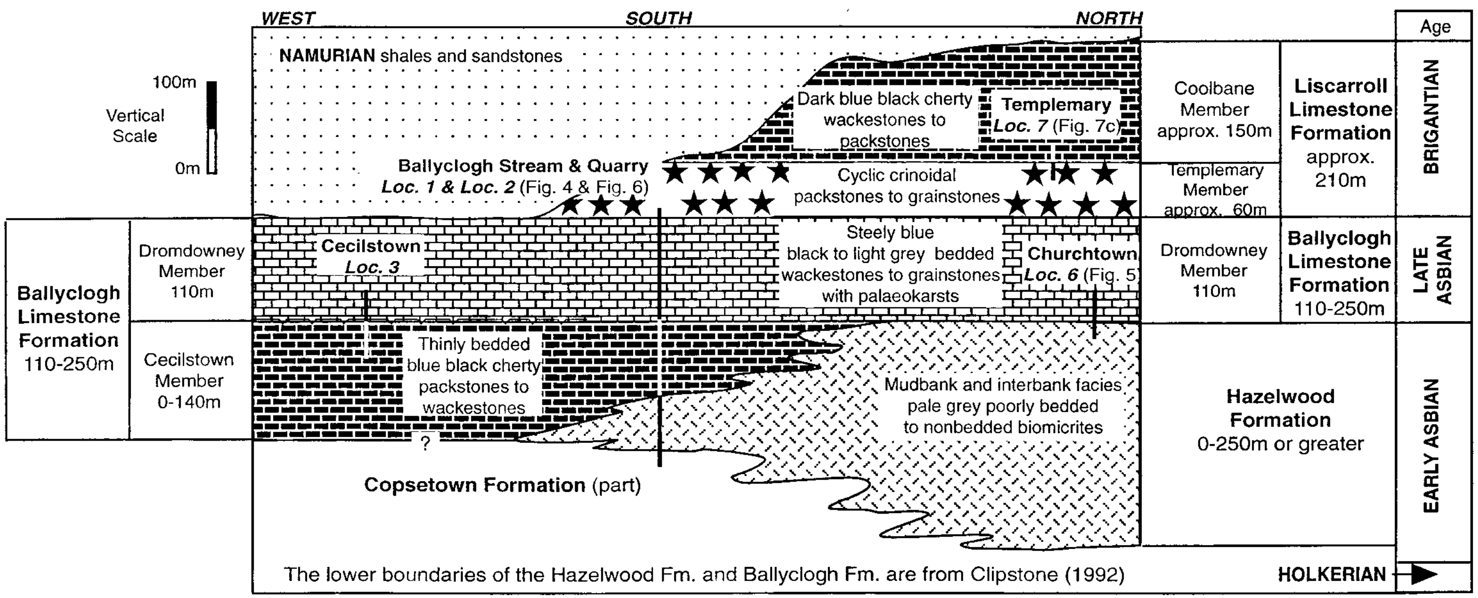

Figure 2. A schematic lithostratigraphic cross-section of the late Dinantian units described in the text. The relative stratigraphic position of key localities is indicated. Note the horizontal distance is not to scale; the vertical scale is indicated

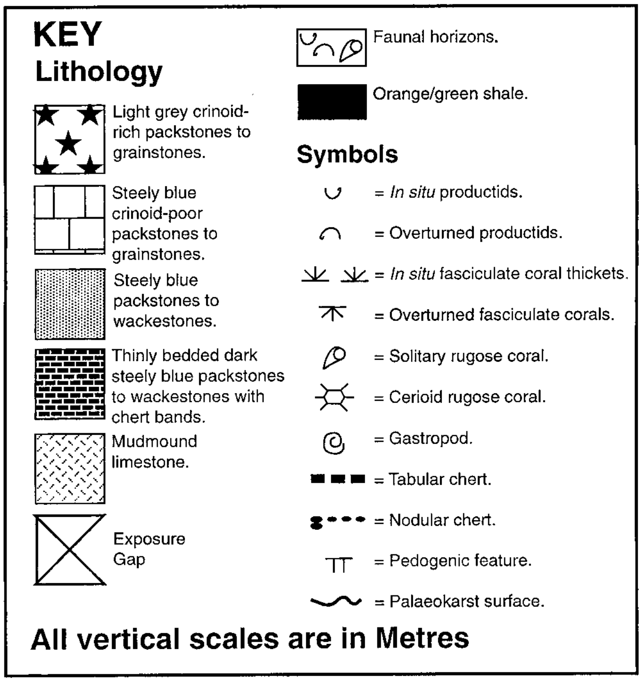

Figure 3. Key to symbols in Figures 4, 5, 6 and 7

Cecilstown Member (here defined) (thickness = *c*. 0–140 m)

The cherty limestones characteristic of the Cecilstown Member are overlain by beds of chert-free limestones which are all assigned to the Ballyclogh Limestone Formation (see below; Hudson and Philcox 1965). This member is named after Cecilstown village (R4694 0219) where beds are exposed for over 500 m along strike in a quarry 1 km west of the village (locality 3, Figure 1). The type section exposes the uppermost 6 m of this member and the contact with the succeeding Dromdowney Member (Figure 2). This upper boundary is also exposed at Ballyclogh (locality 1, Figure 1). The lower boundary is exposed in the Ballyclogh Stream Section and is defined as the first bed of dark cherty limestone overlying the bedded/unbedded pale grey bioclastic limestones of the Hazelwood Formation (Figures 2 and 4). Exposures of this member are rare.

Biostratigraphic data based on a study of foraminifera and calcareous algae establish the Cecilstown member to be of early Asbian age (see below).

The Cecilstown Member consists of thinly bedded (10–50 cm thick), dark steely blue, bioturbated, spicule- and *Kamaenella*-rich packstones and wackestones with tabular chert bands. Beds vary in thickness from 0·1 to 0·5 m and have stylolitic boundaries. Macrofauna is rare and usually consists of scattered brachiopods, gastropods and colonial rugose corals.

Crinoidal material and foraminifera are sparse in all samples. Fenestrate and trepostome bryozoa are common. The member lacks micritized allochems and the dasycladacean alga *Koninckopora* has not been observed.

The Cecilstown Member was deposited in a subtidal, open-marine carbonate environment below fair-weather wavebase. The lack of micritized allochems and *Koninckopora* suggests water depths in excess of 10 m (*cf*. Hennebert and Lees 1991; Horbury and Adams 1996). The presence of rare *Kulikia*, a dasycladacean alga (Skompski 1984), with abundant *Kamaenella* together with the wackestone/packstone depositional textures, suggests a low-energy depositional environment with probable water depths of 15 to 20 m (Horbury and Adams 1996).

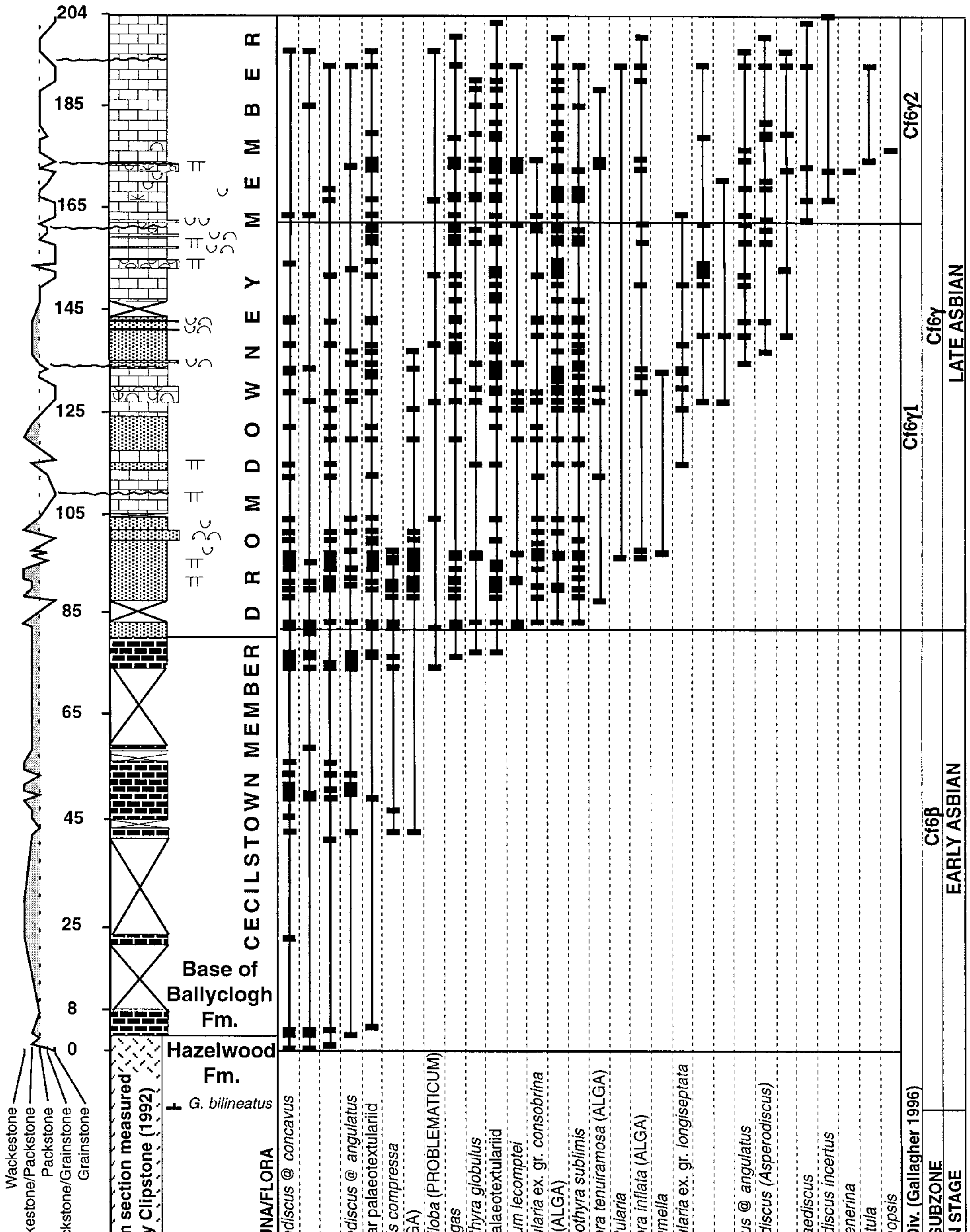

Figure 4. Sedimentary log of the Ballyclogh Limestone Formation from the type section in the Ballyclogh Stream (locality 1, Figure 1). The ranges of biostratigraphically significant microfossils in this section are indicated. The boundary between the Cecilstown Member and the Dromdowney Member is at the 81 m level. The lower 54 m with conodont data is from Clipstone (1992)

