Rialtas na hÉireann
Government of Ireland

LOWER-MIDDLE JURASSIC

Merlin Energy Resources Ltd

PIP
Petroleum Infrastructure Programme

TABLE OF CONTENTS

LIST OF FIGURES

D.6. LOWER-MIDDLE JURASSIC

Lower Jurassic sediments are extensively developed in offshore Ireland. Sediments of this age are widely distributed, and extend from the Slyne, Erris and Porcupine basins west of Ireland, to the Goban Spur Basin well 62/7-1, to numerous well penetrations in the Fastnet and North Celtic Sea basins, extending as far north as the Central Irish Sea Basin and to a sea bed sample in the Kish Bank Basin. Thirty seven of the known well penetrations are in the Fastnet and Celtic Sea basins.

Following the formal definition of the base of the Jurassic System in 2010, the Tilmanni Zone became the basal chronozone of the Jurassic (Hillebrandt & Krystyn, 2009; Morton, 2012). In British sections (including Northern Ireland), the Tilmanni Zone cannot be recognised (due to the absence of the ammonite marker, *Psiloceras spelae*), but the base of the Jurassic may be inferred at a positive organic carbon isotope excursion ("CIE") which falls in the basal Lias Group shale (see Clémence *et al*., 2010, south west England). In offshore Ireland, the base of the Jurassic (Hettangian Stage) is therefore placed at the base of the Lias Group (base of the Caragh Formation/Conn Formation)/top of the Penarth Group (Lilstock Formation) boundary.

Most of the standard stages and substages of the Lower Jurassic have been recognised offshore Ireland in this project. It is rarely possible, however, to define the Hettangian/Sinemurian boundary on the available biostratigraphic data, and typically a "latest Hettangian-earliest Sinemurian" interval is defined around the boundary in this project. In addition, the Toarcian is subdivided here into Early and Late substages, rather than the three-fold (Early, Middle, Late) subdivision that is utilised in some areas. This is due to the constraints of the available biostratigraphic data. According to Gradstein *et al*. (2012), either of the two-fold or three-fold subdivisions are acceptable.

Middle Jurassic sediments are widespread in offshore Ireland and occur in the same areas as Lower Jurassic sediments, typically in stratigraphic continuity, with no major unconformity between the two. Chronostratigraphically, it is not usually possible to separate the Lower and Middle Jurassic on biostratigraphic data from wells and boreholes, which rely on microfossils for dating, typically ostracods, foraminifera, dinocysts and to a lesser extent, calcareous nannofossils. Ammonite records would enable the Lower/Middle Jurassic boundary to be defined, however, there are few cores available around the boundary, and for those that do exist in this stratigraphic interval, ammonites are for the most part not recorded (for the one known exception see discussion of Whitby Mudstone Formation below). For this reason, the Upper Toarcian and Aalenian are usually grouped together in this study and, therefore, the Lower and Middle Jurassic are described together in this chapter.

Summaries of the overall lithological development of the Lower-Middle Jurassic across the various basins offshore Ireland, with the proposed lithostratigraphic subdivisions, are shown in **Figure D.6. 1** and **Figure D.6. 2.** Stratigraphic breaks are also shown in these figures and how these relate to the defined stratigraphic sequences and to the identified seismic horizons.

