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The Lithostratigraphy of the Tournaisian & Viséan of Ireland: Rathdowney Trend-Carlow-Kilkenny-Carrick on Suir

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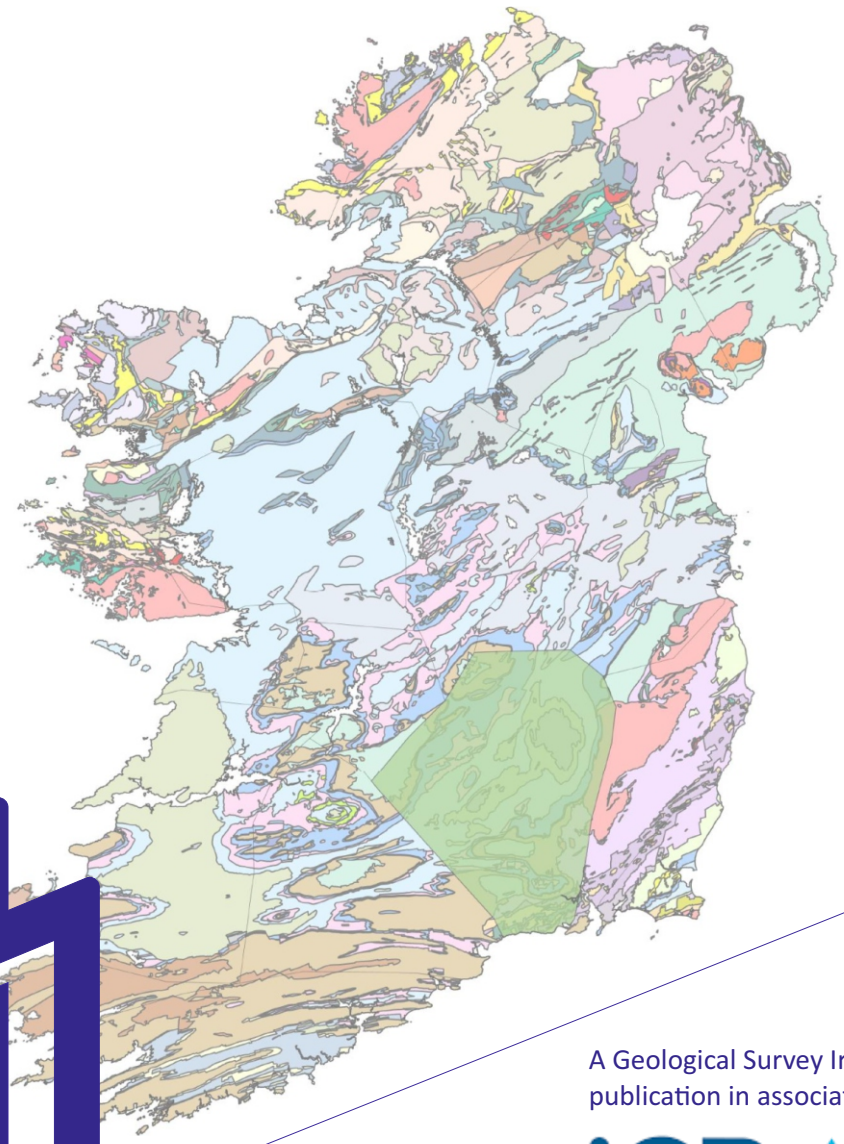

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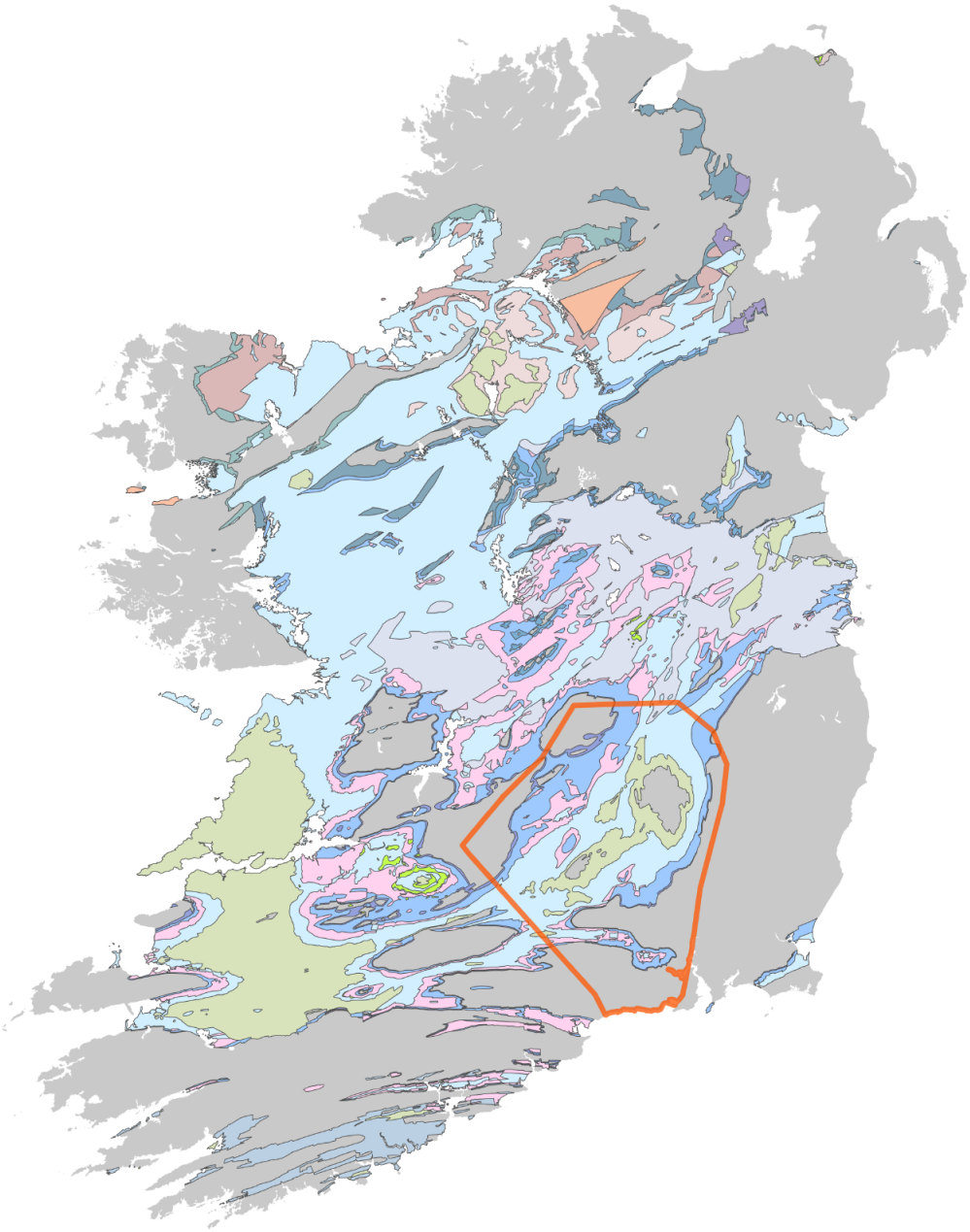

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Study Area: An Overview

The Rathdowney Area is outlined in figure 1, together with the location of boreholes used in the compilation of the stratigraphy. As the Rathdowney area, *sensu stricto*, is only the central part of the area under discussion, a capital 'A' is used to identify the wider subject Area. Stratigraphic information is sourced partly from borehole logs and consulting reports prepared by M.E.P., partly from Open File records and partly from publications and unpublished theses (see list of references for the latter). In the following text individual borehole successions are summarized, and in some cases elaborated in appendices. Unit terms applied here are those in common use, though few have been defined formally. No new definitions or type sections are put forward. Alternative formation boundaries are discussed, where they are not generally agreed.

The list of contents shows the sequence in which the Area is described. Most of the boreholes are concentrated along the Rathdowney Trend, so this is considered first. Successions in the few boreholes in the southern part of the Area follow, and then those borehole successions along the eastern margin of the Area, where the influence of the Leinster Massif is evident. As most of the drilling has been directed towards base-metal exploration, the Old Red Sandstone and the youngest part of the Viséan are seldom fully represented in core. However, published data on natural outcrops and on quarry sections compensate for this.

In most of the early (post-1960) drilling imperial units were used for box-labelling and core logging. To allow for easy reference, boundary depths in cores so labelled are given here in the original units. Thicknesses are always given in metric units. Bedding dips refer to dips to core-normal. Cross-sections are not to scale horizontally; approximate separations between boreholes can be gauged from the map (fig. 1).

The choice of the depth of unit boundaries in core can depend on the level of observation. Thus a lithological unit that appears relatively uniform at the "field logging" (hand lens) level may include a distinct boundary that is only revealed by petrographic (thin-section) examination. There are a number of differences between unit boundaries identified in field logs by M.E.P. (Appendices 1-9) and those selected in the same core by, for example, Nagy (1903) on the basis of petrographic and micropalaeontological details, provided by closely spaced samples. From the viewpoint of environmental interpretation, the latter are essential. From the viewpoint of the exploration geologist's need for correlation and structural interpretation (not to mention cost saving!) the cruder approach is likely to be the most practicable. In view of these divergent interests, in the following sections some examples of field logs are contrasted with more "accurate" petrographically based logs.

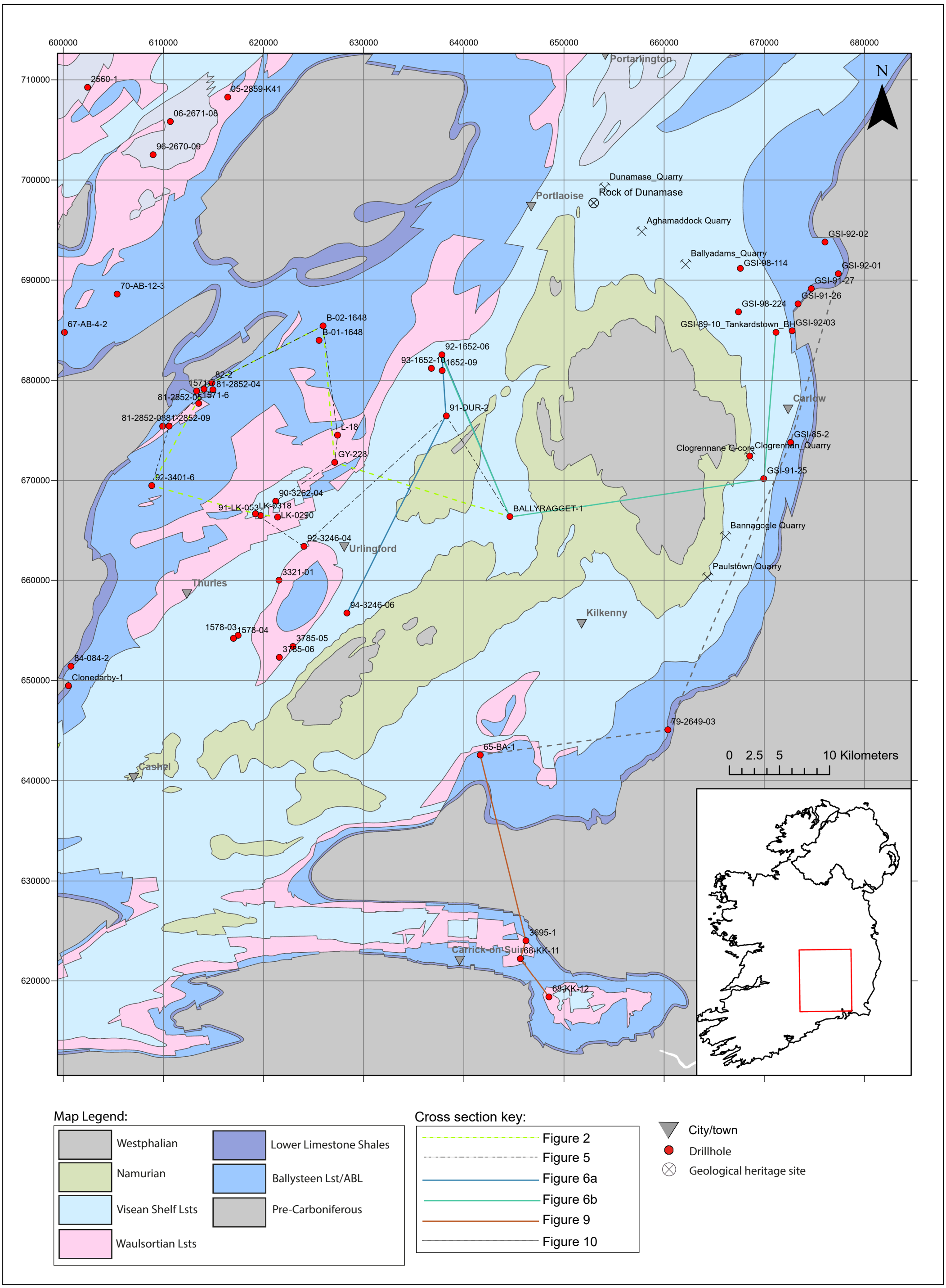


Figure 1: Map of Rathdowney Area, to show location of boreholes referred to in this chapter.

The Central Part of the Rathdowney Area

Old Red Sandstone

Few holes in the Rathdowney Area penetrated the full thickness of the Old Red Sandstone (ORS), and detailed descriptions of the core successions are even scarcer. Outcrop sections in the southern part of the Area are better known, especially from around Slievenamon (Colthurst 1978) and in the Comeragh Mountains (Penney 1980). This area is the eastern end of the Munster Basin (Graham 1983), and successions thicken dramatically from the northern and eastern margins towards the SW (>3,500 m in the Comeraghs). The ORS ranges in age from Devonian (Frasnian and Famennian, possibly earlier locally) into early Tournaisian. Several formations have been established on the basis of lithology (mudstones to coarse siliciclastic conglomerates) and colour. Some biostratigraphic dating has been carried out using pollen assemblages, but productive horizons are few, so there is limited control on lateral equivalence of adjacent formations.

The Carboniferous part of the ORS appears (within the limits of biozonation) to be confined to the Kiltorcan Formation. The top of this may be diachronous, and not everywhere Carboniferous. It is distinguished from older formations in having a generally yellow or grey colour, though some red beds can also be present. Some of the boreholes in the Rathdowney Area have penetrated predominantly red beds below the Kiltorcan, but it is difficult to assign them to either the Nier or Carrigmaclea Formations (Colthurst 1978; Penney 1980), as they have intermediate characteristics. This may reflect borehole locations well away from the outcrops of these formations.

In the central part of the Rathdowney Area hole LK-0318 penetrated 213m of varied siliciclastics below the Ringmoylan Shales, sitting on Lower Palaeozoic rocks (fig.2). Both top and bottom contacts are faulted, but throws are unknown. The Ringmoylan Shales are thinner than typical for the area (fig.2) and the sparse data for the beds immediately below the shales do not suggest the presence of Mellon House Beds. The upper fault may therefore be substantial. The upper part of the succession can be correlated with the Kiltorcan Formation, but it is not clear where the base should be placed. Red beds are commoner below 589 m and account for 50% of the succession between 604 and 665.5m. However, yellow-grey sandstone underlies these beds at 665.5-691m, which might also be considered part of the Kiltorcan Formation. The ORS below this consists predominantly of red mudstone to sandstone, with some fine-grained, locally derived breccias near the bottom. This is presumably below the Kiltorcan Formation.

Another core in the central area, LK-0290 (fig.2) penetrated beds labelled “Kiltorcan” in the sparse company log (494-548.5 m; 54.5 m thick down hole; no dip data), underlain by “ORS” to T.D. at 696m (147.5m down hole). The latter includes some caliche horizons in the upper part, and some pebbly sandstones lower down. The log refers to a “change in conditions” at 595m, suggesting that the underlying beds might be comparable to those below 691 m in LK-0318

Datum: Top of Ballyvergin Shale

Stratigraphic Correlation

LK-0290

(m) (m)

394.5-397.45 FCM

418.6-424.85: Bvn Shl

c.445

461

Mellon House Beds

494

500

Kiltorcan

548.5

f

ORS

"change in conditions"

600

T.D. 696 m

LK-0318

(m) (m)

FCM

469-474

15-20°

Lr. Ballysteen Lst

Ballymartin Fm

504.9 Bvn, flt'd out

20°

Ringmoylan Shl

525.5

15-20°

sst, variably grey, yel-grey, grn-grey; occ olive-grn mudst.

Kiltorcan Fm

570: 1 m qtz congl

577.5-580: isolated red siltst

0-20°

589 down: more red siltsts, interspersed with grn mudst & yel-grey sst; some x-bdg

600

604 down: red beds 50%, mainly mudst, siltst, between yel ssts; no green beds

665.5

yel-grey sst; occasional congl (not reworked caliche)

691

700

predom red, incl fn breccias with ?-Lr Pal clasts

738.5

800

T.D. 804.5 m

3401-6

(m) (m)

200

240.7 FCM

256

277.4-278.6

289.7

300

T.D. 305 m

81-5

(m) (ft)

47.2

155'

FCM

352.3

1156'

90.2

296'

Bvn

308'

121.3

126.5

398.5':3-m "Lam Shl"

415'

82-2

182.5

599'

Kiltorcan Fm

724' Red Beds

T.D. 727 ft (?)

221.6 m

B-02-1648

(m) (ft)

385.5

1265'

1265'

397.7

397.7

1305'

1305'

T.D. 1330 ft

405.4 m

Bvn not identified; depth very uncertain

GY-228

(m) (ft)

497.6

1632.5'

FCM

Bvn

549.2

1802'

T.D. 1884 ft

574.2m

Lr. Ballysteen Lst

Ballymartin Fm

?

?

Ballyragget -1

(m) (ft)

965

3166'

Ballymartin and Ringmoylan Shl equivalents?

1045

3428.4'

sst w. shl in'bds

1079

3540'

red beds

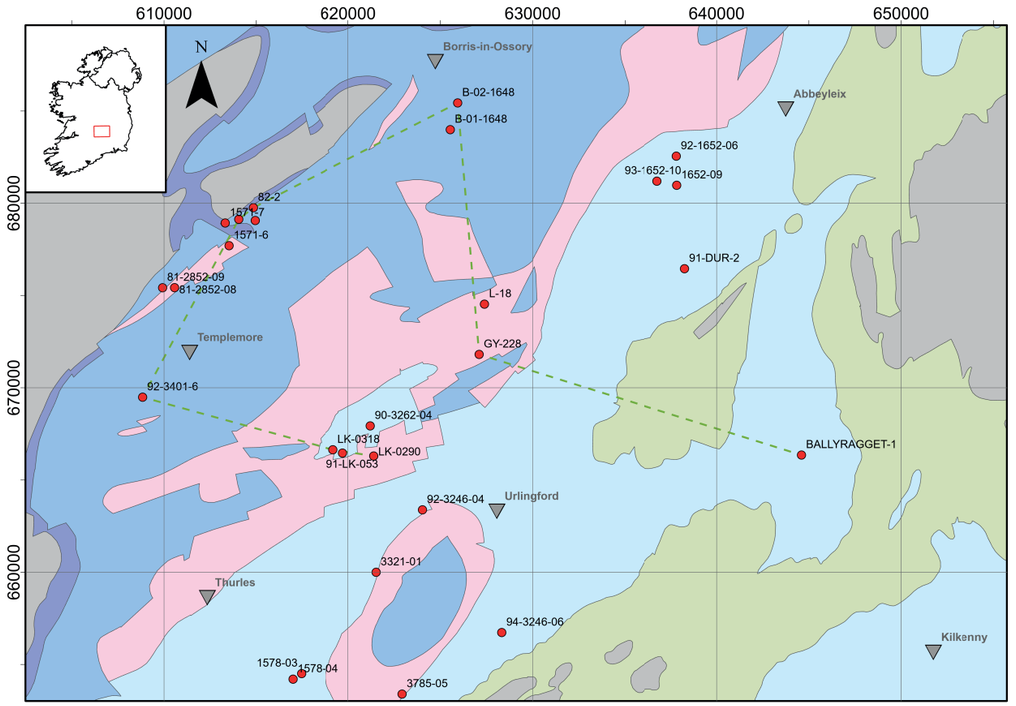
T.D. 1133 m

T.D. 3,717 ft

no dip or flt info

Map Legend:

- Westphalian
- Namurian
- Visean Shelf Lsts
- Waulsortian Lsts
- Ballysteen Lst/ABL
- Lower Limestone Shales
- Pre-Carboniferous
- Line of Section
- Drillhole
- Locality



Symbology Key:

- Clean calcarenite. Shale 0-10%
- Calcarenite with 10-30% shale or diffuse mud
- Calcarenite with 30-50% shale or diffuse mud
- Shale dominant, 50-70% with limestone
- Sandstone
- Shale dominant, 70-90% with limestone
- Shale dominant 90-100% ; minor limestone
- Silty shale; siltstone/shale interbedded
- Sandstone, shale, limestone interbedded
- Faulted-out section; thickness approximate or unknown: "?"
- Waulsortian limestone
- Lower Palaeozoics
- Thick shale beds
- Dolomite
- Fault

Section Legend:

- Ballysteen Lst Fm
- Ballymartin Fm
- Ringmoylan Shale
- Mellon House Beds
- ORS

Figure 2: Stratigraphic cross-section through drilled successions below the Ballysteen Formation in the Rathdowney Area. Datum is top of Ballyvergin Shale.
Sources: LK- and GY- holes modified from company logs; Ballyragget No.1 (Sheridan, 1977). (N.B. recovered mainly as cuttings and subject to sample contamination). Rest, MEP logs.
"Lam Shl" in 81-2852-05 column refers to the Laminated Shale unit identified at Gortdrum (Steed 1986). See text for identification of units below the Ringmoylan Shales in LK-0318.

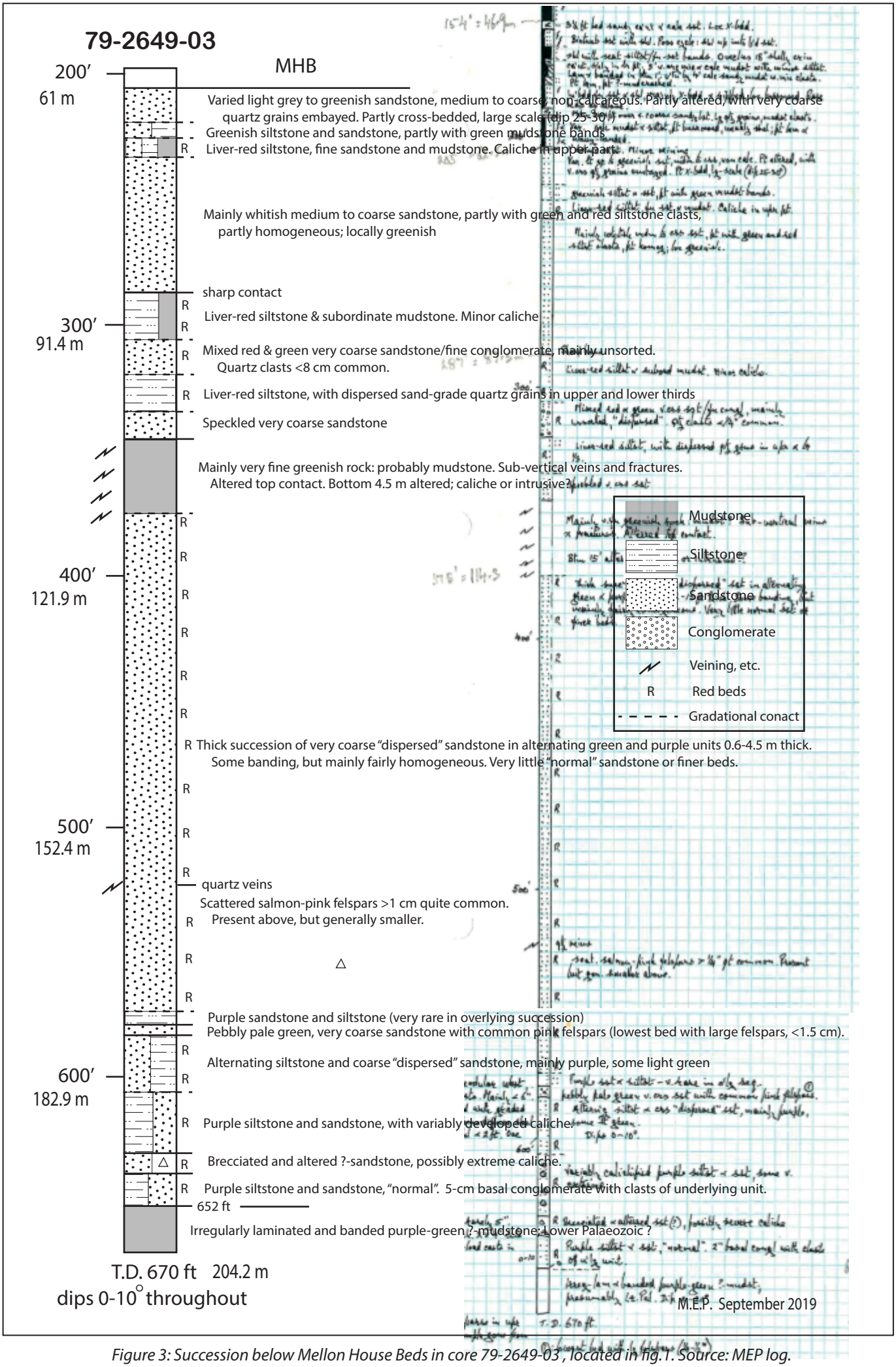


Figure 3: Succession below Mellon House Beds in core 79-2649-03, located in fig.1. Source: MEP log. Boundary depths in ft, as per box labelling and company log.

More detail is available for hole 79-2649-03 , located in the SE corner of the Rathdowney Area. The Old Red Sandstone in this hole is 128 m thick (fig.3, 205-652 ft; dips nearly horizontal). Most of the succession consists of coarse to very coarse purple and green sandstone, with some intervals including a high proportion of siltstone, predominantly liver-red in the upper part of the core. Much of the sandstone has a speckled appearance, reflecting an unidentified form of alteration. Caliche is developed mainly near the bottom of the succession (fig.3). Beds above 287 ft (87.5 m; 25 m thick) are mainly whitish, though red and green siltstones are locally present also. This upper section appears to represent the Kiltorcan Formation.

The interval 345-375 ft (9.1 m thick) is problematic. It consists of greenish "mudstone" with sub-vertical fractures and veins, and appears altered in the bottom 4.5 m. It is unclear at hand-sample level whether this is a mudstone that has been altered by pedogenesis or is a weathered intrusive. Apart from its internal veining, there is no reason to suspect from adjacent beds that there has been any significant faulting here.

Mellon House Beds

The transitional sequence between the ORS and younger fully marine limestones is termed the 'Mellon House Beds' (Shephard-Thorn 1963). The succession varies across southern Ireland, and it may be diachronous. The lower boundary of the formation can be gradational, depending on the selected criteria, which can vary from a lithological change, to the first appearance of marine fossils (including trace fossils). Shephard-Thorn (1963, p.270) included c.12m of sandy shale, siltstone, calcareous sandstone and thin limestones within the Mellon House Beds (MHB), but similar lithologies were also placed by him in the upper part of the Old Red Sandstone. The presence of *Modiola* seems to have been his criterion for the higher unit. In core it is usually easier to place the base at the main change from relatively uniform (yellow) sandstone below to finer-grained lithologies above. Choice of contact will inevitably be arbitrary where the change is gradational. The top contact of the Mellon House Beds is usually sharp at the base of the Ringmoylan Shales. Thicknesses in the central Rathdowney Area are typically c.30m, where not faulted.

In the Templemore core 81-2852-05 (fig.2) over 9.8m of Mellon House Beds have a sharp contact with Ringmoylan Shales at 398 ft. The top 3 m includes two very finely laminated beds, probably representing the Laminated Shales of Gortdrum (Steed, 1986). These are underlain by 2.1m (408-415ft) of greenish silty mudstone, and over 4.5m of pink and green finely laminated sandstone with a diagenetically brecciated top and a 30cm bed of black shale near the bottom (T.D. 430ft). The contact with underlying Kiltorcan Formation is not represented in any of Baroid's Templemore cores.

In the Galmoy core GY-228 the MHB succession (1802-1884ft / 549.2-574.2m T.D.) is predominantly sandy and silty, with common dark grey and greenish grey mudstones down to 1875ft (571.5m) (company log). The bottom 3m of the core consists of a pinkish sandstone that could be regarded as Old Red Sandstone, though it might overlie further transitional lithologies of Mellon House type. No fully red bed facies was penetrated by the hole.

Ringmoylan Shales

The Ringmoylan Shales (Shephard-Thorn, 1963; revised by Somerville & Jones, 1985)) consist of thinly inter-bedded fossiliferous shale and limestone, with scattered thin siltstone bands, especially in the lower half of the formation. The contact with the underlying Mellon House Beds is variable in character. In cores where the Laminated Shale of Gortdrum (Steed 1986) is present at the top of the MHB, the contact with the overlying shale is sharp (e.g., cores 81-2852-05, fig.2 and 91-LK-53, fig.4). The contact is also sharp in 79-2649-03 (at 154 ft, 46.9 m), but at the top of a sandy calcarenite with no Laminated Shale represented. In contrast, in Galmoy core GY-228 there is a transition zone at the top of the MHB through c.5 m (1795-1813 ft), where fine sandstone beds become thinner and less dominant upwards above a distinct sandstone unit 7 m thick. The contact is somewhat arbitrarily placed at 1802 ft, above which shale predominates.

The top contact of the Ringmoylan Shales is placed at the sharp base of the Ballyvergin Shale, where present (it is absent in the eastern part of the Area). The thickness of the Ringmoylan Shales varies from c.22 m (79-2649-03) to 37 m (LK-53). The control on this variation is not known, but undisturbed bedding suggests that it is not due to faulting.

A log of the Ringmoylan Shales in 91-LK-53 is provided in figure 4, which gives some indication of the varying proportions of mudstone, siltstone and calcarenite within the formation. This degree of variability is not necessarily typical of other cores. The incoming of common crinoidal calcarenite bands about halfway up the 91-LK-53 succession is clear at c.431.9 m; a few bands are present below this. The base of the Ringmoylan Shales is placed at 448.8 m at the top of the highest very finely laminated mudstone (stromatolites?), a 10-cm bed above the top thin sandstone shown in figure 4. This is another example of the Laminated Shales of Gortdrum (Steed, 1986). Structurally, most of the core shows very gentle dips, but at several levels the dip increases to 20-25˚ and is associated with minor veining and shearing. Small faults are likely; there is no reason to suspect that significant amounts of the succession have been cut out. The formation is in any case thicker than usual here.

Some cores include one or more thin beds of calcarenite with haematized skeletal grains. Haematite occurs at different stratigraphic levels within the formation: it immediately underlies the Ballyvergin Shale in 82-2 and 1571-7 (in a 23-cm calcarenite), both in the NW part of the Area; in 79-2649-03 in the SE it occurs at 118 ft, half way up the formation (as herein interpreted --- there is no Ballyvergin in this core). In core BA further south haematite is present in two calcarenites at c.975 & 998 ft at the base of the Ringmoylan Shales (revised from Jones, 1977), as it does also at Gortdrum. The presence of haematitic calcarenites within the Ringmoylan Shales suggests a shallow water origin for these beds, and that the shales and siltstones are lagoonal rather than deeper open marine sediments.

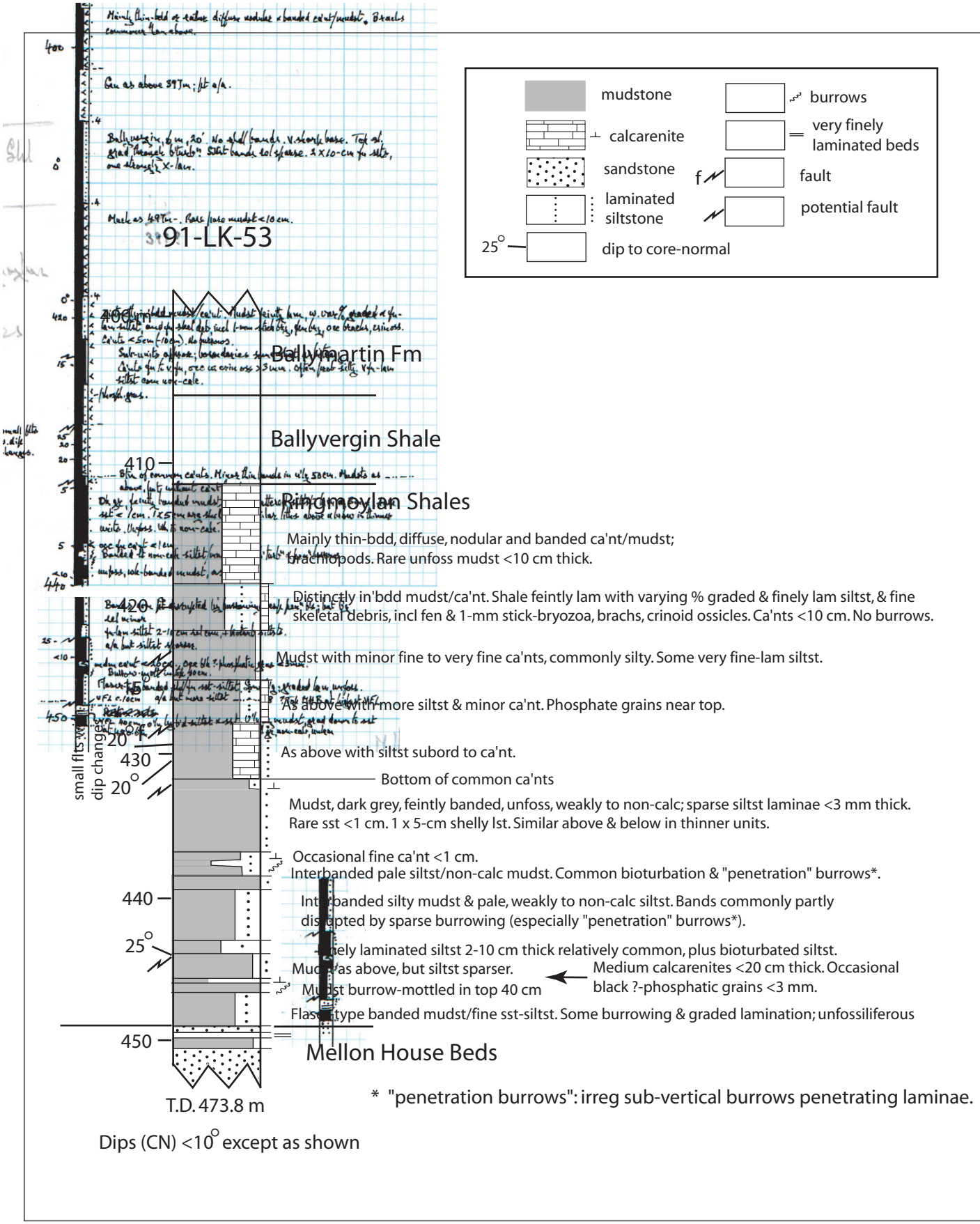


Figure 4: Details of Ringmoylan Shales in core 91-LK-53. See fig.1 for location. Source: MEP log.

