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12. Cambrian of Ireland

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As discussed in Chapter 11 of this Report, some authors have considered that the uppermost part of the Southern Highland Group of the Dalradian in Scotland might be Lower Palaeozoic, possibly Early Cambrian to Early Ordovician. The age of the Irish Dalradian is also not fully clear (Daly 2001). Thus, in Ireland, strata that are clearly Cambrian in age are restricted in outcrop, being confined to some areas of the southeast (Fig. 16) in the Leinster Terrane (Murphy *et al.* 1991; Woodcock 2000; Holland 2001, 2009). There they comprise the Bray and Cahore Groups and part of the Lower Palaeozoic Ribband Group (Figs 18, 19). In addition, in southernmost Leinster (Fig. 20), palynological studies have now shown that the Cullenstown Formation is Cambrian. In the same area, the Ballycogly Group mylonites, which occur along the boundary between the Leinster Terrane and the Precambrian basement of the Rosslare Terrane, are considered to be Cambrian (Tietzsch-Tyler & Sleeman 1994a) although there is no direct biostratigraphical evidence.

The Leinster Terrane is made up of several sub-terranes: particulars of these and the relevant references are given in Chapter 6 of this Report. Within these terranes, Brück *et al.* (1979) grouped the Lower Palaeozoic rocks into three belts. More recent work has shown that, as far as the Ribband Group is concerned, a fourth belt can be established (McConnell *et al.* 1999). Each of these belts, termed "tracts" by McConnell *et al.* (1999), has a separate Ribband Group lithostratigraphy. Two of the tracts are separated by a major fault, the Wicklow Fault Zone (Max *et al*. 1990; McConnell *et al.* 1999). This fault has also been termed the Tramore-Enniscorthy Fault (Tietzsch-Tyler & Sleeman 1994a) and the Courtown-Tramore Fault (Tietzsch-Tyler & Sleeman 1994b).

The Cambrian outcrops are seen in the Bray-Wicklow district of Co. Wicklow and south Co. Dublin (Bray Group, column 23); in the peninsula of Howth and the adjacent small island of Ireland's Eye in north Co. Dublin (Bray Group, columns 24 and 25); in northeast Co. Wexford (Cahore Group and part of the Ribband Group; column 26); and in south Co. Wexford (Cahore Group, Cullenstown Formation,

Booley Bay Formation of the Ribband Group, and the Ballycogly Group; columns 27-31). The rocks comprise turbidite strata, usually fine grained, in which the macrofaunas seen are largely trace fossils. Our knowledge of their biostratigraphical age comes almost entirely from palynology. Fairly precise biostratigraphical ages, based on acritarchs, are available for some of the formations in seven of the nine stratigraphical columns presented here. We comment below on the information available, and for two of the columns, for which the acritarch data are quite old (Howth and Ireland's Eye), we give a re-interpretation of the age.

Trace fossils are locally abundant and include (a) the enigmatic trace fossil *Oldhamia*, (b) structures which until recently were considered to be a possible Ediacaran biota and (c) various other traces. The first is confined to the Bray and Cahore groups and was initially recorded from Bray Head by Oldham (1844) and described by Forbes (1848). For many years there was debate as to its possible organic or inorganic origin but it is now generally accepted as being a trace fossil consisting of radiating trails made by a deposit-feeding organism (Ruedemann 1942). *Oldhamia* has also been recorded in early Cambrian strata in the eastern United States (Dale 1904; Howell 1922; Fisher 1956; Palmer 1971) and in association with *Paradoxides* in the Oslo Graben (Kjerulf 1880). It also occurs in early Cambrian rocks in north-western Argentina (Buatois & Mangano 2003; 2005). In addition it has been noted in Lower Palaeozoic strata of less certain age, but probably early Cambrian, in other parts of North America and in Europe (Dhonau & Holland 1974; Lindholm & Casey 1990; Hofmann *et al.* 1994; Seilacher *et al.* 2005**).**

Structures considered until recently as a possible Ediacaran biota occur in the Ribband Group at Booley Bay in south Co. Wexford, and have been described in detail by Crimes *et al*. (1995) and MacGabhann *et al*. (2007). The former authors interpreted the structures as Ediacarans, but the latter have suggested that the structures recorded are possibly in part biogenic, and that none of those seen should be classed as Ediacarans. The Cambrian age of the host sediments at Booley Bay has been investigated by Moczydłowska & Crimes (1995) and Vanguestaine & Brück (2005, 2008).

The various turbidite sedimentary structures, the direction of slumping, the mineralogy and the nature of the trace fossils all point to deposition of the sediments in a fault-controlled subsiding marine basin, the Leinster Basin, west of the Rosslare/Monian Terrane.

Bray Group

The Bray Group is a distinctive lithostratigraphical unit (Gardiner & Vanguestaine 1971; Brück & Reeves 1976). It comprises predominantly green and purple greywackes, but also present are subordinate pale quartz arenites, the whole making up a relatively proximal turbidite sequence. Brück *et al.* (1979) classified all the strata in southeast Ireland with these lithologies as making up parts of the Bray Group. However, more recent work includes only the principal outcrop in the Bray-Wicklow district (Fig. 16) and similar rocks on Howth (Fig. 18) and Ireland's Eye (McConnell & Philcox 1994). Strata further south, with similar lithologies, are better classified as the Cahore Group and the Cullenstown Formation (Tietzsch-Tyler & Sleeman 1994a, 1994b; Brück & Vanguestaine 2004).

The Bray Group sequence is everywhere devoid of macrofossils, with the exception of local occurrences of trace fossils, particularly *Oldhamia* and *Monocraterion* (Brück & Reeves 1976). However, the Geological Survey of Ireland (Jukes & Du Noyer 1869) regarded the Bray Group rocks as Cambrian on lithological grounds. Those authors also differentiated them from the surrounding adjacent Ribband Group strata, which they classed, also on their lithology, as what is now known as Ordovician. It has only been with the advent of palynology that there has been any objective attempt at biostratigraphic dating, which now indicates an early Cambrian age (Vanguestaine *et al*. 2002; Brück & Vanguestaine 2004).

Cahore Group

Rocks of the Cahore Group are lithologically very similar to the Bray Group, the term being applied to strata in Co. Wexford (Fig. 16). There they are best exposed in northeast Co. Wexford at Cahore Point (Crimes & Crossley 1968) and also on the south Co. Wexford coast (Tietzsch-Tyler & Sleeman 1994a). *Oldhamia* is present and, using palynology, an early Cambrian biostratigraphical age has recently been obtained (Brück & Vanguestaine 2004).

Ribband Group

The Ribband Group stratigraphically overlies the Bray and Cahore groups and is the most extensive lithostratigraphical unit in southeast Ireland (Fig. 18). It comprises very distinctive medium to dark grey laminated greywacke siltstones and mudstones

with occasional green beds (Crimes & Crossley 1968; Gardiner & Vanguestaine 1971; Brück *et al.* 1979; Brück & Vanguestaine 2004). Turbidite structures are locally prominent and the unit is dominantly a distal turbidite succession. Intercalated volcanic rocks, largely intermediate to basic, are locally abundant.

Most of the Ribband Group is unfossiliferous. However, locally, extremely sparse graptolite faunas have been recorded (Elles 1910; Crimes & Crossley 1968; Brenchley & Treagus 1970; Brenchley *et al.* 1977; Rushton 1996). In addition, acritarchs have been obtained from several locations (Gardiner & Vanguestaine 1971; Brück *et al.* 1974; Brück *et al*. 1979; Mozcydłowska & Crimes 1995; Maziane-Serraj *et al*. 2000; Brück *et al.* 2001; Brück & Vanguestaine 2004; Brück & Vanguestaine 2005; Vanguestaine & Brück 2005, 2008). These macro- and microfaunas indicate that the Ribband Group extends without a break from the early Drumian in Cambrian Series 3 to the late Arenig, a level now considered early Middle Ordovician (Cocks *et al.* 2010). The stratigraphy of the Ordovician part of the group has been summarized by Harper & Parkes (2000). The Cambrian part of the group is described below.