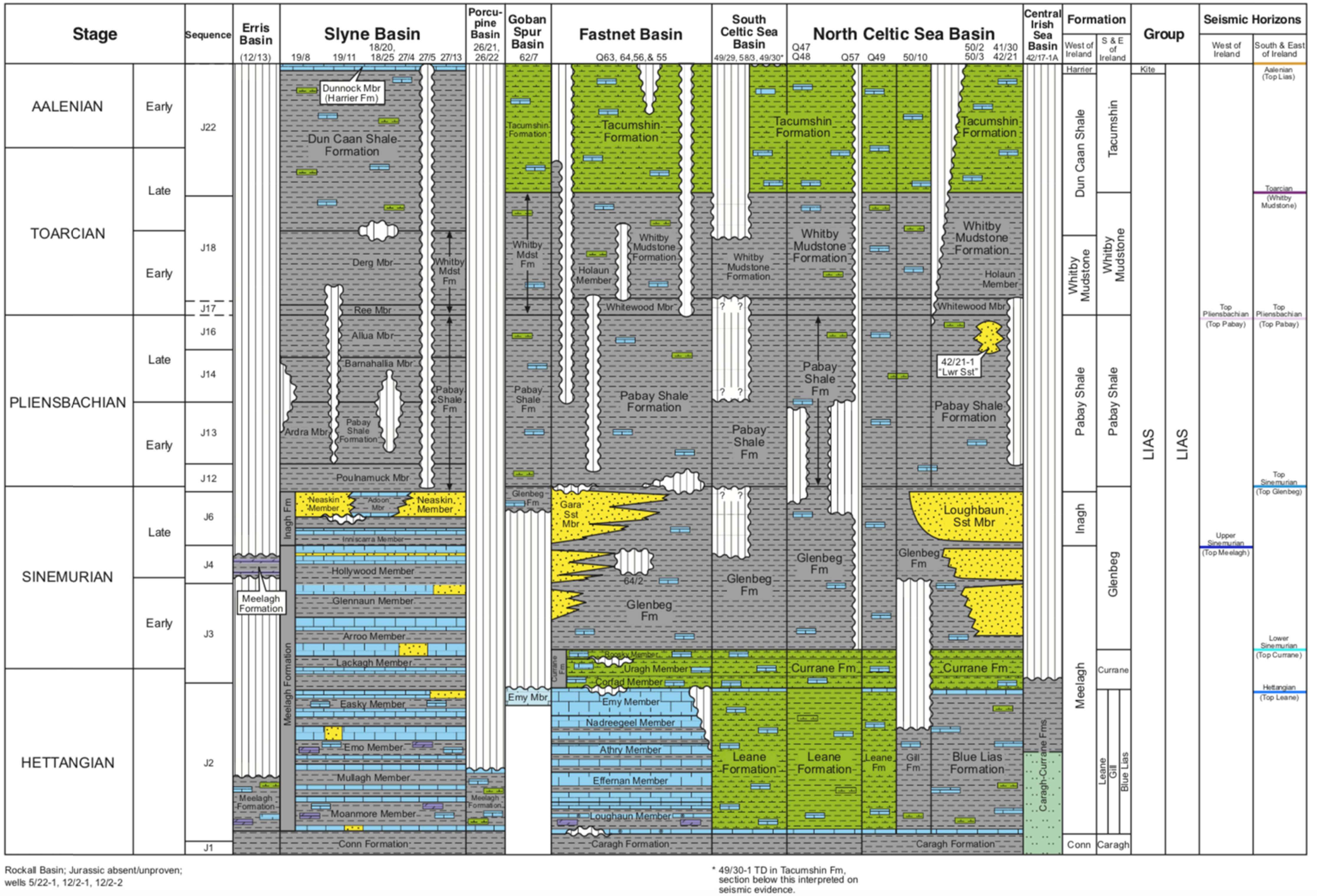

Figure D.6. 1. ***Stratigraphic summary diagram showing Lower and lowermost Middle Jurassic stratigraphy by basin, offshore Ireland.***

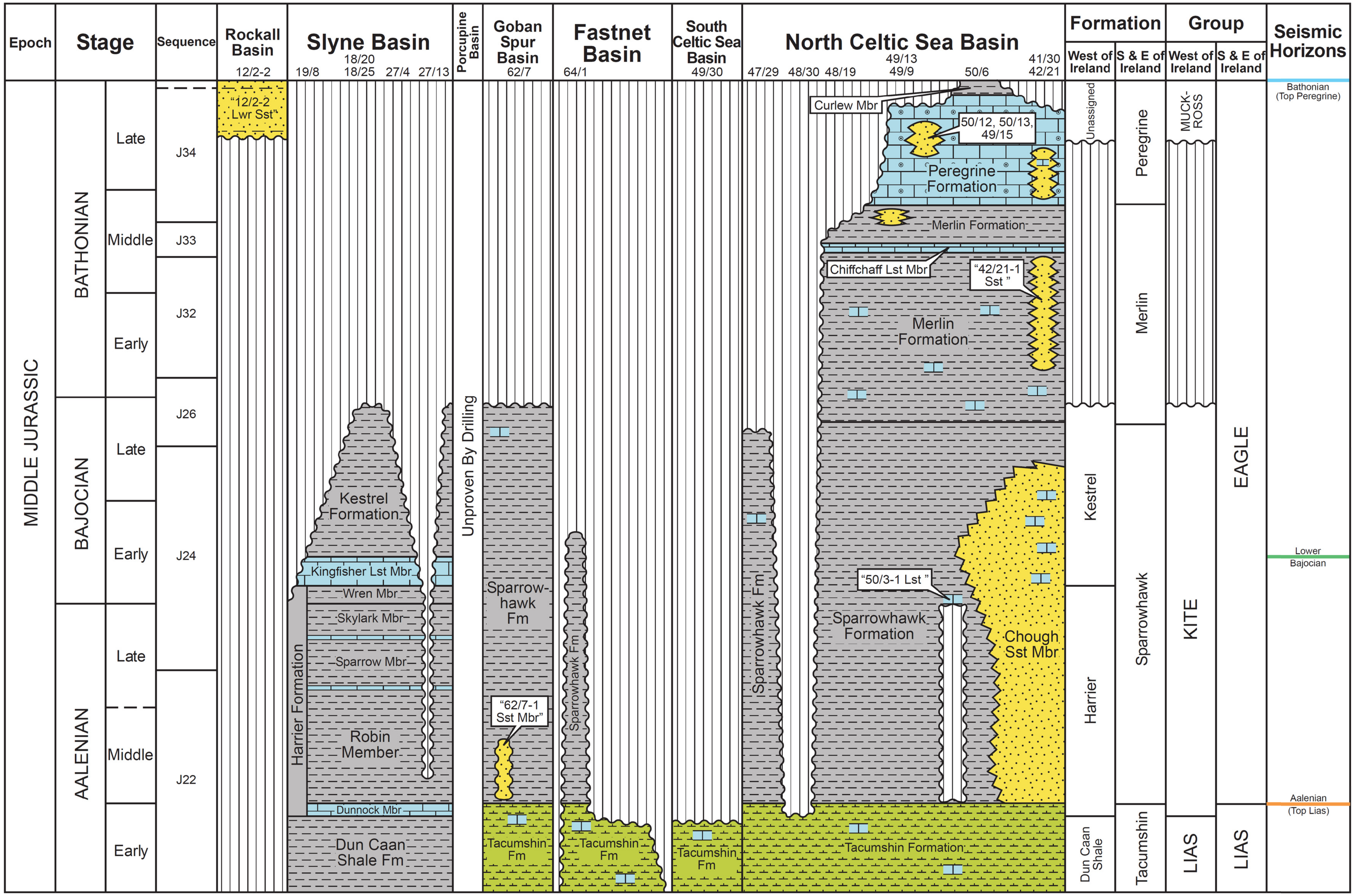

Figure D.6. 2. ***Stratigraphic summary diagram showing Middle Jurassic stratigraphy by basin.***

LOWER-MIDDLE JURASSIC SEQUENCE STRATIGRAPHY

The Lower-Middle Jurassic is developed in marine to marginal marine facies in offshore Ireland. A succession of depositional cycles, defined between horizons of transgression and regression, can be recognised in all offshore Ireland basins where sediments of this age are present. Detailed, biostratigraphically calibrated well correlations demonstrate that a number of these depositional cycles can be correlated across the whole Ireland offshore region. This provides the basis for the recognition of a regional sequence stratigraphic subdivision. Furthermore, the ages of these sequences indicate that many, if not all of the sequences over the Lower-Middle Jurassic interval appear to correlate with the published J sequences of Partington, Copestake *et al*. (1993) which have been defined for the North Sea and the onshore UK areas. These sequences are presently being more fully described (Copestake & Partington, in prep.) and this as yet unpublished work (relevant parts of which are used in the current atlas) provides further support for their identification offshore Ireland. The J sequences of Partington, Copestake *et al*. (1993), in the Lower to Middle Jurassic succession, have also been recognised by Millennia (1997) in the Slyne-Erris basins. Millennia used graphic correlation to aid the identification of the sequences.