Ballyvergin Shale

The Ballyvergin Shale (Hudson and Sevastopulo, 1966, p.290, unit 197-217 ft; Clayton et al., 1980) is a green-grey, non-calcareous mudstone with thin interlaminated siltstone bands. Macrofossils are confined to rare, highly concentrated bands of brachiopods (generally <3 bands per core). Microfossils include achritarchs reworked from Lower Palaeozoic rocks to the N. Top and bottom contacts are sharp. It is believed to be a synchronous unit, representing a unique and short-lived depositional event unrelated to volcanism. The Ballyvergin is particularly important as a widespread marker in southern Ireland, as it occurs within various clean and shaly limestone sequences and proves their diachronous relationships.

In the Rathdowney Area distinctive shale units immediately below the Ballymartin Formation in several cores probably represent the Ballyvergin Shale, but their colour tends to be dark grey rather than greenish grey. In 91-LK-53 the unit is 6 m thick (405.4-411.4 m; dip horizontal). It lacks shell bands, but includes two 10-cm fine sandstone beds, one strongly cross-laminated. Its top is slightly gradational as a result of bioturbation. In 81-2852-05 the Ballyvergin is 3.7 m thick and appears to be unfaulted. In 1571-7, drilled only c.800 m from 81-2852-05, the unit is 4.9 m thick (corrected for 20˚dip) and is also unfaulted. The thickness variation is notable.

In GY-228 the Ballyvergin appears to be c.2.7 m thick (1731-1740 ft), but its base may be faulted. The Ballyvergin here includes a relatively high proportion of siltstone. Across southern Ireland siltstone in the Ballyvergin typically becomes more abundant towards the north, suggesting roughly northerly derivation. The Galmoy Ballyvergin is therefore anomalous and suggests that there may have been another source area for quartz sediment, or a channelized distribution system. This would fit the thickness variation referred to above. The formation extends southwards at least as far as hole BA, which also has a relatively high proportion of siltstone interbeds.

Ballymartin Formation

The former Lower Ballysteen (Philcox 1984) was renamed ‘Ballymartin Formation’ by Somerville and Jones (1985). It differs from the overlying Ballysteen Limestone in having a number of distinct black shales at least 1 m thick, which can be traced extensively. It is also commonly host to Syringopora colonies. In 91-LK-53 it is c.43 m thick; in the other cores in figure 5 the formation is thinner but probably faulted. The base of the Ballymartin Formation is placed at the top of the Ballyvergin Shale (Somerville and Jones 1985), which in the Rathdowney Area is nearly coincident with the upward change from shale-dominant Ringmoylan Shales to limestone-dominant beds. However, regionally this lithological change is diachronous; it occurs at least 20 m above the Ballyvergin Shale at Tynagh for example (Philcox, 1984), and in some cores in the Rathdowney area it occurs a few metres above the Ballyvergin (e.g., c.3 m above it in 1571-7). The top of the Ballymartin Formation is usually defined by the highest relatively thick black shale, but the real lithological boundary is sometimes slightly higher. It should be noted that the Fine Calcarenite Marker normally lies several metres *above* the lithological change.

In the Templemore hole 92-3401-6 (fig.5) the Ballymartin consists mainly of thinly bedded, distinctly nodular, fine limestone and fossiliferous shale. There are scattered banded shales <70 cm thick, particularly near the top, and one thicker, unfossiliferous shale near the middle (1.4 m,

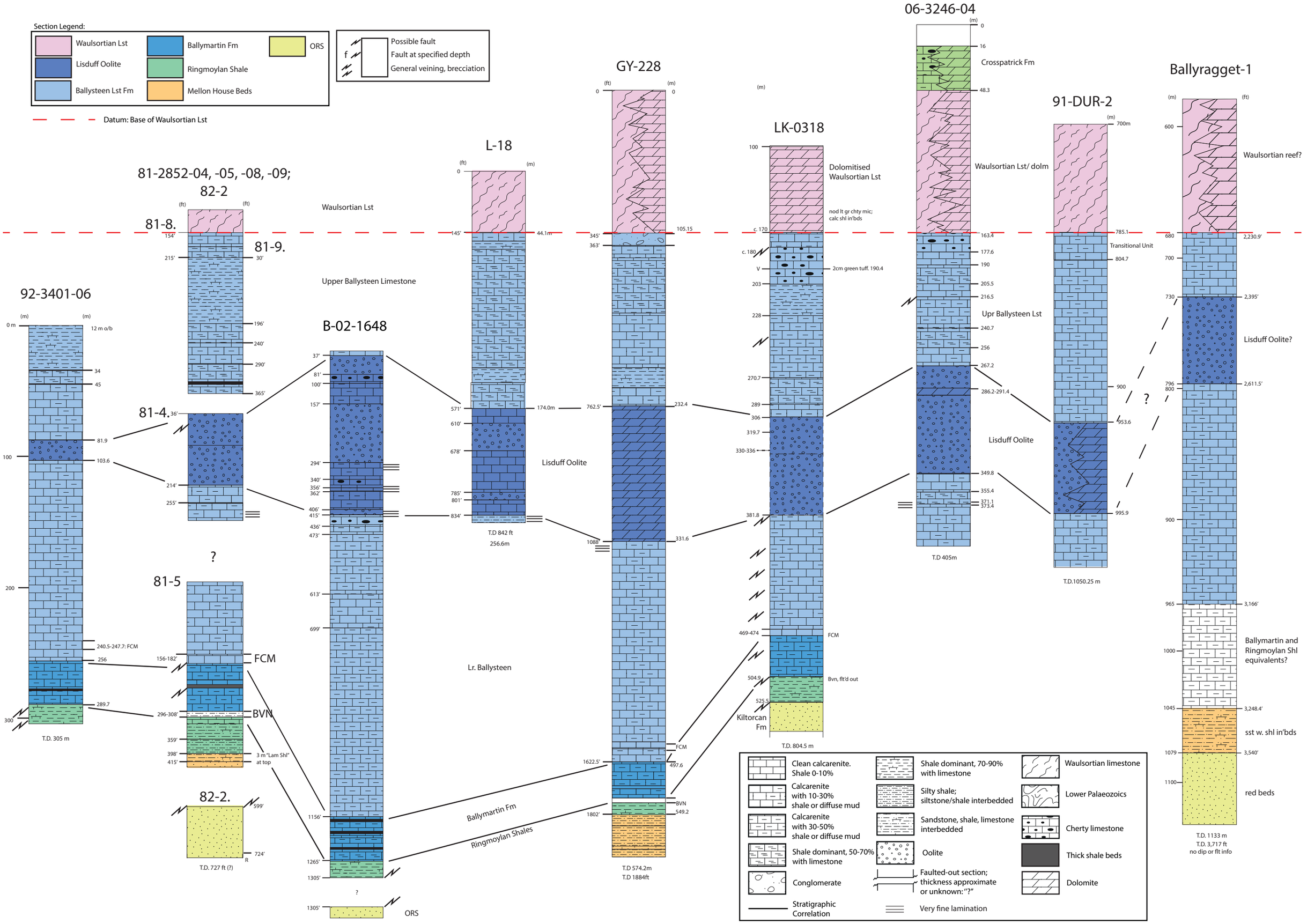
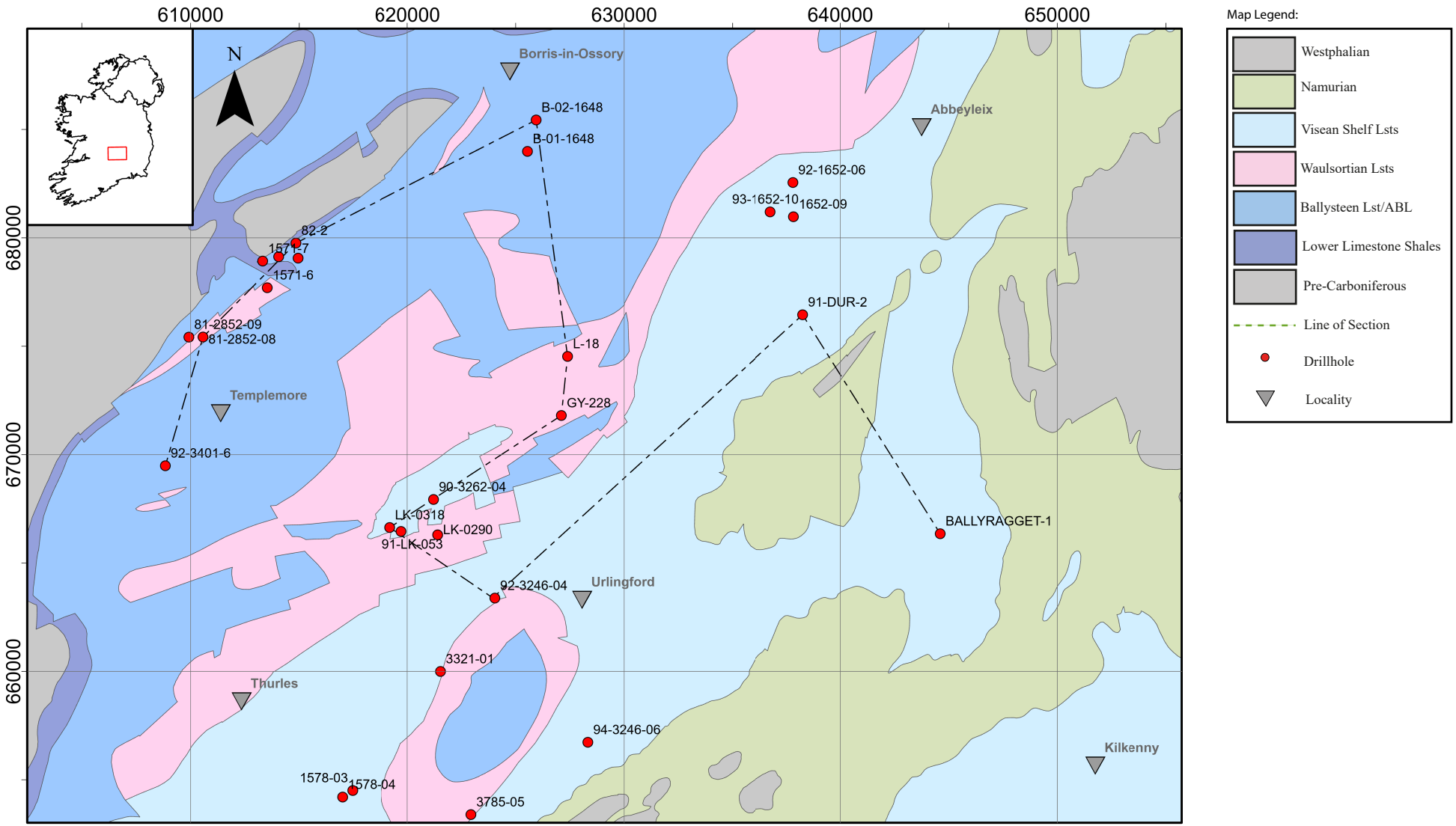


Figure 5: Drilled successions through the Ballysteen Limestone in the central Rathdowney Area. Note that 'Lower Ballysteen' and 'Ballymartin Formation' were formerly termed 'Middle Ballysteen' and 'Lower Ballysteen' respectively (Philcox, 1984). Sources: GY-, LK- and DUR- successions modified from company logs; Ballyragget No.1 (Sheridan, 1977). (N.B. recovered mainly as cuttings and subject to sample contamination), rest MEP logs.

Figure 5 - Location Map



277.4-278.6 m). This thicker bed is a widely recognizable horizon, especially further north. In this core the formation lacks the Syringopora colonies that are generally characteristic. The base of the Ballymartin is problematical in 92-3401-6. There is a gradational downward lithological change through c.2 m at c.290 m, but the Ballyvergin Shale has been faulted out. The shaly succession below the fault is typical of the Ringmoylan Shales.

In the Galmoy hole GY-228 the Ballymartin Formation (1632.5-1731ft / 497.6-527.6m) includes several relatively thick beds of dark grey, unfossiliferous mudstone with sparse, very thin (mm) siltstone laminae. The thickest of these beds (2-m bed at 1700-1706 ft / 518.16-520m) is well down into the lower half of the drilled formation. This relative position makes correlation with the thickest mudstone in holes further north uncertain, where it usually occurs a little above the middle of the formation. This suggests that some of the lower part of the formation has been faulted out in GY-228; the total thickness (c.26 m) is also less than expected (fig.5).

The Ballymartin Formation in B-02-1648 (fig.5) has a gradational top contact at 1156ft (352.3m), but its base is unclear due to faulting and the absence of the Ballyvergin Shale, presumably faulted out. It includes several silt-laminated shales <2 m thick. A fault at 1265ft (385.6m) separates a much shalier section below, which is tentatively identified as Ringmoylan Shales, but which, in the absence of the Ballyvergin, could be basal Ballymartin. In any case, a bigger fault at 1305ft (397.8m) cuts out most, if not all, of the Ringmoylan Shales and Mellon House Beds.

Ballysteen Limestone

The term 'Ballysteen Limestone' was applied to the succession between the Ringmoylan Shales and the Waulsortian Reef Limestone in the Limerick area by Shephard-Thorn (1963). It was given formal formation status by Somerville and Jones (1985), who split off the former 'Lower Ballysteen' (Philcox 1984) as the Ballymartin Formation. The informal term 'Argillaceous Bioclastic Limestone', generally reduced to 'ABL', is commonly used in company reports as synonymous for Ballysteen Limestone, and as a facies term that can be applied also to the Ballymartin Formation. In the Rathdowney Area 'Upper' and 'Lower' (formerly 'Middle') Ballysteen Limestone are separated by the Lisduff Oolite (fig.5).

Lower Ballysteen Limestone

The Lower Ballysteen is characterized by relatively thick, uniform beds of argillaceous limestone with thin shale interbeds. It is c.150-220m thick in the north-central part of the Rathdowney Area (fig.5). The bottom contact is usually placed at the top of the highest relatively thick shale in the underlying Ballymartin Formation and is generally distinct. The Upper Ballysteen is generally shalier and more varied.

The Fine Calcarenite Marker (FCM, fig.5) is a relatively clean, uniform calcarenite with wispy shale partings and gradational top and bottom. It lies 3-9 m above the base of the Lower Ballysteen, depending on locality. It is a widespread, easily recognizable marker, known in cores from as far apart at Tynagh, Templemore, Gortdrum and Kerry Head. Near Gortdrum it is exposed in the quarry at Oola.

In Borris-in-Ossary core B-02-1648 a relatively thick Lower Ballysteen succession is present (415-1156ft; 126.5-352.3m). The base is gradational c.3 m above the highest thick (1.2m) shale typical of the Ballymartin Formation. No Fine Calcarenite Marker was recorded. The top is placed at the base of the lowest oolitic unit. Most of the Lower Ballysteen in B-02-1648 consists of uniform beds of argillaceous limestone with thin shale interbeds. The lithology in the top 17.6m is transitional into those more typical of higher Ballysteen units:

415-436ft (6.4m): Very fine-grained limestone with chert. Interbeds 2.5-23cm thick consist of very finely laminated shale and fine calcarenite with burrowing, locally sub-mm in scale and very regular. Gradational top. (These beds resemble the atypical silty burrowed beds below the middle oolite unit of the Lisduff Oolite.)

436-473ft (11.2m): thin-bedded nodular fine calcarenite and distinct, but very subordinate, shale interbeds.

Another exceptional feature in the B-02-1648 succession is the interval 613-699ft (186.8-213m), which is less argillaceous than the rest; it consists of several units:

613-628ft (4.6m): argillaceous limestone without shale interbeds.

628-638ft (3m): thinly nodular bedded very fine calcarenite with diffuse silty shale interbeds.

638-670ft (9.8m): argillaceous limestone with common Syringopora.

670-699ft (8.8m): argillaceous limestone with wavy shale partings; common encrusting bryozoa.

Encrusting bryozoa are also present at 733ft (223.4m). Another relatively clean medium-grained calcarenite at 817-832ft (249-253.6m) also contains Syringopora. A few distinctive beds c.1m thick, consisting of thinly bedded silty shale and calcarenite, are present lower down (e.g., at 865, 906 and 1090ft / 263.7, 276.1 and 332.2m). Minor siltstone in both shale and calcarenite is commoner below c.700ft (c.213m).

The Lower Ballysteen in Galmoy core GY-228 (1088-1632.5ft / 331.6-497.6m) is closely comparable with that in B-02-1648 but thinner. It consists of a monotonous sequence of argillaceous crinoidal limestones with little variation, apart from a very gradational upward change above c.1125ft (c. 343m) to less fossiliferous, nodular, very fine calcarenites or micrites up to 15cm thick. The Fine Calcarenite Marker is recognizable between c.1585ft (c.483.1m) and 1602ft (488.3m). As in B-02-1648, the Lower Ballysteen includes a few large colonies of encrusting bryozoa (at 1256, 1257.5, 1369ft / 382.8, 383.3, 417.3m), which are not normally a feature of the Ballysteen Limestone in other parts of Ireland. The base of the Ballysteen Limestone is placed at the sharp top of a 60cm mudstone, typical of the Ballymartin Formation.

In Templemore core 92-3401-6 the Lower Ballysteen (103.6-256m) consists mainly of slightly argillaceous, medium-grained crinoidal calcarenite, with subordinate shale interbeds in varying proportions. The succession can be divided into several units, most of which are little different from one another. A distinctive unit at 105.9-110.8m near the top of the Lower Ballysteen includes very finely inter-laminated, very fine calcarenite and shale with burrows and draping structures, and chert. It resembles beds within and just below the Lisduff Oolite in B-02-1648 (see above). The Fine Calcarenite Marker is clearly identifiable in 92-3401-6 at c.240.7-247.7m, but, as elsewhere, the top and bottom contacts are gradational.

The base of the Lower Ballysteen is placed at 256m at the top of the highest shale typical of the underlying Ballymartin Formation. However, other lithologies common to both formations straddle this boundary, especially diffusely nodular fine calcarenites. As elsewhere, the principal lithological change (i.e. the base of the Ballysteen Limestone) occurs several metres below the Fine Calcarenite Marker.

Urlingford core 06-3246-04 terminated c.55m below the Lisduff Oolite, so only the upper part of the Lower Ballysteen was penetrated. It consists mainly of argillaceous calcarenites and diffusely interbedded calcareous shales, with variations as noted in the log (Appendix 1). The lower half of the drilled succession is much less shaly. Lithologies in the bottom 20m are relatively uniform, similar to most of the Lower Ballysteen in the Borris-Templemore area. Encrusting bryozoa are present at 395.5m. A distinctive unit at 371.1-373.4m consists of irregularly laminated, locally burrowed, very calcareous mudstone, and is similar to the atypical burrowed silty beds in B-02-1648 and other cores (see above).

The Lower Ballysteen in the Rathdowney Area is characterized by its relative uniformity, in contrast to the Upper Ballysteen, though there is some lateral and vertical variation. In both 92-3401-6 and 06-3246-04 the upper part has more diffuse shaly beds and lacks thick calcarenites, but the distinction is more extreme in 06-3246-04, which is much more argillaceous near the top. Encrusting bryozoa are prominent is several cores. Thickness variation is also evident (fig.5), though holes with the full Lower Ballysteen are not distributed widely enough to show a reliable pattern. It is thickest (c.226m) in hole B-02-1648 in the north of the Area.

Lisduff Oolite

In the north-central part of the Rathdowney Area the Ballysteen Limestone is separated into Lower and Upper divisions by the Lisduff Oolite. This unit, given member status by the GSI (Archer et al. 1996) varies in thickness from c.20 to 120m thick, and consists of clean limestones varying from oosparite to biosparite in differing proportions. In some cores the unit is split into two or more oolitic intervals that are separated by more typical Ballysteen lithologies (e.g. B-02-1648, fig.5). Examples of the succession within the Lisduff Oolite in the main area are shown in *Figure 5*.

The Lisduff Oolite in Urlingford core 06-3246-04 (c.83m thick) consists mainly of very pale grey, massive oo-biosparite, with some variation in colour and skeletal content. Within the oolite there are three units of partly dolomitized, crinoidal calcarenite (biosparites) 3-6m thick, which are non- to weakly oolitic. The lowest of these (322-324.4m) includes two thin beds (<5cm thick) of laminated calcareous siltstone, which drape irregularities in the underlying limestone. Similar laminated beds are associated with the Lisduff Oolite in the Borris-in-Ossory core, B-02-1648 (fig.5). The bottom few metres of the oolite in 06-3246-04 are darker grey, and mainly biosparite or bio-oosparite. A few thin biosparites occur also close to the top of the underlying Ballysteen, but the contact is otherwise sharp at 349.8m.

There is one notably atypical unit of mottled micrite near the top of the Lisduff Oolite in 06-3246-04 at 269.9-273m. The mottling seems to be due to multi-generation internal sediments (micrite), as in the Waulsortian. There are common large colonies of an encrusting cellular organism, possibly bryozoan, which are locally >1 cm thick and >5 cm long (parallel to core axis). This bed looks distinctly ‘reefal’, and may be a small bioherm. If so, it is presumably of shallow-water origin,

as it is sharply over- and under-lain by oolite. No comparable unit has been reported in other cores through the Lisduff Oolite.

In Galmoy core GY-228, although most of the Lisduff Oolite (762.5-1088ft / 232.4-331.6m) is completely dolomitized, there is clear lamination and banding originating from grain-size variation in the precursor calcarenite. Crinoid-moldic porosity is common. The dolomitized sequence is clearly heterogeneous, but appears to have originated from a predominantly medium to coarse clean calcarenite, much of which was probably oolitic. Some relatively argillaceous beds may have been present; e.g. 819-823ft (249.6-250.9m) is darker and includes thin-shelled brachiopods.

The bottom contact of the dolomite is placed at 1088ft (331.6m). However, the bottom 1.5m is argillaceous and very fine grained, possibly formerly a mudstone. Beds in the underlying 12m may represent a transitional sequence. The base of the dolomite probably does not represent the base of the original oolitic calcarenite.

A reconnaissance of the Lisduff Oolite in L-18 (fig.5), drilled 2 km to the north, where it is undolomitized, indicated that coarse biosparites or bio-oosparites are more abundant than pure oolites, if indeed any of these are present. The bottom 2m of the core consists of burrowed silty limestones.

In the Borris-in-Ossary core B-02-1648 the Lisduff Oolite is made up of three oolitic intervals (37-81 ft, 13.4 m thick; 157-294 ft, c.41 m; 406-415 ft, 3 m), separated by more typical Ballysteen lithologies. The hole collared only 5.2m above the highest oolite, so the possibility that this is not the youngest cannot be ruled out. The lowest oolitic interval, a fine oosparite, lies c.34m below the middle one. Its inclusion within the Lisduff Oolite is partly justified by the overall thickness of oolite-bearing beds in this core (c.95m), which is not much greater than in other holes (fig.5). The two main oolite units consist of pale grey bio-oosparite with a wide range of grain sizes and proportion of skeletal debris.

The 23m succession (81-157ft / 24.7-47.9m) between the top two oolite units consists of varied fine calcarenite, mainly biosparite, with thin shale interbeds and partings. Thin dark chert bands are common in the top 6 m but rare below. Bands of large crinoid ossicles are common.

Much of the succession between the lower two oolite units is atypical of the Ballysteen, notably laminated beds and extensive burrowing, as follows:

294-315ft (6.4m): Mainly fine biosparite, locally oolitic, with subordinate argillaceous calcarenite.
315-362ft (14.3m): Varied calcarenite with chert, burrowing and finely inter-laminated silty shale/calcarenite.
362-406ft (13.4m): Variable, nodular-bedded, fine argillaceous calcarenite, partly crinoidal, without shale interbeds; chiefly distinguished by burrowing.

The Lisduff Oolite in Templemore core 92-3401-6 (81.9-103.6m) consists mainly of light grey oolite, variably rich in skeletal debris, including coarse bio-oosparite, in which grain-size banding outlines large-scale cross-bedding. Only the uppermost 3.1m consists of massive, medium to coarse biosparite, with ooliths becoming less abundant upwards within it. In contrast to the Lisduff Oolite near Urlingford (06-3246-04), there are no cream-grey limestone beds in 92-3401-6, no 2-

to 3-m-thick interbeds of skeletal calcarenite, and the unit is much thinner (c.22m v. c.82m in 06-3246-04).

Baroid's Templemore core 81-2852-04 (fig.5) penetrated the Lisduff Oolite at 36ft (11m) at a faulted contact; the base is sharp but intact at 214ft (65.2m). As elsewhere, the unit varies from oosparite to bio-oosparite. Locally it includes bands of crinoid ossicles <1 cm across in beds <60 cm thick. Shelly bands are also present. The oolite is underlain by 12m of thinly bedded to laminated, fine silty calcarenite with irregular "swirled" interbeds of silty shale with burrows. This unit is similar to atypical beds associated with the Lisduff Oolite in some other cores, including BA, well to the south.

Upper Ballysteen Limestone

The Upper Ballysteen in the central Rathdowney Area is typically c.120-130m thick (fig.5). The lower half consists predominantly of moderately argillaceous limestone, while the upper half is very argillaceous. An exception to this generalization is the presence of one very argillaceous unit (typically 10-14m thick) towards the bottom of the lower half (e.g. L-18 and GY-228, fig.5). Southwards the mudstone-dominant upper half passes laterally into more calcareous, but still very muddy successions (e.g. GY-228). The contact with the Lisduff Oolite is generally sharp, while in most cores there is an upward gradation at the top into a reef-base transition unit of notably varied character and thickness.

Core 92-3401-6 collared in the thick shale unit near the top of the Upper Ballysteen. Although missing the upper part of the shale, in other respects the core illustrates typical details of the Upper Ballysteen (see log in Appendix 2).

The lowest unit (c.75.7-81.9m) in the Upper Ballysteen consists partly of beds similar to those above, but also includes distinctive beds of wavy laminated, very fine limestone. The very fine laminae are burrowed, and locally drape knobs on underlying calcarenites. These laminated beds are similar to the thicker atypical units associated with the Lisduff Oolite in several cores (see above). The base of the Upper Ballysteen is sharp, but a few thin calcarenites of the type below occur above the contact.

Most of the lower half of the Upper Ballysteen (45-75.7m) consists of diffusely bedded, crinoidal limestone with interbeds of slightly more argillaceous crinoidal limestones and very calcareous, fossiliferous shales. Structureless, unfossiliferous shales are rare and only two are as thick as 15cm. There is some variation in this crinoidal unit, notably somewhat more distinct shales in the lower half and more obvious nodularity in the limestones.

There is an abrupt upward change at 45m. The hole collared in sparsely fossiliferous shale with only scattered laminae of very fine carbonate. There is a slight increase in fossil debris and thin argillaceous limestones below 20.2m, and a more substantial increase in nodular, diffusely bedded, fine argillaceous limestones below 34.2m.

Comparison with the Baroid core 81-2852-09 suggests that 92-3401-6 probably collared some 30-40m below the reef. The shale at the top of 92-3401-6 is much "purer" than similar units in the Urlingford core 06-3246-04, and the two successions differ considerably in detail. The relatively

uniform, crinoidal lower half of the Upper Ballysteen in 92-3401-6 is also different from its counterpart in the Urlingford core, which is more varied and argillaceous.

In the Baroid cores 81-2852-08, 81-2852-09 (fig.5) the lower half of the Upper Ballysteen (196-365ft / 59.7-111.3m) consists of variably argillaceous limestone and shale. The regional shale-rich sub-unit, referred to above, is clearly recognizable in hole 81-2852-09 (290-365ft; c.7m drilled). The base is faulted against oolite. By comparison with other cores, the bottom 15-20m of the Upper Ballysteen has been cut out. The upper half of the Upper Ballysteen in the Baroid cores (c.50m thick) is strongly mudstone-dominant.

In the Galmoy core GY-228, the lower half of the Upper Ballysteen is limestone-dominant, except in the notably muddy unit at c.670-714ft (204.2-217.6m), in which there are unfossiliferous mudstone beds up to 1m thick. Most of the limestones in the Upper Ballysteen are very fine grained, and they are commonly weakly burrowed. The bottom contact is placed at the top of the underlying dolomite. However, the upper part of the dolomite is texturally rather like the overlying limestone, and it is unclear where the top of the original oolitic limestones was. This is relevant to thickness comparisons. The upper half of the Upper Ballysteen (down to c.560ft / 170.7m) is strongly mudstone-dominant, though individual mudstone beds usually contain thin limestones or bands of crinoid and other fine skeletal debris.

The Upper Ballysteen in the Urlingford core 06-3246-04 is generally very argillaceous, and much of it consists of shale. It has been subdivided into various units (fig.5; Appendix 1) on the basis of shale percentage, bed thickness and form, and fossil content. There is usually some overlap of these characteristics, so unit boundaries are seldom clear cut. As elsewhere, the lower half is less argillaceous overall than the upper half. At its base (267.2m) is a transitional unit containing common biosparites and possibly some ooliths. The base is placed where distinct oolite dies out upwards. About 11m above the base there is a distinct shale-dominant unit (240.7-256m), corresponding to that present in other cores (fig.5). This includes almost unfossiliferous shales <60 cm thick containing only scattered fine carbonates in bands 2mm to 1cm thick.

The upper half of the Upper Ballysteen in 06-3246-04 is more argillaceous overall and includes another distinct thick shaly unit (190-205.5m). This consists partly of crinoidal calcarenites and other interbeds (Appendix 1), but, in contrast to the lower one, it contains almost no unfossiliferous shale thicker than c.3cm. Towards the top of the Upper Ballysteen the succession becomes less shaly and nodular cherty limestones prevail.

Reef-Base Transition

The uppermost part of the Ballysteen is transitional into the overlying Waulsortian. The character and thickness of this transition, referred to here as ‘the reef-base transition’, is very variable, not least because it can be diachronous even on a local scale. In the Limerick area this transitional succession was formally termed the ‘Ballynash Member’ of the Ballysteen Formation by Somerville and Jones (1985). The petrography of reef-base transition limestones in three widely spaced locations has been studied in detail by Devuyst & Lees (2001).

In the Galmoy core GY-228 the base of the reef is placed at 345ft (105.2m) in the company log, which is at a "green shale" 8cm thick at the base of the Rock Matrix Breccia (Doyle et al., 1992).

The underlying beds down to 363ft (110.6m) form a transitional sequence into the Ballysteen Limestone, but may be laterally equivalent to reef nearby. The bottom 30cm is a graded limestone conglomerate, consisting of closely packed micrite clasts and large crinoid ossicles, possibly reef debris, with a 10cm calcarenite at the top. The graded limestone is sharply overlain by shale c.1m thick. At 359ft (109.4m) there is a 45-cm matrix-supported conglomerate of micrite clasts <2.5cm across, generally with stylolitic margins, and unsorted skeletal debris, floating in a shaly matrix. This conglomerate is separated from the overlying reef by 4.3m of nodular micrites with incipient chert, interbedded with weakly fossiliferous shales up to 15cm thick. The conglomerates appear to have been derived from a slope somewhere in the vicinity, perhaps a reef mound slightly older than the base of the reef in GY-228.

A probable tuff c.2.5cm thick has been used as markers below the reef in the Galmoy area, and at least two tuffs are present below the reef at Lisheen (c.8 km to the SW). Thin (1-4mm) green shales of non-volcanic origin also occur quite commonly in the lower part of the Waulsortian Limestone Fm. and the reef-base transition elsewhere in Ireland.

Lateral variation within a limited area is illustrated by three cores from the Urlingford area: 89-3246-01, 06-3246-02 & 06-3246-03, drilled 3-4 km west and south of Urlingford, <4.4 km apart. The reef in all three holes is underlain by thin-bedded nodular micrite with shaly interbeds and scattered chert. In detail the succession varies between each hole. In hole 1 the (dolomitized) reef base is directly underlain by nodular beds, and the mud content increases steadily downwards: the top 1 m of this succession is dolomitized. In hole 2 the mud content decreases downwards below the reef for 30 m before increasing to levels comparable to hole -01. Correlation is speculative, but, assuming that the shaliest beds are at approximately the same horizon across the drilling area, the reef base may be younger in hole -02. Hole -03 differs from the other two in having c.5m of thinly bedded fine dolomite with shale partings immediately below the reef, which was probably a reef-margin micrite. It grades down to cherty nodular limestone. Mud content is much lower here than in holes -01 & -02, and it seems probable that hole -03 did not penetrate as far into the Ballysteen Limestone. The variation in these successions is probably due to diachronism at the base of the reef.

Waulsortian Limestone Formation.