Cullenstown Formation

The Cullenstown Formation comprises green and buff greywackes and is confined to southern Co. Wexford (Figs 18, 20). The unit has undergone substantial tectonic deformation with the development of an intense fabric, together with a higher grade of metamorphism than occurs in any of the adjacent Lower Palaeozoic rocks, shown up by the presence of chlorite porphyroblasts. These strata have been variously referred to as the Cullenstown Group (Crimes & Dhonau 1967; Max *et al*. 1990), the Cullenstown Formation (Max and Dhonau 1974; Brück & Vanguestaine 2004), the Bray Group (Brück *et al*. 1979) and the Cullenstown Formation of the Cahore Group (Tietzsch-Tyler 1989, 1996; Tietzsch-Tyler & Phillips 1989; Bennett *et al.* 1989; Tietzsch-Tyler & Sleeman 1994a). The term Cullenstown Formation is used here. Recent palynological studies have indicated a latest middle to early late Cambrian age (Brück & Vanguestaine 2004).

Ballycogly Group

The Ballycogly Group makes up most of an area of mylonitized rocks that flank the Precambrian Rosslare Complex on its northwestern margin (Figs 18, 20). The

mylonite zone is developed along a major shear zone, referred to as the Ballycogly Mylonite Zone (Murphy 1990). The group is made up of mylonitized metasediments (Baker 1970; Max *et al*. 1990; Murphy 1990; Murphy *et al*. 1991; Tietzsch-Tyler & Sleeman 1994a; Tietzsch-Tyler 1996). The unit has been classed as Cambrian (Tietzsch-Tyler & Sleeman 1994a) although there is no clear proof of a Cambrian age (Holland 2009).

Cambrian correlation in Ireland

Bray-Wicklow District: Column 23. This area comprises the principal outcrop of the Irish Cambrian (Fig. 18). The strata have the lithologies of the Bray Group outlined above and make up a total thickness of 4,500 m+ (Brück & Reeves 1976). Two formations have been distinguished: an older Devils Glen Formation (2,000 m+) and a younger Bray Head Formation (2,500 m+). The former unit comprises generally green and purple, coarse to fine, thick bedded, massive greywackes. Slump deformation is widespread throughout. Sand volcanoes a few centimetres across are occasionally seen. Most of the structures recorded as "*Histioderma hibernicum*", a trace fossil, by the 19th century Geological Survey workers (Jukes & Du Noyer 1869) have more recently been considered to be small sand volcanoes (Brindley *et al.* 1973; Brück & Reeves 1976). Some of the smaller ones may be the trace fossil *Monocraterion* (Brück & Reeves 1976).

The Bray Head Formation, in contrast, is characterized by well-laminated green and purple greywackes with an abundance of internal and external turbidite structures. An additional important feature is the presence of prominent interleaved pale quartz arenites, 10 m to 100 m thick. Slump deformation is common, with many large- and small-scale slump structures. Brück & Reeves (1976) suggested that the major Great Sugarloaf–Little Sugarloaf Syncline, which forms a distinctive topographic feature in north Co. Wicklow, might be a huge pre-cleavage slump fold. Rare occurrences of *Oldhamia* are seen within the finer topmost parts of graded green and purple greywacke beds, particularly at Bray Head. Two forms are present: *Oldhamia radiata*, consisting of ridges radiating from a centre, and *Oldhamia antiqua*, having semicircular 'fans' of radiating ridges occurring in linear series (Holland 1974, pl. 4, p. 160). Sand volcanoes and probable *Monocraterion,* as in the Devil's Glen Formation, have also been noted (Brück & Reeves 1976). Some more problematical trace fossils were recorded from Bray Head in the nineteenth and early

twentieth centuries; details are summarized in Gardiner & Vanguestaine (1971). Brück & Reeves (1976) also observed a quantitative difference in mineralogy between the greywackes of the Devil's Glen and Bray Head Formations, the former with less quartz, more K-feldspar and a higher proportion of matrix. Provenance indicators include epidote, clinozoisite and allanite. Neither the base of the Devils Glen Formation nor the top of the Bray Head Formation are seen. The junction with the adjacent Ribband Group is everywhere faulted and is probably a major thrust.

Brück *et al.* (1974) collected 23 samples from the Bray-Wicklow district of the Bray Group for palynological analysis. Very poorly preserved acritarch assemblages from one locality approximately half way up the Bray Head Formation were taken to indicate a "late Early to early Middle Cambrian age". More recently, a new study of 58 samples collected from throughout the succession was undertaken. Of these, four were productive (Vanguestaine *et al.* 2002), yielding acritarchs and prasinophytes. The productive samples came from the same locality that had yielded material in the earlier work, but the new study produced a much more stratigraphically diagnostic assemblage than the previous investigation. In particular, there are five different species of *Skiaga*, of which *Skiagia oribicularis* and *Skiagia* sp. cf. *S. brevispinosa* are the most frequent, together with rare specimens of *Skiagia* sp. aff. *S. insignis*, *Skiagia* sp. cf. *S. scottica* and *Skiagia* sp. Three species of *Lophosphaeridium* were also recorded. The possible occurrence of two Middle Cambrian markers, *Cristallinium cambriense* and *Eliasum llaniscum*, was discussed and discounted. Vanguestaine *et al.* (2002) were thus able to restrict the age to "mid or late Early Cambrian". The occurrence of *Skiagia* shows that the assemblage is not older than Series 2 (Stage 3). In addition, *Lophosphaeridium dubium*, *Skiagia* sp. aff. *S. insignis* and *S. orbicularis* suggest that the assemblage is not younger than early Series 3, mid Stage 5 (*Baltoparadoxides oelandicus* Trilobite Zone), according to the ranges published by Moczydłowska (1998). Although the determinations are not definite, *Skiagia* sp. aff. *S. insignis* and *Skiagia* sp. cf. *S. brevispinosa* might restrict the age to mid to late Series 2, latest Stage 3-Stage 4 (the *dissimilare–ciliosa* and *dentifera–plana* Acritarch Zones).

The sedimentological and mineralogical features outlined above, together with palaeocurrent data, suggest deposition of turbidites in the marine Leinster Basin, with derivation of most of the sediment from the north, from a source similar to the

exposed Precambrian of southeast Ireland. The quartzites represent periodic influxes of sand sheets from a mature sediment source to the east.

Howth and Ireland's Eye: Columns 24 and 25. Strata in part lithologically very similar to those of the Bray-Wicklow district make up the peninsula of Howth and the small island of Ireland's Eye, north of Dublin (Fig. 18). The most recent detailed studies of Howth are by Van Lunsen & Max (1975), and of Ireland's Eye by Gardiner & Robinson (1970). Those authors recognized five formations on Howth and three on Ireland's Eye. Brück *et al.* (1979) classed the strata as part of the Bray Group. According to Van Lunsen & Max (1975), the three formation sequence proposed by Gardiner & Robinson (1970) for Ireland's Eye was erected in the reverse stratigraphical order; the successions for both Howth and Ireland's Eye given by Van Lunsen & Max (1975) are outlined here. The boundaries between most of the formations are syn-sedimentary slides and the thicknesses of the formations are not known.

The lowest unitcomprises the Drumleck Formation on Howth and the equivalent Steer Formation on Ireland's Eye. It consists of a melange of pale quartz arenite blocks in a variably coloured mudstone to siltstone matrix. This is followed by the less disturbed Hippy Hole Formation on Howth and its equivalent Carrigeen Formation on Ireland's Eye, comprising red, purple and green, coarse to fine greywackes with internal sedimentary structures. There are also occasional intercalated white-weathering bentonites. The overlying Gaskin's Leap Formation on Howth and its equivalent Thulla Formation on Ireland's Eye lie unconformably on the older units due to slumping. They comprise slump-deformed quartz arenites in a grey siltstone and shale matrix. The Elsinore Formation of Howth is a polymict melange of pebbles and huge blocks, some up to hundreds of metres across, of quartz arenites and various other sandstones in a green mudstone to sandstone matrix. The Pipers Gut Formation (Howth) comprises green-grey undisturbed greywackes with turbidite structures.

Trace fossils occur at Howth, and were studied by Crimes (1976). He gave a detailed morphological description of *Oldhamia radiata* and *Oldhamia antiqua* and noted that these occurred in the Elsinore Formation. He also recorded and described *Planolites*, *Arenicolites*, *Skolithos linearis* and *Granularia* [the trace-fossil, not the

trilobite formerly known by that name], which occur largely in the Drumleck and Hippy Hole formations.