The Dromdowney Member (here defined) (thickness = 110 m)
The Dromdowney Member is characterized by well-bedded chert-free limestones with faunal-rich horizons and subaerial exposure surfaces. This member is named after the townland of Dromdowney just east of Ballyclogh (Figure 1). The base of the Dromdowney Member is placed at the first limestone bed overlying the last chert-rich bed of the Cecilstown Member. The type section is in the Ballyclogh stream section (locality 1 at 81 m in the logged section, Figure 4), where over 100 m of this unit is exposed in a continuous section. A section through the lower part of the Dromdowney Member occurs at Egmont Quarry near Churchtown (locality 6, Figures 1, 2 and 5) where 48·5 m have been recorded. At Ballyclogh Quarry (locality 2, Figures 1 and 6) the uppermost 22 m of this member together with 16·5 m of the overlying Liscarroll Limestone Formation are exposed. Macrofaunal and microfauna studies (see below) establish the Dromdowney Member as late Asbian age.

Limestone facies in this member are variable, ranging from mainly thin-bedded (20–50 cm thick), dark grey, peloidal packstone/wackestones with *Kamaenella* in the lower half (81–145 m), to predominantly thicker bedded (50 cm–2 m thick), steely blue, peloidal packstone/grainstones with *Kamaenella/Ungdarella* in the upper half (145–204 m) of the member (Figure 4). Foraminifera are abundant in most samples and bioturbation is common. *Ungdarella*, oolitic, foraminiferal and crinoidal grainstones are present but rare. Brachiopod and coral bands are common throughout. Unfossiliferous orange-green shale horizons are also present and commonly overlie irregular bedding planes in the limestones; the upper surfaces upon which the shales lie exhibit evidence of dissolution and the rocks below these palaeokarst surfaces typically contain pedogenic features such as alveolar septal fabrics and pedotubules (Gallagher 1992, 1996); the former, found beneath shale horizons, are typically formed by rootlet bioturbation (Esteban and Klappa 1983). The shales themselves are considered to be relict soil profiles (*cf*. Walkden 1987).

The Dromdowney Member can be subdivided into several cycles; peloidal and palaeoberesellid packstones and grainstones form the base of the cycles whereas skeletal: grainstones characterize the upper part. Each cycle is capped by an exposure surface as witnessed by the development of the pedogenic features noted above.

The facies in the Dromdowney Member represent various environments ranging from subtidal to subaerial. The peloidal packstones to wackestones that characterize the lower part of the member are likely to have been deposited in a subtidal, open-marine environment within the photic zone, which was subject to periodic reworking. The palaeoberesellid-rich packstone to grainstones in the upper part of the member probably represent deposition at a depth of around 10 m, the optimal depth for the development of *Kamaenella* thickets (Adams *et al*. 1992; Horbury and Adams 1996). The algal/oolitic grainstones are likely to have been deposited in high-energy, shallow marine, oolitic systems. The dissolution surfaces noted at the top of the cycles are typical of limestones exposed to emergence (Davies 1991; Vanstone 1996) and are supported by the presence of pedogenic features in the rocks below the cycle tops.

2c. The Liscarroll Limestone Formation (emended) (thickness = *c*. 210 m)

The formation was originally defined by Hudson and Philcox (1965) from discontinuous sections in the Liscarroll region (Figure 1). They noted at this location that 'the top 700 feet of Carboniferous limestone are dark grey, bedded, chert-bearing limestones, generally bioclastic'. Hudson and Philcox (1965) define the Liscarroll limestones as the beds above the non-cherty limestones of the Ballyclogh Limestone Formation. They also recognized the presence of dark grey bioclastic limestones, cherts (most common at the top), purple grey shaly limestones (rare) and a sparse fauna of D_2 (Brigantian) age for this formation.

Mapping and logging of sections in Templemary (localities 4 and 7, Figure 1) and Liscarrol (locality 9, Figure 1) reveals the presence of a non-cherty crinoidal unit where Hudson and Philcox (1965) had mapped the Liscarroll Limestone Formation. Furthermore, this unit is exposed at Ballyclogh (locality 2, Figure 1) and 6 km ENE of Ballyclogh (localities 11 and 12, Figure 1; where Hudson and Philcox mapped it as the Ballyclogh Limestone Formation). The unit is also exposed at Doneraile (locality 10, Figure 1; 6 km to the

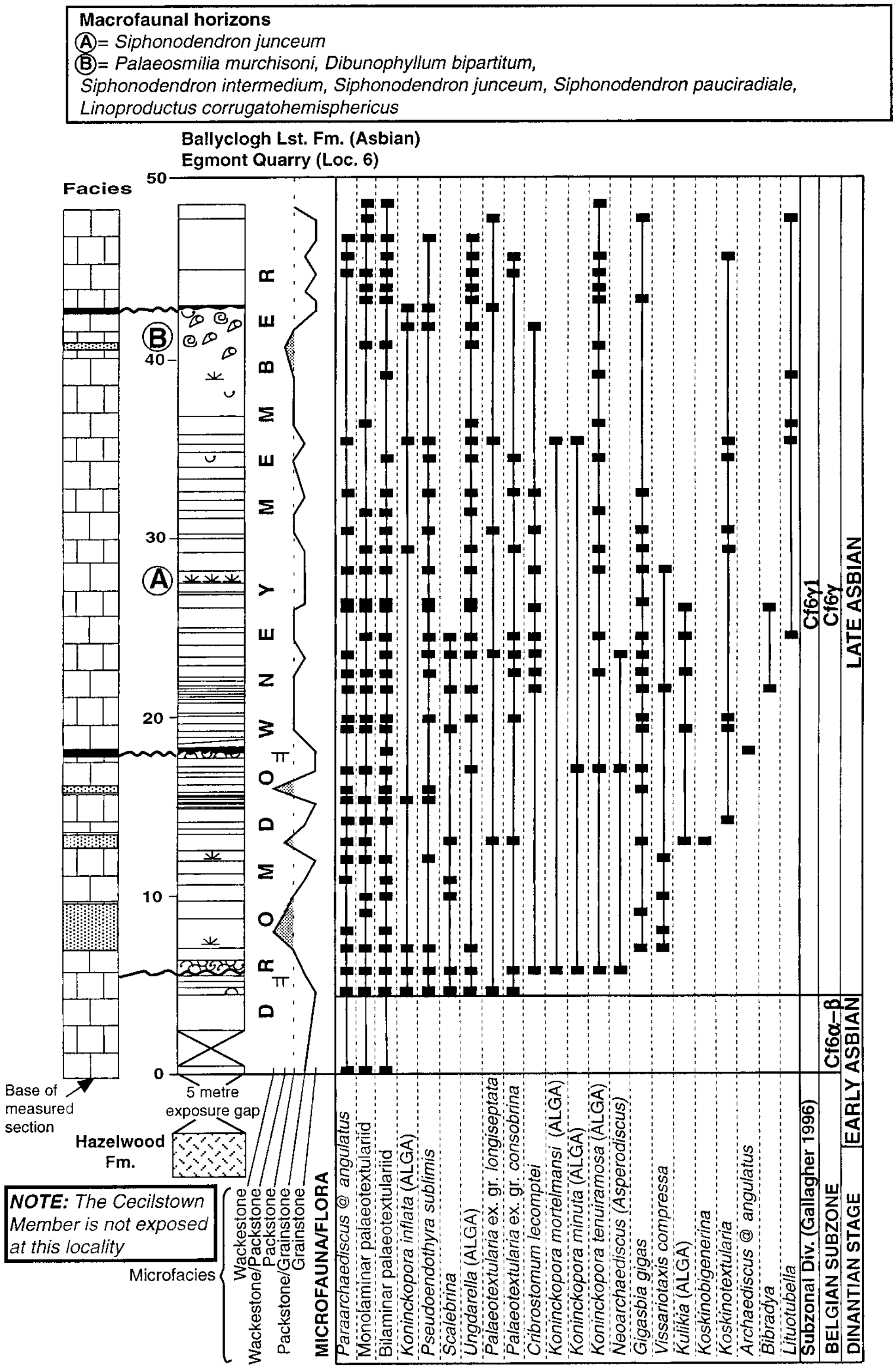

Figure 5. Sedimentary log of the Ballyclogh Limestone Formation at Egmont Quarry (locality 6, Figure 1). The ranges of biostratigraphically significant microfossils in this section are indicated together with macrofaunal lists for key horizons. Note that the Cecilstown Member is not developed below the Dromdowney Member, see Figure 2)