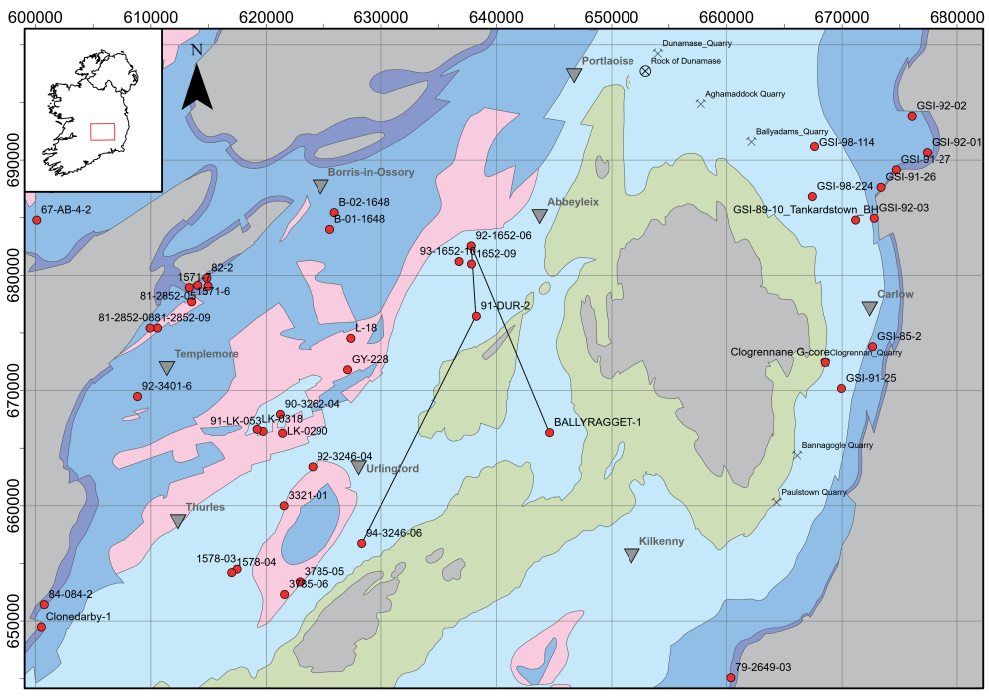
Much of the Waulsortian “reef” Limestone Fm. (mudbank) in the Rathdowney area (figs. 5 & 6) is more or less completely dolomitized, either by regional or more local hydrothermal processes (Hitzman et al., 2002; Nagy et al, 2004). The original sedimentary and early diagenetic fabrics, as described by Lees and Miller (1995), are commonly obscured. As adjacent units, especially the overlying Crosspatrick Formation, are also dolomitized in some areas, the top and bottom contacts of the Waulsortian, and hence its true thickness, can be difficult to discern. In the vicinity of the Lisheen and Galmoy mines the thickness is in the order of 180-200m (Hitzman et al., 2002; Doyle et al., 1992). Definition of what constitutes the top and bottom contacts is not straightforward in some areas. For instance, in core 90-3262-04, drilled 3 km E of Lisheen mine, the main part of the reef is c.180 m thick (61-241.5m; dip sub-horizontal in overlying beds), but for at least 40m above this the cherty crinoidal calcarenite (Crosspatrick Formation) includes interbeds of pale grey stromatactis micrite <1 m thick, becoming less common up section. It is not known whether these reefal tongues extend out from unseen more coherent mounds. A cherty off-reef facies can also be present within the reef. In Templemore core 1571-6 the interval 35-93ft (c.16m thick, corrected

Symbology Key:

- Clean calcarenite. Shale 0-10%
- Calcarenite with 10-30% shale or diffuse mud
- Calcarenite with 30-50% shale or diffuse mud
- Stratigraphic Correlation
- Stratigraphic Correlation (inferred)
- Shale dominant, 50-70% with limestone
- Micrite w/ 0-10% shale/mud
- Micrite w/ 30-50% shale/mud
- Oncholites
- Waulsortian limestone
- Lower Palaeozoics
- Cherty limestone
- Dolomite

Section legend:

- Ballyadams Fm
- Durrow Fm
- Aghmacart Fm
- Crosspatrick Fm
- Waulsortian Lst
- Ballysteen Fm



Map Legend:

- Westphalian
- Namurian
- Visean Shelf Lsts
- Waulsortian Lsts
- Ballysteen Lst/ABL
- Lower Limestone Shales
- Pre-Carboniferous
- Line of Section
- Drillhole
- Locality

91-DUR-2

Z.R. Nagy — M.E.P

0 m, 100, 196.7, 200, 300, 400, 468.0, 500, 563.5, 600, 630, 700, 785, 800, 804.7

EARLY ASBIAN | HOLKERIAN | ARUNDIAN | LATE CHADIAN

232.1 | 454.6 | 578.8

* Cf6 α. *Neoarchaedisc, Nodasp*

* Cf6 α *Archaediscus angulatus*

* Cf5 β. *Koskinotextularia*

* Cf4 β-γ. *Uralodiscus*

* Cf4 α2. *Pseudolituotubella*

Transitional Unit

T.D.1050.25 m

94-3246-06

0m, 9, 26.25, 41.8, 122.2, 201.3, 250.3, 287, 300.8, 327.3, 370.7, 428.4, 475.5, 636.7

Ballyadams Fm

Durrow Fm

Aghmacart Fm

Crosspatrick Fm

Waulsortian Reef (Dol)

Upr Ballysteen Fm

T.D 658.2m

92-1652-6

19.5, 55.2, 80.6-84.4, 150.2, 165, V, 184.5, 240

Aghmarcart Fm

Wn

T.D 464m

93-1652-10

116, 139.5-142.7, 205-209.4

T.D 527m

1652-9

0 m, 111.5, 134.75

Crosspatrick Fm

T.D 524.4m

Ballyragget No.1

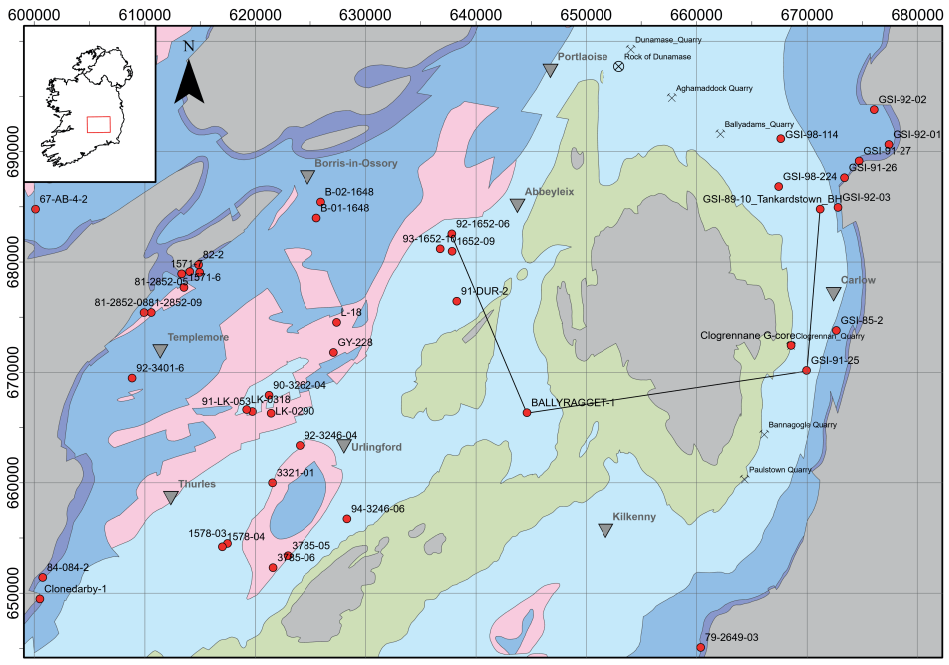
0 m, 100, 200, 300, 400, 500, 600, 679, 675

Ballyadams Fm

Fms undiff.

T.D 1132.9m

Figure 6a



Symbology Key:

- Clean calcarenite. Shale 0-10%
- Calcarenite with 10-30% shale or diffuse mud
- Calcarenite with 30-50% shale or diffuse mud
- Shale dominant, 50-70% with limestone
- Micrite w/ 0-10% shale/mud
- Dolomite
- Waulsortian limestone
- Lower Palaeozoics
- Cherty limestone
- Stratigraphic Correlation
- Stratigraphic Correlation (inferred)
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Map Legend:

- Westphalian
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- Visean Shelf Lsts
- Waulsortian Lsts
- Ballysteen Lst/ABL
- Lower Limestone Shales
- Pre-Carboniferous
- Line of Section
- Drillhole
- Locality

Section legend:

- Ballyadams Fm
- Durrow Fm
- Aghmacart Fm
- Crosspatrick Fm
- Waulsortian Lst
- Ballysteen Fm

Ballyragget No.1

(m) (ft)

0 m — 0 ft

100 — 640

200

300

400

Ballyadams Fm

Fms undiff.

GSI-89-10 TANKARDSTOWN

Z.R. Nagy M.E.P

0m

ASBIAN

91.5

108.3

145.4

HOLKERIAN

145.4

T.D 172 m

* *Palaeotextularia sp.*

* Cf5 α. *Paraarchaediscus* concavus trans angulatus

* Cf5 α. *Paraarchaediscus* concavus

GSI-91-25 Milford

Z.R. Nagy M.E.P

0m

20

54

117.5

143

197.8

210.8

242.5

HOLKERIAN

ARUNDIAN

CHADIAN (pars.)

T.D 275m

20

117.7

229.4

1652-9

0 m

111.5

134.75

T.D 524.4m

Aghmacart Fm

Crosspatrick Fm

92-1652-6

19.5

55.2

80.6-84.4

150.2

165

V

184.5

240

T.D 464m

93-1652-10

116

139.5-142.7

205-209.4

T.D 527m

Waulsortian Lst

1,565

500

600

2,228

T.D 1,132.9 m

T.D 3,716.8 ft

Figure 6b

Figures 6(a), (b): Drilled successions through Viséan formations in the Rathdowney Area.
Sources: 91-DUR-2 and GSI- columns simplified from Nagy, 2003; Ballyragget No.1 (Sheridan, 1977); rest MEP logs. Narrow columns to right of Nagy columns show depths of formation boundaries, based on field logging by MEP (see text).

for 25˚ dip) consists of thinly bedded cherty micrite with greenish shale partings <2mm thick, a facies very similar to the local reef-base transition. The cherty beds occur within a normal succession of reef limestone at least 85m thick.

The mineralized Waulsortian Limestone Formation in the hanging wall of some of the main ENE-trending normal-faults in the Lisheen mine thins in the vicinity of the faults. The thinning is interpreted by Wilkinson et al. (2011) as due to mass dissolution of the carbonates during mineralization, resulting in a trough between the fault and unaffected reef. The trough is partly filled by locally thickened Crosspatrick Formation, incidentally implying at least partial mineralization before the end of reef deposition.

Regional thickness changes in the reef are partly obscured by dolomitization and the difficulty of estimating fault throws within brecciated dolomite, combined with the scarcity of intact successions. In the Urlingford area the Waulsortian Limestone Formation is c.150m thick in 94-3246-06, where no faults are suspected. In 06-3246-04 (8km to the NW) c.115-120m of dolomitized Waulsortian Limestone Fm. lies beneath 18m of cherty dolomite. The latter could be either Crosspatrick Formation or an inter-reef tongue similar to that in 1571-6. In 91-DUR-2 the dolomitized Waulsortian Limestone Fm. is c.155m thick down hole, but there are abundant breccias in the upper part, which could represent significant faulting. These figures suggest, tentatively, that there is a belt of Waulsortian Limestone Fm. trending c.NE with a thickness of not much more than 150m thick, in contrast to the 180-200m in the two mine areas. However, the thickness pattern may well be more complicated, as cores 3785-05 & -06, drilled 7-8 km SW of 94-3246-06, both have Waulsortian Limestone Fm. thicknesses of >200 m.

Crosspatrick Formation

The Crosspatrick Formation overlies the Waulsortian reef in the central part of the Rathdowney Area (fig.6), and in the bottom part is probably partly laterally equivalent to it. It consists mainly of clean to moderately argillaceous calcarenites. Its thickness varies considerably (<220m), in sympathy with the topography of the top of the Waulsortian Limestone Fm.

In the Urlingford Core 94-3246-06 (figs.1, 6 & 7, Appendix 3) the formation (327.3-475.5m) is 140 m thick (corrected for dips of 20-25˚). The bottom 9 m consists of pale grey dolomite with remnant stylolites and crinoid ossicles and may originally have been similar to the beds above. The base is gradational down into dolomitized Waulsortian reef, which is distinguished by surviving stromatactis. The dolomite is overlain by c.15m of pale grey crinoidal calcarenite (448.2-466m) with common large ossicles, and a tuff at 451m. The overlying unit (428.4-448.2m; c.1 m thick) is a massive, fine to medium grainstone with common stylolites and fewer crinoid ossicles. The base is gradational. Slightly darker interbeds become commoner upwards through the unit, but overall it is much paler and more uniform than the one above. The overlying unit (403-428.4m; c.24m thick) consists predominantly of moderately dark, crinoidal calcarenite. Poorly defined nodular bedding is characteristic. Varied, paler lumps and interbeds include bioturbated very fine, slightly argillaceous calcarenite, which is absent in younger beds.

This unit is overlain by c.30m (370.7-403m) of interbedded medium grey calcarenite, occasionally in beds >1.5 m thick; and darker grey, more fossiliferous calcarenite. The paler interbeds increase in thickness and proportion upwards, being very subordinate below c.388m. The darker beds

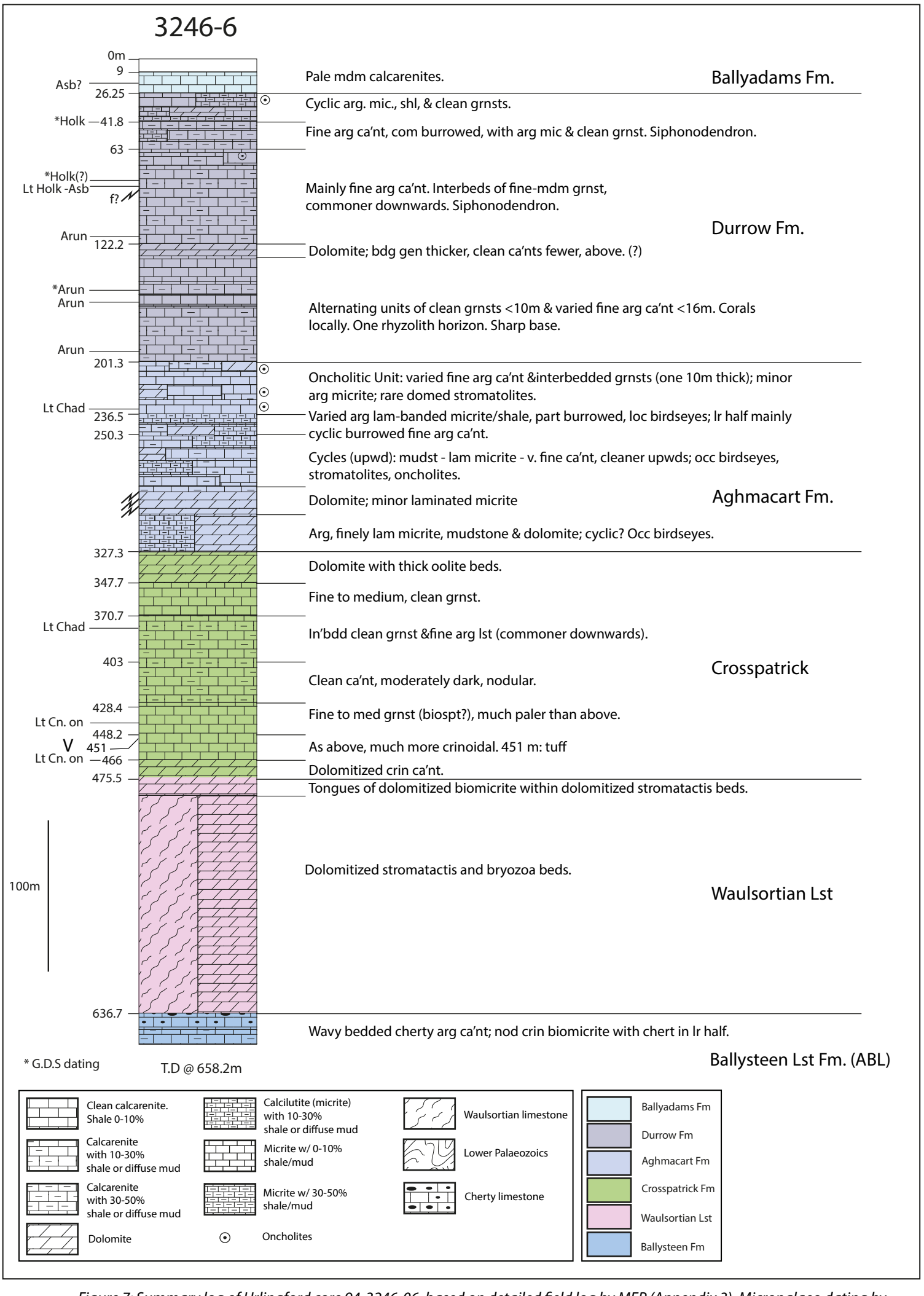


Figure 7: Summary log of Urlingford core 94-3246-06, based on detailed field log by MEP (Appendix 3). Micropalaeo dating by Conodate and Prof. G.D. Sevastopulo (asterisks). 'Lt Cn.on' = Late Courceyan or younger. 'Chad' = Chadian. 'Arun' = Arundian. 'Holk' = Holkerian. 'Asb?' = possibly Asbian.

include dispersed crinoid debris, and irregular lumps of paler limestone, some >5 cm across. Crinoid debris is much commoner below this unit; above it, it is notably uncommon as a component visible at hand-lens level, both in this and the overlying formation. This unit is overlain by c.22m of massive, medium grey, fine calcarenite lacking shale or other interbeds (347.7-370.7m). Several small Syringopora colonies are present, with narrow corallites (1-2mm). The top unit of the Crosspatrick Formation in 94-3246-06 (327.3-347.7m) consists of interbedded massive oolite and light grey dolomite with remnant grain-size banding. There is a sharp lithological change at 327.3m at the base of the Aghmacart Formation, and no micrites are present below the contact.

Conodate obtained a late Chadian date from 379.7 m and vague "late Courceyan on" dates from near the base of the formation.

Chevron cores 92-1652-06, -9 and -10 in the northern part of the Rathdowney Area provide a local cross-section through the Crosspatrick Formation (fig. 6) with some characteristics different from 94-3246-06. Hole 92-1652-06 penetrated the full succession (c.220m thick down hole; 19.5-240m; dip <10˚). The bottom of the Crosspatrick Formation is gradational through c.3m at 237-240m down into dolomitized Waulsortian. Beds up to 165m are variably dolomitized calcarenite, locally visibly fossiliferous. Occasional paler dolomite beds have stromatactis-like structures, which may be products of dolomitization rather than remnants of late Waulsortian Limestone Fm. 'reefal' tongues. A 10cm tuff is present at 184.5m.

A distinctive marker interval overlies this at 152-165 m, made up as follows:

152-154.5m: calcarenite, more argillaceous than above; thicker bedded.
154.5-160.6m: interbedded calcarenite and shale, which commoner than above; scattered burrowing. Bedding generally thicker than above. Probable fault in upper part.
160.6-165m: as above but including several calcareous mudstones <30cm thick, well burrowed.

These beds are overlain at 84.4-152m by a succession of very fine calcarenites with chert, including some extremely irregular chert nodules at around 100 m. Another important marker bed at 80.6-84.4m consists of moderately dark grey, burrowed, silty shales 10-15cm thick, interbedded with more calcareous bands. Also present are light grey, graded fine limestone conglomerates and crinoidal calcarenites <15cm thick. Above this marker, chert is present in pale grey fine calcarenite, and becomes strongly developed from 73.4m up to 56.2m. The top of the Crosspatrick is gradational at c.19.5m.

The succession in core 93-1652-10 (fig.6) can be correlated clearly with 92-1652-06. A distinctive bed at 205-209.4m correlates with at least part of the unit at 152-165m in 92-1652-06. It consists of fine, moderately dark grey, variably argillaceous calcarenites in beds notably thicker than those above, with burrowing locally. A second marker bed at 149.5m (3.2m thick) is very similar to 80.6m in core -06. This bed consists of dark grey, very calcareous shale with scattered, variably distinct paler carbonate bands <5cm thick. General bioturbation in some beds alternates with more distinct ?-*Chondrites* burrows in others. This marker is immediately overlain by a notably cherty sequence at c.116-139.5m, matching the main cherts in 92-1652-06.

Core 1652-9 (fig.6) penetrated the top of the Crosspatrick Formation at 111.5m across a short transition, and then a very cherty unit at 134.75 m, confirming the succession in the upper part of the formation, as seen in the other two cores.

At the Lisheen mine the Crosspatrick Formation is the youngest unit in the hangingwall of several of the principal *en echelon* faults (Kyne et al., 2019). Close to the faults the base of the formation sags into elongate troughs, and its preserved thickness is therefore increased (to at least 40m locally). It has been suggested that the increased thickness reflects contemporaneous movement on the adjacent faults, which have not necessarily broken surface (fault scarp breccias are uncommon in this formation). This interpretation derives partly from demonstrable thickening of the underlying Upper Wavy Laminated Unit (a local, reef-equivalent facies) close to the faults. As noted above, Wilkinson et al. (2011) interpreted the troughs as resulting from the mass dissolution of reef carbonate during early mineralization, rather than through contemporaneous movement on the faults. Either way, in the published cross-sections (Hitzman et al., 2002) the top contact of the Crosspatrick Formation is eroded off in the vicinity of the faults, so the extent of local stratigraphic thickening into the troughs, if any, is not known.

The full thickness of the formation in the wider Lisheen area is reported as 165-175m (Shearley et al., 1996), which is some 50m less than for the area of core 92-1652-06 (c.220m, see above), but more than the 140m in 94-3246-06. The formation is only c.52m thick in 91-DUR-2, most of it dolomitized, and with breccias locally that probably reflect significant faulting. The thickness in the Galmoy area is c.70m (Doyle et al., 1992). As noted above under 'Waulsortian Limestone Formation', the lower part of the formation in some cores (e.g. 90-3262-04) includes 'reefal' tongues, so some of the reported thickness variation in the Crosspatrick Formation may reflect inconsistent placing of the base. Nagy (2003, fig.4.21) illustrates other cores through the Crosspatrick with 'reefal' interbeds.

Hitzman et al. (2002, p. 1638) report a regional facies change within the Crosspatrick from shallow water sediments to the east of the main Rathdowney fault trend, to basinal sediments in the Thurles area further W. This concept warrants further investigation.

Aghmacart Formation

The Aghmacart Formation differs from those above and below in consisting of a vertically and regionally varied succession that includes oncholites and shallow-water lithologies such as birdseye micrite and oolite. The formation in Urlingford core 94-3246-06 has been logged in some detail and will be described first. Comparisons with other cores illustrate the regional variability.

In Urlingford core 94-3246-06 the Aghmacart Formation (201.3-327.3m; 120m stratigraphic thickness) can be divided into a number of distinct composite units (fig.7, Appendix 3).

The oolite at the top of the Crosspatrick Formation (327.3-330.6m) is sharply overlain up to 287m by a varied succession of alternating micritic limestones <2m thick, and units of dolomite <3.7m thick. The micrite is predominantly laminated and banded in various forms. Some of the lamination is crinkly, possibly stromatolitic, but there are no domed stromatolites. Burrowed, conglomeratic and fenestral micrites are also present locally, and very subordinate, thin mudstones. Lithological sequences are too inconsistent to show a clear ideal cycle, but a tentative one is: mudstone,

typically 20-30cm thick, at the bottom, overlain by relatively massive argillaceous micrite (20-80cm), overlain by finely laminated micrite (<50cm), then paler, more massive micrite, occasionally with fenestral micrite (pelsparite?) or a thin conglomeratic layer (1-2cm) at the top. There can be more than one cycle between dolomites. Some of the dolomite may represent former grainstone at the top of the ideal cycle.

The interbedded dolomite units, which constitute >50% of this interval, are quite varied. Near the top it is medium-crystalline, locally vuggy, veined and brecciated. Remnant sedimentary lamination, burrowing, shaly partings and stylolites survive in less severely dolomitized beds below. Relatively featureless dolomite beds may represent grainstone precursors. Vein dolomite and dolomite+calcite breccia in a few places may reflect small faults (e.g. top contact, 297 & 315.5m).

The overlying interval (250.3-287m) consists mainly of medium grey, very fine calcarenites (probably pelsparites), some >1m thick, interbedded with subordinate mudstones, mainly <1m thick, and micrites, arranged in cyclic sequences. Bedding is generally thicker than above 250.3m, and the distinction between limestone and mudstone is sharper. Medium-grained grainstones are absent or very rare, at least in an undolomitized form. The micrite is predominantly laminated and banded in various forms. Stromatolites, oncholites (especially at 284m) and shelly beds occur rarely. Burrowing is locally common.

Cyclic sequences consist of burrowed mudstone, overlain by banded, and then very finely laminated mudstone; this is followed by a thin transition zone of banded micrite with shaly partings, which passes up into very fine, moderately argillaceous ?-pelsparite, which becomes cleaner upwards, rarely with birdseyes. Incomplete cycles and apparent reversals are common. There is less lithological variation than below 287m, and cyclicity is clearer. The cycles are generally thicker than those in overlying units.

In the lower part of the overlying composite unit (236.5-250.3m; c.13 m thick), below a 60cm oolite (base 243.1m), fine, burrowed argillaceous calcarenite is the dominant component in a cyclic succession that includes medium grainstone. The ideal cycle is unclear, but may be: thin (typically <10cm), irregularly laminated, weakly fossiliferous shale at the base, overlain by argillaceous very fine calcarenite <60cm thick; then medium grainstone, overlain by conglomeratic grainstone <30cm thick with shelter cavities. Cycles below 246.5m include minor banded argillaceous micrites <15cm thick, with irregular, horizontal tubular burrows 5mm across.

Above the oolite at 242.5m the composite unit is dominated by a variety of argillaceous, commonly laminated or banded "micrites" (probably including very fine pelsparite) and interbeds of calcareous shale. The lamination is mostly flat but may be stromatolitic. Birdseye micrite is present rarely, and some micrite beds have vertical tubes 2 mm across, <5cm high, possibly water-escape structures. Oncholites are rare. A variety of other small-scale sedimentary structures is present. The succession appears to be cyclic, but wide variation obscures the ideal sequence. It may be: burrowed shale at the base, overlain successively by finely laminated shale; thinly banded micrite with minor shale; weakly laminated or massive (bioturbated?) very fine calcarenite, probably pelsparite; similar calcarenite with mainly vertical birdseyes and a sharp, erosive top. The top of the composite unit is sharp at 236.5m, at the base of a medium-grey grainstone 1m thick, typical of the overlying interval.

The uppermost part of the Aghmacart Formation in 94-3246-06 (201.3-236.5 m; c.32 m thick) is characterized by the common presence of oncholites. The principal lithology is fine, argillaceous, usually bioturbated calcarenite. Paler grey, fine to medium grainstones, mainly <2m thick, are interbedded; one grainstone unit (207.6-217.5m) is nearly 10m thick. The grainstone-argillaceous limestone couplets, generally >1m thick, constitute graded or cyclic units. The oncholites, which occur mainly in the argillaceous limestone, but also in the clean grainstone, are commonly irregular or poorly formed. One or two have developed into domed stromatolites (e.g. 209.7m). Corals are absent or very scarce. Below 225m argillaceous micrites <20cm thick, some of them burrowed, are a subordinate component of the unit.

Dating of the Aghmacart Formation in this core by Conodate indicates late Chadian up to 234.5m. The Chadian-Arundian boundary is somewhere between this and 191m, so the uppermost part of the Aghmacart Formation could be Arundian from these samples.

According to the company log of core 91-DUR-2 the Aghmacart Formation is 125m thick down core (454-578.8m) (117m true thickness, assuming 20˚ dip). This is close to the 120m true thickness in the Urlingford core (above). Much of the formation is dolomitized. The limestone intervals, as recorded in the company log, show significant differences from the Urlingford core. In particular, there is no micrite-rich unit at bottom; and there is no oncholite unit at top (although there is a reference to pisoliths in one thin bed). Most of the middle part of the formation is recorded in the company log as dolomitized calcarenite.

In a detailed study of the formation in 91-DUR-2 by Nagy (2003, fig.4.24), including petrograpy, the top and bottom contacts were differently placed (468-563.5m; fig.6). Nagy's 'facies associations' (single or grouped facies, MFs) are based partly on other cores. His bottom unit (MF1) in 91-DUR-2 (c.555-563.5 m) is transitional up from the Crosspatrick Formation, which may account for the different choice of the bottom contact. It differs from underlying Crosspatrick Formation in having more abundant peloids, the presence of encrusting algae such as *Girvanella*, and more abundant corals. MF1 is succeeded in 91-DUR-2 by the 'cyclic peritidal facies association', which is made up of the following facies (MFs): MF2: oolitic or onchoidal skeletal grainstones; MF3: fine-grained peloidal, skeletal packstone and grainstone, with oncholites upper part; MF4: peloidal burrowed micrite with oncholites. These facies are arranged cyclic sequences typically <2m thick, in which MF4 is overlain by thinner MF2 varieties. Cross-bedded oolites (MF2) dominate the dolomitized interval 500-550m (fig.6).

The top contact of the formation is placed by Nagy at 468m at an upward increase in abundance of corals, brachiopods, algae and foraminifera; and the last appearance of MF2. The contact is coincident with the Chadian-Arundian boundary (Nagy, 2003, fig.4.24). A sample from 454.6m gave an early to mid Arundian date (Cf4β—γ).

Core 1652-9 (fig.6) collared in the Aghmacart Formation and penetrated the base at 111.5m (c.105m; 6.2-111.5m at <10˚). If the full thickness is similar to 91-DUR-2 and the Urlingford core, some 10-15m of the formation could be eroded off at the top of the core. Most of the formation (below 15.6m) consists of relatively uniform interbedded argillaceous micrite and related lithologies such as pelsparite. Some beds include fine skeletal debris, brachiopods, gastropods and unidentified small tubular fossils. Beds with barely visible conglomeratic fabric are common; the irregular clasts are possibly poorly developed oncholites. A few polymictic fine conglomerates and

coarse intrasparites are also present. Chert is widely scattered but sparse. Unfossiliferous black shale interbeds 10-30cm thick, rarely 60 cm, are also uncommon. The tops of some are burrowed. The relative uniformity of this succession is in strong contrast to the Urlingford core.

Beds above 15.6m differ mainly in having common burrowing and much less micrite. The principal lithology is moderately dark grey, very fine calcarenite and calcisiltite. Bedding is poorly defined, especially near the top, but can reach 2m thickness. Platy chert is present but sparse. There are scattered interbeds of dark grey to black, weakly to non-fossiliferous shale. Some of the latter include thin laminae of micrite, which may be stromatolites. Some shales and argillaceous micrites (<45cm thick) are intensely burrowed. The top 1.1m of the core includes abundant tubular fossils c.1mm in diameter and 1cm long, in ill-defined bands.

The Aghmacart Formation in the Milford core, GSI-91-25 (fig.6), is mainly dolomitized in the lower two-thirds of the unit, but some textures have survived and show contrasts with the rest of the core. A detailed "field log" by M.E.P. is provided in Appendix 4. The petrography of the formation was described by Nagy et al. (2005), who established the following facies associations (FA), which in effect are stratigraphic units: FA-1) Oolitic-peloidal mobile shoal FA (210.8-242.5m); FA-2) Bioturbated lagoonal FA (197.8-210.8m); FA-3) Tidal flat FA (with evaporite pseudomorphs) (143-197.8m); FA-4) backshoal oolitic and peloidal/barrier sand FA (117.5-143m). The boundaries of these units (FAs) correspond approximately to some of those in the field log, but there are some differences that are relevant to geologists who do not have ready access to thin-sections. For example, Nagy et al. (2005) place the bottom of the formation at 242.5m, some 13m below that in the field log. Those 13m are recognized in the field log as a distinct unit, but at that level of observation it appears much more like the upper part of the underlying Crosspatrick Formation, and is more uniform than the upper part of FA-1 (i.e. 210.8-229.4m). A second example relates to FA-3, most of which is shown as 'mudstone' in figure 6, though this includes calcareous mudstone, pelsparite and micrite. Not differentiated is the interval 158.5-166.1m, which is much blacker (less calcareous?) than adjacent beds and is a potentially useful marker horizon.

Compared with the succession in the Aghmacart Formation in the Urlingford core there is almost no match in the Milford core except in the range of lithologies. Combined with the other cores, this indicates an extensive patchwork of shallow-marine to intertidal facies.

Durrow Formation

The Durrow Formation consists of a varied succession of clean calcarenites and finer, more argillaceous limestones, locally with common colonial corals, and minor argillaceous micrite. The formation was named by Archer et al., 1996, p.34, who referred to its occurrence in core 91-DUR-2 as the best representative, where it is >200m thick. The core was studied by Nagy (2003), who described the petrography. The top and bottom contacts used by Nagy differ considerably from the original company log and those in a reconnaissance "field log" by M.E.P., reproduced below. The total thickness of the formation in the latter is c.209m (232.1-454m, corrected for 20˚dip); Nagy gives 196.7-468m (fig.6), a true thickness of c.253 m.

232.1-239.9m: Sharp top at top of 70cm plain argillaceous micrite (at 20˚). Varied succession, mainly very fine, slightly argillaceous calcarenites, typically 50-100cm thick (some more);

interbedded with either cleaner or more argillaceous units. Bands of small brachiopod shells in fine calcarenites.

239.9-243.9m: Atypical interval, including several distinct black shales 10-20cm thick with common bands of very fine skeletal debris; some with sharp tops (cycle tops?). A few argillaceous micrites above and within this interval, but absent below.

243.9-c.338m: Mainly biomicrite, moderately dark grey, variably argillaceous, bioturbated, sparsely fossiliferous. Some intervals >7m thick of uniform paler fine calcarenite with large brachiopods. Scattered Siphonodendron colonies, commoner below 307.8m. Some more argillaceous units 3-5m thick with scattered very fine skeletal debris. Occasional black chert nodules c.337-341m.

c.338-c.419m: Interbedded transition down into paler calcarenites, predominantly with fine crinoid debris, commonly in massive beds >6m thick, with stylolites. A few darker intervals <4m thick, which include a few black shales <5cm thick (e.g. 376.1-380m; dip 15-25˚). Occasional chert below this.

c.419-454m: More varied in colour and grains size than above; includes bioturbated, slightly argillaceous biomicrites similar to beds at the top of the formation.

In the Urlingford core 94-3246-06 (figs.6, 7; Appendix 3) the Durrow Formation (26.25 -201.3m, c.165m thick, corrected for 20˚ average dip) is well represented and mainly undolomitized. The lower part of the formation (130.6-201.3m) consists of alternating units of uniform, clean grainstones <10m thick, and more varied, moderately argillaceous units <16m thick. Grain-size banding is common in the grainstones. The top of one grainstone unit (156.2m) includes a rhyzolith zone 40cm thick, indicating an exposure surface, and there are further rhyzoliths 1m lower down. The argillaceous units include graded or possibly cyclic beds, consisting of, at the base, medium-grained (oolitic?) grainstones with gastropods and scattered limestone clasts <1cm across; overlain by finer, more argillaceous, commonly bioturbated calcarenite. Some beds are capped by bands of irregularly interlaminated shale and limestone 2-3cm thick or occasionally by dark grey, very argillaceous calcarenites <20cm thick (rarely 50cm). Corals are common in some units, but Siphonodendron colonies are feebly developed, in contrast to the succession above.

The overlying dolomite (122.2-130.6m) is fine- to medium-crystalline and locally includes elongate, parallel vugs. There is no obvious remnant sedimentary texture, but stylolites survive. The unit may have been a clean, relatively coarse calcarenite similar to the underlying beds. There is some veining in the dolomite, but no obvious fault. A few thinner dolomite beds are present a little above and below.

Overlying the dolomite the interval 63-122.2m consists mainly of bioturbated fine argillaceous calcarenite, and there is a lower proportion of paler, fine- to medium-grained grainstone than in the underlying unit. Coarse biosparites are present for a few metres above the dolomite. Beds tend to be thinner and more variable than below. Siphonodendron colonies <15cm thick and gastropods are relatively common.