Trueblood & Morton (1991) recognised five stratigraphic sequences in Slyne Basin wells that Morton (1989) had previously recognised in the Hebrides Basin, western Scotland, with reference in particular to the 27/13-1A well. The allocation, however, of Morton's (1989) Hebrides Basin sequences to this well does not always accord with the new stratigraphy defined in the current project. For example, Morton's (1989) Sequence A, which is of Triassic to intra Sinemurian in age in the Hebrides area, is placed by Trueblood & Morton (1991) up to the Pliensbachian as interpreted herein. Sequence B corresponds with the J13-J16 sequences, Sequence C with the J17 to lower J18, Sequence D to upper J18 to near top J24. Trueblood & Morton's (1991) interpreted Sequence E equates to the upper part of the Kestrel Formation (J26) and overlying Upper Jurassic Minard Formation, as interpreted herein in the 27/13-1A well. This discrepancy is due to the correlation of the Minard Formation with the latest Bajocian-Bathonian Great Estuarine Group by Trueblood & Morton (1991). The Minard Formation in this study is regarded as being of Late Jurassic age.

Kessler & Sachs (1995) carried out a sequence stratigraphic analysis of the Lower and Middle Jurassic in the North Celtic Sea Basin and recognised six sequences through the Lias and Eagle groups, based on the recognition of well based and seismic sequences. These authors believed that these sequences were controlled by increases in sediment accommodation space related to pulses of basin subsidence and related relative sea level change. Each of their sequences contains a basal onlapping marine shale followed by a coarsening upwards succession culminating in a shallow marine sandstone or limestone. This concept, of defining sequences on a marine flooding surface, accords with the approach taken in this project.

Ewins & Shannon (1995) showed six sequences through the Lower and Middle Jurassic in the North Celtic Sea and Fastnet basins, LJ1-LJ5 (Hettangian-Aalenian) and MJ1 in the Bajocian-Bathonian interval. These sequences were not defined or described by these authors, with the exception of one sequence, LJ3, which is illustrated with reference to the Liassic Sandstone Unit of Murphy & Ainsworth (1991) which equates to the Gara Sandstone Member of the Glenbeg Formation in the new stratigraphy defined herein, and with the J4 and J6 sequences as interpreted in the current study.

De Graciansky, Jacquin *et al*. (1998) and De Graciansky, Dardeau *et al*. (1998) described sequences in the Lower Jurassic of onshore France, some of which can be tied to the J sequences recognised in offshore Ireland.

Several levels of carbon enrichment and associated geochemical changes have been identified in the Lower Jurassic succession in onshore Britain and other countries. These levels are considered to represent major and minor fluctuations in climate, palaeoenvironment and global geochemical cycles (Jenkyns *et al*., 2002; Xu *et al*., 2016). The most significant of these perturbations, the Early Toarcian Oceanic Anoxic Event (T-OAE) (Jenkyns, 1988), was characterized by a geographically widespread negative carbon-isotope excursion (CIE) of as much as *ca* 7‰ in marine and terrestrial organic matter and a 3 to 6‰ negative excursion in coeval carbonate and biomarker compounds (Hesselbo *et al*., 2000; Jenkyns *et al*., 2002). Other levels of similar, but smaller magnitude perturbations in carbon-cycle changes have been recognised at lower levels in the Lower Jurassic. These are in the Lower Sinemurian (Bucklandi Zone), Upper Sinemurian (Obtusum to Oxynotum Zones), and at the Sinemurian–Pliensbachian and the Pliensbachian–Toarcian stage boundaries (Littler *et al*., 2010; Jenkyns & Weedon, 2013; Riding *et al*., 2013; Duarte *et al*., 2014; Porter *et al*., 2014). It is notable that several of these carbon enrichment levels are also apparent in the offshore Ireland area, and will be referred to in the descriptions below. Two levels have been identified by Silva *et al*. (2017) in the 18/25-1 well from the Slyne Basin[1].

While the papers cited above consider the controls on isotope variations to be astronomical, it is evident also that several of the levels at which these events occur also tie to maximum flooding surfaces in the sequence scheme documented here. Therefore, the events relate to levels of marine transgression over wide areas, in the North West European area at least. Thus, the Late Sinemurian (Obtusum-Oxynotum Zones) event equates to the base J6 MFS, the earliest Early Pliensbachian (Jamesoni Zone, Taylori Subzone) event equates to the base J13 MFS, the earliest Toarcian event relates to the base J17 MFS and the Early Toarcian Ocean Anoxic Event corresponds with the base J18 MFS.

The Lower Jurassic is represented by the J00 and J10 second order sequences of Rattey & Hayward (1993), with the base of J00 being placed at the base of the Lower Jurassic and the top of J10 (J18 third order sequence) is taken a short distance below the top of the Lower Jurassic (uppermost Toarcian). The Middle Jurassic is represented by the J20 and J30 second order sequences. In each of these second order sequences, third order sequences were originally numbered (Partington, Copestake *et al*., 1993; Partington, Mitchener *et al*., 1993) with even numbers (for example J02, J04, J06, J12, J14), to allow the future insertion of additional sequences. Such additional sequences have now been recognised (Copestake & Partington in prep; Charnock *et al*., 2001). Three stratigraphic sequences, J22, J24 and J26 are recognised within the latest Toarcian to Early Bathonian J20 second order sequence and three sequences, J32, J33 and J34 within the Early to Late Bathonian J30 second order sequence. The J36 sequence, of Early Callovian age, is not recognised in offshore Ireland due to the absence of sediments of this age in studied wells and boreholes across the offshore area.