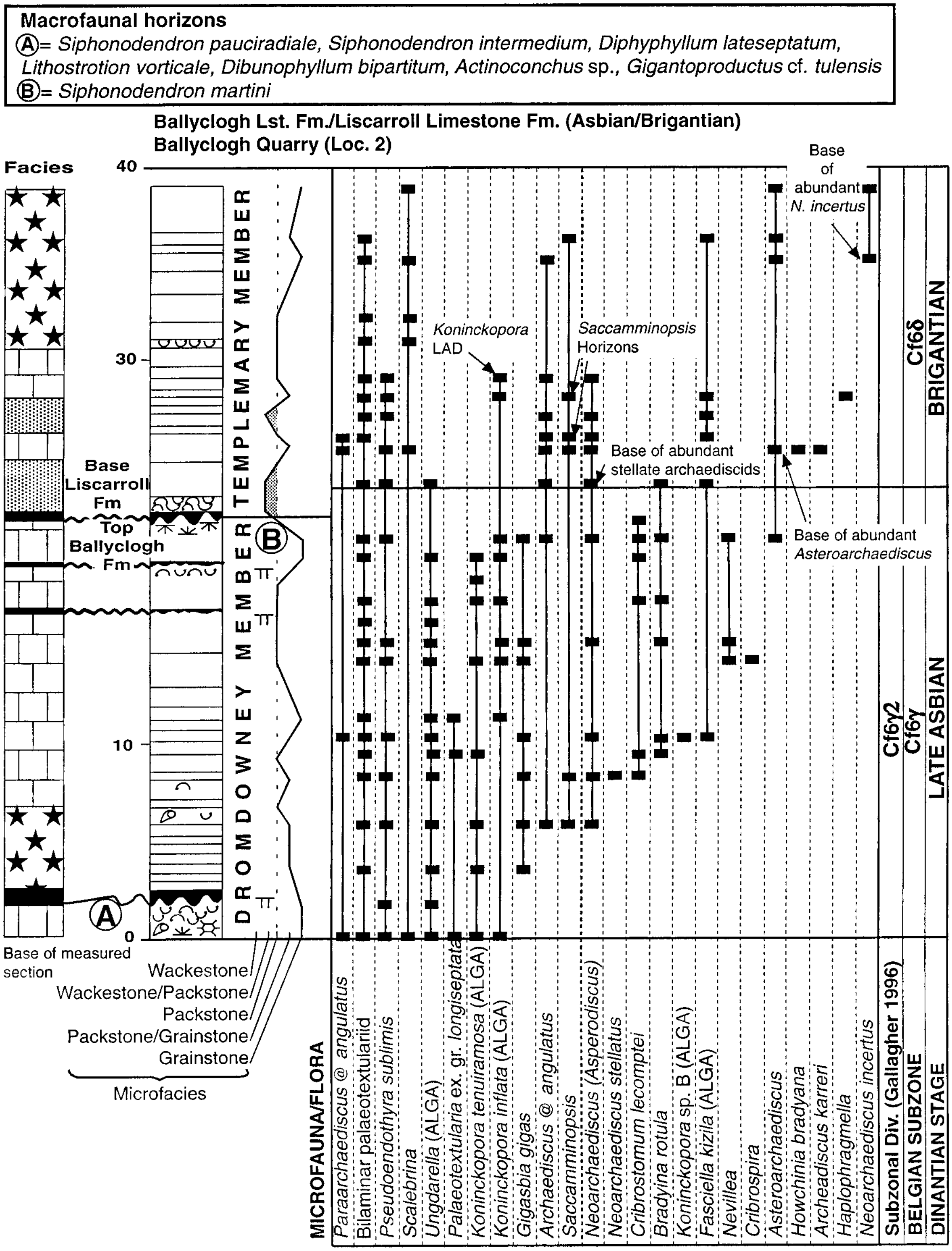

Figure 6. Sedimentary log of the Ballyclogh Limestone Formation/Liscarroll Limestone Formation boundary in Ballyclogh Quarry (locality 2, Figure 1). The ranges of biostratigraphically significant microfossils in this section are indicated together with macrofaunal lists for key horizons

east of the area mapped by Hudson and Philcox (1965)) where a thickness of at least 30 m could be logged (Figures 1 and 7a). Microfaunal and macrofaunal, data suggest this unit is Brigantian in age. On the basis of the lateral continuity of this unit and its age, it is proposed that the base of the Liscarroll Limestone Formation be redefined to incorporate this non-cherty unit. Therefore, the Liscarroll Limestone can now be mapped south of Ballyclogh where Hudson and Philcox (1965) had previously mapped the Ballyclogh Limestone. The Liscarroll Limestone Formation can be subdivided into two new members, the Templemary Member and the overlying Coolbane Member (Figure 2).

The Templemary Member (here defined) (thickness = *c*. 60 m)

The Templemary Member is typified by thickly bedded crinoidal limestones which alternate with thin beds of limestone with coral thickets. The name of this member is derived from the townland of Templemary and the type section occurs at Ballyclogh Quarry (locality 2, Figures 1 and 6), where 16·5 m of the member are exposed. The lower boundary, at log level 21·7 m, is the base of the limestone that overlies the youngest palaeokarst of the Ballyclogh Limestone Formation. *Saccamminopsis* horizons occur just above the base of the Liscarroll Limestone Formation, but are not exposed at any other locality. In the Liscarroll region the base of the member is defined below the first thick-bedded (*c*. 2 m) crinoidal limestones approximately 20 m above the *Davidsonina septosa* bands. The paratype section for the Templemary Member is at locality 7 (Figures 1 and 2) 2 km east of Templemary. At this locality the upper boundary of the member is exposed at log level 9·5 m (Figure 7c). Exposures of the Templemary Member occur in a few quarries south and west of Doneraile town, at localities 10, 11 and 12 (Figures 1 and 7a). Other quarries in the member include localities 4 and 5 (Figure 1) in the Templemary area. Near Liscarroll the Templemary Member is exposed at locality 9 (Figure 1).

The Templemary Member is characterized by amalgamated thick beds of light grey, medium to coarse grained, crinoidal packstones to grainstones, alternating with thinly bedded, dark grey, fine grained, peloidal packstones to wackestones, that usually contain horizons of *in situ* coral thickets. Sponge spicules and molluscan material are abundant in the peloidal facies, but foraminifera, crinoids, bryozoans and brachiopods are much rarer. Light grey, sparsely crinoidal limestones with chert nodules are subordinate. The member is cyclic. A typical cycle consists of thick beds of crinoidal grainstones in the lower part passing up into fine grained, crinoid-poor wackestones and packstones with coral thickets in the upper part. In rare instances pedotubules have been recorded from the top of the cycles.

Crinoid limestones are considered by Aigner (1985) to have been produced by allochthonous accumulation of material that was then reworked by physical processes into a 'complex system of shallow-water bars, banks and blankets'. Storm reworking and bioturbation may also contribute to their sedimentary fabric (Cain 1968; Aigner 1985). The fine grained spicule-rich peloidal limestones which cap cycles were probably deposited in a low-energy, subtidal 'lagoonal' environment with a restricted fauna. The presence of rare pedotubules suggests rootlet bioturbation of a subaerially exposed limestone in this unit. The paucity of pedogenic features in this member may be the result of erosional processes such as ravinement, associated with the ensuing transgressive episode, or possibly short exposure times (*cf*. Vanstone 1996).

The Coolbane Member (here defined) (thickness *c*. 150 m)

Well-bedded cherty limestones characterize this member. The name of this member is derived from the townland of Coolbane, near Liscarroll. Here the thickest sequence of the Coolbane Member occurs in a quarry at locality 8 (Figures 1 and 7b) 1 km SW of Liscarroll town. The base of the member in the type section is at locality 7 (Figures 1 and 7c) and is defined at log level 9·5 m by the first appearance of bedded, dark steely blue limestones with chert overlying the last crinoidal limestones and coral thickets of the Templemary Member. This lower boundary is not observed at any other locality. The upper boundary is not exposed but it is usually marked by a change in topography or a spring line at the boundary with the overlying Namurian Clare Shales. The shales are inferred by Hudson and Philcox (1965) to rest unconformably on both the Liscarroll and the Ballyclogh Limestone Formations. Most quarries in the Coolbane