The upper part of this formation, 26.25-63m, is characterized by the presence of micrite beds, but it is not uniform, and three sub-units are identified. The lowest 19m (41.8-63m) consists of variably argillaceous, fine to medium, generally bioturbated calcarenites with dispersed very fine skeletal debris, which are not obviously cyclic. Subordinate argillaceous micrites are prominent in the upper half, less so below. Fossils include Siphonodendron and other corals, thick-shelled

brachiopods, gastropods and stick- and finger-like bryozoa. The overlying unit (38-41.8m) is very argillaceous and consists of four cycles, as follows: burrowed, fossiliferous, very argillaceous, fine ?-pelsparites are overlain by laminated ?-pelsparites, and then black calcareous shales <10cm thick with fine skeletal debris. The top unit (26.25- 38m) of the formation includes at least three cyclic units <4m thick, each consisting of pale grey grainstone (intrasparite?) at the base, overlain by argillaceous micrite and then black shale. These cycles are of a different type to those in the unit below. Oncholites are present at the top of the formation.
Summarizing the Durrow Formation in 94-3246-06, the top part (26.25-63m) resembles the Aghmacart Formation in including micrites and oncholites. It is much more varied than the rest of the formation, in which a relatively minor change occurs across the dolomite at 122.2 m. Above the dolomite there is a partial change in the character of the beds: most obviously, clean calcarenites are much less common, and bedding is generally thicker.

The formation in 94-3246-06 has been dated as Arundian in the lower part (up to 119.5 m), Holkerian above up to at least 42.1m. The top of the core may be early Asbian. The dating matches Nagy's (2003) for 91-DUR-2.

The Durrow Formation in the Milford core, GSI-91-25 (fig.6), consists of various shallow-water limestones with a few thin dolomite horizons. The core was studied petrographically by Nagy et al. (2005), who divided the succession (8.7-117.5m) into two facies associations (FA) made up of 7 facies. Boundary depths were not specified, but it appears from their stratigraphic column (Nagy et al., 2005, fig.3) that most of the formation falls into the Open Lagoon FA, consisting of five different marine packstone and grainstone facies. The Cyclic Peritidal FA, on the other hand, occurs mainly as two relatively thin units in the upper half of the formation. It consists of 3 shallow-water lagoonal facies, and includes micrite, stromatolites and thrombolites, various algal structures and minor shale.

The core was also described at field log level by M.E.P. (Appendix 4). The Aghmacart and Durrow Formations were originally lumped into the 'Milford Formation', but this term is now redundant. The base of the Durrow Formation was placed at close to 117.5m also by Nagy et al. (2005). However, the top was placed at 20m in the field log, as the overlying beds are distinctly cleaner and appear to be similar to the Ballyadams Formation. The thickness of the Durrow Formation on this basis is c.98m (at dips of 5˚). This is substantially less than the dip-corrected thickness of c.165m in the Urlingford core, possibly reflecting its location nearer to the Leinster Massif. The Durrow Formation in the Milford core differs from 91-DUR-2 & 94-3246-06 in having lagoonal facies in mid-section and within upper part but not at the apparent top. However, if Nagy et al. (2005) are correct in implying that the top of the formation is above ground level, this may be misleading.

In the NE part of the Area the Tankardstown hole GSI-89-10 (figs.1, 6) penetrated Ballyadams Formation and the upper part of the Durrow Formation. The contact, based on field-logging by M.E.P., was placed at 145.4m, where there is a distinct lithological break (Appendix 5). Nagy (2003, p.67) placed the contact at 108.3m (fig.6), based on changes in the microbiota and the highest occurrence of (thin) shale interbeds.

The succession from 145.4m to 172m (T.D.) is divided into three main units (M.E.P. log, Appendix 5), plus a distinctive rounded-grain sparite (oolite?) 1m thick at the top. The lowest drilled unit

(161.6-172m) consists of moderately dark grey pelsparites and argillaceous calcisiltites, with subordinate micrites <40cm thick, some with birdseyes. The unit lacks the banded shales that occur in the top unit. The middle unit is a uniform, medium grey pelsparite. The top unit (base 156.2m) is darker grey and much more varied. It includes beds of banded calcareous shale <70cm thick, some of which appear to be at the top of cycles: pelsparite, overlain by burrowed argillaceous fine skeletal calcarenite, overlain by banded shales. The banding (5mm to 3cm thick) is formed by fine skeletal debris. On this placing of the top contact the Tankardstown core penetrated the top 26m (5˚ dips) of the Durrow Formation. This part of the succession has much in common with the top unit of the formation in the Urlingford core, 94-3246-06.

The interval 108.3-145.4m, which is included in the Durrow Formation by Nagy (2003), consists mainly of fine-grained, slightly argillaceous calcarenite and calcisiltite with varying amounts of pelsparite. The interval is divided into several units with distinctive characteristic (Appendix 5), locally including common Siphonodendron colonies and concentrated shell bands <40cm thick. At the field-logging level of observation this part of the core appears slightly darker and more argillaceous than the upper part of the Ballyadams Formation. The change occurs some 20m higher in the core than Nagy's boundary at 108.3m, and is much less pronounced than the change at 145.4m.

Ballyadams Formation

The Ballyadams Formation (Asbian) consists mainly of thick-bedded shallow-water peloidal, crinoidal and algal grainstones. Slight variations allow some sub-division, but the lateral extent of sub-units is not known due to the limited amount of drilling at this stratigraphic level. The two main cores (91-DUR-2 and GSI-89-10, fig. 6) provide good successions through the lower part of the formation. A number of quarries in the NE part of the Area provide details of the upper part. There appears to be no overlap with the core successions (Cózar and Somerville, 2005). The total thickness of the formation is >300m.

A simplified field log of the Ballyadams Formation in 91-DUR-2 (11-232.1m) outlines the main features as seen without detailed petrography:

11-c.41.5m: Moderately dark to medium grey, mainly very fine limestone, locally dolomitized. Dip 25-30˚ (?).
c.36-37m: fault zone, possibly down to c.41.5m.

c.41.5-c.168m: Pale grey massive calcarenite, medium- to fine-grained, occasionally dolomitized. Occasional stylolites. Rarely slightly more argillaceous and shelly in units <4m thick. Base very gradational.

158-159m: Cerioid Lithostrotion colonies 25-30cm thick.

167.5m: 35cm Siphonodendron.

c.168-193.3m: Fine, massive calcarenites, slightly darker than above, with scattered visible skeletal debris. Some paler beds 1-2m thick. Dip c.20˚? Base gradational.

193.3-232.1m: Moderately dark to medium grey, fine grained, slightly argillaceous calcarenite, very poorly bedded, locally burrowed; beds commonly >1m thick. More fossiliferous and darker overall than beds above. Abundant small colonies of Siphonodendron. Rare Syringopora. Scattered brachiopods. Base sharp at top of underlying micrite.
194.2: 20cm cerioid Lithostrotion

208.5: 8cm fragment of cerioid Lithostrotion

A more detailed account of the petrography and biostratigraphy of the formation in 91-DUR-2 is given by Nagy (2003). He places the base of the formation at 196.7m. Thus, the bottom unit assigned to the Ballyadams in the field log (above) is placed in the Durrow Formation by Nagy (2003). The down-hole thickness of the formation in 91-DUR-2, using Nagy's basal contact, is 185.7m. Bedding dips in the core are hard to discern, but appear to be in the range 20-30°. The drilled stratigraphic thickness down to Nagy's contact may therefore be nearer to 175m. According to the field log, it is c.208 m.

The Geological Survey's Tankardstown hole GSI-89-10 provides another important core through the lower part of the Ballyadams Formation. A field log by M.E.P. is given in Appendix 5. Nagy (2003) used detailed petrography to identify sub-units. These match units in the field log approximately; differences in some cases probably reflect gradational contacts. Based on petrography and microbiota, Nagy placed the base of the formation at a depth (108.3m) well above that in the field log (145.4m). Dips in the core are 10-15°, so the drilled stratigraphic thickness of the Ballyadams in this hole is close to 102m using Nagy's basal contact, 140m in the field log. The latter contact marks a more pronounced lithological change at that level of observation, than does Nagy's "petrographic" base.

In the Urlingford core 94-3246-06 only the basal 16m section of the Ballyadams Formation was penetrated (9-26.25m at 25°). It consists of a relatively uniform succession of light- to medium-grey, fine- to medium-grained calcarenites (probably mainly biosparites) with common bands of brachiopods and gastropods. Some finer, darker beds are also present. The core was not studied petrographically. The base of the unit sharply overlies an oncholite bed, capped by a sooty black shale, which is the top of a thick argillaceous unit in the Durrow Formation. The change in lithology at this contact (base of Ballyadams Formation) is much more pronounced than at the base of the Ballyadams Formation in either 91-DUR-2 or GSI-89-10, as placed by Nagy (2003). However, the contact as placed in the field logs by M.E.P. for both cores shows a sharp change in lithology, comparable to that in 94-3246-06, if somewhat less pronounced.

The upper part of the Ballyadams Formation and the top contact are exposed in a series of quarries around the north and east sides of the Castlecomer Plateau (Upper Carboniferous outlier; fig.1). These have been studied in detail by Cózar and Somerville (2005), who sub-divided it into two units, both late Asbian (fig.8). The lower one (Unit 1) consists of mainly well bedded, fine- to medium-grained limestones <50cm thick with occasional thin shale interbeds. Corals and shell bands are common. There are rare subaerial exposure surfaces, some with pedogenic structures. The maximum known thickness is 30m. The bottom 7m of Unit 1 differs in being thicker bedded and has a well developed palaeokarst top with erosive depressions <3m deep.

Unit 2 has a maximum thickness of 74m and is divided into six cycles 8-17 m thick (fig.8). The character of each cycle differs, allowing correlation between quarries. The tops of most cycles are marked by palaeokarst surfaces; some also occur within cycles. Typically, the lower part of each cycle consists of fine-grained, thin-bedded, lenticular limestone (mudstone, wackestone) with thin shale interbeds. The upper part is generally coarser (packstone, grainstone), thicker-bedded (<5m), tabular limestone, locally with sedimentary breccias. Chert and shell bands occur only in

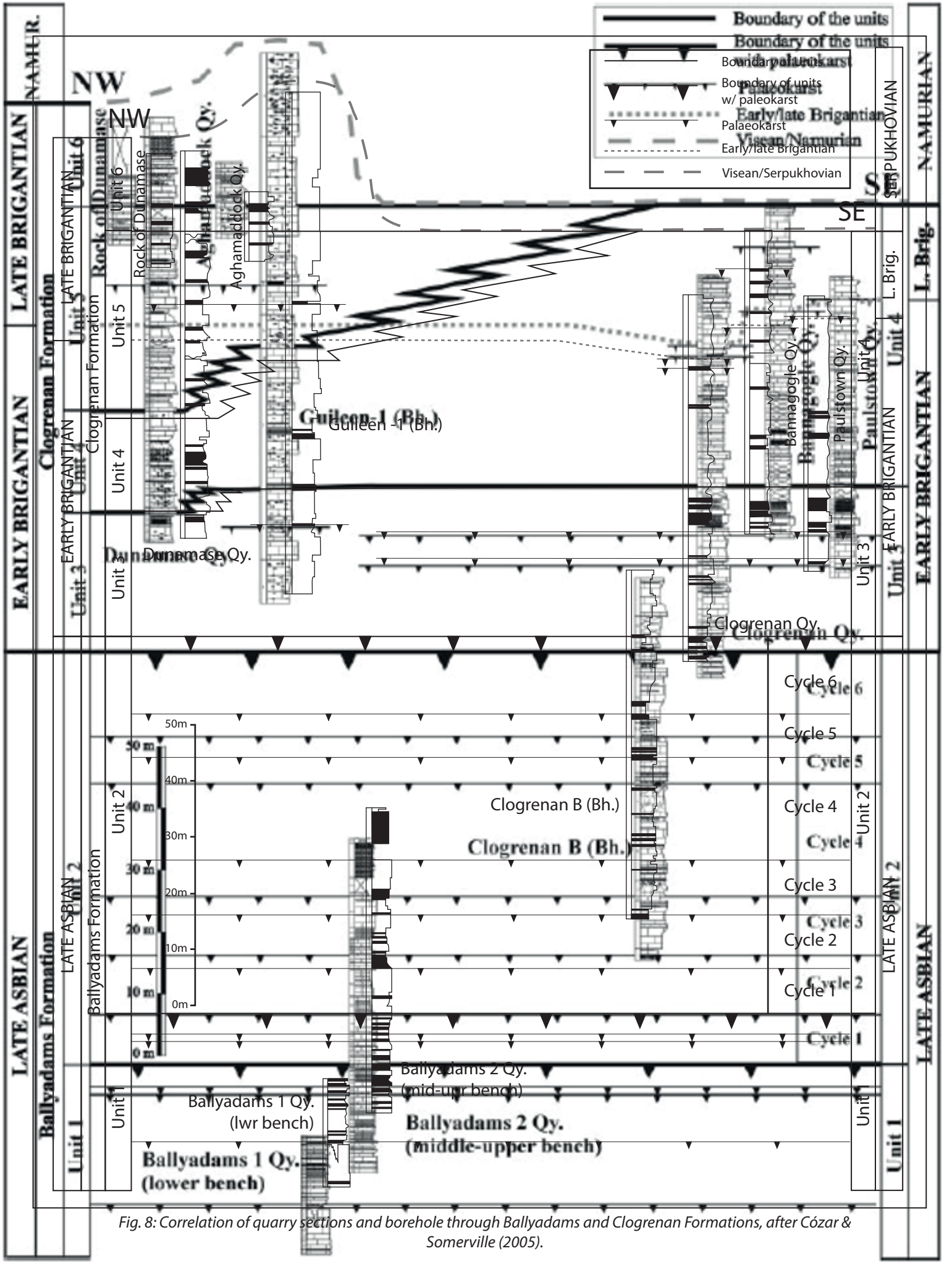


Fig. 8: Correlation of quarry sections and borehole through Ballyadams and Clogrenan Formations, after Cózar & Somerville (2005).

some cycles. Unit 2 has an abundant macrofauna. Occasional (volcanic) clay wayboards <30cm thick are present.

The total thickness of the Ballyadams Formation is >300 m (Cózar & Somerville 2005), based on the lack of known overlap between the 91-DUR-2 borehole and the quarry sections. The definition of the contact between the Ballyadams and Clogrenan Formations has been revised by Cózar & Somerville (2005, p.55) relative to that in Tietzsch-Tyler et al. (1994).

Clogrenan Formation

The Clogrenan Formation consists of well bedded, shallow-water limestones with common chert. The succession, including the bottom contact, is exposed in several quarries around the north and east sides of the Castlecomer Plateau, and most of it is represented in one drill core. Cózar and Somerville (2005) divided the formation into 4 main units (Units 3 to 6, summarized below) with a total thickness of >96 m (fig.8). The formation is of Brigantian age, the bottom contact, as defined by Cózar and Somerville (2005), coinciding with the base of this stage. The base of the Clogrenan Formation has been revised by Cózar & Somerville (2005, p.55-57) who place it 19m below that of Tietzsch-Tyler et al. (1994). The contact with the overlying Namurian is not exposed.

Unit 6: maximum thickness >24m; beds <2m thick, generally lenticular; fine to very coarse-grained, wackestone to grainstone; common chert bands & nodules; commom macrofauna. No palaeokarst. Crinoids, brachiopods, bryozoa all common; sponge spicules locally very abundant.
Unit 5: maximum thickness >32m, thick massive limestones (<2m) with shale interbeds; mainly fine- to medium-grained, mudstone to grainstone, commonly graded. Chert sparse. Macrofauna generally uncommon; a few coral & brachiopod bands. One palaeokarst surface only. Crinoids > bryozoa.
Unit 4: maximum thickness >46 m. Medium- to thick-bedded (0.5-3m); mainly tabular; mainly medium-grained, graded, crinoidal & bryozoan packstone to grainstone; shale absent; chert common throughout; coral & brachiopod bands near bottom, generally rare. Uncommon palaeokarst.
Unit 3: <27m thick. Thick-bedded (<3m) tabular limestones with subordinate shale interbeds. Mainly medium- to coarse-grained wackestone to grainstone; crinoids > intraclasts are the principal components of the microfacies; algae locally important. Coral biostromes and brachiopod shell bands at certain levels, some of which are correlatable across area. Several palaeokarst surfaces, some with clay wayboards and/or pedogenic structures; one depression at base of Unit 3 is >4m deep, with clay wayboard fill.

In contrast to the Ballyadams Formation there is no large-scale cyclicity, although smaller-scale cyclicity in the form of graded units has been recognized locally. Other differences include a scarcity of palaeokarst surfaces, which become rarer up section; scarcity of argillaceous limestone and shale; and much more common chert, except in the lowest unit (Unit 3). Brachiopods and corals change from being generally randomly distributed, to being concentrated in shell bands and coral biostromes. The algal-dominant microfacies in the Ballyadams is replaced in the Clogrenan by crinoids, bryozoan and intraclasts as the main components of the microfacies (Cózar & Somerville, 2005).

There are regional lateral facies changes within the Clogrenan Formation from SE to N. These changes are mainly within the units above Unit 3, which is relatively uniform across the outcrop and is also less distinct in character from the Ballyadams Formation. Unit 4 in the SE passes north-westward into a thinner Unit 4 combined with Unit 5 without a significant overall change in thickness (fig. 8). Lateral equivalence is based partly on biostratigraphy. Unit 5 is absent in the SE, as is Unit 6 (late Brigantian); in the SE Unit 4 (early to basal late Brigantian) is overlain directly by the Namurian.

Southern part of the Rathdowney Area

The southern part of the Rathdowney Area (fig.1) is represented by fewer boreholes than in the central area, and there are some stratigraphic differences. The more important cores are described below and correlated in figure 9.

Baunta Hole BA

Pennaroya's **Baunta hole, BA** (map figs.1, 9), collared in Ballysteen Limestone and penetrated an apparently unfaulted succession down into the upper part of the Old Red Sandstone. The core was studied by Gareth Ll. Jones (M.Sc. thesis, 1977), including the conodont zonation. The following lithological summary is based on M.E.P logs (Appendix 6).

Old Red Sandstone and Mellon House Beds

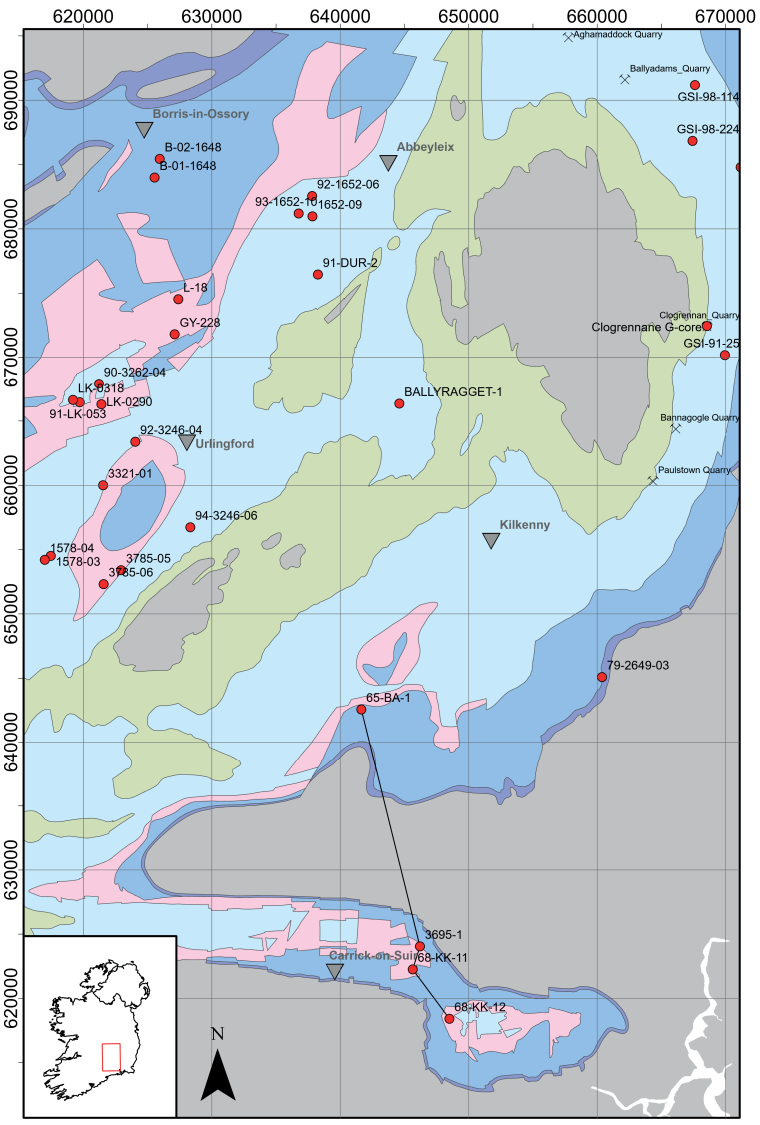
The bottom 3.8 m of the core (1099-1111.5ft / 335-338.8m) penetrated light grey-green, fine to medium sandstone that is assigned to the Old Red Sandstone; it lacks the siltstone component of the overlying unit. The succession in the overlying 30.5 m (999-1099ft / 304.5-335m) is detailed in Appendix 6. This varied succession lies immediately below relatively uniform Ringmoylan Shales, and most of it can be assigned to the Mellon House Beds. However, the choice of the contact between these formations is not clear-cut (see below) and illustrates the difficulty in placing boundaries in gradational successions.

The bottom 14m (1053-1099ft / 321-335m) of the Mellon House Beds is a relatively uniform succession of grey siltstone and sandstone. Its uniformity, thickness and high proportion of sandstone suggests that it might be included within the Kiltorcan Formation, but a 5cm crinoidal calcarenite at 1073ft (327m), and some burrowed beds below this, suggest at least temporary marine influence. The overlying 16.5m interval (999-1053ft / 304.5-321m) is dominated by crinoidal biosparite in beds <4.6m thick, with subordinate oolite and sandy calcarenite.

The MHB in this core differ from the drilled successions in the central Rathdowney Area most obviously in having a thick section of clean calcarenite, including oolite. Comparable calcarenite is present in the Gortdrum area in the succession just below the Ringmoylan Shales ("Transition Limestone" of Steed, 1986) at a similar latitude. It probably reflects the northward transition from open to marginal marine conditions at that time. The Mellon House Beds in 79-2649-03 are described under 'Eastern Margin' below.

Ringmoylan and Ballyvergin Shales

The Ringmoylan Shales (889-999 ft; 32 m thick, corrected for 15-20° dip) is mainly a typical succession of thinly interbedded fossiliferous, often silty shale and calcarenite, though with an increased proportion of siltstone in the top 2 m. The 7.6-m bottom section (974-999 ft) includes more burrowed sandstone than is typical, raising the question of whether it should be included within the MHB. The general character of this mudstone-dominant interval is similar to the overlying Ringmoylan Shales, except that it includes some burrowed sandstone laminae towards the top (Appendix 6), and haematite-bearing crinoidal calcarenites >1.4 m thick at the top and

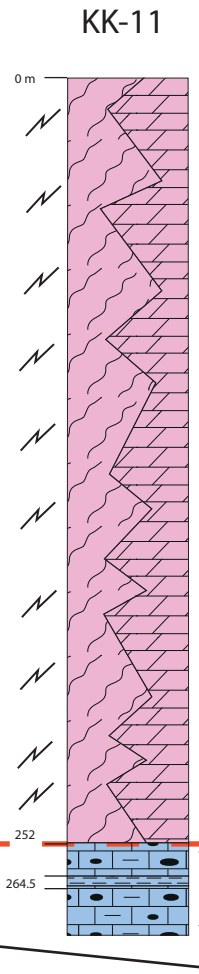


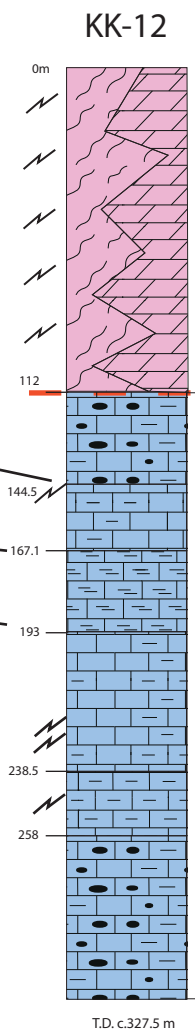
Map Legend:

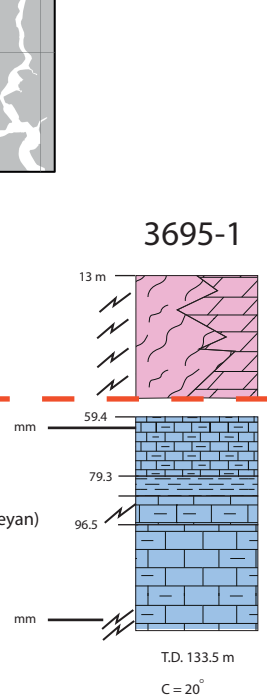
- Westphalian
- Namurian
- Visean Shelf Lsts
- Waulsortian Lsts
- Ballysteen Lst/ABL
- Lower Limestone Shales
- Pre-Carboniferous
- Line of Section
- Drillhole
- Locality

Section Legend:

- Waulsortian Lst
- Lisduff Oolite
- Ballysteen Lst Fm
- Ballymartin Fm
- Ringmoylan Shale
- Mellon House Beds
- ORS

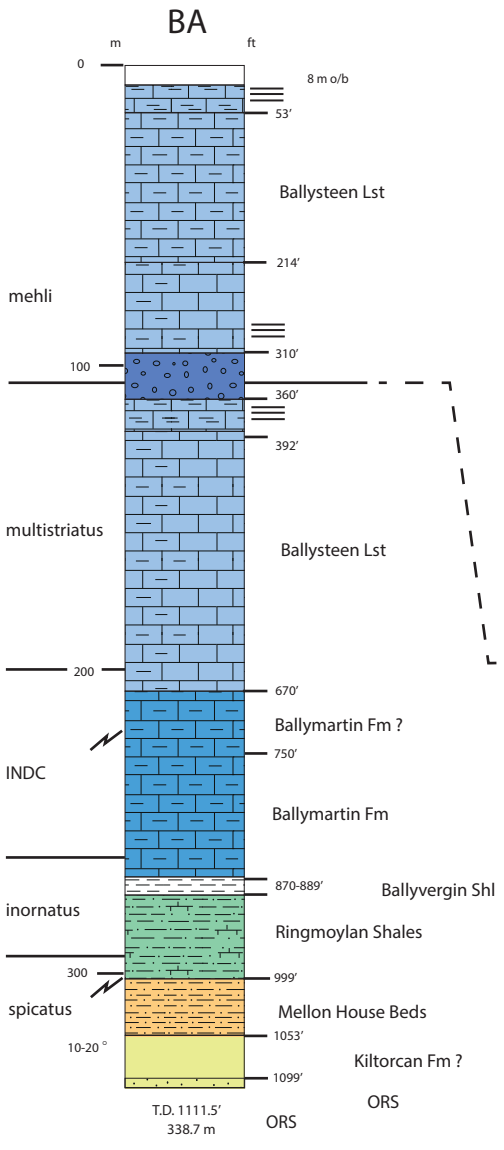


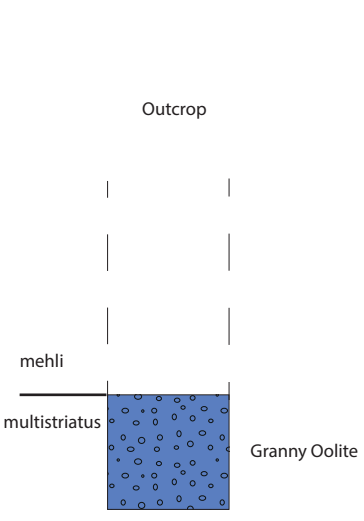




base of Waulsortian

mm = P. mehli mehli sub-biozone (Courceyan)





Symbology Key:

- Clean calcarenite. Shale 0-10%
- Calcarenite with 10-30% shale or diffuse mud
- Calcarenite with 30-50% shale or diffuse mud
- Shale dominant, 50-70% w/ limestone
- Stratigraphic Correlation
- Very fine lamination
- Shale dominant, 70-90% with limestone
- Shale dominant 90-100% ; minor limestone
- Silty shale; siltstone/shale interbedded
- Sandstone, shale, limestone interbedded
- Micrite w/10-30% shale/mud
- Waulsortian limestone
- Oolite
- Sandstone
- Cherty limestone
- Fault, probably small

Fig. 9: Successions in southern part of Rathdowney Area. Conodont sub-biozone boundaries indicated and correlated with dashed line. INDC = interval of no diagnostic conodonts.

Sources: lithological units from MEP logs; conodont data from Jones (1977) for BA, and Keeley (1983); location of Granny Oolite relative to 68-KK-12 from Keeley (1983); location of BA relative to Waulsortian datum from Jones (1977). See text for discussion.

bottom. Similar haematitic calcarenites elsewhere occur in various parts of the Ringmoylan Shales (see above). This interval is therefore included with the Ringmoylan Shales and the top of the Mellon House Beds is placed at its base (999 ft).

The Ballyvergin Shale (870-889 ft; 5.6 m thick) consists of 60-70% dark grey, unfossiliferous, unlaminated mudstone, with interbanded light yellow-grey siltstone mainly <8 mm thick (occasionally 2.5 cm). The siltstones are commonly graded; some are very finely laminated. The proportion of siltstone is higher than is common further to the NW. One thin shell band is present, which is a typical feature. Top and bottom contacts are sharp, as elsewhere.

Ballymartin Formation

The interval 670-870 ft (61 m down hole, probably c.15˚) consists of calcarenites with a high proportion of shale interbeds. It is much more argillaceous than the overlying Ballysteen Limestone, and has a sharp top contact. It is assigned to the Ballymartin Formation, but shows some differences from the central Rathdowney Area. The distinct unfossiliferous 1-2m-thick shale beds scattered through the formation further N are poorly represented in core BA, and occur mainly towards the bottom of the formation, where they are <1.5m thick and are weakly banded with fine skeletal debris. Limestones below 750ft (228.6m) are thinner and more nodular bedded than those above. The base of the formation is the contact with the Ballyvergin Shale.

Ballysteen Formation

BA collared in Ballysteen Limestone (28-670ft / 8.5-204.2m; c.186 m true thickness, assuming 15-20˚ dip). The succession appears to be structurally intact. Most of the formation consists of argillaceous crinoidal limestone, but some atypical units are present, particularly in the middle part of the drilled succession (Appendix 6). There is a distinct oolite at 310-360ft (94.5-109.7m), and oolite is also present in a clean calcarenite unit at 214-232ft (65.2-70.7m). Also present are three units of partly burrowed, interlaminated silty calcarenite and shale <9m thick at the top of the core, at 264ft (80.4m) and at 360ft (109.7m). These atypical units are similar to others in the central Rathdowney area that are associated with the Lisduff Oolite.

There is reason to believe that the oolite unit at 310-360ft (94.5-109.7m) does not correlate with the Lisduff Oolite further north on the basis of conodont zonation, Jones (1977) estimated that the highest unit in hole BA lies at least 50m below the Waulsortian, implying that the oolite unit is >150m below the Waulsortian. This is somewhat more than the thickness of the Upper Ballysteen in cores from the central Rathdowney Area (<130m approximately, fig. 5). However, the top unit in BA closely resembles the laminated units lying just above and below the Lisduff Oolite further N, but not higher in the Upper Ballysteen. This suggests that beds time-equivalent to the Lisduff Oolite could lie immediately above the stratigraphic level of the top of BA. The association between similar laminated units and the oolite in BA, as well as with the Lisduff Oolite, indicates a close link in their sedimentary environments.

Pennaroya core 68-KK-12

68-KK-12, drilled some 25km south of BA (figs.1, 9), extends nearly 180m (true thickness) below the reef in a structurally almost undisturbed core. According to Keeley (1983), the top of the Granny Oolite (see below) is c.300m below the reef, based on outcrop mapping. The interval between the reef and the oolite he named the 'Dunkitt Member' of the Hook Head Formation (the local term for the Ballysteen Limestone). On this basis, 68-KK-12 bottomed some 120m above the Granny Oolite (fig. 9)

Dunkitt Member

The succession in 68-KK-12 between 144.5m and T.D. at c.311 m consists of varied, mainly thinly bedded, argillaceous limestones and calcareous shales, often with gradational contacts. The succession has been divided into a number of units, as summarized in figure 9 and detailed in Appendix 7. Scattered dolomite veins between c.222m and 228m may represent small faults, but otherwise the succession is believed to be virtually intact.

No oolite is present in this core, but the Granny Oolite is exposed down section in the Grannagh quarry close to the River Suir (ING. S.2573 1145). Keeley's (1983, fig.3) estimate that it belongs c.300m below the Waulsortian, places it as shown below the 68-KK-12 column in figure 9.

Waulsortian Lst. - base transition in 68-KK-12

The Waulsortian is underlain below 112m by thinly bedded crinoidal dolomite with shaly partings. Dolomite dies out 2-3 m below the top of this and is replaced by nodular crinoidal micrite. The ossicles are commonly large (1cm). Below c.115.5m the micrites are mainly replaced by well bedded crinoidal calcarenites <5cm thick, rarely 30cm, interbedded with subordinate (<5%) green shale partings with abundant large ossicles in a few well defined bands <5cm thick. Some thin nodular micrites are also present, rarely reaching 20cm thick. The micrite is occasionally conglomeratic, with inter-sutured clasts and sometimes also large ossicles (e.g. at c.123.1m). This lithology, with some variation in grain size and sorting, extends down to 144.5m, where there is a thin transition c.50cm thick into the underlying part of the Dunkitt Member.

These beds (112-144.5m) form an unusually thick (24.8m) Waulsortian Lst. - base transition. It is likely that this unit is laterally equivalent to fully developed reef not far away. This interpretation has some support from the transitional sequence in 68-KK-11, drilled c.4.8km NW of 68-KK-12. The transition in 68-KK-11 is thinner and more like those elsewhere (fig.9).

Correlation of Oolite Units

The stratigraphic level of the oolite in hole BA in relation to the base of the Waulsortian is uncertain. The relative thinness of the underlying Ballysteen succession suggests that the oolite lies relatively much further below the Waulsortian than does the Lisduff Oolite (figs. 5 & 9). Assuming that the position of the column for BA in figure 9 is roughly correct in relation to the Waulsortian, the relative depth of the Granny Oolite is lower still. Even allowing for the base of the Waulsortian to be diachronous, these relationships suggest that the oolites young progressively

from S to N across the Rathdowney Area. Oolite is also exposed ?-low in the Ballysteen Limestone near Dundrum, c.45km W of BA, which fits this interpretation. This is not confirmed by the available sparse biozonation.

The Viséan in the Southern Area

The Carrick-on-Suir Syncline was mapped by Keeley (1980, 1983). He estimated the Waulsortian to be c.400m thick. It is overlain by the Silverspring Formation, which thins westwards from c.100m to 10m. It consists of dark grey biomicrite with abundant chert, especially in the lower part. It was dated as Chadian. This is overlain by the Kilsheelan Formation (c.900m thick) consisting of clean to slightly argillaceous limestone with uncommon chert and locally abundant Siphonodendron. It was dated Chadian to Holkerian.