Eight seismic horizons are recognised in the Lower and Middle Jurassic interval across large parts of offshore Ireland. Most of these tie to and aid recognition of the J sequences described over this interval. This, together with the detailed calibration of the well and seismic based sequences to detailed biostratigraphy will provide stratigraphic control in areas where seismic markers have been previously recognised in areas without stratigraphic calibration, such as the Amergin and Rosscarbery areas (48/21, 48/22 and 48/18 blocks) in the North Celtic Sea Basin (as reported by Wright & Donato, 2012).

Reference wells in offshore Ireland for Lower and Middle Jurassic sequences include 18/20-1 and 19/11-1A wells from the Slyne and Erris basins, and 56/21-1 and 50/3-3 wells in the Fastnet and North Celtic Sea basins (see **Figure D.6. 3**).

J1 SEQUENCE

Age: Early Jurassic, early Hettangian.

Well definition of basal boundary; In offshore Ireland the base of the sequence is placed at the base of an upwards increase in gamma ray values which occurs at the base of the Caragh Formation in the Fastnet-North Celtic Sea basins and the base of the Conn Formation in the Slyne and Erris basins, at the top of the Penarth Group (Lilstock Formation, Langport Member). This feature is well displayed in the 18/20-1 and 19/11-1A wells from the Slyne and Erris basins, and many wells in the Fastnet and North Celtic Sea basins (for instance 56/21-1 and 50/3-3), in which the MFS is also well calibrated biostratigraphically (see **Figure D.6. 3**).

Remarks: The J02 sequence of Partington, Copestake *et al*. (1993) is subdivided into J1 and J2 sequences by Copestake & Partington (in prep). Both of these new sequences can be recognised in offshore Ireland wells. The base of the J1 sequence is placed in this project at the base of the Tr MFS used by Partington, Copestake *et al*. (1993) to define their J02 genetic stratigraphic sequence, and also the base of the J00 second order sequence.

Van Buchem & Knox (1998) recognised a phase of "worldwide transgression" at the base of the Hettangian and considered this to be of eustatic origin. Placed in the Planorbis Zone by these authors, this correlates with that taken here to define the

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[1] It is notable that this well contains a significant unconformity within the Pliensbachian, omitting three whole sequences. It would be instructive to see carbon isotope analysis carried out on a complete succession, for example that from 18/20-1.

base of the J1 sequence in offshore Ireland. This level in onshore Britain is associated with the well-documented marine transgression that follows a world-wide sea level fall in the latest Triassic (Rhaetian) (Hallam & Wignall, 1997; Hillebrandt & Krystyn, 2009; Hesselbo *et al*., 2004). This transgressive event is well displayed in several offshore Ireland wells, both east and west of Ireland, as well as in onshore UK sections, for example in south west Britain. In onshore UK, the base J1 MFS (near base Jurassic) defines the base of the Lias Group and the top of the Langport Member (White Lias) of the Penarth Group as it does in offshore Ireland. This is the approximate level for the newly defined base of the Jurassic system (see discussion of the definition of the base of the Jurassic above).

Seismic expression: The base of the J1 sequence as recognised in the well data (top of the Penarth Group) matches the Triassic (Top Penarth) seismic horizon, that is recognised in the Erris, Slyne, Porcupine, Fastnet and North Celtic Sea basins.

Distribution and lithostratigraphical development: The sequence is widespread in offshore Ireland and falls at the base of the Lias Group (base of the Caragh Formation in the Fastnet-North Celtic Sea basins; and base of the Conn Formation in the Slyne and Erris basins).