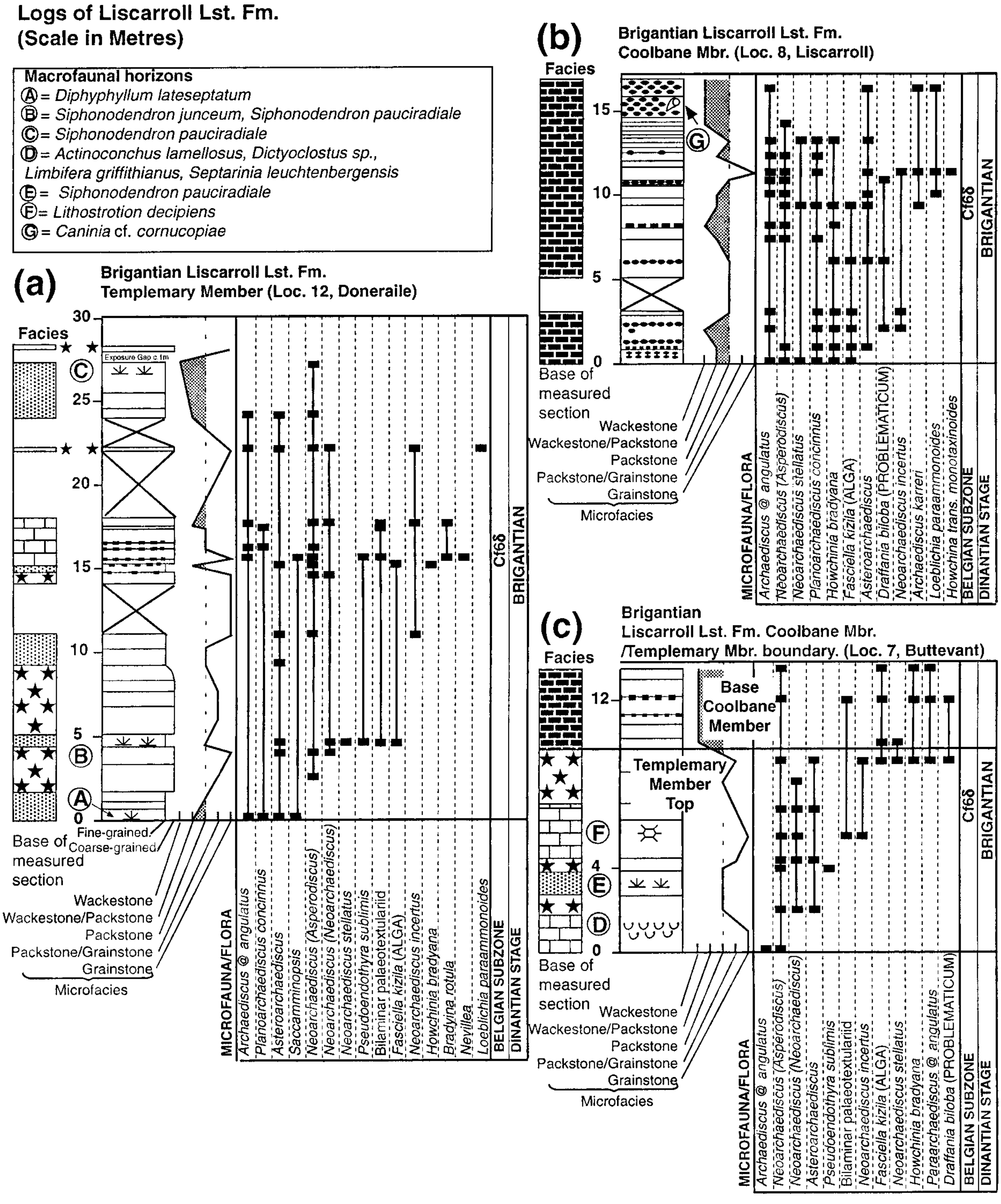

Figure 7. (a) Sedimentary log of the Liscarroll Limestone Formation from a section of the Templemary Member near Doneraile at locality 12 (Figure 1); (b) sedimentary log of a section of the Coolbane Member of the Liscarroll Limestone Formation at locality 8 (Figure 1); (c) sedimentary log of the Liscarroll Limestone Formation from the paratype section of the Templemary Member at locality 7 (Figure 1). The Templemary/Coolbane Member boundary is at log level 9·5 m. The ranges of biostratigraphically significant microfossils in this section are indicated together with macrofaunal lists for key horizons

Member occur around the town of Liscarroll, on the flanks of a small anticline. Other localities include those in the Templemary region (Figure 1). This member is Brigantian in age, on the basis of microfossil data (see below).

The Coolbane Member consists of well-bedded (0·1–2·5 m), steely blue, bioturbated, spicule-rich peloidal packstones and wackestones. Irregular intraclasts of wackestone are abundant and often partially coated with the problematic alga *Fasciella* (Figure 9z). Bedding planes are stylolitic. Chert is common and occurs as a replacement of former burrows, as tabular sheets and as nodular horizons. Shaly limestones are rare and some (as noted by Hudson and Philcox (1965)) have a purple appearance. Macrofauna is rare and can be partially silicified. Shell accumulations, which are typically laterally discontinuous, consist of scattered *in situ* thin-shelled productids or a mixed fauna of *in situ* articulated gigantoproductids, gastropods and rugose corals. Small solitary rugose corals occur sporadically in the sequence. One horizon of algal laminations 0·1 m thick was found at locality 9 (Figure 1). The laminations consist of peloidal grainstones that lack microfauna. This stromatolite horizon is not exposed at any other locality.

The bulk of this member was deposited in a deep-water, subtidal, open-marine environment, below fair-weather wavebase, but above storm wavebase. Bioturbation and occasional storm events in this environment are considered to have combined to generate the abundant intraclasts in this member.

3. BIOSTRATIGRAPHY

A detailed micro- and macrofaunal biostratigraphy was used to date the succession. This involved the documentation of over 27 macrofaunal, 55 microfaunal and over 11 microfloral and problematic taxa. Several of these taxa are age-diagnostic and form the basis for biostratigraphic analyses. The use of litho- and microfacies analyses with detailed biostratigraphy using four different groups of fossils, has provided a well-constrained stratigraphy for the area; this stratigraphy can be correlated with other parts of southern and western Ireland (Gallagher 1996). The biostratigraphic zonation schemes and the ranges for individual organisms used in this section are described in George *et al*. (1976), Conil *et al*. (1980), Fewtrell *et al*. (1981), Paproth *et al*. (1983), Somerville and Strank (1984), Mitchell (1989), Conil *et al*. (1990), Pickard *et al*. (1992), Riley (1993), Gallagher (1996) and are reviewed in Jones and Somerville (1996).

3a. Macrofaunal biostratigraphy

Over 200 corals and brachiopods were collected and identified from the Ballyclogh and Liscarroll Limestone Formations. Each unit is dated using the coral zonation schemes of Conil *et al*. (1990) and Mitchell (1989). Macrofaunal data indicate that the Dromdowney Member of the Ballyclogh Formation is late Asbian in age. The ranges of all the macrofauna collected and identified in this work are shown in Figure 8 and data from individual faunal bands are listed in Figures 5, 6 and 7.

Hudson and Philcox (1965) concluded that the Ballyclogh Limestone in the Buttevant area was mostly of D_1 (Asbian) age, based on the presence of the solitary corals *Dibunophyllum bipartitum*, *Palaeosmilia murchisoni* and the brachiopod *Davidsonina septosa*. Hudson and Philcox also suggested that the lower part may be of S_2 (Holkerian) age and would therefore be, in part, the lateral equivalent of the Hazelwood Formation, based on the occurrence of the brachiopod *Daviesiella llangollensis*. Conversely, microfossil dating of the Hazelwood Formation by Clipstone (1992) suggests that this formation has an Asbian age (see below). Hudson and Philcox (1965) suggested a D_2 (Brigantian) age for the Liscarroll Limestone Formation based on the occurrence of the colonial coral *Lonsdaleia* (*Actinocyathus*) *floriformis*.

Macrofauna from the Ballyclogh Limestone Formation

Many of the sections in the Dromdowney Member contained corals at or near the top of cycles. Fourteen quarries were sampled for macrofauna in the Ballyclogh Formation. The substage divisions early and late

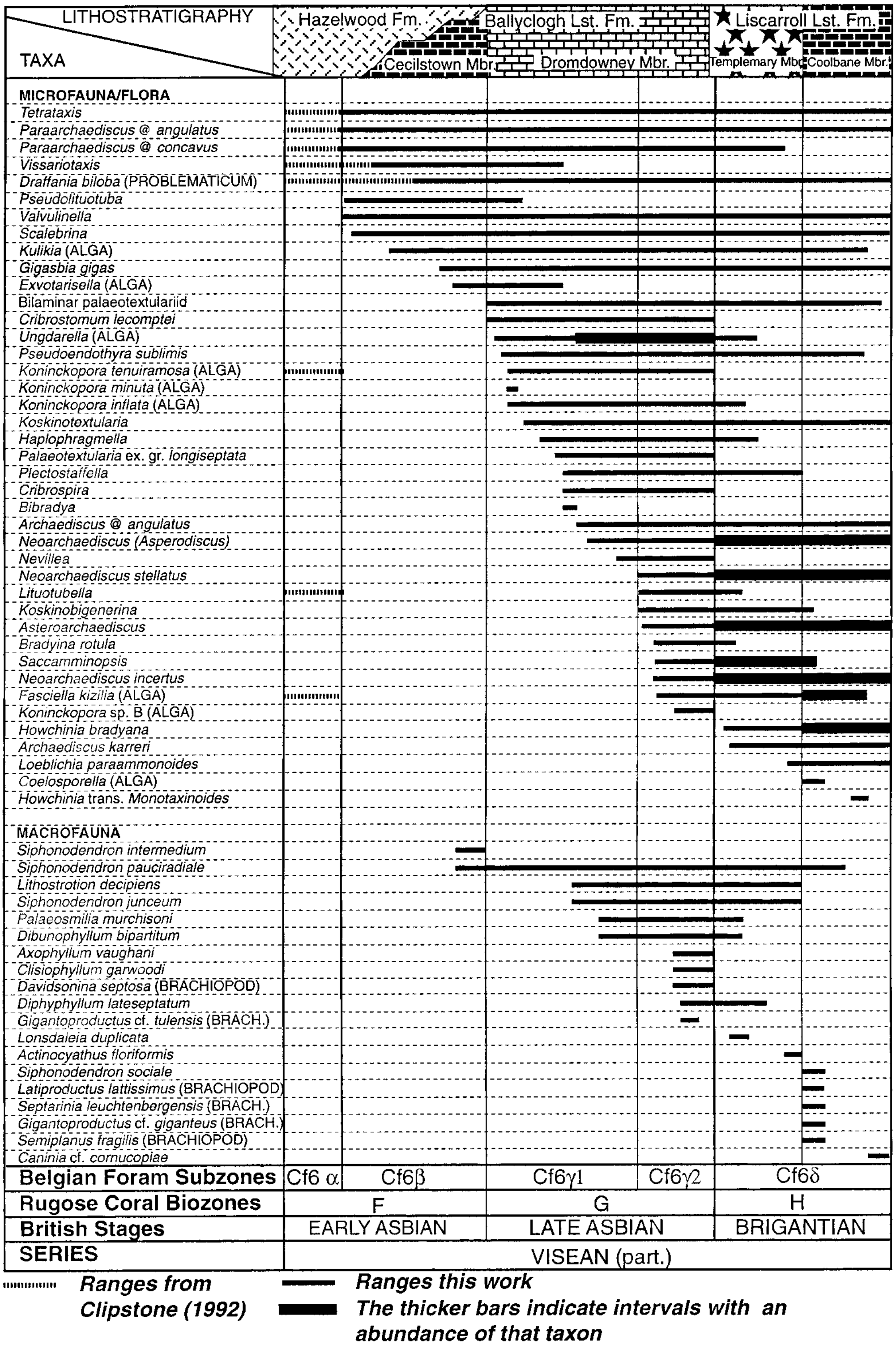

Figure 8. Biostratigraphic ranges of selected taxa in the Late Dinantian of the Buttevant area. Note: the ranges of particularly important biota are extended into the Hazelwood Formation based on data in Clipstone (1992)

Asbian are used in this work and correspond to the rugose coral assemblage biozones F and G respectively (Mitchell 1989; Jones and Somerville 1996).