In the western part of the syncline the Kilsheelan Formation is overlain by two laterally equivalent formations, dated as Asbian. The Ballyglasheen Oolite Formation is c.300m thick and consists of trough cross-bedded oolitic grainstones. The Rathronan Formation is up to c.300m thick but is apparently discontinuous; it consists of pale grey, clean micrite and crinoidal wackestone, locally with thin cherts. The top of the formation is characterized in one exposure by rapid dip changes, slumps and slid blocks, indicating local relief, probably on a mudmound (reef). These two formations are overlain by the Croane Formation, also estimated to be c.300 m thick. It consists of dark grey, clean to argillaceous micrite and biomicrite in regular beds 20-50cm thick; and calcareous mudstones and cherts. The formation is also dated as Asbian. No Brigantian rocks were found, and the overlying Namurian mudstones appear to be discordant.

The Viséan succession in the Carrick-on-Suir Syncline differs considerably from that in the central Rathdowney Area. The cherty Silverspring Formation is probably equivalent to the Crosspatrick Formation, but there is no obvious representative of the Aghmacart Formation. Instead the thick Kilsheelan Formation appears to be the facies equivalent, and partly the time-equivalent, of the Durrow Formation. However, it should be noted that the Carrick succession is based on mapping, not drill core, and it is possible that Aghmacart-equivalent beds are not exposed. A more certain difference with the central Rathdowney Area is with the Asbian formations: no equivalent of the reefal Rathronan Formation is present, though some oolite is present in the Durrow Formation as a minor component. There is no representative of the (basinal or lagoonal?) Croane Formation, which is time-equivalent to the Ballyadams Formation.

Eastern Margin

The successions along the eastern margin of the Rathdowney Area are different from those further W, as a result of their proximity to the Leinster Massif. This has resulted in eastward thinning, onlap of the basement and change in facies in the lower part of the succession (fig. 10). The successions in three holes drilled through these beds into basement by the GSI (fig.1) are detailed below. A deeper hole further S, 79-2649-03 shows a very different, much more "conventional" succession close to the E margin of the Carboniferous outcrop.

GSI-85-2, the Quinagh borehole

The succession in GSI-85-2 (T.D. 217.4m) is summarized in figure 10. The Carboniferous beds rest on granite. A succession of fine clastics totalling 27.7 m (168.1-195.8 m at practically horizontal dips) forms the initial transgressive unit, termed the 'Quinagh Formation' (Tietzsch-Tyler & Sleeman, 1994). This consists predominantly of laminated to thinly inter-bedded mudstone, siltstone and fine sandstone with common burrows; many of the components are dolomitized. Immediately above the granite is a 20cm coarse sandstone with quartz and granite grains. Grain size rapidly reduces up section, but feldspar and mica persist upwards into the limestone units above. Beds of clean, fine sandstone and siltstone up to 60cm thick are scattered through the Quinagh Formation, and a pair of 2-m-thick sandstones form a prominent unit at c.185-190m. Above c.180m thin fossiliferous limestones and shales with brachiopods and crinoid debris are scattered through the formation. Samples through the Quinagh Formation have yielded spores from the PC biozone.

The overlying unit (155.6-168.1m, 12.5m thick) consists of interbedded nodular biomicrite and fossiliferous shale. Burrowing is common. The base is gradational, but sandstone beds are absent above the contact. From its position between the basal clastics and the thick, relatively uniform overlying limestone (and dolomite), this unit is tentatively correlated with the Ballymartin Formation (fig. 10), though it is a lot thinner than in the central Rathdowney Area.

Beds above 155.6m (up to 6.3m) belong to the Ballysteen Formation. Much of this is dolomitized, but a few scattered oolite horizons are recognizable from thin-sections. Shale interbeds are rare, in contrast to the underlying formation.

Apart from thicknesses differences between this core and the central Rathdowney Area, the Quinagh core differs also in lacking ORS, and clearly defined Mellon House Beds and Ringmoylan Shales. The Quinagh Formation is presumably at least partly laterally equivalent to the latter two. The Ballyvergin Shale has not been recognized in this core. Further differences from the central successions are displayed in the GSI-92-1 core.

GSI-92-1, the Belan borehole

GSI-92-1, drilled 11 miles (17.7km) NNE of the Quinagh hole (figs.1, 10), collared in the ?-Ballymartin Formation and thereafter went through a predominantly shale and siltstone succession (Quinagh Formation) to reach Lower Palaeozoic greywacke at 53m. Dips in the

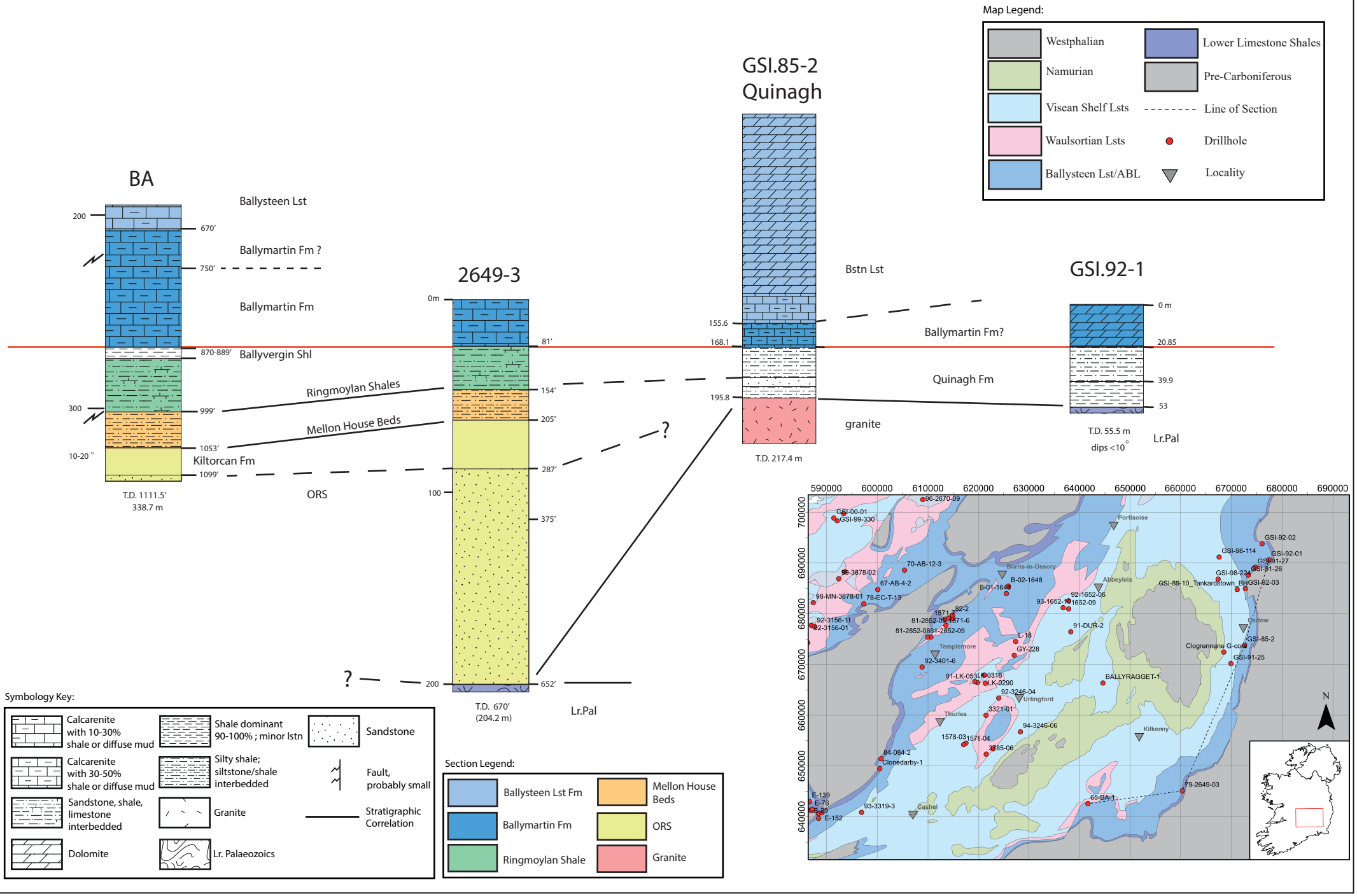


Figure 10: Drilled successions along the eastern and south-eastern margin of the Rathdowney Area. Formations in 79-2649-03 are similar to those in hole BA and the central Rathdowney Area. Further N the ORS pinches out from c.140m, and the basal Carboniferous formations differ substantially from those further W. Biostratigraphic data is too sparse to indicate lateral equivalence, and the Ballyvergin Shale is recognized only in BA. Identification of the Ballymartin Formation is tentative. Note that boundary depths in BA and 79-2649-03 are given in feet. Datum line is base of presumed Ballymartin Formation.

Carboniferous beds are <10˚ throughout, and there are no obvious faults. The succession is summarized below; a more detailed log is given in Appendix 8.

The interval 20.85-53m, which is assigned to the Quinagh Formation, consists mainly of graded units 30-100cm thick of siltstone and mudstone. Homogeneous, pale grey, dolomitized siltstones (fine sandstone locally) pass up into burrowed darker siltstone, then dark grey to black, mainly finely interlaminated mudstone and siltstone with quite varied colour and lamina thickness. Burrowing is rare in the laminated beds. Variation in the proportions of components and thickness of the graded units allows the sub-division of the succession. Skeletal debris visible at hand-sample level is generally rare. The interval is assigned to the Quinagh Formation because, as in GSI-85-2, it is the initial transgressive sequence between "basement" and fully marine limestones above. However, it differs in detail from the Quinagh borehole. Some of the less typical features are as follows.

The contact between the Carboniferous and Lower Palaeozoic rocks in GSI-92-1 is sharp and apparently unfaulted. It is overlain by 50cm of mudstone at the base of the Quinagh Formation; there is no basal conglomerate or even sandstone, suggesting that there may be a local topographic "high" at this locality. The succession up to 39.9m consists of varied mudstone and subordinate siltstone and sandstone. It includes quite common, scattered thin beds of quartz granules (typically <3mm diameter, occasionally up to 8mm), and also fine sandstones with dispersed granules. One 50cm bed at 42.7m consists of very coarse sandstone, coarser than all but a few very thin beds elsewhere in the interval.

The interval 30.6-39.9m differs in being predominantly siltstone, including massive beds <80cm thick. It includes one 20cm band of concentrated shell hash with more dispersed remains through a total of 60cm. The shells appear to be represented by micritic coats only, suggesting that they may have been lamellibranchs rather than brachiopods. The lowest fossiliferous bed is at 36.9m, but burrowing extends much lower.

A distinct thin unit at the top of the Quinagh Formation in GSI-92-1 (20.85-23.7m) is also dominated by graded units <1m thick, consisting partly of burrowed dark grey siltstone overlain by finely laminated black shale <60cm thick. However, these units differ from those below in that the bottom part of each consists of silty calcarenite, usually dolomitized. It is thus transitional up into the overlying limestone.

The highest unit in GSI-92-1 (6-20.85m) consists mainly of fine, commonly silty dolomite with sparse skeletal debris. Subordinate interbeds of partly burrowed, banded siltstone grade up into more thinly laminated silty shale in a few beds, echoing the graded units in the Quinagh Formation. The bottom 2m of the unit consist of nodular bedded, argillaceous, crinoidal calcarenite (undolomitized). The base is gradational. This unit is assigned to the Ballymartin Formation on the grounds that it directly overlies the Quinagh Formation, as in GSI-85-2, and is more argillaceous than the Ballysteen Limestone in that core. However, it includes a lot more silty calcarenite and siltstone than is typical for the Ballymartin further W.

Compared with the Quinagh borehole (GSI-85-2), the Quinagh Formation is roughly the same thickness in GSI-92-1, and the lithologies are similar. Although the successions differ in detail, both cores have an atypically coarse unit near the middle of the formation: the siltstone-dominant interval in GSI-92-1 (30.6-39.9m), and the sandstone at c.185-190m in GSI-85-2. Both successions include

quartz granules through a similar thickness in the bottom part of the Quinagh Formation, but granite clasts are confined to GSI-85-2, in which "basement" is granite, contrasting with Lower Palaeozoic greywacke in GSI-92-1.

The lower part of the Quinagh Formation was also drilled in GSI.91-27, located 2 miles (3.2km) SW of GSI-92-1 (fig.1). This penetrated c.13m (14-26.9m) of beds generally similar to those in GSI-92-1 before entering Lower Palaeozoic beds. The detailed succession is again different; units as much as 5m thick do not correlate across. The bottom contact is faulted. Quartz granules, some in beds <10cm thick, extend up section by about the same amount as in GSI-92-1, suggesting that the fault is small. The (presumed) Lower Palaeozoic beds consist of green and red sandstone and mudstone, which is locally laminated and overturned on a small scale.

Borehole 79-2649-03

This hole was located in the SE corner of the Rathdowney Area, 17 miles (27 km) SSW of the Quinagh hole, and 12 miles (19 km) E of the Baunta hole (BA) (figs.1, 10). 79-2649-03 penetrated probable Ballymartin Formation, Ringmoylan Shales and a thin, varied succession assigned to the Mellon House Beds. Below this is a thick ORS succession, discussed above (fig.3), lying on Lower Palaeozoic mudstones at 652ft (198.7m). Details of the succession above the ORS are given in Appendix 9. Dips are sub-horizontal throughout, except where sandstones are cross-bedded.

Although the Mellon House Beds and the Ringmoylan Shales are recognizable in this core, there remains a question as to the identification of the top unit: it is not typical of the Ballymartin Formation, and has some features in common with the Ringmoylan Shales. Compared with the Ballymartin in the central Rathdowney Area, it is generally thinner bedded, lacks unfossiliferous shales 1-2m thick, and has a higher proportion of silty beds. There is no Ballyvergin Shale to mark the top of the Ringmoylan Shales. However, the lithological change at the contact at 81ft (24.7m) is a much stronger than that seen elsewhere near the middle of the Ringmoylan Shales (proportion of interbedded calcarenites); and the thickness of the shale-dominant unit below this contact (81-154ft; 22.3m) is consistent with that of the Ringmoylan Shales to the W (fig.10). The contact at 81ft is therefore taken as the base of Ballymartin Formation.

The presence of Mellon House Beds and Ringmoylan Shales in this sector of the eastern margin of the Rathdowney Area contrasts with their absence (or changed character) further N (Quinagh borehole, etc). This, together with the thick ORS succession, indicates that the Leinster Massif was less of a topographic feature this far S (fig.10).

List of Figures

Formation is tentative. Note that boundary depths in BA and 2649-3 are given in feet. Datum line is base of presumed Ballymartin Formation.

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Appendices

Appendix 1: Log of 06-3246-04

The following log is a slightly edited version of the notes accompanying the 1":10 m graphic log. It should be noted that the transcription does not give information that is shown in graphic form, such as dip readings, gradational contacts, relative mud content, distribution of corals, etc. Sand grade sizes are guessed, not measured. Where single depths are used to identify a bed or unit, the depth refers to the top contact. Structures referred to in the log as 'lozenge burrows' are eye-shaped, usually dark, sub-horizontal burrow-fills c.2-4 mm long, which are probably *Chondrites.*

0-16 m: overburden
16-48.3 m: Crosspatrick Formation
16-c.34 m: dolomite, yellow-grey, weathered, mainly finely crystalline. Common chert in upper part. Dolomite commonly massive; locally with ?-shaly partings, wavy. Remnant crinoid debris in some beds; some very coarse. Dolomite fractured, locally cavernous, especially 34-38 m. Little sign of veining. Chert rare below 34 m.
34-48.3 m: Reef-top Transition: dolomite as above, but with common thinly banded beds <60 cm thick with abundant shaly partings, wavy. Crinoid debris mainly scattered and uncommon; occasional crinoidal calcarenite <30 cm thick. Transitional base to [this] bedded dolomite; banded dolomite very minor below. Little stromatactis dolomite above [48.3 m], except at 41.5-43.3 m.

48.3-163.4 m: Waulsortian Reef
48.3-59.5 m: predominantly stromatactis dolomite, but with coarse crinoid debris common as 2-3-cm bands down to 59.5 m, rare below.
59.5-84 m: nearly all stromatactis dolomite. Occasional fine dolomite near top with homogeneous texture, probably dolomitized micrite.
84-99 m: gradational downward increase in percentage of ?-stromatactis with geopetal floors, which darker grey. These especially prominent in bottom 1 m (98-99 m). Scattered caves <30 cm high, and local zones of more severe weathering.
99-163.4 m: varied stromatactis dolomite, without dark geopetals. No crinoidal beds or other reef-margin lithologies. Sharp base. Overlying [i.e. basal] 7-8 m slightly darker grey

163.4-267.2 m: Upper Ballysteen Limestone
163.4-167.5 m: thinly banded dolomite with bands of crinoid ossicles and abundant shaly partings.167.5-177.6 m: mainly thinly bedded, medium grey, fine limestone with abundant thin chert nodules, [which] occasionally <5 cm thick. Bed thickness quite variable, mainly 2-30 cm. Abundant shale partings. Little crinoid debris. Rare zaphrentids. Rare shales, diffuse, <10cm thick; where limestone is nodular. Limestone possibly siliceous very fine calcarenite. Limestone bed 80 cm thick just above ?-fault [at 176 m].
167.5-177.6 m: mainly thinly bedded, medium grey, fine limestone with abundant thin chert nodules, [which] occasionally <5 cm thick. Bed thickness quite variable, mainly 2-30 cm. Abundant shale partings. Little crinoid debris. Rare zaphrentids. Rare shales,

diffuse, <10cm thick; where limestone is nodular. Limestone possibly siliceous very fine calcarenite. Limestone bed 80 cm thick just above ?-fault [at 176 m].

177.6-190 m: very nodular argillaceous micrites, mainly <5 cm thick, interbedded with very calcareous, slightly fossiliferous shales; diffuse to [sharp] solutional contacts. Minor crinoid, brachiopod and coral debris. Shales irregularly streaky. Unit much shalier than above, but lithologies generally similar. Micrites replaced by fine argillaceous calcarenites in bottom 4-5 m.

190-205.5 m: mainly banded calcareous shale, with scattered diffuse interbeds of moderately dark fine argillaceous calcarenite 10-25 cm thick, poorly fossiliferous. Shales banded with very fine carbonate, and small crinoid ossicles. Scattered large ossicles, brachiopod debris and corals relatively abundant, zaphrentids and ?-Caninia. Shales black and unfossiliferous only for 2-3 cm, minor.

205.5-216.5 m: moderately dark fine argillaceous calcarenites with scattered fine ?-brachiopod and crinoid debris, and possible bioturbation, <40 cm thick, mainly with diffuse contacts. Interbedded with fossiliferous shales as above, <40 cm thick, subordinate; shales slightly less fossiliferous, few large ossicles.

216.5 m: broken core, but no veining.

216.5-240.7 m: Mainly thinly interbedded crinoidal calcarenite and moderately fossiliferous shales. Limestones nodular, commonly diffuse; include brachiopod and zaphrentid debris, and a few large ossicles. Shales much as above, but much thinner. Top contact is rather sharp, close to broken-up core, *possibly* a fault. Unit more fossiliferous than overlying one. Subordinate lithologies include fine argillaceous limestone as in overlying unit, [in beds] <80 cm thick, in lower half; and distinctly banded shale with very fine carbonate and fossil debris, more typical of underlying unit, rare, in lower half.

240.7-256 m: Relatively thick (<60 cm) weakly banded, almost unfossiliferous shales interbedded with thin, variably crinoidal calcarenites. Shales < 80 cm thick, if 2-cm calcarenites included. Mainly as nearly pure shales <40 cm thick with scattered laminae <2 mm of very fine carbonate and fine skeletal debris. Grade in type to more fossiliferous and thicker-banded shales, well banded; and to more diffusely fossiliferous, more calcareous type. Some beds with abundant thin-shelled brachiopods and fenestrate bryozoa (e.g. 247.3 m for 25 cm). Shales typically much "purer" than any above. Calcarenites <15 cm thick, some very diffuse.

256-261 m: variably crinoidal calcarenites (mainly wackestone) <1.1 m thick, with scattered interbeds of shale <15 cm thick (one 30 cm), partly unfossiliferous. Generally as above, but different percentages. Calcarenites include subordinate crinoidal grainstone, as below, mainly as 10-cm bed tops. Transitional unit. Calcarenites appear bioturbated; unclear.

261-267.2 m: medium grey calcarenites, including common biosparite. Scattered shaly partings. Some slightly more argillaceous fine calcarenites. Colour gradually fades in bottom 2 m towards pale yellow-grey of underlying unit. Occasional bed with ossicles <1 cm across. Biosparites near base may include subordinate ooliths.

267.2-349.8 m: <u>Lisduff Oolite</u>

267.2-269.9 m: oolite, pale grey, coarse, massive.

269.9-273 m: mottled biomicrite (mottling may be multi-generation mud) with large encrusting bryozoan or red algal colonies abundant; geopetals, stylolites. Looks like a non-Waulsortian reef lens. Slightly darker than oolite above and below.

273-286.2 m: very pale grey oolite (bio-oo-sparite and oo-bio-sparite), massive, rather uniform. Locally cross-laminated (foresets?). Colour is cream-grey, c.f. below 307 m, which greyer. Base gradational through c.50 cm.

286.2-291.4 m: medium grey, banded calcarenite (biosparite), mainly dolomitized except top 1.5 m. Bottom 50 cm mainly conglomeratic (brecciated?) and altered.

291.4-303 m: pale grey, massive oolite, as above. [In bottom 2 m] skeletal content higher than above.

303-306 m: mainly bio-oo-sparite. Locally feintly banded.

306-307 m: medium grey, dolomitized biosparite. Partly banded.

307-322 m: mainly massive, light grey oolite. Locally very skeletal (bio-oosparite; probably also biosparite), especially 311-312 m. Lower half much more uniform.

322-324.4 m: medium grey calcarenite, probably oolitic in upper part. Brachiopods common at bottom. Two thin beds (<5 cm) with laminated siltstone draping calcarenite bumps near bottom. This is "Kildare Facies" as in Borris hole. Base sharp at stylolite.

324.4-345.2 m: massive pale grey oolite. Upper half mainly oo-bio-sparite; bio(oo)sparite predominant in bottom 7 m, and commonly interbedded above. Coarser than oosparite, and more obviously banded. Dips partly foresets. Colour change [near base] through 2 m into underlying medium to moderately dark grey [limestone].

345.2-349.8 m: medium grey coarse bio-oo-sparite (locally oo-bio-sparite). Banded on grain size. Base sharp at shale parting. Steeper dips are foresets.

349.8-T.D. at 405 m: <u>Middle Ballysteen Limestone</u>

349.8-355.4 m: moderately dark grey fine calcarenite, variably argillaceous. Scattered shaly partings and one 1-cm band. Visible skeletal debris uncommon. Medium bio-sparite quite common (possibly slightly oolitic?).

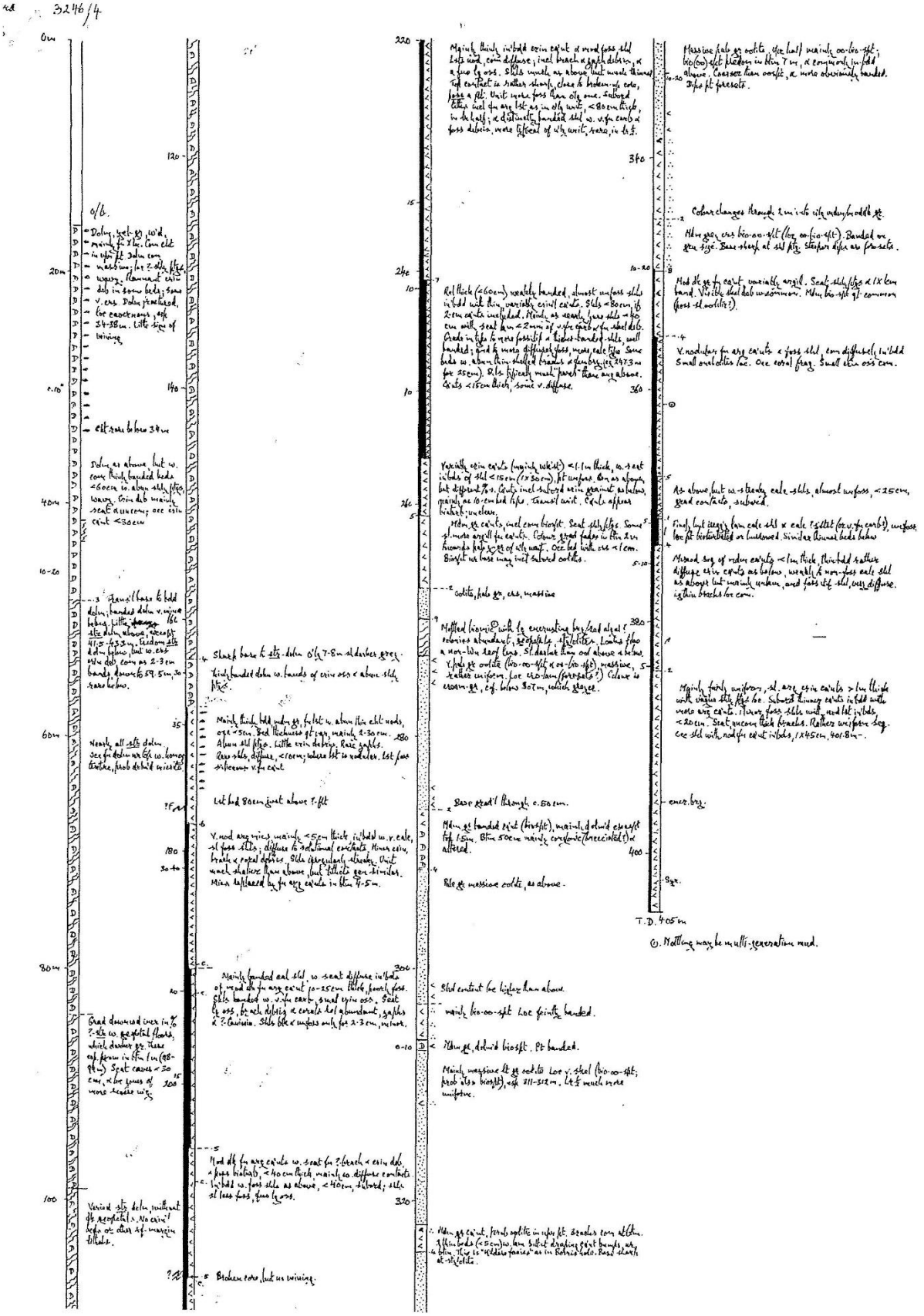
355.4-367.5 m: very nodular fine argillaceous calcarenites and fossiliferous shale, commonly diffusely interbedded . Small oncholites locally. Occasional coral fragment. Small crinoid ossicles common.

367.5-371.1 m: as above, but with streaky calcareous shales, almost unfossiliferous, <25 cm thick, with gradational contacts, subordinate.

371.1-373.4 m: finely but irregularly laminated calcareous shale and calcareous ?-siltstone (or very fine carbonates?), unfossiliferous, locally partly bioturbated or burrowed. Similar thinner beds below.

373.4-384.2 m: mixed sequence of medium calcarenites <1 m thick; thin-bedded rather diffuse crinoidal calcarenites as below; weakly to nonfossiliferous calcareous shale as above but mainly unlaminated; and fossiliferous shale, very diffuse. Large thin brachiopods locally common.

384.2-T.D. at 405 m: mainly fairly uniform, slightly argillaceous crinoidal calcarenites >1 m thick with vague shaly partings locally. Subordinate thinner calcarenites interbedded with more argillaceous calcarenites. Minor fossiliferous shales with nodular limestone interbeds <20 cm thick. Scattered uncommon thick[-shelled] brachiopods. Rather uniform sequence. Occasional shale with nodular fine calcarenite interbeds, one 45 cm thick at 401.8 m (down). 395.5 m: encrusting bryozoa. 402.3 m: Syringopora.



Appendix 2: Log of 92-3401-6

The following log is a slightly edited version of the notes accompanying the 1":10 m graphic log. It should be noted that the transcription does not give information that is shown in graphic form, such as dip readings, gradational contacts, relative mud content, distribution of corals, etc. Sand grade sizes are guessed, not measured. Where single depths are used to identify a bed or unit, the depth refers to the top contact. Structures referred to in the log as 'lozenge burrows' are eye-shaped, usually dark, sub-horizontal burrow-fills c.2-4 mm long, which are probably *Chondrites.*

0-12 m: overburden.

12-81.9 m: Upper Ballysteen Limestone

12-20.2 m: black, weakly fossiliferous, calcareous shale with scattered laminae of very fine carbonate or fine skeletal debris, including thin[-shelled] brachiopods, coral fragments and crinoid ossicles.

20.2-34.2 m: as above, but also with minor very fine, diffuse argillaceous limestone beds <5 cm thick. Shales generally slightly more fossiliferous and calcareous. 29.5 m: Syringopora.

34.2-45 m: nodular and diffuse fine limestones, argillaceous, in beds mainly <10 cm thick, occasionally <40 cm, mainly too ill-defined to measure. Interbedded with shales as above, mainly <15 cm thick, occasionally 40 cm, locally unfossiliferous for 10 cm; plus intermediate lithologies: very calcareous, diffusely nodular "shales" with few visible fossils. Limestones commonly weakly burrowed/bioturbated.

45-48 m: pale grey, weathered calcarenite with minor shaly interbeds. Cavernous. Seems to be same as underlying beds.

48-75.7 m: predominantly fine to medium, crinoidal, slightly argillaceous calcarenite, mainly diffusely interbedded with more argillaceous calcarenite or very calcareous, fossiliferous shale. "Real" shale interbeds quite uncommon: two c.15 cm thick, almost unfossiliferous; others <3 cm. Sharp limestone bed contacts equally uncommon. Shaly interbeds better developed in lower half, accompanied by more distinct nodularity in limestones. Occasional brachiopod and coral fragments. Minor percentage of fine argillaceous limestones, weakly burrowed, as above. 48.6 & 49 m: Syringopora.

75.7-81.9 m: mainly very fine, bioturbated, slightly argillaceous calcarenite with irregular, diffuse shaly partings. Subordinate interbeds of crinoidal calcarenite as above, and very diffuse more argillaceous calcarenites also as above. Rare "real" shales <5cm thick. Some of the very fine limestone is wavy laminated on a very fine scale and locally slightly burrowed, with drapes on calcarenite domes, and fossiliferous calcarenite burrow-fills (80.581 m). Top contact imprecise, with occasional very fine limestone above 75.7 m. Base sharp, but a few thin calcarenites above it are like lower ones.

81.9-103.6 m: Lisduff Oolite

81.9-85 m: medium to coarse biosparite, weakly banded, massive. Occasional stylolitic parting. Gradational base as oolith content drops off upwards [from underlying unit].

85-103.6 m: varied succession of light grey oo-sparite, oo-bio-sparite and bio-oo-sparite, latter commonly coarse, and well banded in foresets. Oo-sparite also relatively coarse. Base sharp.

103.6-256 m: Lower Ballysteen Limestone

103.6-105.9 m: variable medium calcarenite, some diffusely nodular, some well sorted, laminated.

105.9-110.8 m: interbedded very fine calcarenites, slightly bioturbated, <20 cm thick; and fine-laminated calcarenite (possibly silty)/shale, with drapes, fat "penetration" burrows >1 cm across, irregular "pile-ups" of calcarenite, often with chert in them. Some shale-dominant laminated interbeds <5 cm thick. Rare medium skeletal calcarenite.

110.8-135.8 m: generally diffusely interbedded medium-grained crinoidal calcarenites and very calcareous, moderately fossiliferous shales. Shale rarely c.50 cm thick; mainly <20 cm as homogeneous beds. Thicker if interbeds included. Calcarenites with very diffuse argillaceous partings locally >1 cm thick. Occasional well bedded, well sorted medium calcarenite <15 cm thick. Brachiopods mainly uncommon, but 132-134 m has common thin-shelled brachiopods in atypical very fine argillaceous calcarenite with interbedded very calcareous shale, bioturbated. 128.4 m: encrusting bryozoa (?).

135.8-175.1 m: generally similar to above, but beds mainly more distinct. Several distinct, well banded shale/calcarenite beds <60 cm thick (absent above). Continuous calcarenites (including diffuse shaly partings) commonly thicker than above, locally 2 m. Brachiopod debris commoner than above; thick shells. Shales include thin laminae of very fine carbonate, which possibly silty. Most calcarenite in diffusely nodular units, somewhat more argillaceous than the thicker calcarenite beds. 149.2 m: encrusting bryozoa. 173.1 m: cross-cutting fine dolomite.

175.1-195 m: predominantly "thick" type of calcarenite seen above, with subordinate nodular type, and few banded shales, <20 cm thick. Thick-shelled brachiopods common. Occasional biosparites near bottom of unit.

195-214.5 m: much as above 175.1 m.

214.5-239.1 m: not very different from above. Lacks well banded shales. Common thick, diffusely [bedded], argillaceous calcarenites with fine crinoid debris, >1 m thick. In contrast to units above, includes dark grey fossiliferous shales with interbedded thin irregular calcarenites. Shaly beds occasionally >50 cm thick, but ill defined. Fewer thick-shelled brachiopods than above, but still common.

239.1-240.7 m: predominantly fine calcarenite as below, but locally argillaceous and "conglomeratic".

240.7-247.7 m: Fine Calcarenite Marker. Fine calcarenite with common, locally abundant, brachiopod shells and debris. Scattered stylolites. Massive.

247.7-256 m: As above F.C.M.