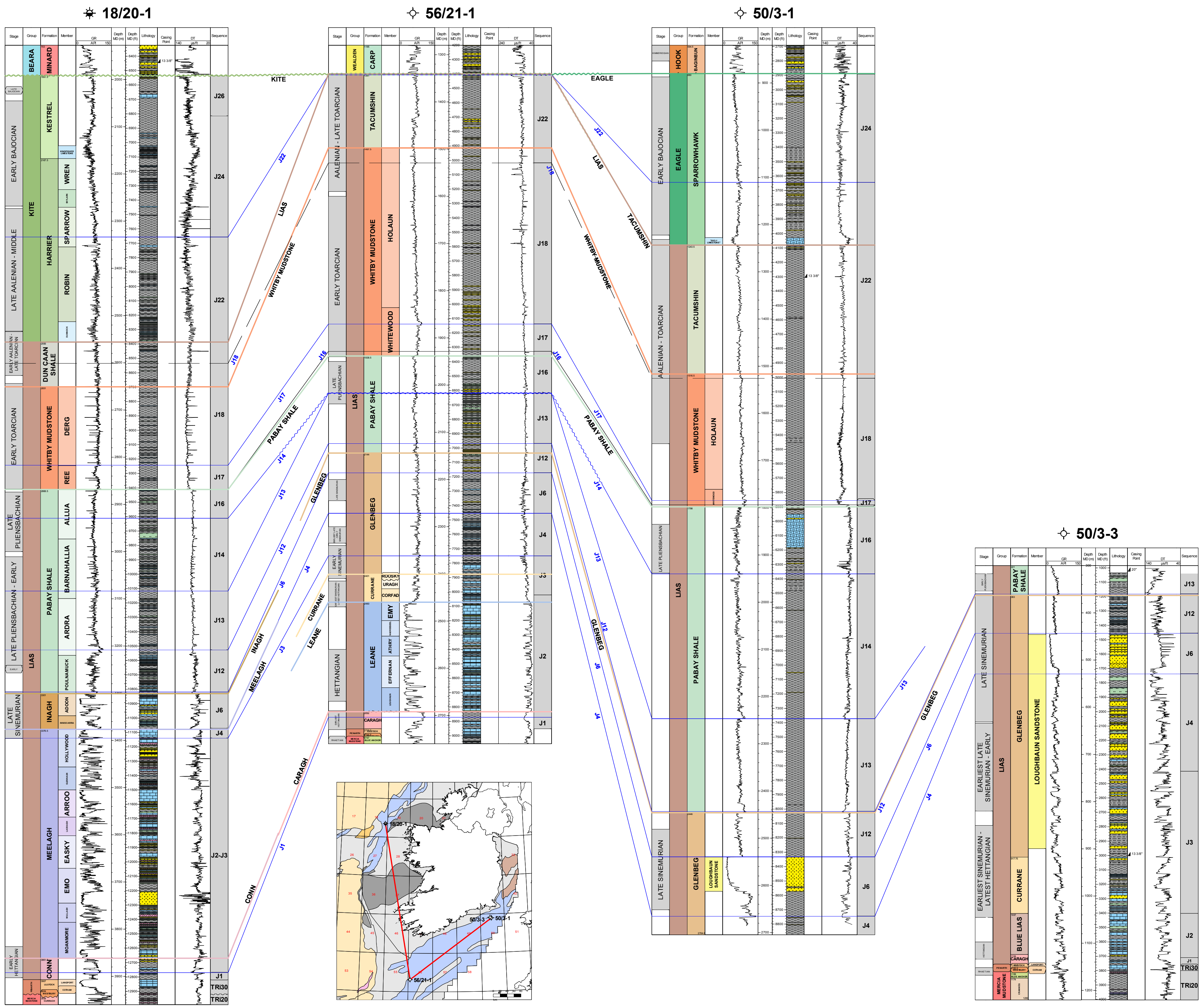


Figure D.6. 3. ***Hettangian-Bajocian well sequence correlation from North Celtic Sea to Fastnet to Slyne basins.***

J2 SEQUENCE

Age. Early Jurassic, Hettangian.

Well definition of basal boundary. In offshore Ireland the base of the sequence is placed at a distinctive gamma ray log peak which occurs within the Caragh Formation in the Fastnet-North Celtic Sea basins and within the Conn Formation in the Slyne and Erris basins, in the basal part of the Lias Group. This feature is well displayed in the 18/20-1 and 19/11-1A wells from the Slyne and Erris basins, and many wells in the Fastnet and North Celtic Sea basins (for instance 56/21-1 and 50/3-3) (see **Figure D.6. 3** in which the MFS is also well calibrated biostratigraphically).

Remarks. On microfaunal data, the base J2 MFS is located within the IFJ1 biozone. The latter biozone is defined on the common occurrence of *R? planiconvexa*, which is a bioevent that is also associated with the base J2 in onshore Britain and which spans the upper part of the Planorbis Zone to lower Liasicus Zone in onshore UK ammonite-dated sections. The J2 MFS is considered to fall within the Liasicus Zone on the basis of this macrofaunal calibration. Such robertinid foraminifera floods are diagnostic of many transgressive units in the British Jurassic (another being the abundance of *Reinholdella* at the base J18 level, see below).

The J02 sequence of Partington, Copestake *et al*. (1993) is subdivided by Copestake & Partington (in prep.) into the J1 sequence and a restricted J2 sequence. The subdivision of the former J02 sequence is based on the formal recognition of a demonstrably regional MFS that was mentioned by Partington, Copestake *et al*. (1993) as the “Liasicus” MFS, though not used by them to define a formal sequence subdivision. There is now sufficient evidence in onshore and offshore UK sections, as well as offshore Ireland, to confirm the regional development of this additional MFS, within the originally designated J02 sequence, to justify the recognition of an additional sequence, J1.

Hesselbo & Jenkyns (1998), Hesselbo (2008) suggested the presence of a mid Liasicus Zone candidate maximum flooding surface in onshore UK successions, recognised also in South Wales (Sheppard, 2006), that is equivalent to the base J2 MFS interpreted here. De Graciansky, Jacquin *et al*. (1998) and De Graciansky, Dardeau *et al*. (1998) recognised this as the peak transgression of their 2nd Order Cycle 4a and 3rd Order Cycle He_2 in the Paris Basin and in Dorset, southern England. The same event has been recognised by Nielsen (2003) in the Hettangian (Fjerritslev Formation) of the Danish Basin and Fennoscandian Border Zone area and by Barth *et al*. (2018) within the Liasicus Zone in Germany, Poland and southern Sweden, termed the “mfs He2”.

Within the J2 sequence, the upwards lithostratigraphic transition to less than fully marine sedimentation, at the base of the Leane Formation (Fastnet and Celtic Sea basins) and of the Meelagh Formation (Porcupine, Slyne and Erris basins), above fully marine sediments (Caragh Formation) suggests a regressive change (basinward shift of facies) that is quite widespread within offshore Ireland. This may correlate with the mid Angulata Zone regression (relative sea level fall) interpreted by Hesselbo & Jenkyns (1998) in UK onshore successions in Glamorgan (South Wales) and Somerset. This may equate with a depositional sequence boundary.

Distribution and lithostratigraphical development. The sequence is widespread in offshore Ireland and is proven in the western (Slyne, Erris and Porcupine basins) and eastern offshore (Fastnet and Celtic Sea basins) areas. In the former area, it is represented lithostratigraphically by the upper part of the Conn Formation and lower part of the Meelagh Formation, and in the latter area by the upper part of the Caragh Formation and lower part of the Leane Formation (and age equivalent Blue Lias and Gill formations).