(i) *Early Asbian*. With the exception of the coral *Siphonodendron intermedium* and the diagnostic Asbian coral *Siphonodendron pauciradiale*, the cherty facies of the Cecilstown Member yielded a sparse macrofauna. The early Asbian indicator *Daviesiella llangollensis* (George *et al*. 1976) was not collected by us, but this brachiopod was recorded by Hudson and Philcox (1965) in the Ballyclogh Formation, and they suggested it may indicate a S_2 (Holkerian) age for the lower part of the Ballyclogh Formation. Further microfossil studies have revealed an early Asbian age for the Cecilstown Member (see below).

(ii) *Late Asbian*. Most of the sections that yield rich macrofauna lie stratigraphically within the Dromdowney Member in the Ballyclogh Limestone Formation. The cerioid coral *Lithostrotion decipiens* is relatively rare and is present in the Templemary Member of the Liscarroll Limestone Formation. The majority of the corals found in the Dromdowney Member are solitary rugose forms such as *Palaeosmilia murchisoni* and the diagnostic late Asbian taxon *Dibunophyllum bipartitum* (Figure 9y; Jones and Somerville 1996). Fasciculate rugose corals such as *Siphonodendron pauciradiale* and *Siphonodendron junceum* are also present. Other rare macrofauna in the Dromdowney Member include the corals *Axophyllum vaughani*, *Clisiophyllum garwoodi* and the brachiopod *Gigantoproductus* cf. *tulensis*. Two horizons of the late Asbian brachiopod *Davidsonina septosa* occur in the upper part of the Dromdowney Member in the Liscarroll region. *Diphyphyllum lateseptatum* first occurs in the uppermost part of the late Asbian just below the Asbian/Brigantian boundary at locality 2, (Figures 1 and 6). This is similar to the distribution reported by Somerville and Strank (1984) for the British Isles.

The assemblage data suggest that the Dromdowney Member is late Asbian in age and belongs to the rugose coral assemblage biozone G of Mitchell (1989).

Macrofauna from the Liscarroll Limestone Formation.

The occurrence of *Lonsdaleia duplicata* (Figure 9x) in the Liscarroll Limestone Formation suggests that the unit is Brigantian in age, corresponding to the rugose coral assemblage biozone H of Mitchell (1989) and the RC8 Belgian Subzone (Poty *in* Conil *et al*. 1990). Hudson and Philcox (1965) recorded *Actinocyathus floriformis* from a locality near Liscarroll town, confirming the Brigantian age for this formation. This coral was also recorded by the authors in float near an outcrop of the Templemary Member in Doneraile (locality 11, Figure 1). The brachiopod assemblage found in the Coolbane Member (listed in Figure 8) ranges from the late Asbian to Brigantian.

Figure 9. Illustrations of selected, biostratigraphically important micro- and macrofossils from the Asbian to Brigantian formations in the Buttevant area, North Co. Cork (see Appendix for details of localities and stratigraphic horizons). Taxa a–c, h, j, k, m, q–s, v, w, y (late Asbian Dromdowney Member–Ballyclogh Lst. Fm.) Taxa l, o, x (Brigantian Templemary Member–Liscarroll Lst. Fm.). Taxa, g, t, u, z (Liscarroll Fm. Undiff.). (a) *Koskinobigenerina breviseptata* (Eickhoff) locality 6, log level 13 m on Figure 5 (×30); (b) *Cribrostomum lecompteii* (Conil and Lys) locality 6, log level 28 m on Figure 5 (×30); (c) *Bibradya grandis* (Strank), locality 6, log level 24·3 m on Figure 5 (×50); (d) *Loeblichia paraammonoides* (Brazhnikova), locality 8, log level 11·3 m on Figure 7b (×50); (e) *L. paraammonoides* (Brazhnikova) locality 8, log level 10 m on Figure 7b (×50); (f) *Howchinia* trans *Monotaxinoides* sp. locality 8, log level 11·3 m on Figure 7b (×50); (g) *L. paraammonoides* (Brazhnikova) locality 14 sample 8 (×50); (h) *Haplophragmella* sp. locality 1, log level 97·5 m on Figure 4 (×50); (i) *Howchinia bradyana* (Howchin), locality 8, log level 3·1 m on Figure 7b (×65); (j) *Vissariotaxis compressa* (Brazhnikova) locality 6, log level 10·9 m on Figure 5 (×50); (k) *V. compressa* (Brazhnikova), locality 1, log level 83·2 m on Figure 4, (×50); (l) *Bradyina rotula* (Eichwald), locality 12, log level 16·5 m on Figure 7a (×20); (m) *Asteroarchaediscus* sp., locality 1, log level 162·5 m on Figure 4 (×25); (n) *Neoarchaediscus* (*Neoarchaediscus*) *incertus* (Grozdilova and Lebedeva) locality 8, log level 2 m on Figure 7b (×90); (o) *Asteroarchaediscus baschkiricus* (Krestovnikov and Teodorovitch) locality 4, log level 6·9 m (×25); (p) *Neoarchaediscus (Asperodiscus) stellatus* (Bozorgnia) locality 8, log level 9·3 m on Figure 7b (×25); (q) *Plectostaffella* sp., locality 1, log level 97·8 m on Figure 4 (×50); (r) *Scalebrina compacta* (Conil and Longerstaey) locality 1, log level 100·1 m on Figure 4 (×50); (s) *Cribrospira mira* (Rauser-Chernoussova) locality 13, log level 5·3 m (×50); (t) *Saccamminopsis fusulinaeformis* (M'Coy) locality 15, log level 5·8 m (×30); (u) *Coelosporella jonesii* (Wood) locality 15, log level 5·8 m (×30); (v) *Koninckopora* sp. B locality 2, log level 10·3 m on Figure 6 (×50) (w) *Kulikia* sp., locality log level 101·8 m on Figure 4 (×50); (x) *Lonsdaleia duplicata* (Martin) locality 4 (×2); (y) *Dibunophyllum bipartitum* (M'Coy), locality 16 (×1·5); (z) *Fasciella kizilia* (Ivanova 1973), locality 15, log level 3 m (×50)