Palynological studies have been carried out on two occasions on these rocks. Gardiner & Vanguestaine (1971) collected two samples from the Thulla Formation on Ireland's Eye, and these yielded *Micrhystridium* cf. *dissimilare*, *M. pallidum, M. obscurum, M. spinosum, Stictosphaeridium brayense,* '*Visbysphaera* sp. A', *Leiosphaeridia* div. sp., *Leiosphaeridia*? sp. A. and *Cymatiosphaera* sp. This assemblage was considered to indicate a "middle Lower to early Middle Cambrian age", but Moczydłowska (1998) placed the first appearance datum (FAD) of *Stictosphaeridium brayense* at the base of the traditional Middle Cambrian (i.e. about the base of Series 3, Stage 5). Other species recorded by Gardiner & Vanguestaine (1971) have FADs in Series 2 but do not range above the *oelandicus* Trilobite Zone (*Micrhystridium* [=*Heliosphaeridium*] *obscurum*) or middle *paradoxissimus* Trilobite Superzone (*Micrhystridium* [*Heliosphaeridium*] *dissimilare*). Combined with the range of *S. brayense* from Moczydłowska (1998), these occurrences suggest a Stage 5 age for the formation. Moczydłowska (1998), however, also placed Gardiner & Vanguestaine's figured specimens of *M. obscurum* in synonymy with *Heliosphaeridium exile*, a species that Vanguestaine & Brück (2008) showed to occur in the *Adara alea* Acritarch Zone (see Chapter 3). This suggests that a younger age is possible for the Thulla Formation, as the *A. alea* Zone correlates with the mid Drumian, upper *T. fissus* and *H. parvifrons* trilobite zones of the mid *paradoxissimus* Superzone. Hence, based on these taxa, an early to mid Series 3 age is most likely for the Thulla Formation (but see also below).

Smith (1977) studied one sample from the lithostratigraphically equivalent Gaskin's Leap Formation on Howth. The following acritarchs were identified in the sample, the preservation of which was described as 'only fair': *Baltisphaeridium* [*Skiagia*] *ciliosum*, *Leiomarginata simplex*, *Lophosphaeridium tentativum*, *Micrhystridium* [*Asteridium*] *lanatum*, *M.* [*Heliosphaeridium*] *obscurum*, *M. parvum* (now *Heliosphaeridium radzynicum*) and *Protoleiosphaeridium*. Smith (1977) considered that a "middle Early Cambrian age" was likely for the Howth succession, equivalent to the Atdabanian or *Holmia* Trilobite Zone (see Fig. 3), but a younger age is also possible. *Skiagia ciliosa*, *Leiomarginata simplex*, *Lophosphaeridium tentativum*, *Asteridium lanatum* and *Heliosphaeridium obscurum*, for example, all range into the base of Stage 5 (*oelandicus* Trilobite Zone; Hagenfeldt 1989a, b;

Moczydłowska 1998). The exception is *Heliosphaeridium radzynicum*, which ranges into the *dentifera–plana* Acritarch Zone (Moczydłowska 1991), although Smith (1977) commented that the stratigraphical significance of this form (*M. parvum*) was doubtful. Smith's (1977) description and illustrations suggest that his specimens of *Skiagia ciliosa* might be better placed in a species such as *Globosphaeridium cerinum*, a taxon that is restricted to Series 2 (a possibility that he acknowledged). However, Smith also noted that Gardiner & Vanguestaine's (1971) '*Visbysphaera* sp. A' resembled his specimens of *S. ciliosa*, suggesting that similar forms are present in the Thulla Formation. Nothing in the list of acritarch taxa from the Gaskin's Leap Formation contradicts its lithostratigraphical correlation with the Thulla Formation. However, *Asteridium lanatum* does not range above the lower part of the *oelandicus* Biozone according to Moczydłowska (1998), so if they are correlatives, the Thulla and Gaskin's Leap formations might both be best placed at the base of Stage 5.

Palaeocurrent indicators and the orientation of slump folds suggest that the Howth turbidites came from the southeast and east, whereas the slumping appears to have been generated from the southwest (Van Lunsen & Max 1975).

Cahore Point – Courtown: Column 26. A well-exposed coastal section occurs in northeast Co. Wexford, comprising the Cahore Group in the south of the section and the overlying Ribband Group further north (Fig. 18). The Cahore Group is entirely Cambrian, while recent work (Brück *et al.* unpublished) shows that the oldest part of the Ribband Group is Middle Cambrian, mid-Series 3. The lithostratigraphy was described in detail by Crimes & Crossley (1968), but was revised slightly by Tietzsch-Tyler & Sleeman (1994b) on a Geological Survey of Ireland 1:100,000 map. The formations seen along the coastal section are, from base to top, the Glascarrig, Cahore Point, Roney and Askingarran formations. All four formations were classed by the Geological Survey as making up the Cahore Group (Tietzsch-Tyler & Sleeman 1994b). However, the lithologies of the first three comprise massive green, buff and purple greywackes and some pale quartz-arenites, lithologically very similar to the Bray Group to the north. The Askingarran Formation, in contrast, comprises black and grey, finely laminated siltstones and mudstones, which are typical Ribband Group lithologies (Brück *et al.* 1979; Brück & Vanguestaine 2004); thus the Askingarran Formation is classed as part of the Ribband Group in the present compilation.

In the Cahore Group, the Glascarrig Formation is 600 m thick and comprises massive green and purple greywackes. The Cahore Point Formation consists of approximately 700 m+ of massive green, buff and purple greywackes with some subordinate pale quartz-arenites, and the Roney Formation (600 m+) is made up of thick, massive, pale quartz-arenites with green, buff and purple, generally massive greywackes. Occasional trace fossils are present. Crimes & Crossley (1968) noted *Oldhamia radiata* and *Histioderma* in the Cahore Point Formation, while Kinahan (1879) additionally recorded *O. antiqua*. The early Geological Survey workers also observed *O. antiqua* and *O. radiata* in the Roney Formation (Kinahan 1879).

Recently, seven samples were collected for palynological analysis from very rare grey horizons which are seen in the Glascarrig Formation (Brück *et al.* unpublished), but all of the samples were barren. Thus our knowledge as to the age of the Cahore Group has to rest on the presence of *Oldhamia*, which suggests an early or middle Cambrian age (Crimes & Crossley 1968), tentatively shown here as equivalent to Stage 4.

The Cahore Group passes up northwards into the Ribband Group, although the boundary between the two groups is faulted (Clegg & Holdsworth 2005). The Askingarran Formation, reassigned to the Ribband Group from the Cahore Group as noted above, comprises black and grey laminated siltstones and mudstones with occasional green beds, totalling 700 m in thickness that form a clear lithological continuation to Ribband Group strata that overlie them. Internal and external turbidite structures are common. These indicate derivation of the older part of the formation from the west and of the younger part from the southeast. Crimes & Crossley (1968) recorded several gastropods similar to *Orospira* Butts, which they suggested indicated a late Cambrian or very early Ordovician age. Recently, seven samples were collected from the Askingarran Formation for palynological analysis (Brück *et al.* unpublished). Of these, six samples were productive, one yielding diagnostic acritarchs. Important species found were *Adara alea*, *Comasphaeridium* sp., *Retisphaeridium dichamerum* and *Heliosphaeridium* sp. *Adara alea* and *Retisphaeridium dichamerum* indicate the *A. alea* Acritarch Zone (Fig. 4), which correlates with the upper *T. fissus* and *H. parvifrons* trilobite zones (middle *P. paradoxissimus* Superzone, mid Drumian). The Askingarran Formation thus correlates with the Booley Bay Formation at Booley Bay and Clammers Point

(columns 27, 28), and together these formations comprise the oldest strata now assigned to the Ribband Group.

The top of the Askingarran Formation is faulted against the stratigraphically succeeding unit of the Ribband Group unit, the Ballyhoge Formation. The latter is assumed to be Tremadocian in age (Harper & Parkes 2000).