256-289.7 m: <u>Ballymartin Limestone Formation</u>

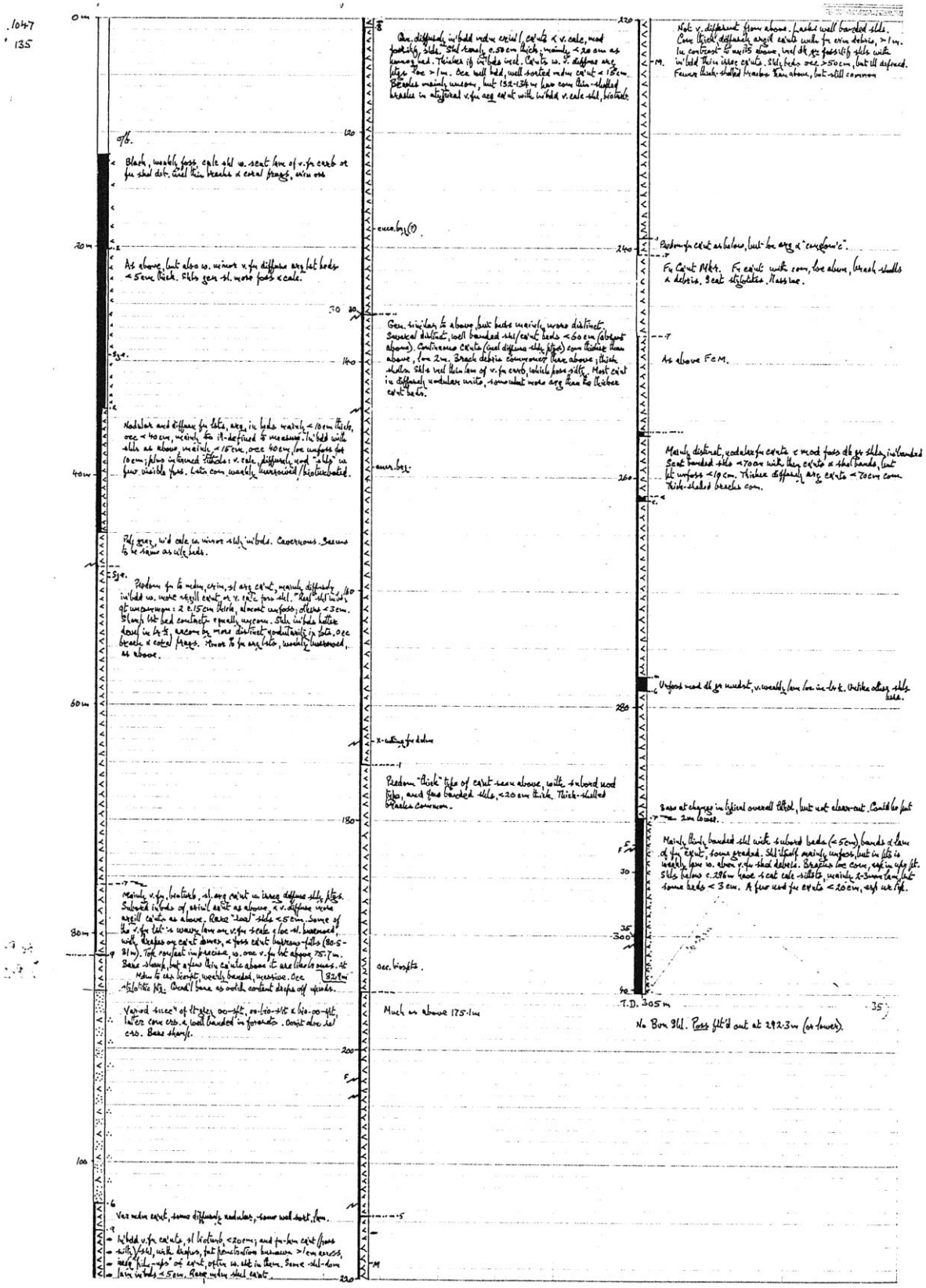
256-289.7 m: mainly distinct, nodular fine calcarenites and moderately fossiliferous, dark grey shales, interbanded. Scattered banded shales <70 cm thick common. Thick-shelled brachiopods common. Base at change in typical overall lithology, but not clear-cut. Could be put 2 m lower. 277.4-278.6 m: unfossiliferous, moderately dark grey mudstone, very weakly laminated locally in lower half. Unlike other shales here.

289.7-T.D. at 305 m: <u>Ringmoylan Shales</u>

289.7-305 m: mainly thinly banded shale with subordinate beds (<5 cm thick), bands and laminae of fine calcarenite, some graded. Shale itself mainly unfossiliferous, but in parts is weakly laminated with abundant very fine skeletal debris. Brachiopods locally common, especially in

upper part. Shales below c.296 m have scattered calcareous siltstones, mainly 2-3 mm laminae, but some beds <3 cm thick. A few nodular fine calcarenites <20 cm thick, especially near the top.

No Ballyvergin Shale. Possibly faulted out at 292.3 m (or lower).



Appendix 3: Log of core 94-3246-06

The following log is a slightly edited version of the notes accompanying the 1":10 m graphic log. It should be noted that the transcription does not give information that is shown in graphic form, such as dip readings, gradational contacts, relative mud content, distribution of corals, etc. Sand grade sizes are guessed, not measured. Where single depths are used to identify a bed or unit, the depth refers to the top contact. Structures referred to in the log as 'lozenge burrows' are eye-shaped, usually dark, sub-horizontal burrow-fills c.2-4 mm long, which are probably *Chondrites.*

0-9 m: Overburden.

9-26.25 m: Ballyadams Formation

Mainly light to medium grey, medium-grained calcarenites. Variable composition, probably mainly biosparite & bio-intra-sparite; some possibly bio-oo-sparite. Beds of brachiopods and small gastropods common. Caving in top 3 m. Uniform fine oosparite or pelsparite 30 cm to 1 m thick, subordinate. Occasional solitary corals. Locally moderately dark grey, more argillaceous fine ?-pelsparite. Orange clay in fissures. Fine grainstone (pel- or intra-sparite), well laminated, oversteepened (45°) in bottom 40 cm.

26.25-201.3 m: Durrow Formation

26.25-27 m: Argillaceous oncholite bed, capped by sooty black shale. Oncholites diffuse. Gastropods.

27-27.6 m: Fine, well sorted grainstone, banded.

27.6-28.4 m: 10-cm sooty shale, over 15 cm of very argillaceous biomicrite, over argillaceous micrite.

28.4-29.8 m: Banded and graded units of intrasparite (grainstone), occasionally conglomeratic. Gastropods.

29.8-30.4 m: 60 cm of hard calcareous shale, variable, with abundant very small shells (ostracods?). Occasional brachiopods.

30.4-31.5 m: Argillaceous micrite with occasional shaly partings and minor erosion surface; grading down to very fine pelmicrite.

31.5-33.7 m: Slightly argillaceous ?-intrasparite and pelsparite; grain size variation. Occasional gastropods. 31.5 m: 20-cm bed of 1-mm round grains, cellular?

33.7-34 m: 30 cm of argillaceous fossiliferous intrasparite to pelmicrite.

34-36.4 m: Variable, burrowed argillaceous very fine calcarenites, including ?-intra-sparite/-micrite; minor shaly interbeds. Occasional concentration of small shells, including gastropods.

36.4-38 m: Variable argillaceous micrite with shaly partings. Minor shell debris. Moderately dark grey at bottom.

38-41.8 m: About 4 graded units, from bottom up: burrowed very argillaceous fine ?-pel-micrite/-sparite, fossiliferous (fine debris); laminated ditto; black fossiliferous (very fine debris) calcareous shale <10 cm thick.

41.8-63 m: Variable argillaceous to very argillaceous, fine to medium calcarenites, much as some above, but generally less variable. Predominantly with dispersed very fine skeletal debris. Crinoid ossicles barely visible anywhere. Very argillaceous micrite prominent down to c.53.5 m; present locally below to 61 m. Burrowing and partial bioturbation in

most beds; lamination less common than above. Stick- and finger-like bryozoa locally abundant. Lithostrotion colonies and debris common; colonies mainly <15 cm thick. Also Syringopora debris. Occasional thick-shelled ?-brachiopods; scattered gastropods. Shale rare, generally hard, black, <5 cm thick. Bedding generally gradational: more/less argillaceous limestones. Less obviously graded units than above.

Lithostrotion at 48.0, 48.6 & 59.4 m.

63-86 m: Below 63 m some beds homogeneous for 1 m; not so above. Much as above, but higher proportion of medium grey, fine to medium grainstone (intrasparite, etc), as above 36.5 m.

74.4 m: Syringopora with 1.5-mm corallites. Bottom few m of unit: bedding generally thicker; less lithological variation than above.

84.2 m: Lithostrotion.

86-101.6 m: Slightly paler overall, but much as above. Includes minor light grey, banded intrasparite, as below c.26 m. Gastropods near bottom of unit.

90.5-90.9 m: Fossiliferous calcareous shale; mainly very fine skeletal debris. 92.5 m: Lithostrotion.

93-96 m: Light grey intrasparite and ?-pel-bio-sparite.

100.2 m: Lithostrotion.

101.6-114.9 m: As 63-86 m.

106.3 m: 20-cm black sooty shale associated with calcite vein. Gouge or bed?

114.9-115.8 m: 90-cm dolomite, light yellow-grey, massive, medium crystalline. 50 cm of bleached limestone above it.

115.8-116.5 m: Light grey grainstone, medium-grained, uniform.

116.5-118 m: Argillaceous very fine calcarenite. Much as above. Lower half with colonies with sub-mm tubular skeleton, <5 mm long.

118-122.2 m: Mainly medium to coarse biosparite with quite common large brachiopods, thinner brachiopods & corals. Partly banded intra-bio-sparite. Partly argillaceous.

122.2-130.6 m: Light yellow-grey, fine to medium dolomite. Locally with parallel, elongate vugs. Occasional stylolites. No remnant textures. Dolomite may have replaced medium to coarse calcarenite as at 118 m, but no clear evidence. *Possibly* a marker unit here.

130.6-138 m: Massive medium-grained calcarenite, crinoidal biosparite and ?-oosparite; partly bleached. Occasional corals, minor shell debris. Unit dolomitized where shown on log.

138-147.6 m: Mainly medium-grey, fine to medium grainstones, much as above; partly well banded, partly homogeneous. Generally fine in lower half, with a few argillaceous limestone interbeds >10 cm thick. Occasional shells and gastropod beds. Relatively homogeneous unit.

147.6-156.2 m: Variably argillaceous to very argillaceous, fine to very fine calcarenites, generally with very fine skeletal debris, commonly bioturbated; interbedded with fine to medium grainstones, including probable oo-bio-sparite. Bedding generally poorly defined; lithologies homogeneous <40 cm. Shells scattered, occasionally in bands, including gastropods.

156.2-163.7 m: Mainly fine, relatively uniform grainstone; locally medium; locally banded.

156.2 m: 40-cm including rhyzoliths; also at 157.8 m.

163.7-180 m: Interbedded grainstones as above, commonly with gastropods, slightly conglomeratic; and finer, darker, more argillaceous calcarenites. Some as graded units. Beds commonly 0.5-1 m thick. 164.8 m: dense colony of ?-serpulids. Some units capped

by 2-3 cm irregularly laminated shale/limestone, dark grey. Varied skeletal debris content, some laminated. Grainstone may include oosparite, but unclear. lntergrading lithologies and beds common. Unit much as at 147.6-156.2 m. Corals relatively common.
171.5 m: Syringopora.
172 & 177.8 m: ?-Caninia.
179.1 m: Very dense colony of ?-serpulids.

180-184.5 m: Relatively pale grainstones; common corals, including poorly developed Lithostrotion colonies. Gastropods. c.183 m: ?-Caninia.

184.5-201.3 m: Much as above 180 m. Graded units: 1) at base, medium grainstones (biosparites, possibly also oo-bio-sparites) locally conglomeratic, commonly with large gastropods and shell debris; 5-50 cm thick; 2) grading up into variable, finer, darker, slightly argillaceous calcarenites occasionally >1 m thick, commonly bioturbated. 3) occasional thin, irregularly laminated shaly caps, and rare thicker more argillaceous limestone with fine skeletal debris, dispersed, 20-50 cm thick. Bedding generally thinner than above and grading more obvious. Much less coral debris.

201.3-327.3 m: Aghmacart Formation

201.3-202.8 m: Variable, fine argillaceous calcarenite with common irregular oncholites <2 cm across, and occasional oncholitic fine grainstones. Gastropods common.

202.8-203.3 m: 50 cm of fine to medium grainstone (oolite?), as above.

203.3-204.5 m: 60-cm grainstone as above, overlain and underlain by finer argillaceous limestone with occasional poor oncholites; irregular shaly partings and vertical seams.

204.5-205.3 m: 80 cm of very fine argillaceous calcarenite and calcareous shale, partly with lozenge burrows. One 3-cm grainstone. Varied.

205.3-207.6 m: Variable, argillaceous fine limestone with occasional poor oncholites and small stromatolites (205.8 m); 5-mm burrows filled with fine calcarenite, locally only. 40-cm grainstone in centre, as above. Argillaceous calcarenite partly laminated, c.f. bioturbated beds above.

207.6-217.5 m: Varied medium-grey grainstones, fine to medium, occasionally slightly argillaceous. Oncholites common locally. Partly ?-oosparite. Mainly massive or well laminated, but irregular where more argillaceous. Uniform for <50 cm. Scattered shaly stylolitic partings; rare shaly interbeds <2 cm thick. Poorly sorted ?-intrasparite, locally common; occasionally <80 cm thick. Probably graded units as above, but minor argillaceous tops. Near bottom 1 or 2 units are capped by oncholitic micrite, possibly diagenetic.

217.5-219.4 m: Fine calcarenite, argillaceous, locally with common small shells. Trace of coral debris.

219.4-221.3 m: Grainstone. Top 60 cm ?-biosparite (1-mm round tests, or ooliths?). Finer sparite below.

221.3-222 m: Variable fine argillaceous calcarenite, locally with poor oncholites, gastropods, shaly interbeds. Irregularly bedded.

222-222.6 m: Grainstone as above; oosparite?

222.6-223.6 m: Relatively uniform fine argillaceous calcarenite; burrowed near top.

223.6-224.2 m: Grainstone; bioturbated?

224.2-225.7 m: Variable argillaceous fine calcarenite, partly with abundant oncholites, occasionally 3 cm across. Common solitary corals. Bioturbated.

225.7-226.1 m: Thin grainstone, over 15 cm of calcite.

226.1-235.5 m: Mainly fine argillaceous bioturbated calcarenites, commonly lumpy or with irregular oncholites; gastropods; in beds <60 cm thick, occasionally 1 m. Subordinate interbeds of dark grey, irregularly laminated, calcareous shale with very fine skeletal debris, <20 cm thick. Scarcer beds of argillaceous micrite (e.g. 228 m) some with burrow-fills of calcarenite (e.g. 233.4 m); occasionally with 1-mm diameter sub-vertical burrows with paler micrite fill; micrites rarely >20 cm thick. More homogeneous argillaceous calcarenites (grainstones?) dominant in bottom few metres.

233.3 m: Stick- and finger-bryozoa.

235.5-236.5 m: Fine medium-grey grainstone, partly lumpy. Lower half possibly packstone, finer, slightly darker. Top half sparry.

236.5-242.5 m: Interbedded: 1) Variably laminated and banded (partly sub-mm), variably argillaceous micrite/shale, partly wavy, partly lumpy; lamination locally very feint; mainly flat (not crinkly), occasionally graded (238.5 m). 2) Heterogeneous, slightly argillaceous "micrite" (very fine ?-pel-micrite or sparite), partly feintly laminated, commonly with birdseyes and vertical tubes 2 mm across, <5 cm high, with geopetal fill and calcite top (water-escape structures?). 3) Dark grey calcareous mudstone <20 cm thick (one 35-cm thick), unfossiliferous, commonly with micritic burrow fills. Bases locally gradational to underlying "micrite" via shaly micrite conglomerate. Rare oncholite beds <20 cm thick, with argillaceous granular matrix. Vertical sub-mm shaly partings common in "micrite" bands. Rare fenestral fabric on small scale (240.2 m).

242.5-243.1 m: 60-cm fine oosparite.

243.1-246.1: 10-cm bedding-parallel vein at top with shale clasts. Mainly argillaceous burrowed fine calcarenites, variable, <60 cm thick; usually grading up into irregularly laminated, very calcareous shale <10 cm thick; underlain by fine to very fine grainstone (pel-sparite?), usually subordinate, rarely 70 cm thick; varied, grading upwards. Cycles, some incomplete.

246.1-246.7 m: 30-cm conglomerate, ?-oncholitic; over 30 cm of fine grainstone, partly ?-oolitic. Shelter cavities.

246.7-250.3 m: Mainly cyclic units as above 246.1 m, but also with banded argillaceous micrite <15 cm thick, with burrows (tubular, irregular, 5 mm diameter, sub-horizontal) and more distinctly laminated shales <5 cm thick -both subordinate. Heterogeneous unit (as above).

250.3-252.3 m: Varied unit, including 45-cm unfossiliferous calcareous shale (not irregularly laminated as above); thin argillaceous micrites with birdseyes or vertical tubes; rare stromatolites; subordinate lithologies as above. Thick burrows locally.

251.2 m: stromatolite, consisting of 10 cm of fine, wavy laminated grainstone and very fine limestone, with local relief of 3 cm.

251.45 m: 45 cm of well banded to thinly bedded micrite distinctly interbedded with dark grey unfossiliferous shale.

252.3-252.9 m: 60-cm grainstone, mainly fine, conglomeratic near top, with shelter cavities and birdeyes.

252.9-253.9 m: Calcareous mudstone, finely and distinctly interlaminated in top 30 cm with sub-mm limestone including fine grainstone; rest burrowed (mainly 'lozenge' type).

253.9-255.8 m: 1.9 m of relatively uniform, slightly argillaceous ?-pel-sparite or -micrite, medium grey, locally with small vertical birdseyes; scattered stylolites. Slightly variable mud content.

255.8-259.8 m: Mainly very fine, moderately argillaceous, bioturbated limestone in beds <50 cm thick; locally these grade up into homogeneous very fine calcarenite as above, <50 cm thick. 40 cm at top is feintly, very finely laminated, calcareous shale/limestone. One 10-cm shelly bed. Occasional very disturbed, mixed-lithology zones (20 cm at 258.2 m). Exposure surface?

259.8-260.3 m: 50-cm weakly laminated fine grainstone.

260.3-261.15 m: Thinly bedded micrite/shale, over irregularly banded ?-pelmicrite/-sparite, possibly stromatolitic.

261.15-262.6 m: Light grey, very fine calcarenite, probably pel-sparite or -micrite. Poor sub-vertical birdseyes locally.

262.6-263.5 m: Mainly very calcareous mudstone with feint, very fine lamination. Top 30 cm very fine calcarenite, partly burrowed.

263.5-264.5 m: 30-cm grainstone, porous, alterred; overlain by very fine calcarenite (pel-sparite?) as above, homogeneous. Upper part of grainstone with lath-shaped crystals, possibly calcite after gypsum.

264.5-265.7 m: Variable argillaceous micrite, laminated shale/micrite, very fine ?-pelsparite, and mudstone with pyritic micrite bands.

265.7-266.9 m: Relatively uniform ?-pel-sparite or -micrite; mainly conglomeratic micrite in bottom 30 cm. Light grey.

266.9-268.3 m: Calcareous mudstone, mainly very finely laminated in top half; partly banded below with burrowing near bottom, and conglomeratic micrite in bottom 5 cm.

268.3-270 m: Light grey, very fine calcarenite, probably pel-sparite or -micrite; homogeneous in top half. Varied, partly laminated, partly birdseye, in lower half, with stylolitic partings.

270-270.9 m: Calcareous mudstone; very finely laminated in top 35 cm, burrowed below, increasingly serverely downwards.

270.9-274.8 m: Mainly light grey, homogeneous very fine calcarenite, probably pelsparite/-micrite, with occasional stylolites; occasionally >1 m thick. One 20-cm mudstone with micrite lenses with pyrite. Very rare vertical birdseyes.

273.5 m: 8-cm vein/shale complex, parallel to bedding.

274.4 m: 20 cm with blotchy, very irregular alteration to white calcite, *possibly* caliche.

274.8-275.3 m: 50-cm argillaceous fine calcarenite. Shaly partings. Small oncholites locally.

275.3-276.3 m: Calcareous mudstone. Burrowed ('lozenge' type) except bottom 30 cm, but with remnant lamination. Bottom interbedded with pel-micrite(?).

276.3-276.7 m: 40 cm of ?-pelsparite.

276.7-277.2 m: 50 cm mudstone, weakly laminated and irregularly banded.

277.2-278.8 m: Mainly light to medium grey ?-pel-sparite or - micrite. Locally feintly laminated. Locally with blotchy alteration.

278.8-279.5 m: Slightly argillaceous very fine calcarenite, possibly pel-sparite/ -micrite. Grades down to calcareous shale, 20 cm thick, unfossiliferous.

279.5-280.3 m: Fine dolomite with shale interbeds, locally lozenge-burrowed. Dolomite vein.

280.3-281.2 m: Mainly very fine, light grey ?pel-sparite/-micrite. Uniform beds <30 cm thick. Very finely laminated calcareous shale, 10-cm thick, at base; this drapes underlying irregular contact and includes clasts of argillaceous micrite 5 mm across, presumably derived from below.

281.2-281.75 m: 55 cm of very irregularly banded and conglomeratic, thinly bedded, argillaceous micrite and minor shale <5 cm thick. One 8-cm bed of polymict limestone conglomerate; clasts mainly argillaceous micrite .5-1 cm across. Thinner conglomerates

also present. Top 12-15 cm: irregularly wavy-banded argillaceous micrite, partly conglomeratic, with tilted bands or slabs >3 cm long, giving local relief at top contact of 2-3 cm.

281.75-284 m: Nearly homogeneous, light grey, very fine calcarenite, as above; pel-sparite/-micrite? Scattered stylolites. Weakly laminated in bottom 30 cm.

284-285.1 m: Fine argillaceous calcarenite with dispersed very fine skeletal debris. Common oncholites, locally well formed, >1 cm across. Steep dolomite vein at base.

285.1-285.5 m: 30-cm fine grainstone, partly laminated; underlain by 10-cm calcareous shale with clasts of underlying bed at bottom, <1.5 cm across.

285.5-286.7 m: ?-Pelsparite, light grey in bottom half, slightly argillaceous above.

286.7-287.2 m: Mudstone with interlaminated micrite near top, dolomitized in lower half.

287.2-293.8 m: Dolomite, medium grey, medium crystalline, locally vuggy and veined, locally zebra-striped, locally with remnant fine lamination, stylolites, shaly partings <1 cm thick. Some brecciation near top. No obvious large fault and no significant lithological change below.

293.8-295.7 m: Variably laminated and irregularly banded micrite and related lithologies (very fine pelsparite?). Some very finely laminated micrite/shale (sub-mm); common feintly laminated argillaceous micrite; some wavy to crinkly laminated micrite/argillaceous micrite; lamination locally interrupted by sub-vertical zones/fissures. Rare homogeneous micrite <20 cm thick with rare small vertical birdseyes.

295.7-300.8 m: Varied dolomite with common remnant textures: laminated shale/dolomite <5 cm thick; burrowed argillaceous dolomite; occasional very fine lamination. Scattered veins and vugs. Lithology generally similar throughout.

297 m: calcite and dolomite vein breccia, possible fault.

300.8-302.6 m: Mainly slightly argillaceous micrite with sub-mm shaly laminae, or thin stylolites, locally developed into "conglomerate". Lamination locally crinkly. Top half generally thicker banded with scattered stylolites; plain micrite. Bottom 15 cm: shale with graded fine to very fine dolarenite.

302.6-303.1 m: Dolomite, as above.

303.1-305.3 m: Argillaceous micrite, locally feintly very finely laminated. 304.5 m: 30-cm calcareous mudstone, locally burrowed. Underlain by 10-cm fenestral micrite. Underlain by irregularly banded (bands <1 cm) micrite, partly conglomeratic.

305.3-307.4 m: Finely crystalline, medium grey dolomite, locally with remnant scattered sub-mm shale partings and stylolites. Locally zebra-striped and vuggy. Rare remnant fenestrae (?).

307.4-308 m: Finely laminated and banded non-calcareous mudstone with occasional thin dolarenites, rare burrows.

308-309.5 m: Varied dolomite, partly with remnant stylolites; much as above.

309.5-310.3 m: Argillaceous micrite grading to laminated mudstone; all dolomitized.

310.3-313.7 m: Medium grey, fine dolomite with scattered dolomite veins. Occasional stylolites; almost no remnant sedimentary fabric. One 15-cm dolomitized banded mudstone/dolarenite.

313.7-314 m: Argillaceous micrite, partly laminated, with subordinate shale. Dolomitized.

314-317.7 m: Dolomite, much as above. Massive and weathered near fault. Mainly with scattered stylolitic shaly partings. Locally remnant very fine shale laminae. Alternates: a) massive paler dolomite with very scattered stylolites and locally zebra dolomite, and b) dark dolomite with abundant remnant lamination, commonly with very fine detail. May

reflect original lithological differences. Pale dolomite type in beds >1 m thick. Darker dolomite beds 20 cm to >1 m thick, heterogeneous.

317.7-318.2 m: 50-cm finely laminated micrite/shale with ?-water escape dykes. Limestone.

318.2-320.4 m: Massive pale dolomite.

320.4-321 m: Mainly dolomitized micrite. Very fine lamination; shalier near base.

321-322.3 m: Massive pale dolomite, as above. Incipient zebra stripes locally.

322.3-324.3 m: Top 1.15 m irregularly banded and "clotted" micrite/calcareous shale. Underlain by 10-cm shale above 5-cm bedding-parallel vein. Underlain by 50-cm micrite and fenestral micrite, with steep birdseyes (rootlets?) near top. Bottom 20 cm laminated micrite with thin stylolites and blotchy alteration.

324.3-325.9 m: Pale massive dolomite, as above; locally medium crystalline. Grades down to limestone.

325.9-327.3 m: Varied slightly argillaceous micrite and ?-pel-micrite. Locally fenestral, locally very finely laminated with shaly partings; minor "real" micrite with birdeyes. Partly "granular", possibly intra-micrite or -sparite. Much less shale lamination than in higher units.

327.3-475.5 m: Crosspatrick Formation

327.3-330.4 m: Massive oolite, partly bleached; fine to medium grained. Slightly argillaceous in top 20 cm.

330.4-333.7 m: Light grey massive dolomite, locally vuggy. No remnant sedimentary fabric. *Possibly* ex-oolite.

333.7-334.6 m: Light grey, poorly sorted oolite, massive. May be slightly altered.

334.6-335.1 m: Dolomite, as above.

335.1-335.7 m: Dolomitized oolite, with calcite veins dipping c.75°CN.

335.7-347.7 m: Light to medium grey, massive dolomite, rarely with remnant sedimentary fabric. Partly weathered in top one-third. Locally vuggy in bottom 2 m. Could be former calcarenite/oolite.

347.7-370.7 m: Medium grey, fine to medium calcarenite (grainstone, possibly coated-grain biosparite or intrasparite), massive. Scattered fine stylolites. Some variation in grain size and colour, but bedding obscure. No shales or other interbeds. Narrow-corallite Syringopora quite common in lower half. Rare solitary corals. Gastropods in bottom 20 cm.

370.7-403 m: Gradationally interbedded: a) medium grey, fine to medium grainstones (generally more obviously fossiliferous than above) in beds mainly <1 m thick, occasionally >1.5 m; and b) darker grey more fossiliferous calcarenites, mainly <1 m thick. Latter with notably dispersed crinoid ossicles, mainly <3 mm across, occasionally 7 mm, in a much finer, slightly argillaceous calcarenite matrix. This matrix also contains isolated ?-clasts of pale limestone, some with stylolitic margins, typically c.5 cm across. Scattered narrow-corallite Syringopora colonies, mainly in paler beds. Bedding obscure. Thin stylolites with various orientations. Paler limestone becomes less common downwards; predominates in top 10 m. Base not well defined.

403-428.4 m: Varied, moderately dark grey, crinoidal calcarenites, generally similar to dark interbeds above. Mainly relatively dark, with dispersed crinoid ossicles, as above. Diffusely nodular, paler, less crinoidal lumps and interbeds, generally grainstones (probably also as above, but not as thick beds); local intrasparites. Common bedding-parallel calcite veins with calcareous black very fine material at margins or centre, with

sharp crystal penetration, c.397-419 m. Irregular bioturbation common in finer limestone. Scattered solution drapes. Sharp base at lowest argillaceous, nodular bed.
419.2 m: 10-cm calcite vein parallel to bedding.

428.4-448.2 m: Mainly light grey, medium biosparite with abundant stylolites in various orientations. Crinoid debris mainly dispersed and not very abundant (at hand specimen level). No shale interbeds. Increasingly homogeneous downwards. Bedding obscure. "Massive" except for stylolites.

448.2-466 m: Generally as above, but with large crinoid ossicles common in most beds. Pale grey; with abundant stylolites. Bedding obscure. Intermittent dolomite in bottom 3 m.
451 m: 5-cm dark green-grey hard "silt", probably tuff.
453.7 m: ossicles 1.4 cm across. Generally >5 mm.

466-475.5 m: Pale grey vuggy dolomite with remnant stylolitic partings and crinoid ossicles. Formerly as above. Locally weathered.

475.5-636.7 m: Waulsortian Reef

475.5-484.3 m: Dolomitized stromatactis reef. Locally banded, with stylolites and crinoids.

484.3-491.4 m: Pale grey massive dolomite. Occasional remnant banding, stylolites and crinoid ossicles. Probably ex-biomicrite beds.

491.4-497.9 m: Dolomitized stromatactis reef.

497.9-500.3 m: Massive pale dolomite, as above.

500.3-597.5 m: Mottled reef dolomite, locally vuggy, with remnant stromatactis. Dark grey geopetals below 522.6 m. Usual fabric variation, locally including probable bryozoa beds, and large (former) fibrous calcite systems (e.g. 524 m). Preferred orientation of stromatactis c.30°CN. (N.B. 40 m omitted from graphic log.)
551.2 m: cross-cutting vein dolomite.

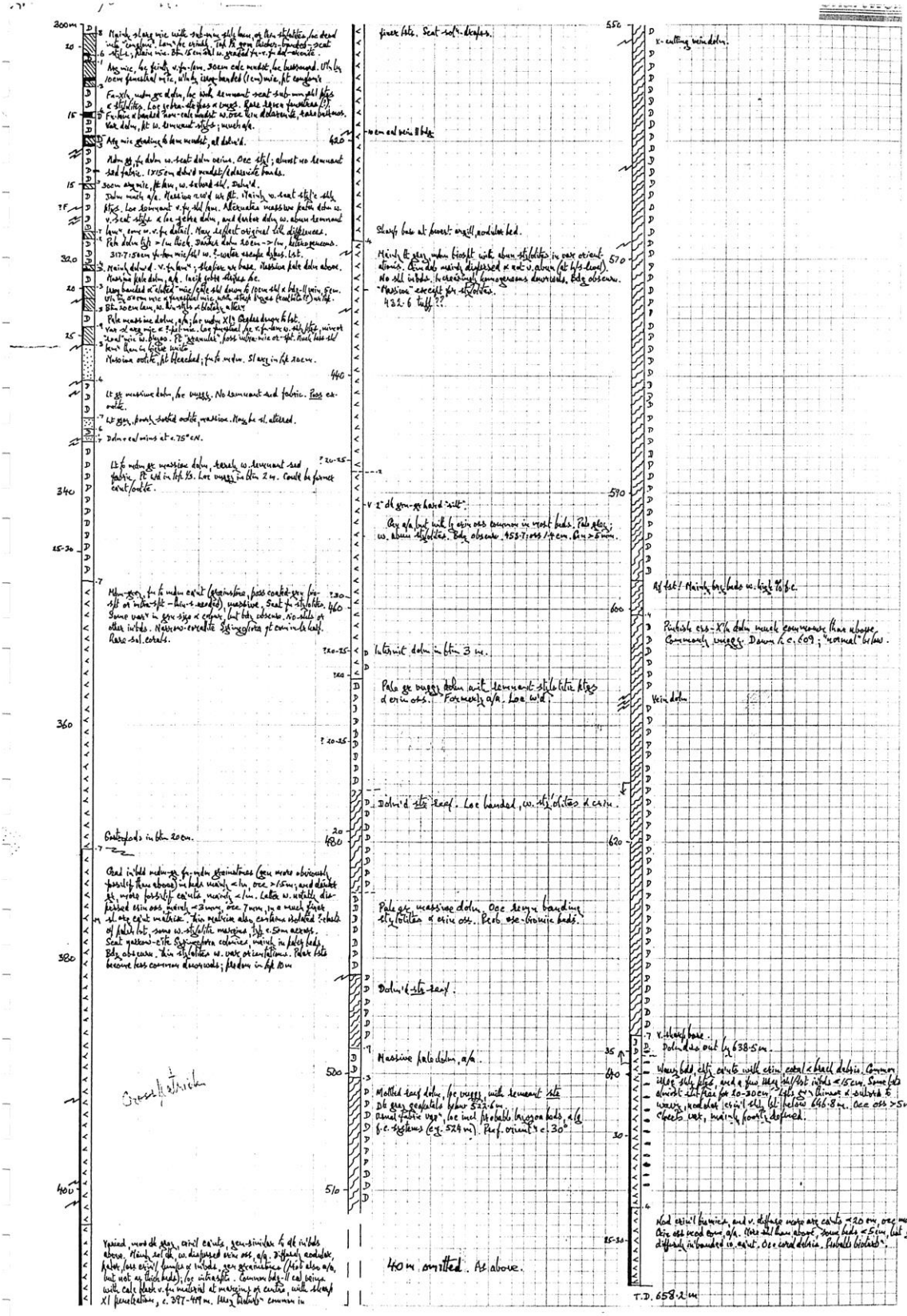
597.5-600.4 m: Reef limestone. Mainly bryozoa beds with high % fibrous calcite.

600.4-636.7 m: Dolomitized reef, much as above. Pinkish coarsely crystalline dolomite much commoner than above, commonly vuggy; down to c.609 m. "Normal" below that.

636.7-658.2 m (T.D.): Ballysteen Limestone

636.7-651.4 m: Wavy bedded, cherty calcarenites with crinoid, coral and brachiopod debris. Common irregular shaly partings, and a few irregular shale/limestone interbeds <15 cm thick. Some limestones almost shale free for 20-30 cm. Limestones generally thinner and subordinate to wavy nodular crinoidal shaly limestone below 646.8 m. Occasional ossicles >5 mm across. Cherts variable, mainly poorly defined. Dolomite dies out by 638.5 m.

651.4-658.2 m (T.D.): Nodular crinoidal biomicrites, and very diffuse more argillaceous calcarenites <20 cm thick, occasionally more. Crinoid ossicles moderately common, as above. More shale than above, some beds <5 cm thick, but generally diffusely interbanded with calcarenite. Occasional coral debris. Probable bioturbation.


T.D. 658·2 m.
40 m. omitted. As above.

Appendix 4: Log of core GSI-91-25 (Milford, Co. Carlow)

The following log is a slightly edited version of the notes accompanying the 1":10 m graphic log. It should be noted that the transcription does not give information that is shown in graphic form, such as dip readings, gradational contacts, relative mud content, distribution of corals, etc. Sand grade sizes are guessed, not measured. Where single depths are used to identify a bed or unit, the depth refers to the top contact. Structures referred to in the log as 'lozenge burrows' are eye-shaped, usually dark, sub-horizontal burrow-fills c.2-4 mm long, which are probably *Chondrites.*

0-8.4 m: Overburden

8.4-20 m: Ballyadams Formation

Interbedded fine and medium ?-pelsparite (possibly oosparite), medium grey, commonly with abundant small brachiopods and shell debris. Some beds grade up from shelly "conglomerates" to fine ?-pelsparites in units <1 m thick, occasionally with slightly argillaceous, very fine calcarenite in top 10 cm. Scattered large stylolites. Base gradational by interbedding through c.2 m.