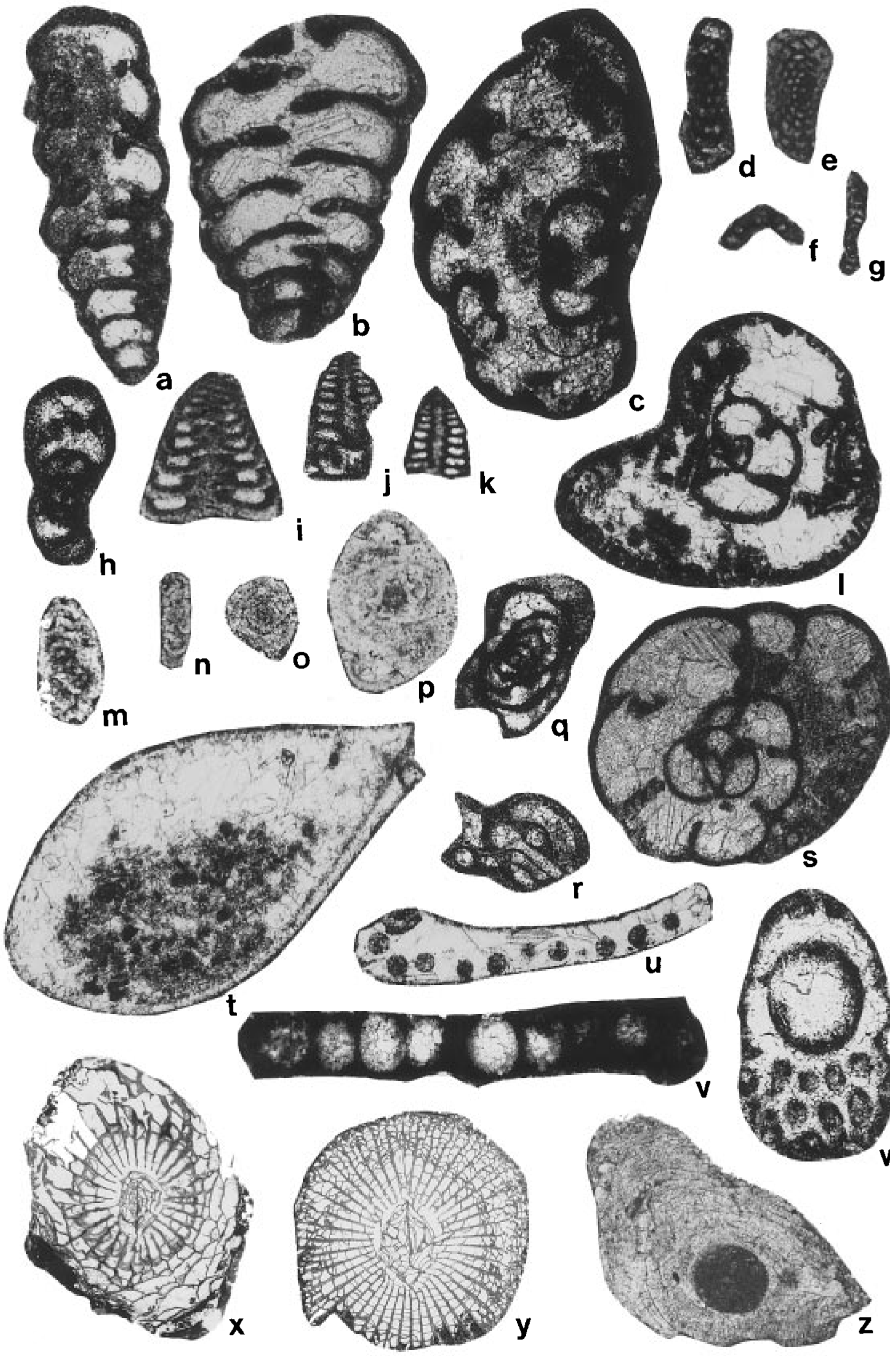

Figure 9. Caption opposite

3b. Microbiostratigraphy

The foraminiferal/algal biostratigraphy of the upper part of the Dinantian platform succession (the Ballyclogh and Liscarroll Limestone Formations), in the Buttevant area of north County Cork, is based on the study of 336 thin sections from 53 quarries. Microfaunal/microfloral data for key localities are presented in Figures 4, 5, 6 and 7. The range of the important constituents in this area is shown in Figure 8. On the basis of on this information, the age and detailed zonal correlations of the sequence are discussed.

The Asbian and Brigantian stages in this work are considered to be age equivalents of the Cf6α to Cf6δ foraminiferal subzones of Conil *et al.* (1990). The definition of the microbiostratigraphic subdivisions used in this work are summarized in Gallagher (1996) and Jones and Somerville (1996).

Microfossils in the Hazelwood Formation

Hudson and Philcox (1965) used macrofossils to suggest a S_2 (Holkerian) age for the Hazelwood Formation. Clipstone (1992) studied the conodonts, calcareous algae and foraminifera in the Hazelwood Formation (her foraminiferal range data are included in Figure 8). She uses the first appearance of the conodont *Gnathodus girtyi girtyi* near the base of the Hazelwood Formation in Ballyclogh Stream (locality 1, Figures 1 and 2) to suggest that the Hazelwood Formation is Asbian in age. This age is confirmed by the presence of the foraminifera *Vissariotaxis* and archaediscids at *angulatus* stage 21 m above the base of this formation at locality 1 (Figure 1). The first appearance of *Gnathodus bilineatus* 16 m below the base of the Ballyclogh Limestone Formation in the Ballyclogh Stream (Clipstone 1992) suggests an early to late Asbian age (equivalent to Cf6β–Cf6γ Subzonal age) for the upper part of this formation (*cf*. Conil *et al*. 1990; Riley 1993; Jones and Somerville 1996). The inferred diachronous nature of the Hazelwood Formation is illustrated in Figure 2.

The lowest part of the succession studied in this work (the top of Hazelwood Formation) in the Ballyclogh Stream (locality 1, Figures. 1, 2 and 4) is characterized by a sparse foram/algal assemblage, consisting mainly of *Tetrataxis*, *Endothyra*, *Paraarchaediscus*, *Pseudoammodiscus*, *Valvulinella* and *Earlandia*. Age-diagnostic foraminifera are scarce, although the Asbian foraminifera taxon *Paraarchaediscus* at *angulatus* stage is present in low abundance.

Microfossils in the Ballyclogh Limestone Formation

Thirty-three quarries were sampled in the Ballyclogh Limestone Formation from which 238 samples were studied from both the Cecilstown ($n = 21$) and Dromdowney ($n = 217$) Members. Foraminiferal and algal abundance were found to be highest in the latter member. The majority of the 238 samples taken were from the Ballyclogh stream section (Figure 4) and the adjacent Ballyclogh Quarry (Figure 6). The remainder came from various smaller quarries throughout the area, including Egmont Quarry (locality 6, Figures 1 and 5).

(i) *Early Asbian*. The occurrence of the foraminifera *Vissariotaxis compressa* and *Gigasbia gigas* in the Cecilstown Member (Figure 4) together with the presence of *Gnathodus bilineatus* in the underlying Hazelwood Formation (Clipstone 1992) suggest at least an early Asbian substage/Cf6β subzonal age for the base of the Ballyclogh Formation in this area. *Kulikia* sp., a chlorophyte alga, also occurs in this part of the succession. Studies of the distribution of this alga in other areas (Gallagher 1992, 1996; Skompski 1984) suggest that it is confined to the Asbian and Brigantian stages of the Dinantian.

(ii) *Late Asbian substage — Cf6γ1 subzonal subdivision*. The onset of the Dromdowney Member deposition is marked by a significant diversification of algal and foraminiferal types. *Koninckopora* (bilaminar) first occurs in low amounts with bilaminar palaeotextulariids and ungdarellids. The presence of the bilaminar palaeotextulariids *Cribrostomum lecompteii* and *Palaeotextularia* ex. gr. *longiseptata*, plus the first appearance of *Pseudoendothyra sublimis*, *Ungdarella* sp., *Kulikia* sp. and *Haplophragmella* sp., suggest a late Asbian substage/Cf6γ1 subzonal age for the base of the Dromdowney Member (see Figures 4 and 5). The assemblage at the base of this member is very similar to the late Asbian fauna recorded by Somerville *et al.* (1992) from the Dromkeen Limestone Formation in Co. Limerick, 30 km to the NNE. At log level 126 m in the

Ballyclogh Stream Section (Figure 4) and other localities in the middle of the Dromdowney Member (Figure 7), endothyrid foraminifera with cribrate apertures become important. *Cribrospira* sp. and *Bibradya* sp. first occur at this level.

(iii) *Late Asbian substage — Cf6γ2 subzonal subdivision*. At log level 162 m in the Ballyclogh Stream Section (locality 1, Figures 1 and 4), in the basal beds of Egmont Quarry (locality 6, Figures 1 and 5) and in other quarries in the upper part of the Dromdowney Member (Figure 7), stellate archaediscids *Asteroarchaediscus* sp. and *Neoarchaediscus (Neoarchaediscus) incertus* first occur in small numbers. Additional taxa, which first appear in the upper part of the late Asbian of the Dromdowney Member, include *Koskinobigenerina* sp., *Bradyina rotula*, *Neoarchaediscus (Asperodiscus) stellatus*, monolaminar *Koninckopora* sp. B (illustrated in Figure 9v), *Fasciella kizilia*, *Saccamminopsis* sp. and the *Archaediscus karreri* group. Very similar assemblages were recorded by Gallagher (1992, 1996) from the upper part of the late Asbian of the Burren Formation, Co. Clare, and the Ballyadams Formation, in Counties Kilkenny and Tipperary, 60 km to the NE. Somerville *et al*. (1992) also list a similar assemblage including *Koninckopora* sp. B for the uppermost part of the late Asbian Dromkeen Limestone Formation in Co. Limerick and the uppermost part of the late Asbian Mullaghfin Formation at Kingscourt, Co. Cavan (Strogen *et al*. 1995). The taxon *Asteroarchaediscus* appears in the upper part of the Cf6γ Subzone in Belgium (Conil *et al*. 1990). The assemblage outlined above is diagnostic of the Cf6γ2 subzonal subdivision of the Cf6γ Subzone (Gallagher 1996; Jones and Somerville 1996).

Microfossils in the Liscarroll Limestone Formation

(i) *Brigantian stage — Cf6δ Subzone*. Twenty quarries were sampled from both the Templemary and Coolbane Members of the Liscarroll Limestone Formation. In the Templemary Member foram/algal abundance varied with alternations of crinoid-rich and crinoid-poor limestones. Crinoidal limestones were observed to yield abundant asteroarchaediscids and few other foraminifera. Foraminifera and algae occur in relatively low numbers in the Coolbane Member. Unfortunately, exposures of the Liscarroll Limestone are scattered, and no thick continuous sections could be logged. The maximum thickness exposed at any one locality was 17 m (locality 8, Figures 1 and 7b) out of a formation that is over 210 m thick.

The base of the Templemary Member is characterized by abundant stellate archaediscids which include *Asteroarchaediscus* sp., *Neoarchaediscus (Asperodiscus)* sp., *Neoarchaediscus (Neoarchaediscus)* sp., *Neoarchaediscus (Neoarchaediscus) incertus*, rare *Howchinia bradyana*, *Bradyina rotula*, *Nevillella (Nevillea)* sp. and *Loeblichia paraammonoides*. Two bands of *Saccamminopsis* also occur at the base of this unit. A Cf6δ subzonal or Brigantian age is assigned to the Templemary Member based on this assemblage.