Booley Bay: Column 27

The Booley Bay Formation makes up much of the northern part of Hook Head in south Co. Wexford and also extends west of Waterford Harbour (Figs 18, 20). Although classed as part of the Cahore Group in the most recent work of the Geological Survey of Ireland (Tietzsch-Tyler & Sleeman 1994a), its lithologies and age indicate that it is better included as part of the Lower Palaeozoic Ribband Group of southeast Ireland (Vanguestaine & Brück 2008). It is best exposed along its type section at Booley Bay (Gardiner 1978). The formation is estimated to be 3000+m thick (Gardiner 1978) and is largely made up of well-laminated medium to dark grey greywackes and mudstones. A coarse conglomeratic unit occurs locally, c. 200+m thick, termed by Gardiner (1978) the Baginbun Paraconglomerate Member, and considered by him to form the youngest part of the formation.

The type section of the Booley Bay Formation is along a 200m-thick, steeply dipping, southern inverted limb of an anticline. Here, diverse and extremely well-preserved erosional and depositional turbidite structures occur abundantly. These include fan flutes, linguiform flutes, longitudinal ridges and furrows, longitudinal pseudoripples, bounce marks, button structures, grooves, grading, convolute laminae, cross-laminae and parallel laminae. In the main, the structures indicate derivation of the sediment from the northeast.

Structures considered until recently as a possible Ediacaran biota occur relatively abundantly on the bases of several beds along the Booley Bay section. The material was described in detail by Crimes *et al*. (1995), who distinguished two species: *Ediacara booleyi* and *Nimbia occlusa*, the former being classed by them as a new Ediacaran species. Recently, however, MacGabhann *et al*. (2007) re-investigated these supposed Ediacaran biotas and concluded that the features of *E. booleyi* are inconsistent with their classification as Ediacarans. They proposed that, while possibly being in part of biogenic origin, *E. booleyi* should be excluded from the

genus *Ediacara*. These authors also consider that the recorded specimens of *Nimbia occlusa* are swing or scratch marks, as reinterpreted for these structures elsewhere (Jensen *et al*. 2002).

The only other macrofossil to have been recorded from the Booley Bay Formation is *Graptolithus hisingeri* (Kinahan 1879). However, Kilroe (1901), Gardiner (1978) and Gardiner & Vanguestaine (1971) reported that the original collection has been lost and this record cannot be confirmed. Thus our knowledge of the age of the strata relies on palynology. Gardiner & Vanguestaine (1971) examined three samples for microfossils, although none of these was from the type section. They recorded poorly preserved acritarch assemblages, which they considered to indicate a "Lower to Middle Cambrian age" for two of the samples, and a very tentative Tremadoc to Lower Arenig age for the third sample. Smith (1981) gave the first account of acritarchs from the type section of the formation at Booley Bay, which he noted as yielding "a remarkably well preserved acritarch microflora of Middle Cambrian age". Moczydłowska & Crimes (1995), based on a study of four microfossil samples from mudstones interleaved with the *Ediacara*-bearing beds at Booley Bay, proposed that the strata there could be referred to the upper part of the traditional Upper Cambrian. Recently, Vanguestaine & Brück (2005, 2008) examined seventeen samples collected from throughout the *Ediacara*-bearing succession at Booley Bay and one sample collected from 140m+ above the *Ediacara*-bearing beds. The former samples were classified as "Assemblage BB1" by Vanguestaine & Brück (2008), and the latter sample as "Assemblage BB2".

Assemblage BB1 occurs through approximately 210m of the Booley Bay Formation. ?*Adara alea* and *Eliasum asturicum* occur in samples from the upper part of the sampled section, and suggest a possible *Adara alea* Acritarch Zone age for this part of the succession (= upper *T. fissus* and *H. parvifrons* trilobite zones, middle *P. paradoxissimus* Superzone, Drumian). Species from lower samples might indicate earlier zones: *Vulcanisphaera lanugo*, for example, is restricted to the *Rugasphaera terranovana* Acritaech Zone (= *T. fissus* Trilobite Zone) in eastern Newfoundland. Vanguestaine & Brück (2008, p. 89), however, considered the BB1 assemblage to correlate with the lower A2 Zone of eastern Newfoundland (= lower *P. forchhammeri* Trilobite Zone). The lower part of the Booley Bay Formation in column 27 is accordingly shown as extending from about the base of the *T. fissus* Biozone into the

lower part of the *P. forchhammeri* Biozone in column 27 (Drumian to lower Guzhangian).

Assemblage BB2 contains *Cymatiogalea virgulta,* which appears in the *Agnostus pisiformis* Trilobite Zone, and *Timofeevia pentagonalis*, which possibly appears in the *Lejopyge laevigata* Trilobite Zone in Newfoundland (Martin & Dean 1988, the upper A2 (Tp-Vt) acritarch Zone), and range into Zones RA5/A5b (*Peltura minor* Trilobite Zone). It also contains *Stelliferidium robustum*, which ranges from about the base of the *Agnostus pisiformis* Biozone, or slightly lower, into the *Parabolina spinulosa* Trilobite Zone (Brück & Vanguestaine (2004). Vanguestaine & Bruck (2008) compared the BB2 assemblage with an assemblage described by Young *et* al. (1994) from the Maentwrog Formation of St Tudwal's Peninsula, North Wales, and concluded that the two assemblages were of about the same age, namely *Olenus* Trilobite Zone (Paibian). There is no clear evidence that the parts of the Booley Bay Formation at Booley Bay are younger than Paibian, early Furongian.

Recently, Landing & MacGabhann (2010) have described what they term large clasts, up to 140mm in size, in siltstone beds in the Booley Bay Formation on the eastern coast of the Hook Head peninsula (Fig. 20) which, based on their characteristics and features in the host siltstones, they consider may be glacial dropstones. They also contend that the age of the Booley Bay Formation is poorly constrained, but state that it is early to middle Cambrian. They thus suggest that an early Cambrian age for the possible dropstones is consistent with the age of an early Cambrian/Terreneuvian diamictite, in which the clasts are also considered by them to be glacial dropstones, which occurs in the Lower Mystery Lake Member of the Chapel Island Formation in southern New Brunswick. They propose that these two possible dropstone occurrences provide evidence for an early Cambrian glaciation in Avalonia.

However, a recent examination by one of us (P.M.B.) of the clast-bearing siltstones described by Landing & MacGabhann (2010) at Hook Head shows that they occur in a strongly tectonized coastal section in which numerous tectonic melanges are present. The melanges display a wide range of evolutionary features, some of which are similar to features in the possible dropstone units. In addition, the possible dropstone horizons also resemble some levels in the Baginbun Paraconglomerate

Member, which Gardiner (1978) considered to be of slump origin and to constitute the youngest part of the Booley Bay Formation.

Landing & MacGabhann (2010) also state that existing palynological studies have produced equivocal results. In reaching this conclusion, however, they gave equal weight to different generations of research, omitting to take into consideration the fact that much has been published on Cambrian acritarch biostratigraphy since the earliest palynological investigation of the Booley Bay Formation by Gardiner & Vanguestaine (1971). In addition, Landing & MacGabhann (2010) did not take into account the arguments put forward by Vanguestaine & Brück (2008) to show that the late Cambrian age proposed by Moczydłowska & Crimes (1995) was unsustainable. Far from being equivocal, the acritarch data published by Vanguestaine & Brück (2008) enable relatively precise correlation of the Booley Bay Formation with the Cambrian succession on the Avalon Peninsula of eastern Newfoundland. The age of the formation at its type locality, as outlined above and discussed in more detail by Vanguestaine & Brück (2008), is clearly mid Cambrian (Drumian) to late Cambrian (Paibian), although extending higher elsewhere (e.g. Clammers Point; see below and column 28), and the formation forms part of the Lower Palaeozoic Ribband Group of southeastern Ireland, which ranges in age from Drumian to late Arenig.

Thus, although a glacial dropstone origin for the clasts within the Booley Bay Formation on the eastern coast of the Hook Head peninsula is possible, the evidence is open to interpretation and a tectonic or slump origin cannot be discounted. In addition, all the available data indicate that the Booley Bay Formation at its type locality is not early to middle Cambrian, but is middle to upper Cambrian (Drumian to Paibian stages).