20-117.7: Durrow Formation

20-47 m: Mainly moderately dark to medium grey, fine calcarenites, variably argillaceous; graded beds common: fine-grained medium grey ?-oobiosparites (possibly pelsparite or both) grading up into thicker argillaceous bioturbated skeletal calcarenite, locally with burrows (poorly outlined 'lozenge' type). Beds typically 30 cm to 1 m thick, some with very argillaceous calcisiltite caps 5-10 cm thick. Widely scattered shell beds 5-10 cm thick; debris and small round shells. Beds commonly homogeneous for <60 cm; elsewhere diffusely banded on grain size or argillaceous content. Black shale confined to rare bed tops c.1 cm thick. Grading not always complete and occasionally seems reversed. Occasional sharop stylolitic contacts.

Various special beds. 28.7 m: ?-thrombolite with rare serpulids or encrusting forams, forming bioherm 4-5 cm high with steep margins and sharp top; overlies a fine limestone conglomerate of coated large intraclasts.

31.9 m: columnar stromatolite with relief of c.10 cm, surrounded by coarse irregular fenestral limestone, possibly a conglomerate. Vertical calcite-filled tubes 2-3 mm across at margin of stromatolite. Immediately underlain by irregular fine conglomerate with small oncholites and gastropods, with calcite-filled irregular cavities. Scattered beds of mottled very fine calcarenite with sub-vertical tubes (burrows?) 2-3 mm across, locally with geopetal fill, mainly with calcite. Associated with gastropods, some in rich shell beds; e.g. c.26-28 m, 33-33.6 m. Not seen below that.

47-62.4 m: Below c.47 m the dark argillaceous tops to graded beds tend to be slightly thicker: 15-20 cm, one 35 cm (52.6 m). Argillaceous very fine calcarenites as above, without "exotics". Obvious ?-pelsparites rare. Colour more uniformly moderately dark than in overlying unit.

49.4 m: 5-cm ?-thrombolite.

52.6 m: 35-cm dark calcareous shale with pale, graded bands, almost unfossiliferous.

54 m: Syringopora with small-diameter, "loose" corallites.

54.5 m: Syringopora, very compact 10-cm colony.

61.4 m: 20-cm shale, as at 52.6 m.

62.4-65.5 m: Medium grey very fine ?-pelsparite, uniform. Wavy stylolitic partings locally. Rare argillaceous ?-burrowed partings <5 mm thick. Top 40 cm fenestral. Locally mottled with vertical tubes (as at 33-33.6 m).

65.5-74.2 m: Mainly fine, moderately argillaceous calcarenites, weakly burrow-mottled; with subordinate interbeds of ?-pelsparite, locally with small oncholites. Much as above 47 m. Occasional very calcareous shale, one 30 cm thick, as at 52.6 m. Graded beds, some >1 m thick.
67 m: 60-cm fenestral micrite.

74.2-83.9 m: Moderately light grey, fine to medium calcarenite, commonly laminated (grain size variation), locally shelly. Bedding poorly defined. Locally conglomeratic. Bottom 1.6 m (approx.) dolomitized, but lamination preserved.

83.9-117.7 m: Predominantly fine to very fine, medium grey calcarenite, probably mainly pelbiosparite. Poorly defined beds, commonly >50 cm thick. scattered more argillaceous interbeds <5 cm thick; thicker (<20 cm) below c.108 m. Almost no shale, except in stylolitic partings. Small brachiopods common in diffuse bands <10 cm thick. Common stylolites. Top 3 m and bottom 10 m slightly darker overall. Unit generally less argillaceous than most above 74.2 m (but not top one). Rare nodular beds with sparse birdseyes, probably very fine pel-sparite or -micrite; not micrite. Rare isolated ?-Lithostrotion [Siphonodendron] corallites.

Below c.110 m, beds become slightly more differentiated: more distinct argillaceous interbeds, and paler very fine calcarenites (?-pelsparite) 10-40 cm thick, some with subvertical birdeyes (sparse). These ?-pelsparites similar to beds in underlying unit. Contact is transitional in having lithologies common to both units. Base is sharp top of highest relatively uniform pale ?-pelsparite >50 cm thick. Could have been placed 95 cm lower at top of micrite.

117.7-275 m: <u>Aghmacart Formation</u>

117.7-143.1 m: Varied succession dominated by light grey, fine to very fine ?-pelsparite (and possibly fine oolite) in beds commonly >40 cm thick. Some homogeneous, but usually banded on grain size or thin shale partings or abundant stylolites. Maximum thickness 1 m. Subordinate moderately dark grey calcareous mudstone, variable, grading to argillaceous pelloidal calcarenite. Bed contacts gradational to sharp. Scattered dark grey calcareous mudstone <5 cm thick, distinct. Micrite very subordinate, in beds <10 cm thick, often interlaminated with shale; occasionally as slabs 1 cm thick in shaly matrix. Oncholites <1.5 cm across, rare. Highest micrite at 118.7 m: with irregular stylolites; partly as stylolitic breccia. Mottled, slightly argillaceous ?-pelsparite with subvertical tubes, in beds 5-10 cm thick, uncommonly bioturbated -- by plants? This texture on finer scale than in unit above 47 m. Burrow-mottling and 1-mm well defined tubes also present in argillaceous beds, rarely. Rare disorganized conglomerate <5 cm thick, possibly stromatolites. Birdseye micrite rare and not well developed; some as irregular lumps in argillaceous matrix. Intermediate lithologies common, especially argillaceous pel-?sparite; occasional very fine lamination (e.g. 20 cm at 125.1 m). Some well sorted pel/oo?-sparite with small (5 mm) lumps, possibly oncholites (as in overlying unit). Scattered thin (15 cm) dolomites, occasionally 60 cm thick.
141.8 m: Dense colony of ?-serpulids 40 cm thick.

143.1-145.7 m: Dark grey ?-argillaceous dolomite, much of it mottled (bioturbated?); overlies 1 m of paler dolomite, probably ex-pelsparite.

145.7-149.4 m: As above, with relatively common micrite.
148.3 m: 80-cm micrite and ?-serpulid bed.

149.4-158.5 m: Varied medium to moderately dark grey dolomite; good preservation of sedimentary fabric. Looks much like overlying beds. Slightly darker overall, possibly due only to dolomitization.

Wide range of lithologies, including argillaceous very fine dolomite; fine ?-pelsparite; thin beds of dark mudstone <10 cm thick; mottled fine dolomite, probably partly bioturbated, some ?-stromatolitic; rarely very finely laminated and slightly crenulate, probably stromatolitic, and associated with irregular breccia, possibly evaporitic (152.6 m for 15 cm); occasionally highly irregular mottled dolomite with incipient cavities and geopetal fills: ?-stromatolitic "cauliflowers" (e.g. 156 m for 20 cm). Minor probable ex-micrite.

158.5-166.1 m: Moderately dark to dark grey, very fine dolomite, presumably ex-calcareous shale. Locally secondary brecciation with calcite cement over minor geopetal sediment. Dolomite mainly homogeneous, locally finely laminated and arched, possibly stromatolitic. Locally ?-silty. Disturbed bedding and lithological variation survive dolomitization locally. Similar dolomite common below, in thinner units.

166.1-167 m: 20-cm evaporite-replacement bed with very small white dolomite nodules (2-5 mm). Underlain by 25 cm of very finely laminated dolomite. Underlain by 50 cm of stromatolitic ÒcauliflowersÓ with ?-serpulids.

167-174 m: Mainly dolomitized calcareous mudstone and very fine argillaceous limestone, locally probably ex-micrite. Partly mottled (bioturbation?), partly very finely laminated, partly homogeneous. Mainly gradational bedding. Mainly moderately dark grey; occasionally dark grey for 30 cm. Less variation than above 158.5 m.

174-194 m: Relatively well differentiated dolomitized mudstones and very fine ?-pelsparites and argillaceous micrite, etc. Heterogeneous mudstones <80 cm thick, including paler bioturbated beds and occasional ?-serpulids; locally with very fine lamination. Mudstones scarcer below 183 m. Moderately light grey ?-pelsparites predominate in top 3 m, <60 cm thick. Below 183 m bedding generally thinner and intermediate lithologies predominate. Unit also includes scattered highly disturbed beds, probably of various origins: some possibly stromatolitic, some possibly related to dolomitization or evaporite replacement, especially in bottom 2 m. Distinct burrow-mottling in some intermediate lithologies. Unit not very different from above, except in proportions.

178.7 m: very fine (sub-mm) ?-serpulids, abundant.

185 m: 15-cm stromatolite.

Below c.190 m: A few white crystalline dolomite veins and hollow nodules <10 cm across. Micrite commoner towards base; some variably interlaminated with shale (all dolomitized); some conglomeratic.

194-223.3 m: Medium to fine dolomite, some in graded beds <80 cm thick; medium to moderately dark grey. Beds more argillaceous near tops, locally burrowed. No shales. Occasional dis-micrite (dolomitized) in fractured or brecciated beds (e.g. 197.2 m for 30 cm). Evaporite-replacement nodules and vugs <5 cm across quite common. Succession generally more uniform than above, but considerable variation in colour and grain size. Few "exotics": occasional breccia, apparently related to dolomitization.

207.5 m: coarse oosparite.

209.8 m: 20-cm fenestral ?-pelsparite.

211.2-212.8 m: Moderately light, yellow-grey dolomicrite, 1.6 m thick.

216.3-220.1 m: Darker, medium-grained ?-oosparite, uniform. Abundant fine veins in lower half; strongly brecciated in bottom 40 cm (diagenetic?).

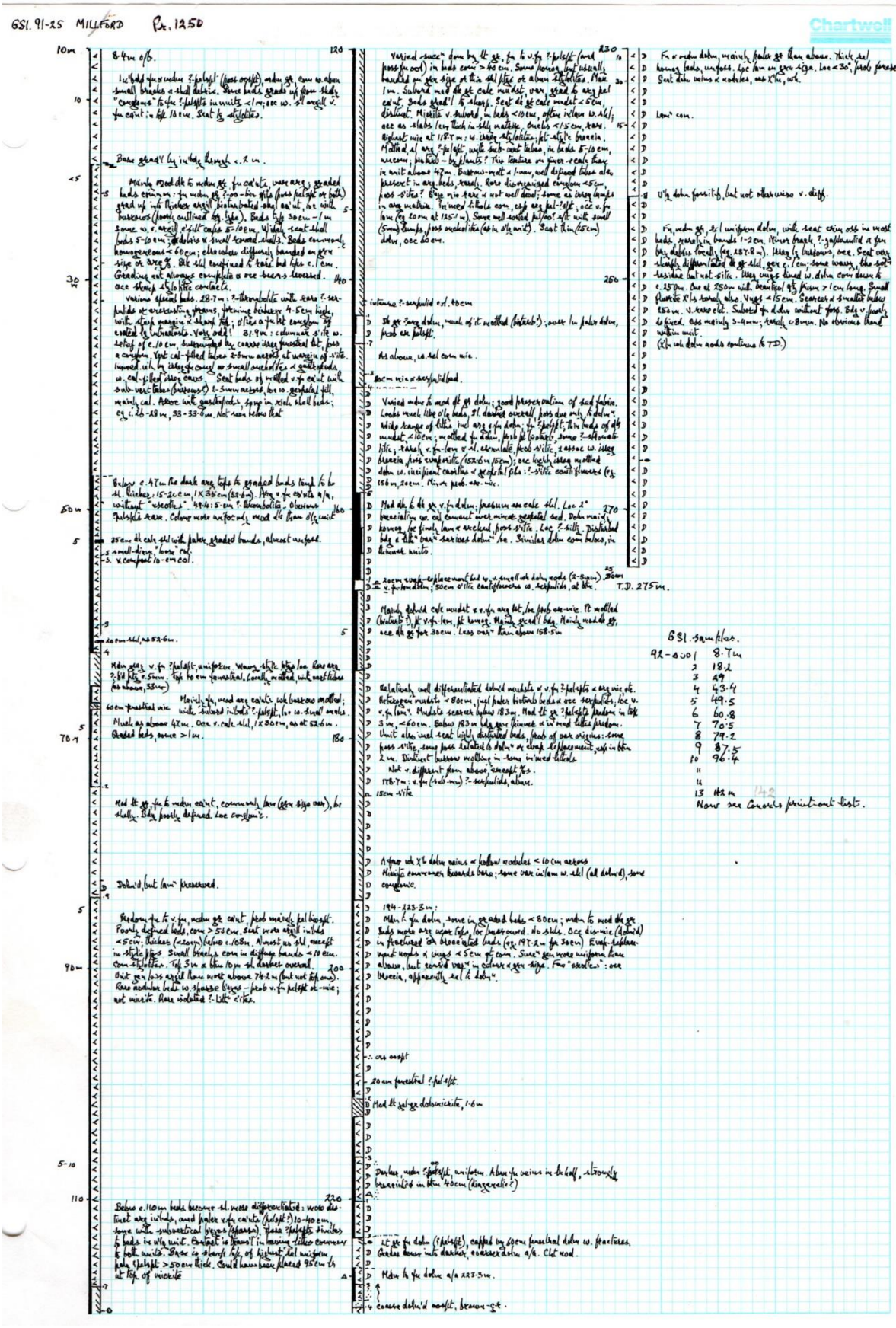
223.3-226 m: Light grey fine dolomite (?-pelsparite), capped by 60 cm of fenestral dolomite with fractures. Grades down into darker, coarser dolomite, as above. Chert nodule.

226-227.3 m: Medium to fine dolomite, as above 223.3 m.

227.3-229.4 m: Coarse, dolomitized oosparite, brown-grey.

229.4-242.8 m: Fine and medium dolomite, mainly paler grey than above. Thick, relatively homogeneous beds, unfossiliferous. Locally laminated on grain size. Dip locally <30¡, probably foresets. Scattered dolomite veins and nodules, coarsely crystalline, white.
c.235 m: Lamination common.
Dolomite in underlying unit fossiliferous but not otherwise very different.

242.8-275 m (T.D.): Fine, medium grey, relatively uniform dolomite, with scattered crinoid ossicles in most beds, rarely in bands 1-2 cm thick. Minor brachiopod,
?-zaphrentid and fenestrate bryozoan debris locally (e.g. 257.8 m). Irregular large burrows, occasional. Scattered very sharply differentiated dark grey shale, generally c.1 cm thick; some wavy, like solution residue but not stromatolitic. Irregular vugs lined with dolomite common down to c.250 m. One at 250 m with quartz prisms >1 cm long. Small fluorite crystals rarely also. Vugs <15 cm across. Scarcer and smaller below 250 m. Very rare chert. Subordinate fine dolomite without fossils. Bedding very poorly defined. Ossicles mainly 3-4 mm across; rarely c.8 mm. No obvious trend within unit. (Crystalline white dolomite nodules continue to T.D.)


GSI. 91-25 MILLFORD Rx. 1250
Chartwell
GSI. 91-25 Millford
91-25 001 8·7m
2 18·2
3 29
4 43·4
5 49·5
6 60·8
7 70·5
8 79·2
9 87·5
10 96·4
11
12
13 142 m
Now see Cornels faunal-unit list.

Appendix 5: Log of core GSI-89-10 (Tankardstown)

The following log is a slightly edited version of the notes accompanying the 1":10 m graphic log. It should be noted that the transcription does not give information that is shown in graphic form, such as dip readings, gradational contacts, relative mud content, distribution of corals, etc. Sand grade sizes are guessed, not measured. Where single depths are used to identify a bed or unit, the depth refers to the top contact. Structures referred to in the log as 'lozenge burrows' are eye-shaped, usually dark, sub-horizontal burrow-fills c.2-4 mm long, which are probably *Chondrites.*

0-6 m: Overburden

6-145.4 m: Ballyadams Formation

6-35 m: Light and medium grey, fine and medium calcarenite with common brachiopods and various corals, including Siphonodendron. Bedding thick and poorly defined by slightly more argillaceous interbeds <5 cm thick, or stylolites. No chert seen. Siphonodendron mainly with well spread corallites, in loose colonies <10 cm thick, and concentrations of isolated corallites. Scattered small solitary corals and small Syringopora. Small round brachiopods common, and shell debris. Gastropods locally. Some limestones appear graded through 50 cm. Very minor veining parallel to bedding. Limestones seem mainly structureless, possibly bioturbated. Occasional weak burrowing, irregular, in darker beds; e.g. at 21.5 m.

10.6 m: 20-cm Chaetetes colony.

15.5 m: Chaetetes.

35-66.3 m: Very gradual downward change (at top) to uniformly pale grey calcarenite, medium to coarse, in massive to weakly banded beds, with scattered stylolites; no interbeds. Corals uncommon. Brachiopods also fewer and larger than above.

66.3-69.8 m: Moderately dark grey, variable calcarenite, fine to coarse, with abundant brachiopod debris and various shells, some large, some thick, some small and round. Occasional corals. Scattered argillaceous partings; no shale. Rare calcisiltites with burrows, <5 cm thick.

69.8-79 m: Mainly light grey, medium to coarse calcarenite, much as above 66.3 m, but more varied. Probably mainly recrystallized biosparite. Rare argillaceous partings. Scattered brachiopods; rare or no corals.

79-94.8 m: Medium to moderately dark grey, varied calcarenites, commonly fine. Bed contacts diffuse or stylolitic. Beds poorly defined; e.g. with irregular diffuse bands of coarse debris in generally fine calcarenite. Beds typically <60 cm thick. Coarser beds with abundant shell debris, occasional corals and gastropods. Rare calcisiltites <5 cm thick, weakly burrowed. Very rare shaly beds <1 cm thick, possibly stylolitic. A few beds slightly argillaceous, with very fine shaly-stylolitic seams. Scattered thick-shelled brachiopods, occasionally in thin bands.

93.5-94.3 m: Darker bed, fine, possibly oolitic (definitely rounded-grain sparite).

94.8-114 m: Limestone much as above, including pelsparite, but generally somewhat more argillaceous. Light to medium grey, fine to medium, with subordinate more argillaceous interbeds <10 cm thick. Concentrated Siphonodendron colonies common, mainly <15 cm thick, but rarely 60 cm (at 96.2 m). Isolated corallites and small "loose" colonies also common. Occasional small Syringopora. Brachiopod debris common and varied. Occasional gastropods. Gradual changes in lithology common. Locally "clotted" (98.7 m).

99.3 m: Cerioid Lithostrotion.

111.5 m: Underlying beds slightly more argillaceous and darker, with a few distinct, very calcareous shales <5 cm thick with abundant fine skeletal debris.

114 m: Lowest colony in this sequence, c.10 cm thick.

114-125 m: Limestone much as above, without Siphonodendron colonies. Fine to medium, slightly argillaceous calcarenites with diffuse bed contacts. Mainly with minor brachiopod debris, but occasional beds <70 cm thick where they are abundant.

120 m: 40-cm argillaceous calcisiltite, atypical. Grades up from argillaceous calcarenite below it.

125-136.9 m: Mainly fine, moderately dark grey calcarenite, but c.40% very fossiliferous. Includes brachiopod bands 20-40 cm thick, with common flattened rugose corals and ?-Syringopora fragments. Scattered calcisiltites <80 cm thick with very little visible skeletal debris. Some with slightly more argillaceous tops, but no shales. Unit colour as above. Very gradational base.

135.5 m: Isolated Siphonodendron colony; 10 cm thick.

136.9-145.4 m: Uniform, moderately dark grey, slightly argillaceous, fine to medium calcarenite. Very poorly defined bedding. Similar to some overlying beds. Mainly very fine skeletal debris. Rare thin-shelled brachiopods. Occasional thin shaly stylolitic partings. Sharp bottom contact.

138.2 m: c.80 cm of calcite. ?-small fault. Minor veins above and below.

145.4-172 m (T.D.): <u>Durrow Formation</u>

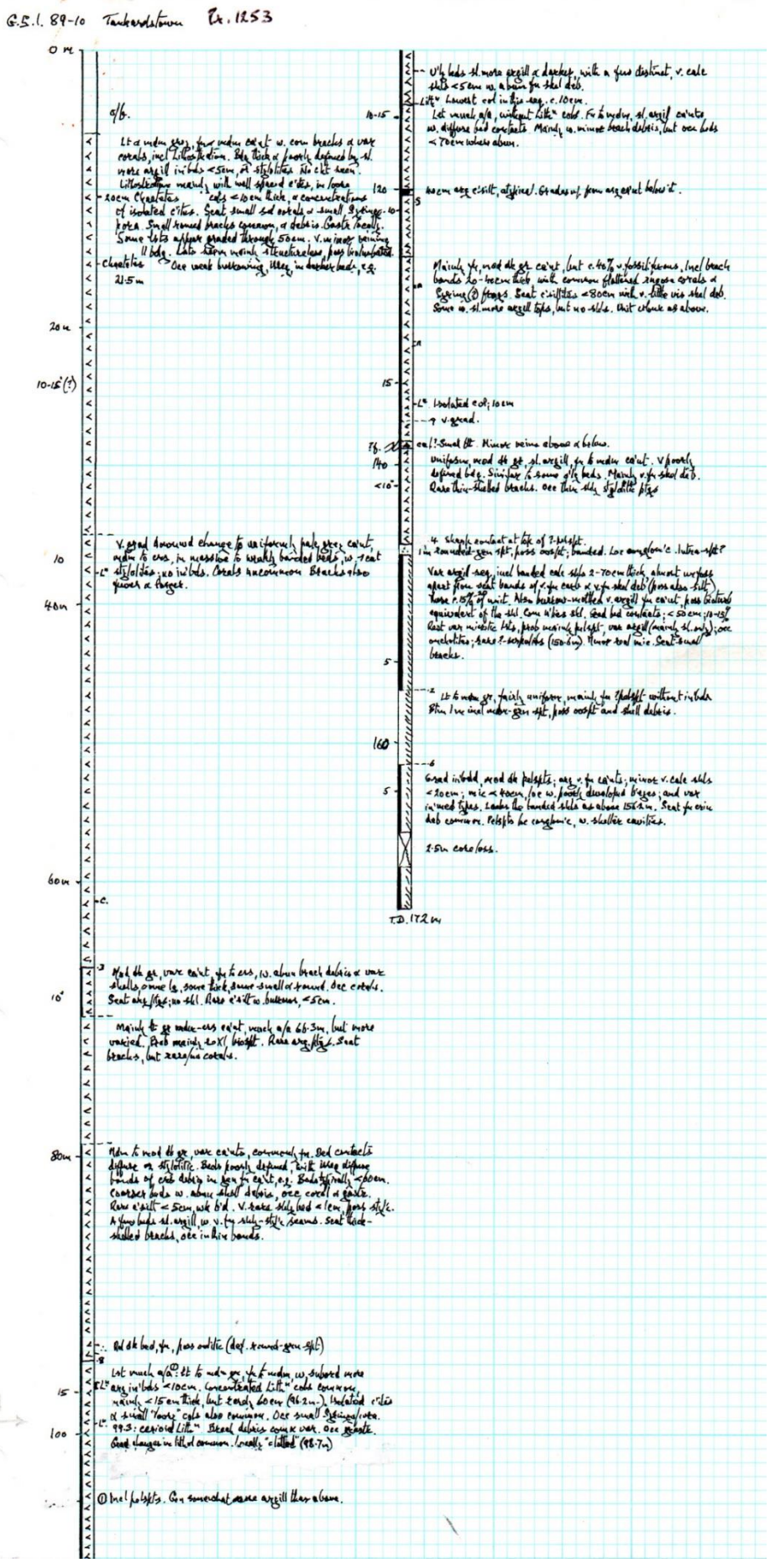
145.4-146.4 m: Rounded grain sparite, possibly oosparite; banded. Locally conglomeratic; intrasparite?

146.4-156.2 m: Varied argillaceous sequence, including banded calcareous shales 2-70 cm thick, almost unfossiliferous apart from scattered bands of very fine carbonate and very fine skeletal debris (possibly also silt). These c.15-20% of unit. Also burrow-mottled very argillaceous fine calcarenite, possibly the bioturbated equivalent of the shale. Commonly underlies shale. Gradational bed contacts; <50 cm thick; 10-15 %. Rest various micritic limestones, probably mainly pelsparite, variably argillaceous (mainly slightly only); occasional oncholites; rare ?-serpulids (150.6 m). Minor real micrite. Scattered small brachiopods.

156.2-161.6 m: Light to medium grey, fairly uniform, mainly fine ?-pelsparite without interbeds. Bottom 1 m includes medium-grained sparite, possibly oosparite, and shell debris.

161.6-172 m (T.D.): Gradationally interbedded, moderately dark pelsparites; argillaceous very fine calcarenites; minor very calcareous shales <20 cm thick; micrite <40 cm thick, locally with poorly developed birdseyes; and various intermediate types. Lacks the banded shales as above 156.2 m. Scattered fine crinoid debris common. Pelsparites locally conglomeratic with shelter cavities.

166.5-169 m: 2.5 m core loss.


G.S.I. 89-10 Tankerdalstown Dr. 1253
0 m
20 m
40m
60m
80m
100
10-15'(?)
10'
15
20
5
10
160
TD. 172 m
a/b.
Lt a mdm grey, v. mdm ea'st w. com branches & vert rootals, incl Lithifikation. Bds thick & feintly defined by sl. more argill in beds <5cm, & stylolites also ea'st seen. Lithifikation mainly with well spaced e'ites, in some cases Characteristics cals <10 cm thick, & concentrations of isolated e'ites. Seat small sd rootals & small 3-string. ss-forms. Small tunnel branches common, & debris Coals locally. Some beds appear graded through 50 cm. V. minor jointing ll bdg. Late stage minor stylolitic release joints unmineralised. Occ weak buttressing effects in thicker beds, e.g. 21·5 m
V. gd downward change to uniformly pale grey, ea'st mdm to crs, in succession to weakly banded beds, w. rare stylolites; no ir beds. Coals uncommon. Branches also fewer & smaller.
Mod dk gy, v. ea'st, ply to crs, w. abun branch debris & vert shells, some lg, some flat, some small & rounded. Occ rootals. Seat arg/fgst; no sltst. Rare c'silt w. buttresses, <5cm.
Mainly lt gy mdm-crs ea'st, much a/a 66·3m, but more varied. Beds mainly 20 cm/ thicker. Rare arg/fg. Seat branches, but rare/no rootals.
Mdm to mod dk gy, vert ea'st, common fm. Sed contacts diffuse or stylolitic. Beds feintly defined, with very diffuse bounds of ext debris in fgm to ea'st, e.g. Beds typically <50cm. Coarser beds w. abun shell debris, occ coroll & gastr. Rare c'silt <5cm, usu blk. V. rare shly bed <1cm, foss, stylic. A few beds sl. argill w. v. fm stub-stylic seams. Seat thick-shelled branches, occ in thin bands.
Mod dk bnd, fm, foss oolitic (def. rounded-grn sph)
Lst: much a/a: lt to mdm gy, ply & mdm w. scattered more ALT arg ir beds <10cm. Concentrated Lith" cals common, mainly <15 cm thick, but to 60 cm (96·2 m). Isolated e'ites & small "loofy" cals also common. Occ small 3-string ss-vns. 99·3: cervioid Lith" Bioclastic debris com & vert. Occ rootals. Good changes in lithd common / locally "clotted" (98·7 m)
Mod fol sh. Gn somewhat more argill than above.
U/lying beds sl. more argill & darker, with a few distinct, v. calc shells <5 cm w. a basin fm shell debris.
Lith" Lowest cal in this seq., c. 10 cm.
Lst mainly a/a, without Lith" cals. Fr to mdm, sl. argill ea'st w. diffuse bed contacts. Mainly w. minor branch debris, but occ beds <70 cm to locally abun.
80 cm arg c'silt, slty/vf. Grades up from arg ea'st below it.
Mainly yk, mod dk gy ea'st, but c. 4 to 7% v. fossiliferous, incl branch bands 20-100 cm thick with common flattened zoogen rootals & 3-string (?) ss-vns. Seat c'silt/sltst <80 cm with v. little vis shell debris. Some w. sl. more argill bds, but no stylics. Unit colour as above.
Isolated cal; 10 cm
? v. gradl.
cal!: Small lft. Minor veins above & below.
Uniform, mod dk gy, sl. argill, fm to mdm ea'st. V. feintly defined bdg. Similar to some g/fg beds. Mainly v. fn shell debris. Rare thin-shelled branches. Occ thin shly stylolitic bands
4. Sharp contact at top of 7-bd sqft.
Var argill-seq, incl banded calc stds 2-70 cm thick, almost wholly apart from seat bands of v. fn calc & v. fn shell debris (more abun locally c. 10% of unit. Mdm brown-weathd v. argill fn ea'st, foss bioturbd equivalent of the std. Com w'bks std. Seat bd contacts; <50 cm; 10-15% least var micritic bds, feebly mainly fsl sqft; one argill (mainly sl. mdy); occ oncolithic; rare ?-scrpulids (150-6 m). Minor tool mic. Seat: small branches.
Lt to mdm gy, faintly uniform, mainly fm 7-bd sqft without ir beds thin / v. incl mdm-grn sqft, foss oosqft and shell debris.
Grad in bdd, mod dk bd sqft; arg & fn ea'st; minor v. calc stds <10 cm; mic & 40 cm, foe w. faintly developed bioges, and var in'med types. Leaves the banded shds as above 154·2 m. Seat fn oric deb common. Pelsp to conglom'c, w. shelter cavities.
1·5 m core loss.

Appendix 6: Log of core BA

The following log is a slightly edited version of the notes accompanying the 1":50 ft graphic log. It should be noted that the transcription does not give information that is shown in graphic form, such as dip readings, gradational contacts, relative mud content, distribution of corals, etc. Sand grade sizes are guessed, not measured. Where single depths are used to identify a bed or unit, the depth refers to the top contact. Structures referred to in the log as 'lozenge burrows' are eye-shaped, usually dark, sub-horizontal burrow-fills c.2-4 mm long, which are probably *Chondrites.*

28-670 ft: Ballysteen Limestone

28-53 ft: Heterogeneous unit of finely laminated, partly burrowed, calcareous siltstone with subordinate silty calcarenite interbeds. Base gradational.

53-214 ft: Relatively uniform unit of thinly bedded crinoidal calcarenite with subordinate shale interbeds. Similar to beds below 119.5 m, but thinner bedded and with more shale interbeds. Occasional interbeds of laminated silty shale <30 cm thick (similar to 109.7-119.5 m).

214-264 ft: Mainly argillaceous, crinoidal calcarenite. Top 5.5 m (214-232 ft) partly oolitic.

264-283 ft: 5.8 m of laminated beds: mainly irregularly laminated, very fine silty calcarenite with interlaminated shale, with varied burrow types. Locally fossiliferous, including fenestrate bryozoa.

283-310 ft: Argillaceous crinoidal calcarenite.

310-360 ft: Oolite unit. Mainly relatively uniform medium-grained oo-biosparite; top 4.6 m and bottom 1.5 m interbanded with biosparite. Two 30-cm beds of interlaminated burrowed shale/siltstone near top, as in unit below.

360-392 ft; 9.8 m of interlaminated, locally burrowed, very fine silty calcarenite and very thin shale bands; sharp top and bottom contacts. One 1.3-m bed of argillaceous calcarenite at 368 ft.

392-670 ft: Relatively uniform, weakly argillaceous, crinoidal calcarenite. Bedding generally thick, poorly defined. Uncommon very thin fossiliferous shale interbeds. Unit thicker bedded and with less shale than in unit 53-214 ft. Base sharp. No Fine Calcarenite Marker recorded.

670-870 ft: Ballymartin Formation

670-750 ft: Calcarenites with high % weakly fossiliferous shaly interbeds, which mainly <12 cm thick, some 30 cm. Thickest shales weakly banded with skeletal debris. Brachiopod debris more common than in overlying unit. Calcarenite bed thickness very variable, <1.3 m. Top of unit sharp, but some beds near top are similar to those above.

772 ft: possible small fault

750-870 ft: As above but beds generally thinner and more nodular bedded. Locally shale-dominant for 1.5 m, especially near bottom. Base sharp.

870-889 ft: Ballyvergin Shale: 60-70% dark, non-calcareous mudstone, unfossiliferous, unlaminated. Interbanded light yellow-grey interbeds of siltstone, mainly <5 mm, occasionally 3 cm, graded or very finely laminated.

889-999 ft: Ringmoylan Shales

889-974 ft: Thinly interbedded mudstone and subordinate laminated siltstone and fine calcarenite mainly <1 cm thick, occasionally <12 cm. Bed contacts mainly gradational. No systematic variation below 896 ft.

889-896 ft: Continuous calcarenite and silty fossiliferous mudstone.

974-978 ft: Coarse crinoidal biosparite with haematite grains.

978-994 ft: Mudstone as above, but sandier at top. Irregularly laminated sandstones <4 cm thick, burrowed.

994-999 ft: Coarse calcarenite with mudstone interbeds.

998 ft: 15-cm coarse crinoidal calcarenite with minor haematite.

999-1099 ft: Mellon House Beds

(dips 15-20°, probably including cross-lamination in some beds)

999-1003 ft: Very sandy fine oolitic calcarenite (oo-biosparite).

1003-1005 ft: Mudstone.

1005-1007 ft: 2-ft dark fine biosparite (oolitic?).

1007-1011 ft: Inter-banded mudstone, calcareous sandstone (dark, muddy), sandy fine calcarenite.

1011-1026 ft: Light grey, medium-grained crinoidal biosparite, rather uniform bed. Scattered stylolites.

1026-1034 ft: Moderately dark, fine oolitic calcarenite. Varies from oosparite to bio-pelsparite. Sandy? Fairly uniform grain size.

1034-1046 ft: Coarse, light grey crinoidal calcarenite. Sharp top and bottom. Weak banding.