On a broader scale, the sequence is present in the North Sea Basin, as well as in northern onshore Europe (Copestake & Partington, in prep.).

J3 SEQUENCE

Age. Early Jurassic, latest Hettangian-Early Sinemurian.

Well definition of basal boundary. In the Fastnet-North Celtic Sea basins, the base of the J3 sequence falls a short distance above the base of the Currane Formation, above the top of the Leane Formation limestones (for example, the 56/21-1 well), and is typically placed at a gamma ray log peak considered to equate to a maximum flooding surface. It represents the transgression and flooding of the transitional marine Leane Formation by the more open marine Currane Formation in the Fastnet Basin and southern part of the North Celtic Sea Basin.

To the north of this area, beyond the depositional limit of the Leane Formation, where fully marine facies is present, the base of J3 falls in the lower part of the Currane Formation, above the Blue Lias Formation, as in the 50/3-3, 50/12-3 and 41/30-1 wells or age equivalent Gill Formation (UK 103/2-1) (see **Figure D.6. 36** showing correlation of 103/2-1 and 50/10-**1**).

In the Slyne Basin, the base of the J3 sequence is interpreted to fall within the Meelagh Formation (for example in the 18/20-1 well), however, where it falls within this formation is very uncertain due to the generally non-marine facies (see **Figure D.6. 3)** and it is often not possible in this area to separate the J3 from the J2 sequence. One exception is the 27/5-1 well, in which a marine ostracod assemblage (*K. translucens* and common *O. aspinata*), proving an earliest Sinemurian (to latest Hettangian) age is seen near the top of the Meelagh Formation. This assemblage is unusual in this area and indicates a marine influence at this well location which is used to help identify the base J3 sequence maximum flooding surface. In the latter well the base of the J3 sequence is picked at the base of a claystone-sandstone succession, within which the latter ostracod assemblage occurs. This is expressed as a gamma ray log peak.

Remarks. The base of the sequence falls in the uppermost Hettangian, most likely the Angulata Zone.

Kessler & Sachs (1995) reported a maximum flooding surface in the North Celtic Sea Basin (offshore Ireland) at the top of the Hettangian Limestone (base of their Sequence 1, equating to the top of the Leane Formation). The current study agrees with this placement and identifies this as the base J3 MFS.

In some areas, there is evidence for the presence of an unconformity at the base of the sequence. This is suggested in wells such as Fastnet Basin well 56/26-2, in which wireline log correlation suggests missing section at this level, at the Currane/Leane formational boundary. A correlative break is also seen in the 50/12-3 well, where the Currane Formation overlies a thin, truncated Blue Lias section.

The J3 sequence equates to the lower part of the J04 sequence of Partington, Copestake *et al*. (1993), recognised in the North Sea Basin and onshore UK areas.

Seismic expression. The Hettangian (Top Leane) seismic horizon, recognised in the North Celtic Sea, South Celtic Sea and Fastnet Basins, falls close to the base of the J3 sequence, appearing to tie to the top of the limestones of the Leane Formation, a short distance below the high gamma log marker that defines the base of the sequence (see seismic tie to 49/29-1, **Figure D.6. 4**).

Distribution and lithostratigraphical development. The sequence is present in the Fastnet, North Celtic Sea basins where it equates to the Currane Formation and lower part of the Glenbeg Formation. In the Slyne and Erris basins, the sequence is interpreted to fall within the Meelagh Formation, however, the development of marginal marine facies renders this interpretation tentative. In this area it is not possible to separate the J2 and J3 sequences as they fall within the non-marine facies of the Meelagh Formation.