Clammers Point: Column 28. On the coast of south Co. Wexford, a few kilometres east of Hook Head, the Ballymadder Shear Zone separates a somewhat different Cambrian succession to the west from that immediately to the east (Figs 18, 20). West of the shear zone, in the Bannow area, the Clammers Point Tectonic Unit (Tietzsch-Tyler 1989) exposes a coastal section comprising Cahore Group and Ribband Group sediments. The former unit is entirely Cambrian in age, while the latter probably extends from the Cambrian into the Ordovician (Harper & Parkes 2000).

Dhonau (1972) established three formations in the Cahore Group here, the stratigraphical order, nomenclature and thicknesses of which have been revised by Tietzsch-Tyler (1989, 1996) and Tietzsch-Tyler & Sleeman (1994a). The formations are, in order from base to top, the Kiln Bay, Cross Lake and Ardenagh formations. The Kiln Bay Formation comprises 1000m of thin-bedded, green and buff greywackes and shales with some internal turbidite structures. The base is not seen. The Cross Lake Formation is made up of 500 m of red, green and buff greywackes with some internal turbidite structures, shales and prominent interbedded pale quartz arenites. The Ardenagh Formation consists of well-bedded green greywackes with abundant internal and external turbidite structures and green shales. *Oldhamia antiqua*, *Histioderma hibernicum*, and *Arenicolites didymus* were recorded from the Kiln Bay and Cross Lake formations by the 19th century Geological Surveyors (Kinahan 1879). Gardiner & Vanguestaine (1971) investigated two samples for palynology from near the base of the Kiln Bay Formation (which they included in the Cross Lake Formation). The bulk assemblage of acritarchs obtained suggested a Cambrian age. More recently, Brück & Vanguestaine (2004) obtained two palynologically productive samples from the Cross Lake Formation (sensu Tietzsch-Tyler & Sleeman 1994a) containing, among other acritarch species, *Comasphaeridium mollicum, Fimbriaglomerella minuta*, *Globosphaeridium cerinum*, *Elektoriskos flexuosus*, *Skiagia ciliosa* and *S. insignis*. The assemblage indicates a *dissimilare-ciliosa* Acritarch Zone age, upper Stage 3 to lowermost Stage 4.

The Cahore Group is faulted against typical Ribband Group lithologies comprising well-laminated medium to dark grey and buff greywackes and mudstones with internal and external turbidite structures. These rocks have been variously termed the Bannow Island and Bannow Bay formations, the Bannow Group and the Blackhall Formation (Gardiner & Vanguestaine 1971; Dhonau 1972; Brück *et al.* 1979; Max *et al*. 1990; Brück & Vanguestaine 2004). However, the lithologies are indistinguishable from those of the Booley Bay Formation as described above and the latter term is used here, following Tietzsch-Tyler (1989) and Tietzsch-Tyler & Sleeman (1994a).

Several specimens of the starfish originally named *Palasterina kinahani* Baily (*in* Kinahan 1878) were collected from these beds by officers of the Geological Survey during the 19th century (Kinahan 1879). Parkes & Sleeman (1997) recently reclassified them as *Petraster kinahani* (Baily, 1878). In addition, Dhonau (1972) recorded graptolites from the shore section, namely *Climacograptus* sp. cf. *minimus*

and *Orthograptus* sp. cf. *calcaratus* group, which he suggested indicated an early Caradoc age. However, Gardiner & Vanguestaine (1971) obtained a "Tremadoc or an early Arenig" age based on an acritarch assemblage from one sample. In order to explain these conflicting age determinations, those authors concluded that the acritarchs were reworked into Caradocian sediments.

A more precise age was determined by Brück & Vanguestaine (2004). Based on diagnostic acritarch species from four palynological samples, the age for the Booley Bay Formation at Bannow was considered by those authors to range from Mid Cambrian to late Arenig or Llanvirn. An assemblage from the lower part of the Booley Bay Formation indicates the lower part of Series 3 (Stage 5 to mid Drumian), based on the occurrence of *Retisphaeridium dichamerum*, *Eliasum llaniscum*, *Cristallinium cambriense*, *Comasphaeridium silesiense* and *Celtiberium* spp. Also *Lophosphaeridium latviense* and *L. variabile*, both recorded with some uncertainty, might further restrict the assemblage to the *oelandicus* Trilobite Zone (Moczydłowska 1998). A sample from higher in the formation suggests an age in the range upper A2 to RA4 acritarch zones (from the *A. pisiformis* Trilobite Zone or possibly the upper *L. laevigata* Biozone to the *P. spinulosa* Biozone) based on the FAD and LAD respectively of *Vulcanisphaera turbata* and *Timofeevia lancarae*. *H. lanceolatum*, questionably present, might restrict this to the upper *L. laevigata* Trilobite Zone (Guzhangian) as it does not range above that zone in the range chart published by Moczydłowska (1998).

Tietzsch-Tyler (1989) considered that the Kiln Bay Formation "passes transitionally laterally and locally downwards, into the thinly bedded turbidites of the Booley Bay Formation". Tietzsch-Tyler (1989) also considered that "its [the Booley Bay Formation's] apparent age from Lower to Middle Cambrian to Tremadoc–earliest Arenig suggests that it is better included in an expanded Cahore Group". However, there is no clear basis for the former statement, and while the latter statement is broadly correct, lithologically the Booley Bay Formation is part of the Ribband Group and is here classed with it.

Cullenstown: Column 29. East of the Ballymadder Shear Zone, at Blackhall, at the western end of Cullenstown Strand (Fig. 20), the Cambrian succession is slightly different from that at Bannow. The rocks here have been placed within the Wexford

Tectonic Unit (Tietzsch-Tyler 1989, 1996). Three formations occur, comprising turbidites considered to be more proximal than those west of the shear zone. They are, in ascending stratigraphical order, the Newtown, Shelmaliere and Cullenstown formations (Tietzsch-Tyler 1989, 1996). The Newtown Formation is 600 m+ thick and comprises thick-bedded green and some purple greywackes and shales; the base is not seen. The Shelmaliere Formation (800 m) is made up of green, red and buff mudstones with prominent pale quartz arenites up to 70 m thick which, at Blackhall, have undergone a significant degree of tectonic deformation. The Cullenstown Formation (500 m+) has similar lithologies to the Newtown Formation, comprising mainly green and buff greywackes with sedimentary slump structures. The unit has also undergone substantial tectonic deformation.

No macrofaunas have been recorded from any of the units of the Cahore Group at Blackhall. However, Brück & Vanguestaine (2004) obtained acritarchs from two palynologically productive samples of the Cullenstown Formation, which they suggested indicated a "latest Middle to early Late Cambrian" age. One of the samples yielded *Timofeevia microretis*?, a species that occurs in the *Agnostus pisiformis* Trilobite Zone and lowest *Olenus* Trilobite Zone in eastern Newfoundland (upper A2 (Tp-Vt) Acritarch Zone). Most of the other taxa present either range through this level (*Cristallinium cambriense*, *Timofeevia phosphoritica*, *T. lancarae*, *Vulcanisphaera turbata*) or have FADs (*Stelliferidium robustum*) or LADs (*Heliosphaeridium lanceolatum*) that are close to this level. The two exceptions are *Heliosphaeridium*? *llynense*, recorded previously from the lower part of the Nant-y-big Formation (see column 3) on St Tudwal's Peninsula (*T. fissus* to *H. parvifrons* trilobite zones), and *Impluviculus* sp. A, recorded from the A3a to A5a acritarch zones (*Parabolina spinulosa* to *Protopeltura praecursor* trilobite zones) in eastern Newfoundland. The co-occurrence of these last two with the other taxa makes interpretation of the age of the sample a little difficult, but the balance of probability puts it around the base of the upper A2 (Tp-Vt) Acritarch Zone (late Guzhangian).

The second sample has a more restricted assemblage, but three of the four taxa listed, *Stelliferidium robustum* (= *Stelliferidium*? sp. A), *Timofeevia phosphoritica* and *Vulcanisphaera turbata* occur in both samples, and the fourth, *T. pentagonalis*, also has its FAD at the base of the upper A2 (Tp-Vt) Acritarch Zone. Hence the sample could be as old as late Guzhangian (*A. pisiformis* Trilobite Zone or possibly *L. laevigata* Trilobite Zone, equivalent to the proposed age of the previous sample), but

could be as young as the *Peltura minor* Trilobite Zone (A5b Acritarch Zone), based on the occurrence of *T. pentagonalis*. It is possible that the two samples from the Cullenstown Formation are from rocks of approximately the same age.