The boundary between the Coolbane and the Templemary Members is marked by the first cherty dark limestones overlying cyclic crinoidal facies (Figure 7c). Typical Brigantian microfossils present in the Coolbane Member are abundant *Fasciella kizilia*-coated wackestone intraclasts with common *Howchinia bradyana*, *Loeblichia paraammonoides*, abundant stellate archaediscids (*Neoarchaediscus (Asperodiscus)* sp., *Neoarchaediscus (Neoarchaediscus)*, *Asteroarchaediscus* sp., *Neoarchaediscus (Neoarchaediscus) incertus*, *Neoarchaediscus (Asperodiscus) stellatus*) and rare *Howchinia* trans. *Monotaxinoides* sp. This ‘intraclast association’ is typical of Gallagher’s (1992, 1996) ‘Lithofacies Sequence 4’ of the laterally equivalent Brigantian platform carbonates in southern and western Ireland (see below).

(ii) *The Asbian/Brigantian* stage boundary. The diagnostic Cf6δ Subzone/Brigantian taxa *Warnantella*, *Loeblichia* and *Janischewskina* are absent from the base of the Liscarroll Limestone Formation. The Asbian/Brigantian boundary in the Ballyclogh Quarry (Figure 6) was therefore taken at the first sample containing abundant stellate archaediscids (including *Asteroarchaediscus*), *Howchinia bradyana* (this taxon is absent in the late Asbian in North Cork) and the occurrence of two *Saccamminopsis*-rich horizons above the last palaeokarst in the Dromdowney Member (locality 2, Figures 1 and 6). Stellate archaediscids increase in abundance across the Asbian/Brigantian boundary in the Cork, Callan and Burren areas (Gallagher 1992). The limiting factor in the use of these foraminifers is that stellate archaediscids are most often associated with crinoid-rich facies or bryozoan packstones and wackestones. Fortunately, these facies often occur above the

Asbian/Brigantian boundary where suitable macrofaunal data are present (in the Burren, Co. Clare abundant stellate archaediscids first occurs with *Actinocyathus floriformis* (Gallagher 1996)). The last appearance of the dasycladacean alga *Koninckopora* is 7·3 m above the highest palaeokarst of the Dromdowney Member (Figure 6). This calcareous alga is generally considered to range from the late Chadian to late Asbian (Conil *et al*. 1990; Jones and Somerville 1996), although Somerville and Strank (1984) reported rare occurrences of *Koninckopora* up to 20 m above the base of the Brigantian. A similar upper limit for this taxon has been reported by Gallagher (1992) from the Burren, Co Clare, where it occurs 17–19 m above the base of Brigantian Slievenaglasha Formation.

The diagnostic Brigantian foraminifer *Loeblichia paraammonoides* appears approximately 30 m above the base of the Liscarroll Limestone Formation in the Templemary Member (Figure 7a). This taxon is more common in the Coolbane Member where it occurs with the diagnostic alga *Coelosporella*. *Loeblichia paraammonoides* is markedly facies-controlled and relatively rare; this limits its utility as a zonal microfossil for the Brigantian stage. The presence of the conodont *Mestognathus bipluti* in samples collected from locality 7 (Figure 1) identified by G. Jones (pers. comm.) also confirm a Brigantian age for the Coolbane Member (see Jones and Somerville 1996).

4. DISCUSSION

4a. *Facies control on fossil distribution*

From the description of the stratigraphy of the late Dinantian units in Sections 2 and 3, it can be seen that changes in facies at key biostratigraphic boundaries correspond closely to lithostratigraphic boundaries. In the Ballyclogh Stream (locality 1, Figures 1 and 4) the first appearance of microfossils that define the early/late Asbian boundary is only a few metres above the Cecilstown/Dromdowney Member boundary. In this case, the cleaner cherty-free facies of the Dromdowney Member probably represented optimum conditions for foraminiferal development in contrast to the underlying deeper-water Cecilstown Member. The Ballyclogh/Liscarroll Limestone Formation boundary in Ballyclogh Quarry (locality 2, Figures 1 and 6) occurs a few metres below the base of the Brigantian stage. Stellate archaediscid foraminiferal abundance increases into the Brigantian whereas the variability of the microfossil assemblages decreases (many taxa do not survive). In this case, the shallow subtidal packstone/grainstone facies of the Dromdowney Member (late Asbian) are succeeded by emergence (a sequence boundary) and then by deposition of subtidal packstone/wackestone facies of the Liscarroll Limestone Formation (Brigantian). The major fall in relative sea-level that led to extensive subaerial exposure at the formation boundary resulted in the extinction of several microfossil taxa. The following transgressive (flooding) event introduced a new assemblage which subsequently radiated. A similar pattern of microfossil distribution occurs in the Burren and Callan areas (Gallagher 1996; Figure 10), where major facies boundaries coincide with the micro- and macrofaunal changes that mark the early/late Asbian and late Asbian/Brigantian stage boundaries. Consequently, the sea-level variations responsible for the facies changes that mark lithostratigraphic boundaries in the late Dinantian platform carbonates of Buttevant, and other areas of southern and western Ireland, also brought in new taxa that define biostratigraphic boundaries.

Elsewhere in the British Isles Ramsbottom (1973) recognized that major cycles approximately correlated with Dinantian stages (but see discussion in Riley (1993) and Jones and Somerville (1996) regarding the positioning of these boundaries without precise microfossil control) and were characterized by major transgressions that brought in new marine macrofaunas, elements of which did not return during the next transgressive event. In Belgium Paproth *et al*. (1983) observed that changes in faunal provinciality (and therefore biostratigraphic boundaries) were attributed to Dinantian transgressions which also coincide with major changes in megafacies. Moreover, recent work by Makhlina (1996) suggests that the most important faunal and facies changes occur at the base of several stages in the Dinantian Russian Platform. Rukina (1996) studied 11 levels of 'foraminiferal reorganizations' caused by lithological and environmental changes

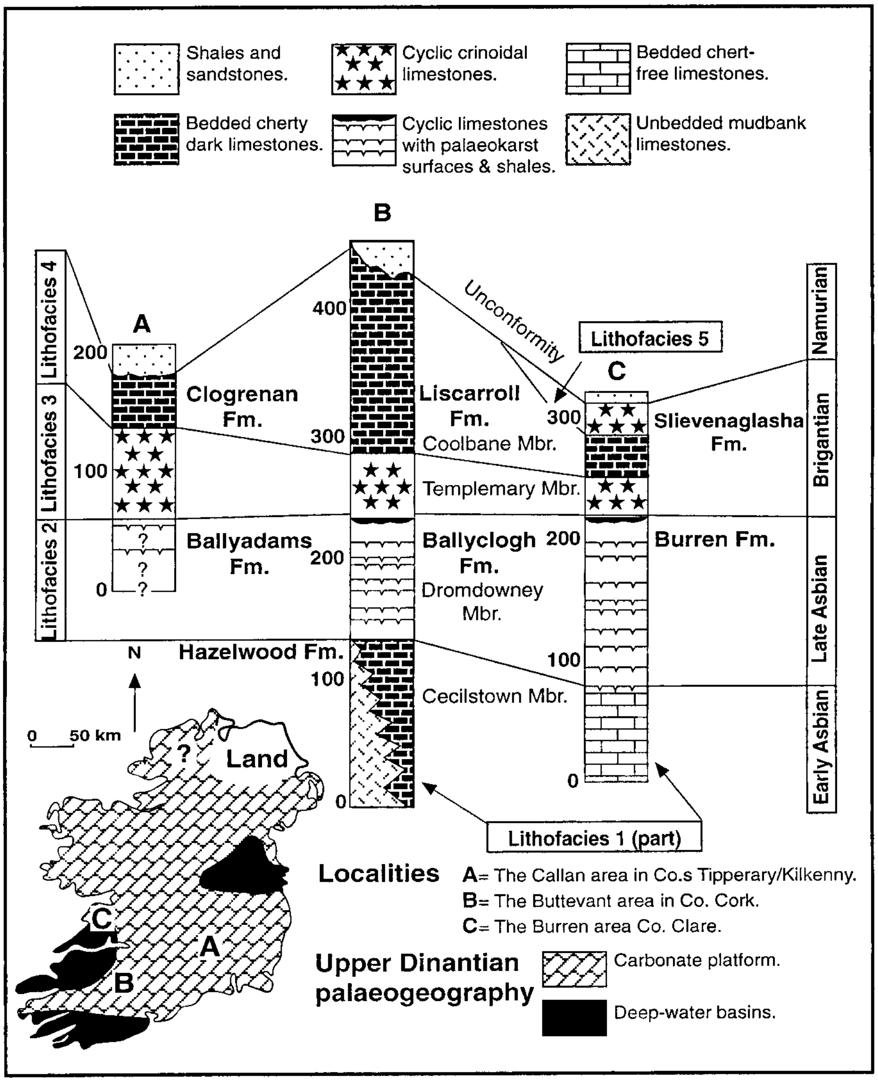

Figure 10. Stratigraphic correlation of the late Dinantian platform carbonates from southern and western Ireland. The vertical scales in columns A, B and C are in metres. Features that dominated the palaeogeography of the late Dinantian of Ireland are illustrated. Modified from Gallagher (1996)

and used these ‘levels’ for sequence biostratigraphy and for the subdivision of the Lower Carboniferous of the Russian Platform. A similar type of study has been undertaken by Hance *et al.* (in press) who have recognized six foraminferal associations in Tournaisian–Visean (Tn-V) transitional strata in South China. They were able to combine biostratigraphical and sedimentological data in erecting a sequence stratigraphy which enabled them to correlate Tn-V transitional strata between platform, slope and basin settings. Furthermore, in the Upper Carboniferous of the Moscow and Donets Basins, important facies changes occur at sequence boundaries, coincident with biostratigraphic zones based on fusulinid foraminferans (see Izart *et al.* 1996, in press), which can be correlated over long distances.