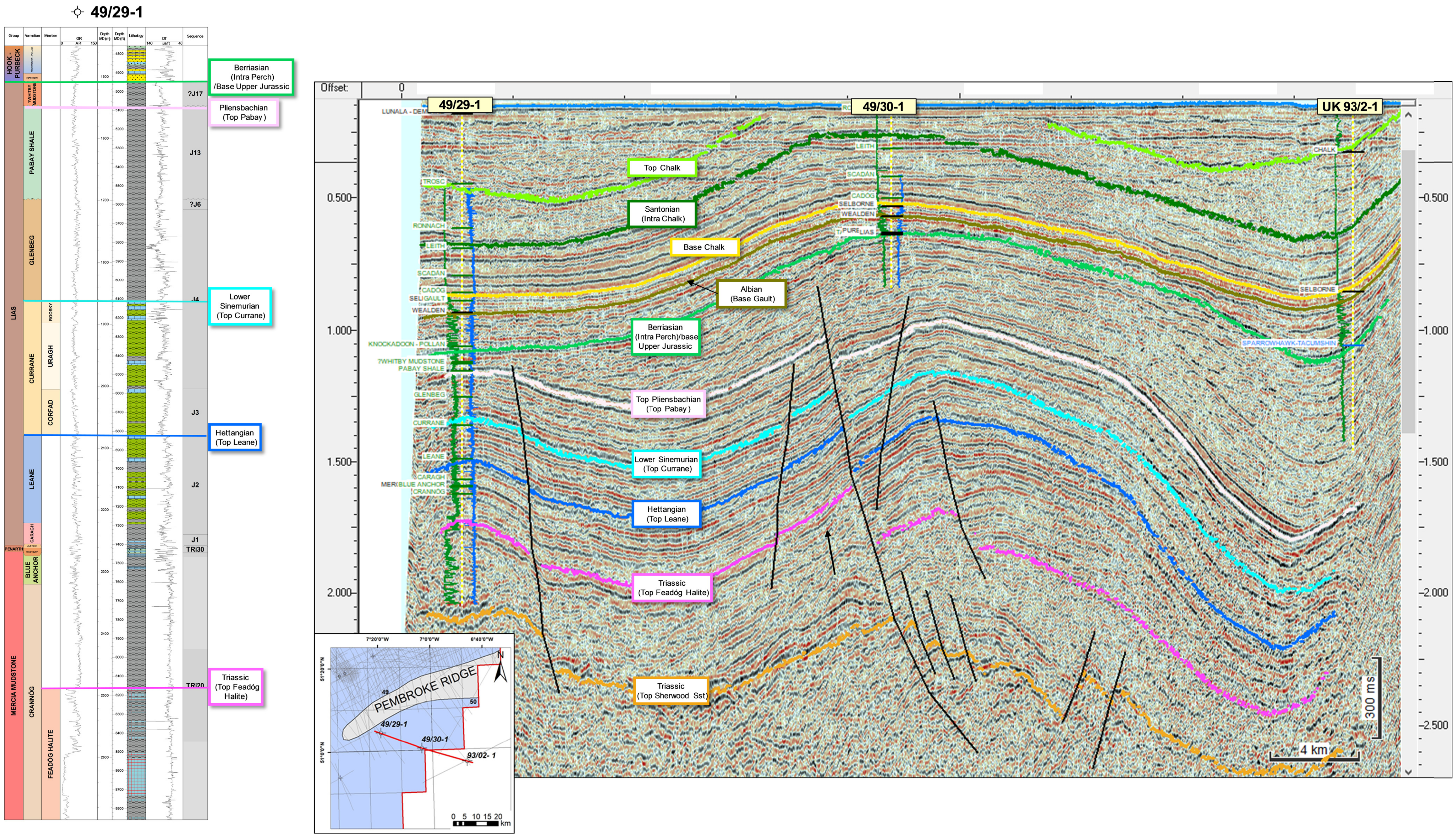


Figure D.6. 4. *Triassic-Lower Jurassic seismic sequences, 49/29-1, 49/30-1 and UK 93/2-1 wells, South Celtic Sea Basin. 2D seismic line MPCR-84-21Recon.*

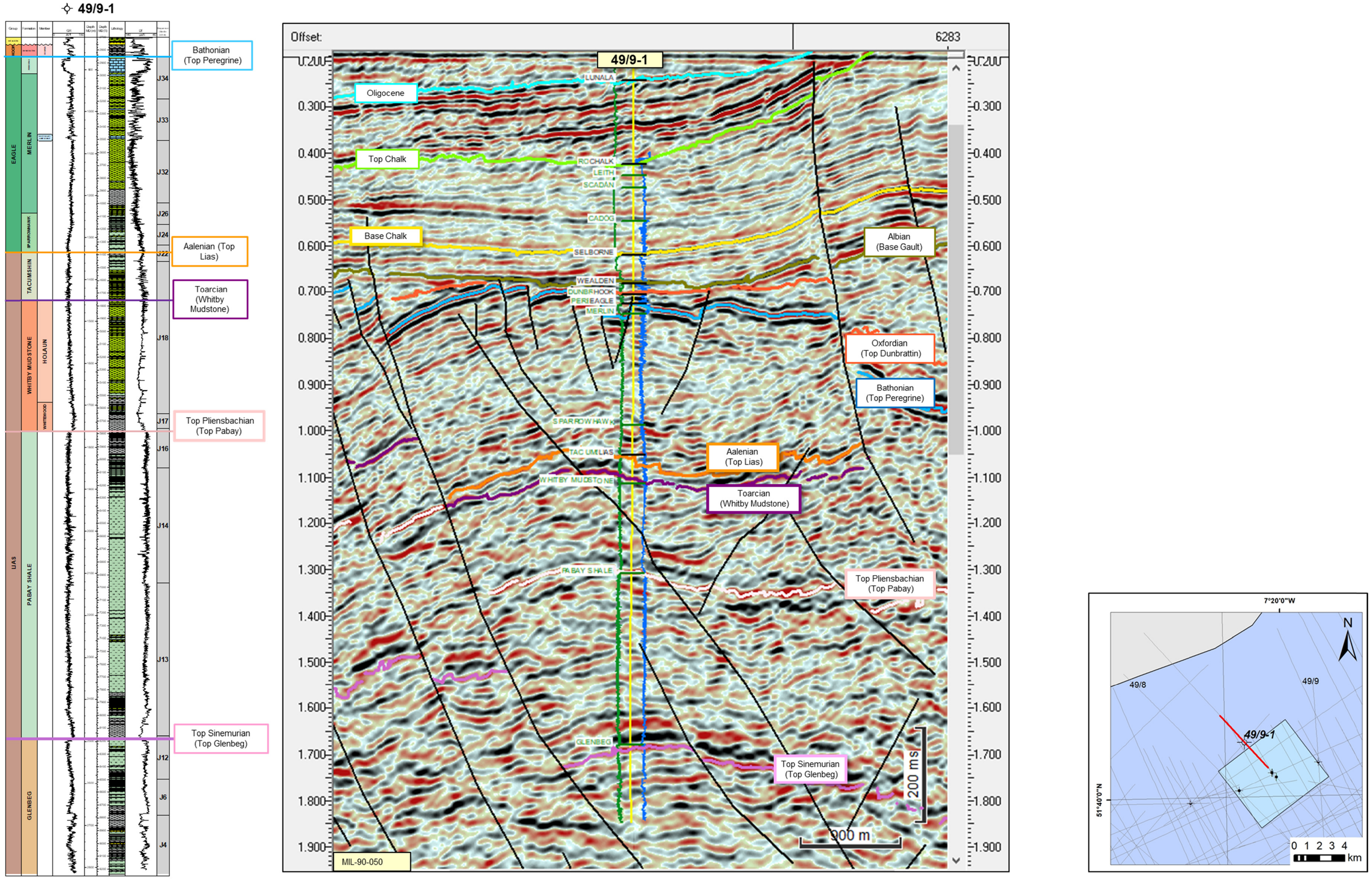


Figure D.6. 5. ***Lower-Middle Jurassic seismic sequences, 49/9-1 well, North Celtic Sea Basin. 2D seismic line MIL-90-050.***