Max & Dhonau (1974) suggested a Precambrian age for the Cullenstown Formation, based on the higher degree of deformation and metamorphism seen in the unit at Cullenstown Strand in comparison with the adjacent Lower Palaeozoic strata. More recently, it has been proposed that the formation be included as an integral part of the Cahore Group (Tietzsch-Tyler 1989, 1996; Tietzsch-Tyler & Sleeman 1994a). However, Max *et al*. (1990) considered that, although the Cullenstown Formation has similar lithologies to the Cahore Group, it has undergone a different tectonothermal history. Brück & Vanguestaine (2004), noting its "latest Middle to early Late Cambrian age", suggested that it is younger than the Cahore Group. The latter, including its Bray Group equivalent, is dated elsewhere as Lower Cambrian (Brück & Vanguestaine 2004), and is here placed in Stage 4 (of Series 2) to early in Stage 5 (Series 3).

SE Co. Wexford: Column 30. A fairly extensive area (Figs 18, 20) of poorly exposed unfossiliferous Cambrian rocks occurs south of Wexford town. The region was investigated in detail by Shannon (1978). Brück *et al.* (1979) and Max *et al*. (1990), on their respective maps, showed the Cullenstown Formation (or Group) extending from Cullenstown Strand northeastwards to Wexford town to include some prominent quartz arenites. More recently, however, Tietzsch-Tyler & Sleeman (1994a) classed these quartz arenites as part of the Shelmaliere Formation as mapped by Shannon (1978), with the Cullenstown Formation making up a lesser part of the area. Their interpretation is followed here.

The succession (Shannon 1978; Tietzsch-Tyler & Sleeman 1994a) is broadly similar to that at Cullenstown, and comprises, in ascending stratigraphical order, the Newtown, Cullentra, Shelmaliere, Cullenstown and Polldarrig formations. Tietzsch-Tyler & Sleeman (1994a) placed all five formations in the Cahore Group. However, as explained above, the Cullenstown Formation, although Cambrian, is not here included in that group. In addition, the Polldarrig Formation is made up of typical Ribband Group lithologies and is here classed with the latter group. The lithologies are as at Cullenstown, with the exceptions of the Cullentra Formation, which is absent at Cullenstown and comprises massive green greywackes and shales, and the

Polldarrig Formation, which is made up of grey and green, fine grained, laminated greywackes and shales. The latter unit is the local equivalent of the Booley Bay Formation at Hook Head (Tietzsch-Tyler 1996) and is here classed as the basal unit of the Ribband Group.

Various turbidite structures occur in the Cahore Group sediments and point to derivation of the sediments from the east-southeast while slump directions indicate a palaeoslope dipping to the northwest during Cahore and Ribband Group times (Shannon 1978).

Because of their similarity and proximity along strike, the metasedimentary successions that lie northwest of the Rosslare Complex have long been compared with the Monian Supergroup of Anglesey. It has been suggested that the Cahore Group together with the Cullenstown Formation may be correlated with the South Stack Group, which is the lowest group of the Monian Supergroup (Tietzsch-Tyler 1989; Tietzsch-Tyler & Phillips 1989; Tietzsch-Tyler 1996). Tietzsch-Tyler (1989) suggested that the Kiln Bay, Cross Lake and Ardenagh formations at Clammers Point perhaps equate with the Newtown, Shelmaliere and Cullenstown formations of southeast Co. Wexford, which may correlate with the South Stack, Holyhead Quartzite and Rhoscolyn formations of the South Stack Group. The more recent acritarch evidence (Brück & Vanguestaine 2004) outlined above now suggests, however, that the Cullenstown Formation is a little younger. Because the South Stack Group forms the lower part of the Monian Supergroup, this correlation suggests that the deposition of the Monian Supergroup took place during the Cambrian rather than in the late Proterozoic (Tietzsch-Tyler & Phillips 1989). See also Chapter 9 and Figure 13.

*Ballycogly***:** Column 31. In the area south of Wexford (Fig. 20) there exists a northeasterly trending belt of mylonitized, fine grained metasediments, which occur within a major, 4 km wide mylonite zone, the Ballycogly Mylonite Zone (Murphy *et al*. 1991). This zone flanks the Precambrian Rosslare Complex on its northwestern margin and is adjacent to an Upper Palaeozoic and Mesozoic basin. The rocks, which are thinly layered siliceous and micaceous phyllonites, are known as the Ballycogly Group (Baker 1970). Detailed studies have been undertaken on the mylonite zone (Murphy 1990; Tietzsch-Tyler & Sleeman 1994a; Tietzsch-Tyler 1996) and have led to slightly different interpretations as to the distribution of the Ballycogly Group

metasediments. Murphy (1990), in his study, mapped the Ballycogly Group as making up the northern half of the mylonite zone. He considered that the southern half of the mylonite zone, known as the Tomhaggard Zone (Murphy 1990), had a gneissic protolith. More recent work, however, has suggested that the Ballycogly Group forms a much wider belt within the mylonite zone, up to 4000 m in width, and that the bulk of the mylonites within the zone were developed from a sedimentary protolith, with only a 300 m wide belt along the southern margin of the zone being made up of mylonitized Rosslare Complex amphibolites and gneisses (Tietzsch-Tyler & Sleeman 1994a; Tietzsch-Tyler 1996). Lenses of unmylonitized metasediments occur within the mylonites, of which the largest is known as the Silverspring Beds. These are in part conglomerates which contain clasts comparable with the Rosslare Complex (Murphy 1990; Tietzsch-Tyler 1996).

At the eastern end of the mylonite zone, the Ballycogly Group is faulted against the upper Arenig to Llanvirn Tagoat Group (Baker 1966; Brenchley *et al.* 1967; Crimes & Dhonau 1967; Tietzsch-Tyler 1989; Murphy *et al.* 1991; Tietzsch-Tyler & Sleeman 1994a; Tietzsch-Tyler 1996; Harper & Parkes 2000), comprising mudstones, siltstones and conglomerates. The Tagoat Group lies unconformably on the Rosslare Complex, and probably also unconformably overlay the Ballycogly Group prior to the episode of faulting (Tietzsch-Tyler 1996). The deformation that produced the mylonites is considered to have occurred during the late Cambrian or very early Arenig, as blocks of mylonite occur as clasts in the Tagoat Group (Baker 1966; Max *et al.* 1990). Murphy (1990) suggested a late Precambrian age for the Ballycogly Group, but the most recent studies have assigned a Cambrian age on the basis of the overall structural evidence (Tietzsch-Tyler & Sleeman 1994a). However, as noted by Holland (2001, 2009), a clear Cambrian age cannot be confirmed. Finally, Tietzsch-Tyler (1996), on the basis of a number of lines of possible evidence, has suggested that the Ballycogly Group may equate with the New Harbour Group, which succeeds the South Stack Group as part of the Monian Supergroup on Anglesey (Chapter 9, Fig. 13; Gibbons *et al.* 1994).

Other areas in southeast Ireland previously considered to be Cambrian

A. *Maulin Formation*, Counties Wicklow and Carlow**.** This very extensive unit (Brück *et al.* 1974) flanks the Leinster Granite on the east ("A" in Fig. 18), extending 100 km southwards from Dublin Bay to Co. Carlow (McConnell & Philcox 1994;

Tietzsch-Tyler & Sleeman 1994a, b). It is made up of typical Ribband Group lithologies comprising dark grey phyllites, slates and thin grey quartzites. Brück *et al.* (1974) gave an estimated thickness of 900m in northern Co. Wicklow.

A distinctive feature is the presence in the formation throughout much of the Leinster Granite aureole of thin, often intricately folded bands of garnetiferous quartzite, 2–20mm thick (Brindley 1954; Brück 1968). Kennan (1972, 1986) has made a detailed study. Kennan & Kennedy (1983) proposed that this distinctive 'coticule package' is of large lateral extent within the Caledonian-Appalachian orogen, and is stratigraphically confined to the Arenig. Accordingly, it would appear that the part of the Maulin Formation containing the 'coticules' may be Arenig in age.