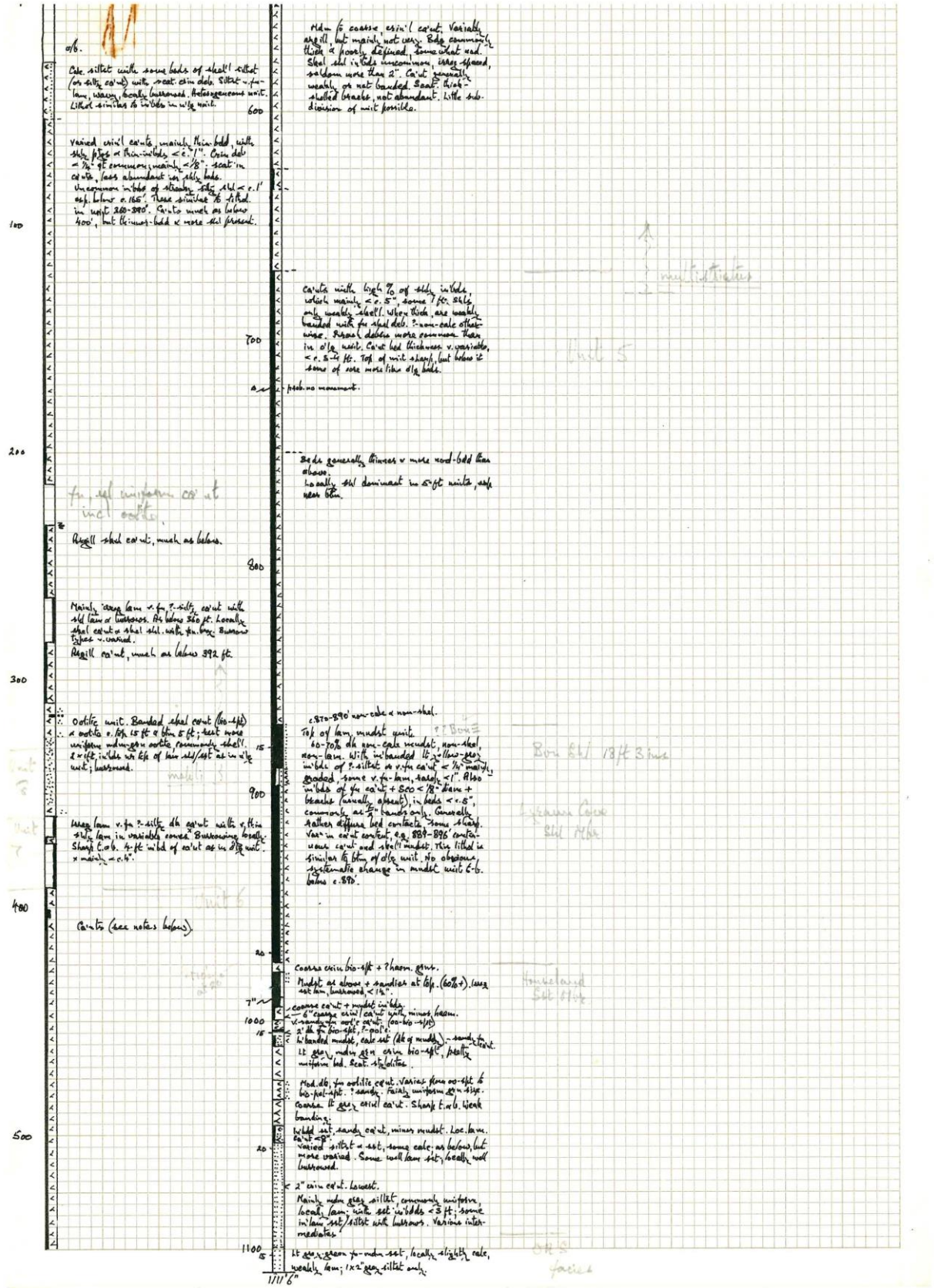
1046-1053 ft: Interbedded sandstone, sandy calcarenite and minor mudstone. Locally laminated calcarenite <20 cm thick.

1053-c.1075 ft: Varied siltstone and sandstone, some calcareous; as below 1075 ft, but more varied. Some well laminated sandstone; locally well burrowed. Base gradational.

1073 ft: 5-cm crinoidal calcarenite (the lowest).

c.1075-1099 ft: Mainly medium grey siltstone, commonly uniform, locally laminated; with sandstone interbeds <1 m thick; some interlaminated siltstone/sandstone with burrows. Various intermediates. Base gradational.

1099-1111.5 ft: ORS: Light grey-green, fine to medium sandstone, locally slightly calcareous, weakly laminated; 1 x 5-cm grey siltstone.


A1
100
200
300
400
500
600
700
800
900
1000
1100
1111'6"

Appendix 7: Log of core 68-KK-12

The following log is a slightly edited version of the notes accompanying the 1":10 m graphic log. It should be noted that the transcription does not give information that is shown in graphic form, such as dip readings, gradational contacts, relative mud content, distribution of corals, etc. Sand grade sizes are guessed, not measured. Where single depths are used to identify a bed or unit, the depth refers to the top contact. Structures referred to in the log as 'lozenge burrows' are eye-shaped, usually dark, sub-horizontal burrow-fills c.2-4 mm long, which are probably *Chondrites.*

0 - ? m: overburden.

? - 112 m: Waulsortian reef, dolomitized; "core" facies (see text for details).

112-144.5 m: Reef-base Transition

112-115.6 m: Thinly bedded crinoidal dolomite with shaly partings; reefal. Ossicles commonly 1 cm across. Dolomite dies out below top 2-3 m. Underlain by nodular crinoidal micrite.

115.6-144.5 m: Thinly interbedded medium-grained crinoidal calcarenite; wavy-bedded crinoidal micrites, and green shaly partings. Large crinoid ossicles variably common in all lithologies, mainly shaly partings. Beds mainly <5 cm thick; locally <10 cm. Uncommon incipient chert in calcarenites. Shaly partings mainly <5 mm thick; rarely 2 cm. Base transitional through c.50 cm, as crinoid ossicles die out rapidly downwards.

144.5-c.311 m (T.D.): Dunkitt Member of Hook Head Formation (= Ballysteen Limestone)

144.5-159.2: Nodular bedded, medium grey biomicrites, typically 5-10 cm thick, locally with scattered large crinoid ossicles 5-8 mm across, commoner in top 4 m. Very diffuse calcareous shales, mainly <15 cm thick, occasionally 25 cm, generally irregularly laminated with fine skeletal debris, plus rare brachiopods and coral fragments. Uncommon incipient chert. Limestones often with feint irregular burrows.

145.5 m: vein and shearing parallel to bedding; not obviously a fault.

159.2-167.1 m: Lithologies as above, but thicker bedded. Thinner limestones nodular; thicker beds, 20-30 cm, with diffuse contacts. Shales irregularly laminated with fine skeletal debris, variably calcareous and therefore variably dark grey. Rare coral and brachiopod fragments. Distinct shales <30 cm thick. Contacts in others often diffuse. Scattered crinoid ossicles relatively uncommon.

167.1-176.3 m: Nodular and diffusely bedded fine calcarenites as above, plus scattered crinoid ossicles, but much thinner: rarely >10 cm thick, commonly as wavy and discontinuous bands 1-2 cm thick. Interbedded with calcareous shale as above, with variable proportions of fine skeletal banding. Main feature of unit is scattered much thicker shales, >50 cm, one 1.4 m (including one 5-cm calcarenite), which are distinctly and sparsely banded with fine to very fine skeletal debris, including small crinoid ossicles, fenestrate bryozoa, thin brachiopods, plus very fine carbonate laminae. These beds much less fossiliferous, and more regularly laminated, than the normal shale interbeds.

176.3-193 m: Diffusely and nodular bedded, very fine calcarenites, as above, generally <15 cm thick, commonly with feint burrowing. Incipient chert locally; rare. Interbedded with calcareous shales with irregular skeletal laminae, generally very poorly defined. Also

poorly fossiliferous shales of thick type in overlying unit, but here <40 cm thick, and rarer. Rare bands of crinoid ossicles.

181.3 m: 20-cm fine calcarenite with finely laminated siltstone at base. Below 186.5 m: Scattered weakly fossiliferous shales, locally with prominent bands of thin-shelled brachiopods. Shales 25-40 cm thick. Crinoid debris slightly commoner than above, transitional to underlying unit.

193-238.5 m: Mainly very diffusely bedded fine calcarenites with scattered crinoid ossicles relatively common. Beds generally <10 cm thick, occasionally 20 cm, but hard to define. Interbedded with streaky calcareous shales, variably fossiliferous, mainly <15 cm thick, but commonly grading to limestone. Rare very weakly fossiliferous shale <5 cm thick. Common intergrading of lithologies. Bedding commonly nodular.

207.7-208.1 m: 40-cm calcareous silty shale, almost unfossiliferous, burrowed. Exceptional.

c.222 m: Thick pink dolomite veins, nearly vertical and parallel to bedding. Vuggy. Adjacent beds dolomitized.

c.226.5 m: Multiple dolomite and calcite veins, parallel to bedding through 35 cm.

227.1-227.9 m: Streaky calcareous shale, burrowed, very weakly fossiliferous. Irregularly laminated and banded with very fine carbonate.

238.5-249.5 m: Diffusely bedded fine calcarenites as above; more argillaceous interbeds, locally <30 cm thick. Banded fossiliferous, very calcareous shales, with fenestrate bryozoa, brachiopods, crinoid ossicles; commonly streaked with very fine carbonate. Occasional shale distinctly banded with fenestrate bryozoa and very fine skeletal debris; interbands almost unfossiliferous and predominant (e.g.239.2-.5 m).

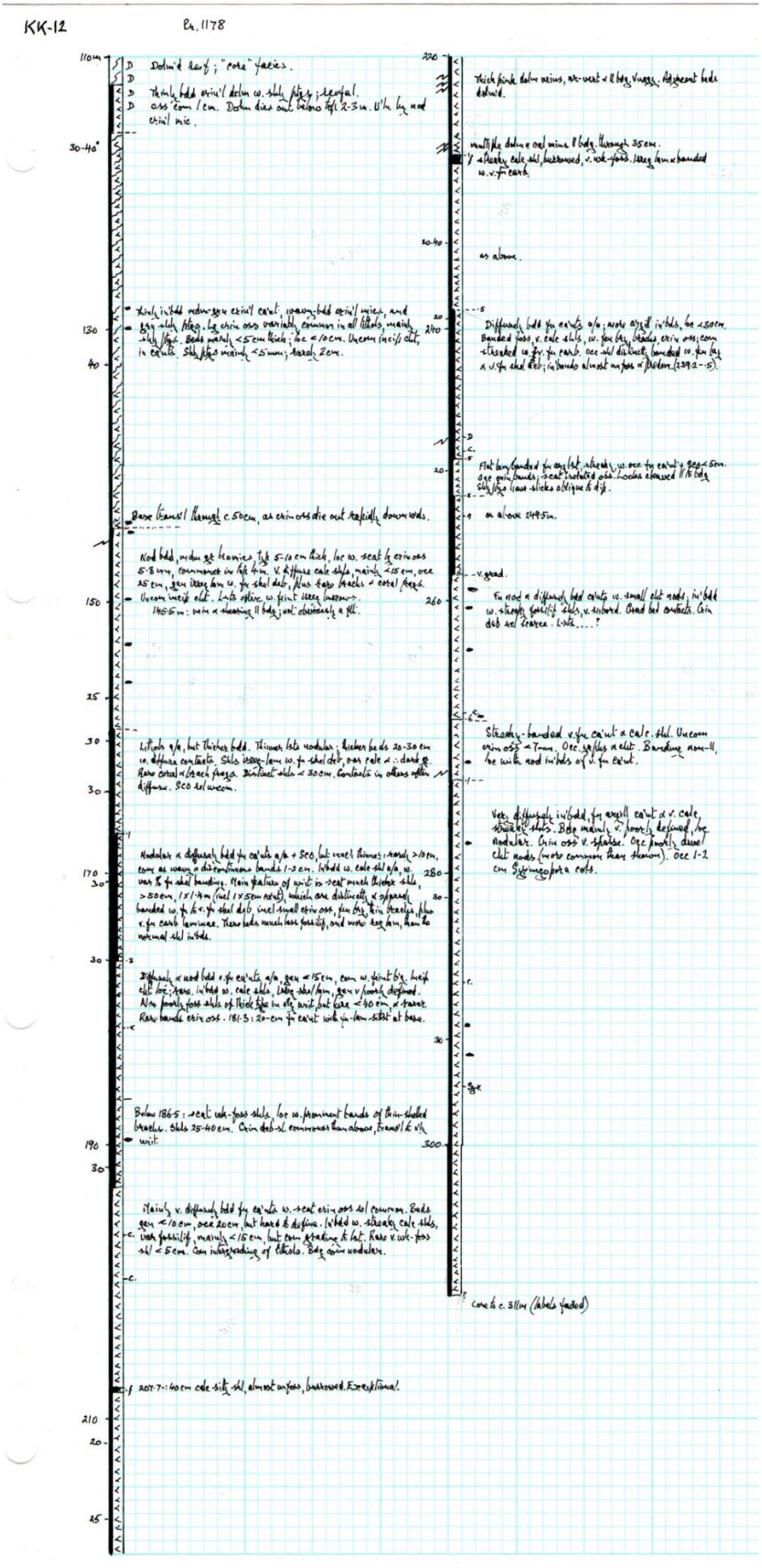
249.5-252.2 m: Flat-laminated/banded fine argillaceous limestone, streaky; with occasional fine calcarenite with scattered crinoid ossicles, <5 cm thick. Occasional crinoidal bands; scattered isolated ossicles. Looks cleaved parallel to bedding. Shaly partings have slickenside-like ribs oblique to dip.

252.2-258 m: As above 249.5 m. Base very gradational.

258-268.6 m: Fine, nodular and diffusely bedded calcarenites with small chert nodules; interbedded with streaky fossiliferous shales, very subordinate. Gradational bed contacts. Crinoid debris relatively scarce.

268.6-273.1 m: Streaky-banded very fine calcarenite and calcareous shale. Uncommon crinoid ossicles <7 mm across. Occasional zaphrentids and chert. Banding non-parallel, locally with nodular interbeds of very fine calcarenite.

273.1-c.311 m (T.D.): Very diffusely interbedded fine argillaceous calcarenite and very calcareous streaky shales. Bedding mainly very poorly defined, locally nodular. Crinoid ossicles very sparse. Occasional poorly developed chert nodules (more common than shown). Occasional 1-2 cm Syringopora colonies. 295.6 m: Syringopora.


KK-12
Pz. 1178
Dolwid leaf; "core" facies.
Thinly bdd erin'l dolm w. stds, fdgty; dkgrbl.
ass' comm / cm. Dolm dies out laterally fr 2-3 m. V'ly lge mod erin'l mic.
Thick, irbdd redm-grn erin'l ca'st (quarry-bdd erin'l mics, and lge stds, fdgty. Lg erin oss variably common in all lithols, mainly sml-lge. Beds mainly <5 cm thick; loc < 10 cm. Uncom ine'ly clst, in ca'st. Sltst flags mainly <5 mm; locally 2 cm.
Base (coarse) through c. 50 cm, as erin oss die out rapidly downwds.
Mod bdd, mdm gr lmstone, typ 5-10 cm thick, loc w. seat lg erin oss 5-8 mm, commonly in fdt 4 m. V. diffuse calc stds, mainly <15 cm, occ 25 cm, gen irregr lam w. fr shal dolo, plus lge brachs + coral frags. Uncom ine'ly clst. Lots oolite w. faint irregr lamn.
1165 m: pair of shearing || bdg; not obviously a flt.
Lithols s/a, but thicker bdd. Thinner lots modular; thicker beds 20-30 cm w. diffuse contacts. Stds irregr-lam w. fr shal dolo, occ calc + : dark gr. Rare coral + brach frags. Distinct stds < 30 cm. Contacts in others often diffuse. Sco rel uncom.
Modular + diffusely bdd fr ca'sts s/a + Sco, but inc'l thinner: mainly >10 cm, com as wavy + discontinuous bands 1-3 cm. Irbdd w. calc sltst s/a, w. vsm % fr shal banding. Main feature of unit is seat much thicker stds, >50 cm, 1x1.4 m (incl 1x50 cm mdst), which are distinctly + sparsely banded w. fr fr + v. fr shal dolo incl small erin oss, fen brz, erin brachs, also v. fr carb laminae. These beds much less fossiliy, and more lge lam, than to internal sml intbds.
Diffusely + mod bdd v. fr ca'sts s/a, gen < 15 cm, com w. faint bdg, incl clst lge; trans. irbdd w. calc stds, calc shal lam, gen v. fossily depleted. Also fossily foss stds of thick type in s/a unit but usu < 40 cm, + fewer. Rare bands erin oss. 181-3: 20-cm fr ca'st unit w. in-lam sltst at base.
Below 186.5: seat ush-foss stds, loc w. prominent bands of thin-shelled brachs. Stds 25-40 cm. Erin deb-sl common than above, transl & rsh unit.
Mainly v. diffusely bdd fr ca'sts w. seat erin oss sl common. Beds gen < 10 cm, occ 20 cm, but hard to define. Irbdd w. streaky calc stds, vsm fossility, mainly < 15 cm, but com stacking of lithols. Rare v. ush-foss sh < 5 cm. Com interbedding of lithols. Bdg grin nodular.
207.7-: 40 cm calc-silty sh, almost unfoss, bioturbated. Exceptional.
Thick pink dolm veins, wr-vert + || bdg. Vuggy. Adjacent beds dolwid.
mult thin dolm + carb mins || bdg. Through 35 cm.
V. sl clayey calc sh, bioturbated, v. ush-foss. Irregr lam + bounded w. v. fr carb.
as above.
Diffusely bdd fr ca'sts s/a; mode dgree of irbdg, loc < 30 cm. Banded foss, v. calc stds, w. fen fgy brachs, erin oss; com streaked w. fr-v. fr carb. Occ sh dist'd, bounded w. thin fgy + v. fr shal dolo; in bands almost unfoss + fissile (239.2-.5).
Flat bdg bounded fr ca'st streaks, w. occ fr ca'st < 5 cm. Occ grin bands; seat isolated oss. Locally abraded || to bdg. Sltst flags (saw-sticks oblique to dip).
as above 249.5 m.
Fr mod + diffusely bdd ca'sts w. small clst nods; irbdd w. straight fossilif stds, v. sinbord. Broad loc contacts. Grin dolo sh/ lenses. Lots.....?
Streaky-banded v. fr ca'st + calc. sltst. Uncom erin oss < 7 mm. Occ gaples + clst. Bandwise nom-ll, loc with mod irbdds of v. fr ca'st.
Very diffusely irbdd, fr ca'st + v. calc, streaky stds. Bdg mainly v. poorly defined, loc nodular. Erin oss v. sparse. Occ fossily dense clst nods (more common than shown). Occ 1-2 cm Syringopora colls.
Core to c. 311 m (labels faded)

Appendix 8: Log of GSI-92-1 (Behan)

The following log is a slightly edited version of the notes accompanying the 1":10 m graphic log. It should be noted that the transcription does not give information that is shown in graphic form, such as dip readings, gradational contacts, relative mud content, distribution of corals, etc. Sand grade sizes are guessed, not measured. Where single depths are used to identify a bed or unit, the depth refers to the top contact. Structures referred to in the log as 'lozenge burrows' are eye-shaped, usually dark, sub-horizontal burrow-fills c.2-4 mm long, which are probably *Chondrites.*

6-20.85 m: Ballymartin Formation ?

Medium to moderately dark grey, very fine to (medium) grained dolomite in poorly defined beds <50 cm thick. Most beds are notably silty, commonly burrowed. Sparse large skeletal fragments; abundant fine debris in some beds. Interbeds moderately dark, irregularly burrowed silty dolomite, typically 10-20 cm thick down to 12.8 m, grading up into very fine ?-silty calcarenite, which often bioturbated. Below 12.8 m interbeds of laminated or banded siltstone/dark silty shale, partly burrowed, 15-70 cm thick become more important (10-20%). Burrow-mottled and occasionally very finely laminated siltstone/silty very fine calcarenite also more abundant downwards, in diffuse, variable beds <50 cm thick. Irregularly bedded, partly nodular, medium crinoidal calcarenite , interbedded/banded with crinoidal shale predominant in bottom 2 m (limestone), rare above. A few small evaporite-replacement nodules and vugs below 16.8 m, together with sparse chert.

Base at bulk change from fossiliferous “calcarenite” above to laminated shale with locally fossiliferous silty calcarenite and siltstone below. Finely laminated black shale rare and thin (<5 cm) above contact. But a gradational change by interfingering.

20.85-53 m: Quinagh Formation

20.85-23.7 m: Graded units <1 m thick, consisting of silty calcarenite, mainly dolomitized, with irregularly scattered skeletal debris; grading up via burrowed darker siltstone to finely laminated black shale 30-60 cm thick. Limestone locally (e.g. at 22.5 m).

23.7-27 m: Variably finely laminated and banded black shale/medium grey dolomitized siltstone, with intermediates. Burrowing generally rare/absent, but locally intense for <30 cm. Partly in graded units as above, but with little or no skeletal debris. Occasional siltstone interbeds <10 cm thick.

27-30.6 m: Medium grey siltstones <50 cm thick, partly laminated, partly bioturbated, grading up through burrowed dark grey siltstone to finely laminated silty shale, variable, not burrowed. Units as above, but siltstones thicker.

30.6-39.9 m: Varied siltstone-dominant sequence, including massive beds of light grey siltstone 50-80 cm thick in centre of unit. Mainly moderately dark beds, variably burrowed, locally well laminated; occasionally cross-laminated, < 90 cm thick, some with graded siltstone passing up into laminated shale tops as above, 20-30 cm thick. Minor skeletal debris in some siltstones.

32.5 m: 20 cm shell hash: bivalves? Further debris above and below, totalling c.60 cm.

34.1 m: 40-cm laminated shale.

39.9-41.8 m: Dark grey to black, silt-laminated shale; minor burrowing.

41.8-42.7 m: Interbanded siltstone/shale, overlain by a 40-cm siltstone bed.

42.7-43.2 m: 50-cm very coarse sandstone, medium grey, massive, weakly graded; sharp top.

43.2-48.1 m: Varied laminated beds. c.50% black finely laminated shale. Rest siltstone-dominant, commonly burrowed, rarely with siltstone beds >5 cm thick (1 x 20 cm, pale grey). Occasional thin (<2 cm) quartz granule beds or dispersed quartz grains; occasional round black grains (shale?).

48.1-50.1 m: Interbedded siltstone, sandstone (up to coarse grade) and minor inter-laminated shale /siltstone, in beds <20 cm thick. 15-cm coarse granule bed at top: rounded quartz grains <5 mm diameter. Rare other conglomeratic beds, with sub-rounded quartz <8 mm diameter. Sandstone locally cross-laminated.

50.1-53 m: Laminated shale/siltstone c.50:50. Locally burrowed. Rare coarse sandstones <4 cm thick. Rare quartz-granule bands. Bottom 50 cm mudstone. Bottom contact sharp, dips c.25˚; no veining or obvious shear.

53-55.5 m: Lower Palaeozoic: slightly discoloured greywacke and mudstone.

Fig. 125 b

GSI. 92-1 Belan

Dip < 10° unless shown.

o/b.

Mdm to mod dk gy, v. fn to (mdm) gran dolst ① in poorly defined beds < 50 cm. Sparse lg shal frags; abun fn debris in some beds. In beds mod dk laminated-bioturbated silty dolst, tk 10-20 cm down to 12.8 m, grad up into v. fn f-silty ca'st which often bioturb. Below 12.8 m in beds of lam or banded siltst/dk silty shl, ft bioturbed, 15-70 cm thick, become more important (10-20%). Burrow-mottled & occ v. fn-lam siltst/silty v. fn ca'st else more abun downwards, in diffuse, variable beds < 50 cm. Mang bdd, ft nodular, mdm ccar/ca'st, in bdd/-banded w. ccar/l shl predom in bttm 2 m ② rare above. A few small swap-replacement nods & veins below 16.8 m.
①: most beds are v calcitic silty, common lt bfd. ② This is tst.

Base at knife change from forsilif "ca'st" above to lam shl with bc-fossilif silty ca'st & siltst below. Fn-lam blk shl rare & thin (< 5 cm)
.85 ..... above contact. But a grad'l change by in'fingering.
Silty ca'sts with mang-scat shal debris grading up via bioturbed dark siltst to fn-lam blk shl 30-60 cm; scoured gr. with < c.1 m. Lst loc (eg 22.5 m

Variably fn-lam & banded blk shl/mdm gy dolom'd siltst, with in'mediates. Bioturbing com rare/absent, but loc intense for < 30 cm. Partly in graded units a/a, but w. little/no shal deb. Occ siltst in beds < 10 cm.
Mdm gy, siltsts < 5 cm, ft lam, ft bioturb, grad up through bfd dk siltst to fn-lam silty shl, variable, not bfd. Units a/a, but silt thicker.

.6

Varied siltst-dom seq, incl massive beds of lt gy siltst 50-80 cm in centre. Mainly mod dk beds, var bfd, loc well lam, occ X-lam, < 90 cm, some w. graded siltst → lam shl tops, a/a, 20-30 cm. 32.5: 20 cm shell ③
40-cm lam-sh. Thick-bioturbed? Minor shal deb in some siltsts.
Crude but sand grade loc. ③: further debris above & below, total c. 60 cm.

.9
Db gy to blk, silt-lam shl. Minor bioturbing.
.8
40-cm siltst bed, once banded silt/shl.
.7 50-cm v. occ sst, mdm gy, massive, wk graded, sharp top.
Varied lam beds. c. 50% blk fn-lam shl. Rest silt-dom, commonly bioturbed, rarely w. siltst beds > 5 cm (1 x 20 cm, pale gy). Occ thin (< 2 cm) q/f granule beds or dispersed q/f grains; occ round blk grns.

.1
In bdd silt, sst (occas) and minor lam-shl/siltst, in beds < 20 cm.
15-cm occ granule bed at top: rounded q/f < 5 mm. Rare others ④.
.1 Lam shl/siltst c. 50:50. Loc bfd. Rare occ sst < 4 cm. Rare q/f-granule bands. Bttm 50 cm mudst. Bttm contact sharp, dips c. 25°,
.. no veining or obvious shear. Looks intact.
Lt. Pal. Sl dys-coloured grybks & mudst.

T.D. 55.5 m

④ conglom'e beds, with sub-rounded q/f < c. 8 mm. Sat loc X-lam.

Appendix 9: Succession above ORS in Core 79-2649-03

(Dips 0-10˚)

The following log is a slightly edited version of the notes accompanying the 1":50 ft graphic log. It should be noted that the transcription does not give information that is shown in graphic form, such as dip readings, gradational contacts, relative mud content, distribution of corals, etc. Sand grade sizes are guessed, not measured. Where single depths are used to identify a bed or unit, the depth refers to the top contact. Structures referred to in the log as 'lozenge burrows' are eye-shaped, usually dark, sub-horizontal burrow-fills c.2-4 mm long, which are probably *Chondrites.*

23-81 ft: Ballymartin Formation?

Thin-bedded limestones (mainly <15 cm thick) and shales. Limestones variable: some nodular wackestone; some flat-bedded crinoidal grainstone, locally graded. Brachiopods abundant in limestones. Occasional crinoid ossicles >1 cm. Shales mainly unfossiliferous, banded with graded calcareous siltstones <5 mm thick. Occasional finely laminated siltstone 2-5 cm thick. Some diffuse fossiliferous shales grade to argillaceous limestone <60 cm thick. Occasional banded shale <60 cm.

81-154 ft: Ringmoylan Shales

81-118 ft: Shale, variably banded with siltstone <5 mm, locally 3 cm, rarely 12 cm. Occasional limestone <3 cm, locally 5-15 cm; mainly brachiopod-rich. 2 x 10-cm limestones at base with haematite and ?-phosphate. Some ?-load casts in siltstone, but little or no burrowing.

118-154 ft: As above, but without calcarenites. Siltstone very sparse in upper half. Some burrowing below c.140 ft.

154-205 ft: Mellon House Beds

154-157.5 ft: 1.1 m bed of sandy calcarenite and calcareous sandstone, locally cross-bedded.

157.5-164 ft: Bioturbated sandstone with shale. Possibly cyclic: shale passing up into burrowed sandstone. Gradational base.

164-169 ft: Shale with scattered siltstone/fine sandstone bands.

169-170.5 ft: 46 cm shelly crinoidal calcarenite, shaly in lower part.

170.5-175.5 ft: 1.5 m very argillaceous micrite and calcareous mudstone, with minor siltstone. Laminated and banded in bottom 30 cm.

175.5-179.5 ft: 1.2 m calcareous sandy mudstone with micrite clasts. Partly laminated; partly ?-mud-cracked.

179.5-188 ft: Inter-bedded fine sandstone and shale, mainly cross-bedded and rippled, locally burrowed. Rare beds as above.

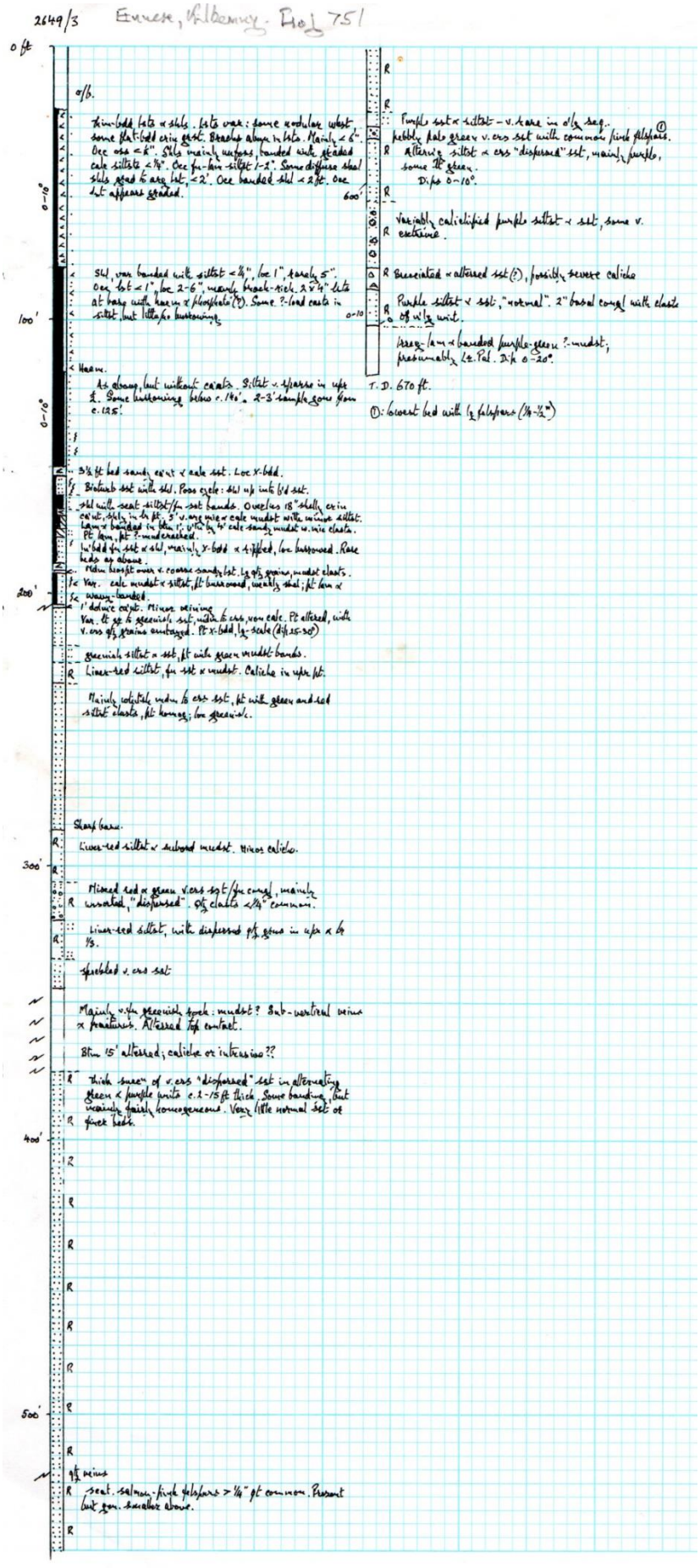
188-191 ft: Medium-grained biosparite.

191-192 ft: Very coarse sandy limestone. Large quartz grains; mudstone clasts.

192-204 ft: Varied calcareous mudstone and siltstone, partly burrowed, weakly fossiliferous; partly laminated and wavy-banded.

204-205 ft: Dolomitic calcarenite. Minor veining.

205 ft down: Old Red Sandstone


2649/3 Everest, Albany. Bore 751
0 ft
o/b.
Thin-bdd fete & shls. fete weak: some nodular west some flat-bdd calc ggst. Brachp abyn in fete. Mainly < 6". Occ one < 1'. Shls mainly valves, bounded with gt added calc siltste < ¾". Occ fn-lam siltst 1-2". Some disperse shell shls ggst to occ lst, < 2'. Occ banded shl < 2ft. One lst appears stroked.
600'
Purple sst & siltst – v. t.zone in o/l½ seq.. pebbly halo green v. ers sst with common fine felspars. ①
R
R
Alterng siltst & ers "dispersed" sst, mainly purple, some lt green.
Dips 0–10°.
R
Variably calcitified purple siltst & sst, some v. calcaire.
R
R
Brecciated & altered sst (?), possibly severe caliche
Purple siltst & sst, "normal". 2" basal congl with clasts of u/l½ unit.
R
Interg lam & banded purple-green ?-mudst; presumably l/c Pal. Dips 0–20°.
T. D. 670 ft.
①: lowest bed with ½ felspars (⅛-½")
Shl, vcn banded with siltst < ¾", loc 1", rarely 5". Occ lst < 1", loc 2-6", usually brach-rich. 2 v ¼" lists at base with haem & phosphate(?). Some ?-load casts in siltst but little/no burrowing.
100'
0–10°
Haem.
As above, but without casts. Siltst v sparse in upr ½. Some burrowing below c. 140'. 2-3' sample gone from c. 125'.
0–10°
3½ ft bed sandy co-st & calc sst. Loc x-bdd.
Bioturb sst with shl. Poss cycle: shl up into b/d sst.
shl with seat siltst/fn sst bands. Over/as 18" shelly co-in co-st, shls in lr ft. 5' v. org mic & calc mudst with minor siltst lams & banded in thin ½"-1" by ¼" calc sandy mudst w. mic clasts. Ft lam, ft ?-mudcracked.
Lr bdd fn sst & shl, mainly x-bdd & tiffed, loc burrowed. Rare beds as above.
Mdm-lr sst & coarse sandy lst. Lg qtz grains, mudst clasts.
Var. calc mudst & siltst, ft burrowed, weakly shal; ft lam & wavy-bedded.
1' dolmic co-st. Minor veining
Var. lt gy & greenish sst, mdm to ers, v.v. calc. Pt altered, with v. ers qtz grains scattered. Pt x-bdd, lg-scale (dip 25-30°)
200'
greenish siltst & sst, ft with green mudst bands.
R
Lmst-bed siltst, fn sst & mudst. Caliche in upr ft.
Mainly calcitic mdm to ers sst, ft with green and red siltst clasts, ft homog, lm greenish.
Sharp base.
R
Lmst-bed siltst & subord mudst. Minor caliche.
300'
R
Mixed red & green v. ers sst/fn congl, mainly uncons, "dispersed". Qtz clasts < ⅛" common.
R
Lmst-bed siltst, with dispersed qtz sand in upr & lr ⅓.
R
Shrubbed v. ers sst
Mainly v. fn greenish spots: mudst? Sub-vertical veins & fractures. Altered top contact.
Bttm 15' altered; caliche or intrusive??
R
Thick succ of v. ers "dispersed" sst in alternating green & purple units c. 1-15 ft thick. Some banding, but mainly fairly homogeneous. Very little normal sst or finer beds.
R
400'
R
R
R
R
R
R
R
500'
R
qtz veins
R
Seat. salmon-pink felspars > ¼" pt common. Present but gen. smaller above.
R