It seems likely that there is a correlation between the biostratigraphic definition of many of the Dinantian stages in northwest Europe and fundamental facies changes resulting from major regressions (sequence boundaries) and subsequent transgressive events. Indeed, major facies changes within stages such as at the early/late Asbian boundary in the Buttevant, Callan and Burren areas in Ireland (Gallagher 1992; 1996) are also associated with changes in micro- and macrofossil assemblages. Studies of the biostratigraphical distribution of Dinantian micro- and macrofossils should therefore be associated with facies studies. A combined approach will lead to better stratigraphic correlations of Dinantian rocks in northwest Europe.

4b. Regional stratigraphical correlation

A stratigraphic study carried out by S.J.G. on comparable late Dinantian platform successions on the Burren (Co. Clare) and Callan (Co. Kilkenny and Tipperary) is summarized in Figure 10 and described in Gallagher (1996). The late Dinantian stratigraphy of these areas can be subdivided into several lithofacies associations (LA) that can be correlated across southern and western Ireland (Figure 10; Gallagher 1996). The informal lithostratigraphic units are as follows.

LA 1: ?Holkerian to early Asbian-aged non-cyclic *Koninckopora*- and bryozoan-rich carbonates; these include the bedded chert-free units of the Burren succession, the cherty limestones of the Cecilstown Member (Ballyclogh Limestone Formation) and the Hazelwood Formation in this work.

LA 2: late Asbian-aged cyclic kamaeniid-rich carbonates punctuated by subaerial exposure surfaces; the Dromdowney Member of the Ballyclogh Limestone Formation is equivalent to Lithofacies Association 2 (Figure 10).

LA 3: early Brigantian-aged cyclic crinoidal limestones; the cyclic crinoidal limestones of the Templemary Member in the Liscarroll Limestone Formation are the direct correlatives of the cyclic LA3 crinoidal facies of the Slievenaglasha Formation in the Burren and the Clogrenan Formation in the Callan area.

LA 4: late Brigantian-aged cherty non-cyclic limestones; the cherty facies of the Coolbane Member correlate with the upper part of the Clogrenan Formation in Callan and the middle of the Slievenaglasha Formation in the Burren (Figure 10) and belong to Lithofacies Association 4.

LA 5: a late Brigantian-aged cyclic crinoidal and cherty limestones; this unit occurs only in the Burren succession (Figure 10)–it was either not developed in the Buttevant area, or has been eroded below the unconformity that marks the contact with the Namurian shales.

4c. Comparison with Upper Dinantian sequences in Great Britain

Cyclicity

The facies and inherent cyclicity present in the units described in this paper are similar to those present in the late Asbian to Brigantian successions of Great Britain (Walkden 1987; Horbury 1989; Horbury and Adams 1996; Vanstone 1996). Three principal controls for cyclicity have been proposed: tectonism, eustacy and autocyclicity. It has been demonstrated in the Dublin Basin that fault activity controlled platform development during the late Dinantian (Pickard *et al.* 1994; Strogen *et al.* 1996). While tectonism may have controlled cycle development in some areas, there is no published evidence of major syndepositional platform-bounding faults that could have controlled the cyclicity observed in Buttevant or southern and western Ireland. Autocyclic controls on the cyclicity may account for some of the smaller scale cyclicity observed for example in the Callan region in southern Ireland (Gallagher 1996) where cycles cannot be correlated over distances of a few tens of metres, but it cannot readily explain the persistent cycles that can be traced along strike for tens of kilometres in the Burren region of western Ireland (Gallagher 1992). Furthermore, since the nature of the cycles observed in the late Dinantian carbonates of southern and western Ireland (including the Buttevant area, cf. Figure 10; Gallagher 1996) are similar to coeval platform carbonates in Great Britain, an autocyclic or tectonic control is unlikely to explain the facies patterns. The transgressive and regressive events recorded by cycles in Ireland and Britain were generally platform-wide, thereby favouring a eustatic origin for their formation. Moreover, even though subsidence may have been an underlying control on Dinantian platform carbonate development, it is likely that eustatic changes were one of the major controls on cyclicity in Buttevant and other areas in Ireland and Britain during the late Dinantian (cf. Walkden 1987).

5. CONCLUSIONS

1. The oldest unit described is the Hazelwood Formation. Microfossil studies using conodonts and foraminifera by Clipstone (1992) have established an early Asbian age for this unit. This differs from Hudson and Philcox (1965) who used macrofauna to assign a S_2 (Holkerian age) to this formation. The mud-mound facies of the Hazelwood Formation underlies, and is in part laterally equivalent to, the Ballyclogh Limestone Formation.
2. Over 500 m of platform limestones overlie the Hazelwood Formation. Four new units with; distinct facies can be distinguished in these carbonates. The oldest of these, the Cecilstown Member, is an early Asbian non-cyclic cherty unit. This is succeeded by the late Asbian chert-free cyclic Dromdowney Member. Both members belong to the Ballyclogh Limestone Formation. Brigantian sedimentation in the Liscarroll Limestone Formation is typified by the cyclic crinoidal Templemary Member, that is overlain by non-cyclic cherty sediments of the Coolbane Member.
3. Early Asbian fossil assemblages are sparse, with archaediscids at *angulatus* stage and *Vissariotaxis* being the zonal fossils with rare *Siphonodendron* thickets.
4. Fossils are abundant in the late Asbian Dromdowney Member. The macrofauna in the late Asbian includes the corals *Siphonodendron pauciradiale*, *Siphonodendron junceum* and *Dibunophyllum bipartitum* and the brachiopod *Davidsonina septosa*. The base of the late Asbian stage (Cf6γ Subzone) can be effectively recognized based on the first appearances of bilaminar palaeotextulariid *Cribrostomum lecompteii*, *Koskinobigenerina* and the calcareous red alga *Ungdarella* in this succession.
5. The Cf6γ Subzone can be further subdivided into two biostratigraphic divisions denoted as Cf6γ1 and Cf6γ2 that can be correlated throughout Ireland (Gallagher 1996; Jones and Somerville 1996). These subdivisions possibly correlate with the Belgian distributional data provided by Conil *et al*. 1990 and suggest the possibility that this zonation may extend to other sequences in Great Britain.
6. Gigantoproductid brachiopods and corals such as *Lonsdaleia duplicata* and *Actinocyathus floriformis* occur in the Brigantian units. The base of the Brigantian stage is recognized by the rarity or lack of *Koninckopora* species, an increase in the abundance and diversity of the stellate archaediscids and the occurrence of *Saccamminopsis*-rich horizons. *Loeblichia paraammonoides* and the presence of *Fasciella*-coated wackestone intraclasts or bioclasts, plus abundant *Howchinia bradyana* also help to define this stage.
7. The change in facies at the Cecilstown/Dromdowney Member and the Ballyclogh/Liscarroll Formation boundaries in the Buttevant area is followed closely by changes in fossil assemblages corresponding to the early/late Asbian and the Asbian/Brigantian boundaries. Many major facies, changes in northwest Europe also seem to correlate with biostratigraphically defined stages. These facies changes were influenced by major regressions (sequence boundaries) and transgressive events. The biostratigraphic utility of Dinantian micro- and macrofossils is enhanced greatly by parallel facies studies. An integration of biostratigraphic and facies data will lead to better stratigraphic correlations of Dinantian rocks in northwest Europe.
8. The late Dinantian platform carbonate succession of the Buttevant area correlates directly with the Burren and Callan areas some 100 km northwest and northeast of the present study in Ireland (Gallagher 1996).
9. The cyclicity observed in the late Asbian to Brigantian aged units of the Buttevant area and in other parts of southern and western Ireland is very similar to that observed in Great Britain. Autocyclic and tectonic controls cannot totally explain the lateral continuity of the late Dinantian cyclic facies in Ireland and Great Britain; a eustatic origin is therefore the most likely explanation for the observed cyclicity.

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APPENDIX

List of cited localities in this paper with their grid references; the locality numbers correspond to those on Figure 1.

	Locality	Irish Grid Ref.
1	Ballyclogh Stream — Ballyclogh Lst. Fm. (Cecilstown/Dromdowney Mbr.)	R492 026
2	Ballyclogh Quarry — Ballyclogh Lst. Liscarroll Lst Fm. (Dromdowney/Templemary Mbr.)	R499 022
3	Cecilstown Quarry — Ballyclogh Lst. Fm. (Cecilstown Mbr.)	R456 022
4	Templemary, 2·5 km west of Buttevant — Liscarroll Lst. Fm. (Templemary Mbr.)	R503 087
5	Ballygrady South, 7 km west of Buttevant — Liscarroll Lst. Fm. (Coolbane Mbr.)	R467 076
6	Egmont Cottage, 2 km South of Churchtown — Ballyclogh Lst. Fm. (Dromdowney Mbr.)	R498 122
7	2 km west of Buttevant — Liscarroll Lst. Fm. (Templemary/Coolbane Mbr.)	R503 092
8	Liscarroll area — Liscarroll Lst. Fm. (Coolbane Mbr.)	R437 144
9	Liscarroll area — Liscarroll Lst. Fm. (Coolbane Mbr.)	R461 123
10	Doneraile Region — Liscarroll Lst. Fm. (Templemary Mbr.)	R625 074
11	Doneraile Region — Liscarroll Lst. Fm. (Templemary Mbr.)	R568 045
12	Doneraile Region — Liscarroll Lst. Fm. (Templemary Mbr.)	R565 046
13	1 km West of Buttevant — Ballyclogh Lst. Fm. (Dromdowney Mbr.)	R508 092
14	1 km west of Buttevant — Liscarroll Lst. Fm. (Templemary Mbr.)	R509 097
15	Liscarroll area — Liscarroll Lst. Fm. (Coolbane Mbr.)	R436 181
16	Liscarroll area — Ballyclogh Lst. Fm. (Dromdowney Mbr.)	R459 126