On the other hand Tremlett (1959) and Downie & Tremlett (1968) have suggested a Cambrian age. Tremlett (1959) classed the rocks in the Trooperstown Hill area in southeast Co. Wicklow as, in ascending stratigraphical order: the Knockrath 'Series', Bray 'Series', Clara 'Series', Dunganstown Sandstones. However, Brück & Reeves (1976), in their investigations of the same area, classed the Bray Series as the Bray Group and re-assigned the other three units of Tremlett (1959) to the Ribband Group, which, in this area, McConnell & Philcox (1994) have mapped as the Maulin Formation. Tremlett (1959) recorded some poorly preserved brachiopods in his Clara Formation. These were examined by C. J. Stubblefield who described them as resembling *Acrotreta* or *Micromitra*, indicating a possible Cambrian age. Subsequently, Downie & Tremlett (1959) reported some very poorly preserved sphaeromorph acritarchs from the same rocks which, although not by themselves conclusive, seemed to confirm a Cambrian age when considered with other lines of evidence.

In summary, it is likely that the Maulin Formation is Cambro-Ordovician; more work is, however, needed.

B. *Carricktriss Formation, Slievenamon.* This formation forms a small area in the southeast of the Slievenamon Lower Palaeozoic inlier in Co. Tipperary ("B" in Fig. 18). The formation comprises volcaniclastic sediments, siltstones and shales. Colthurst & Smith (1977) obtained an acritarch assemblage which they suggested indicated a "late Cambrian age". Subsequently, Smith (1979) re-examined the same palynologial preparations and concluded that the upper Cambrian acritarchs were reworked into early Ordovician (Tremadoc-Arenig) material. Recently, more

diagnostic acritarchs obtained from the formation indicate an early to middle Ordovician age (Maziane-Serraj *et al.* 2000; Brück *et al*. 2001).

C. *Muggort's Bay Lower Palaeozoic inlier, Co. Waterford.* This small inlier ("C" in Fig. 18) forms the most southerly exposure of Lower Palaeozoic strata in Ireland. It comprises fine-grained turbidites and volcanic rocks; no macrofaunas have been recorded. It had been suggested that some of the strata might be Cambrian (Harper & Parkes 2000). Recent palynological studies, however, have shown that Cambrian acritarchs have been reworked into Early to Middle Ordovician material and the age of the succession is most likely Ordovician (Brück & Vanguestaine 2005).

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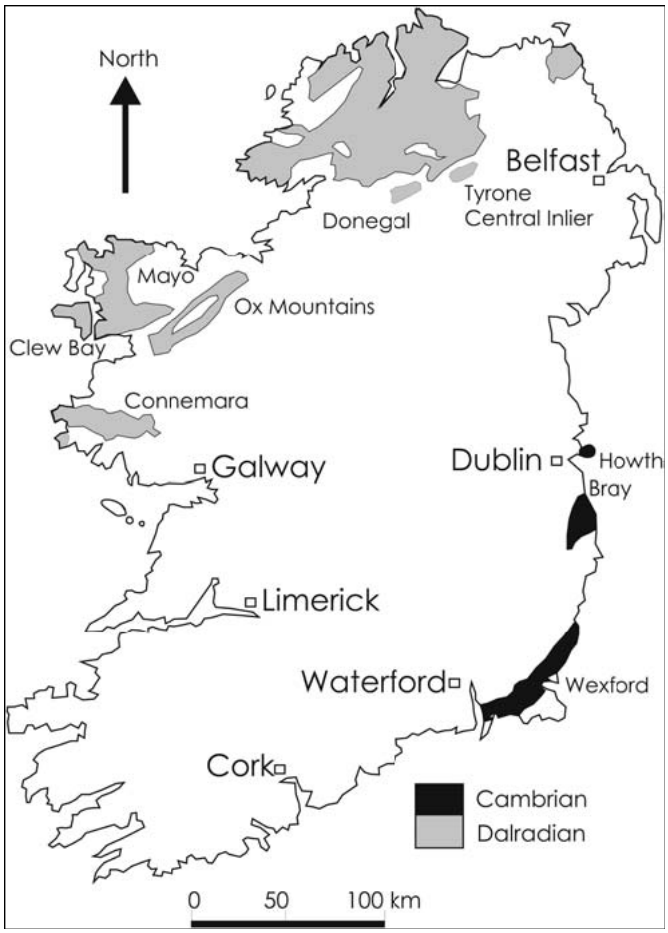

Fig. 17. Distribution of Cambrian rocks and the Dalradian Supergroup in Ireland.

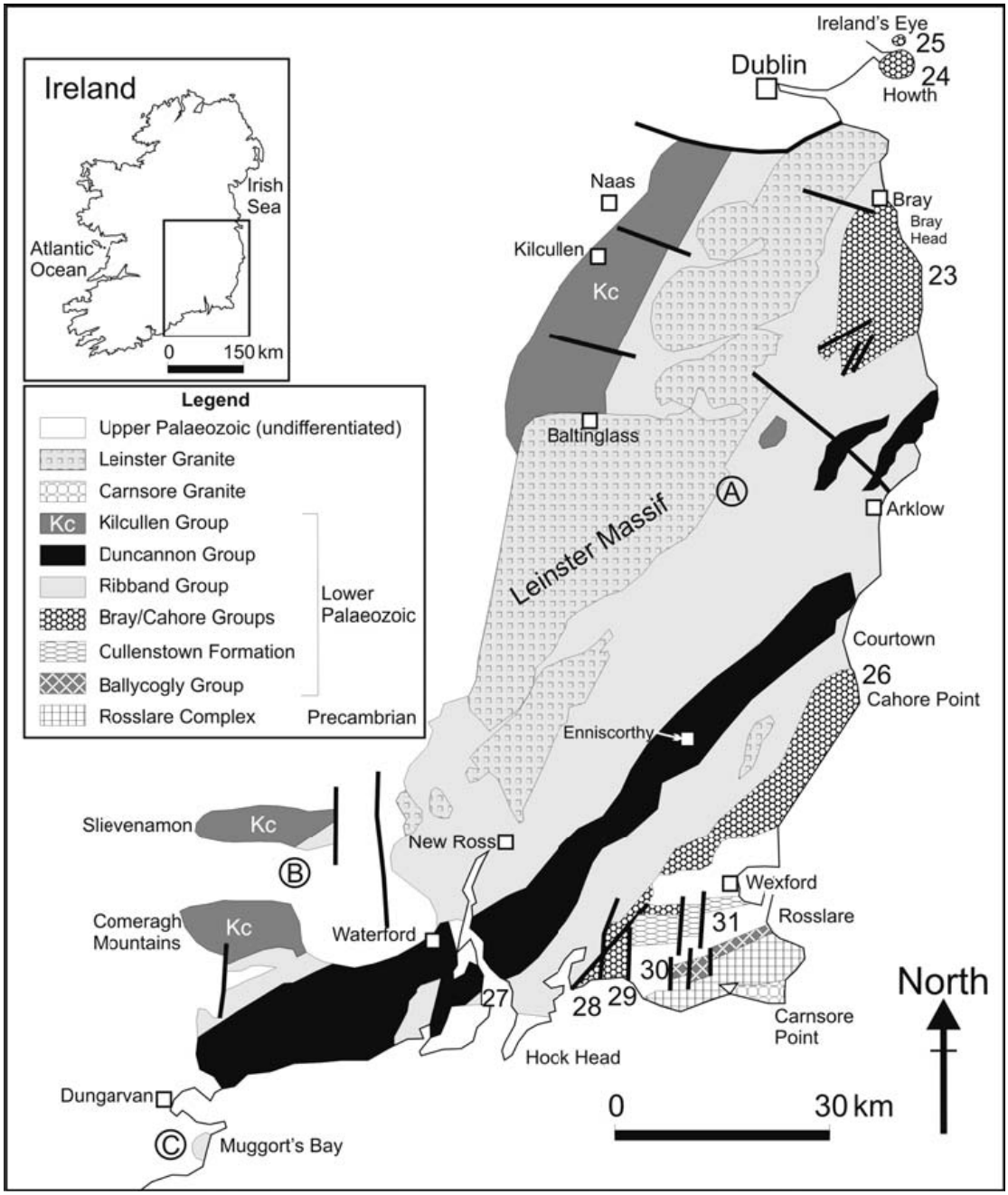

Fig. 18. Distribution of Cambrian rocks in southeastern Ireland (Leinster Terrane). The numbers relate to the general locations of columns 23-31 in Figure 19. The symbols A, B and C refer to areas with formations of doubtful age (see the end of chapter 12).

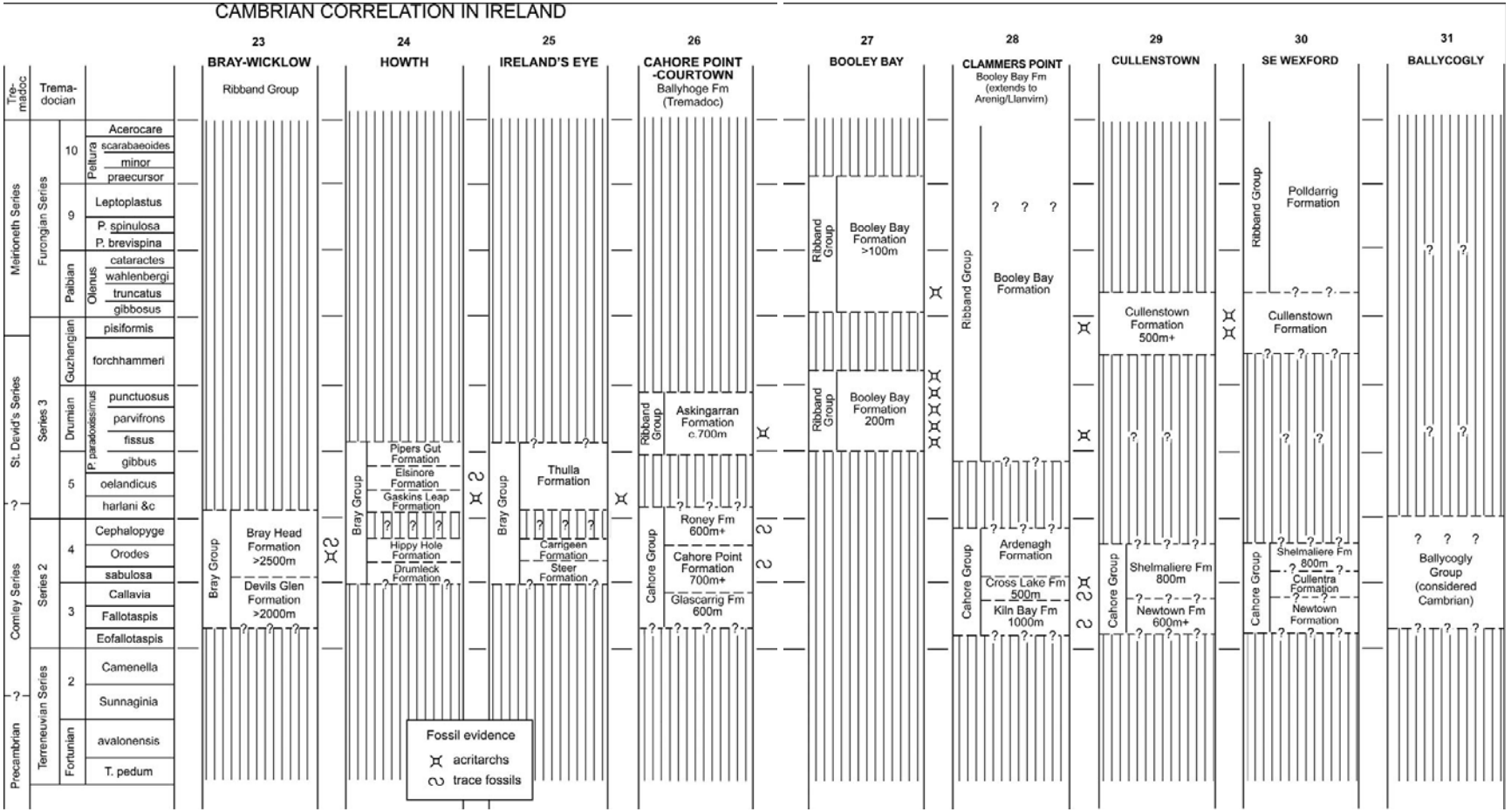

Fig. 19. Correlation of Cambrian rocks in Ireland (Leinster Terrane).

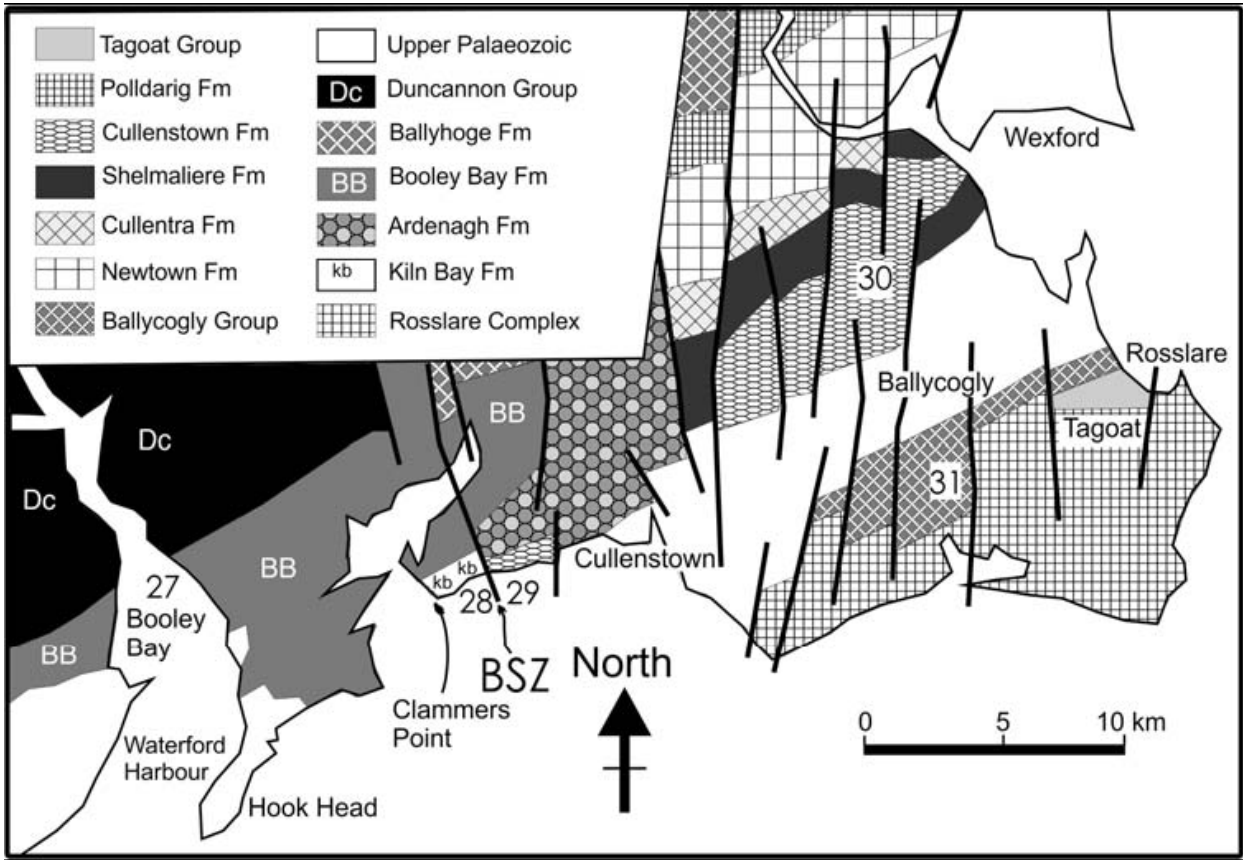

Fig. 20. Distribution of Cambrian rocks in southeast Wexford (Leinster and Monian terranes). The numbers refer to columns 27-31 in Figure 19. BSZ refers to the Ballymadder Shear Zone.