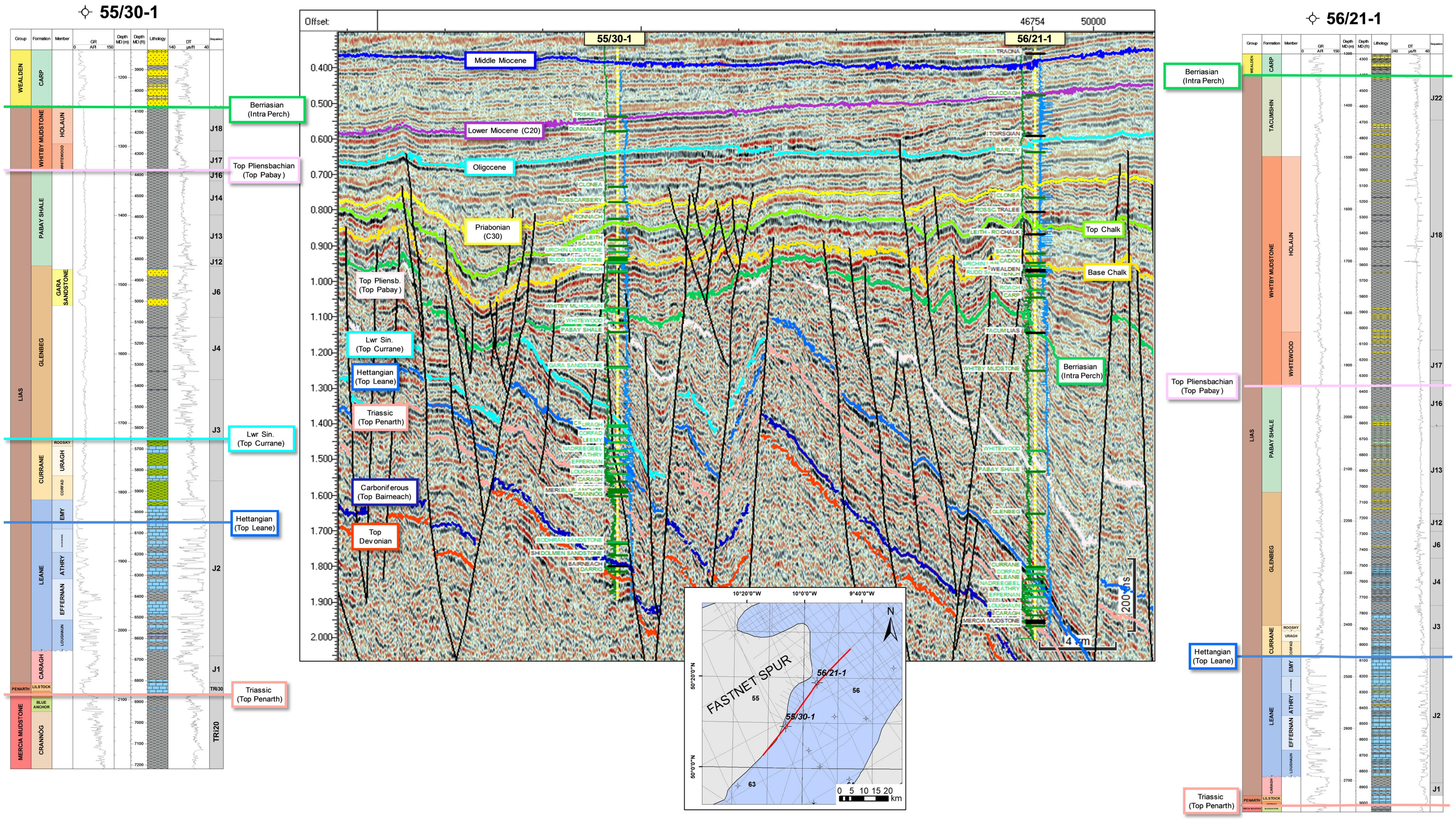


Figure D.6. 6. ***Lower Jurassic seismic sequences tied to the 55/30-1 and 56/21-1 wells, Fastnet Basin. Arbitrary line comprises MPCR-84-06_4-5-6MigRecon and MPCR-84-06/3Recon.***

J4 SEQUENCE

Age. Early Jurassic, Early-Late Sinemurian.

Well definition of basal boundary. In the Fastnet-North Celtic Sea basins, the base of the J4 sequence falls within the Glenbeg Formation and within the Gara Sandstone Member (Fastnet Basin) and age equivalent Loughbaun Sandstone Member (North Celtic Sea Basin) where present, at significant claystone breaks within these sandstone packages. It is typically placed at a gamma ray log peak and associated reduction in sonic velocity.

In west of Ireland basins, such as Slyne and Erris, the base of J4 falls within the upper part of the Hollywood Member of the Meelagh Formation. Here, the interpreted MFS represents the upwards change from non-marine sediments (including anhydrite/gypsum) to shallow marine deposition; this is reflected in the change from the IOJ2 to the IOJ3 biozone, that is defined on the upwards change from non-marine dominated ostracod associations (including common *Darwinula hettangiana*) to marine assemblages (as in the 27/4-1 well). At the same level is seen the upsection incoming of dinocysts, as in the 27/13-1A well, within the Hollywood Member of the Meelagh Formation.

Remarks. The J4 sequence equates to the upper part of the J04 sequence of Partington, Copestake *et al*. (1993). These authors recognised the presence of an additional candidate MFS within their J04 sequence in some areas. The identification of the presence of this MFS in offshore Ireland, in the present study, allows the confirmation of the splitting of the J04 sequence of the latter authors into J3 and J4 sequences in this study. The base of the modified J4 sequence is revised to fall at the base of an intra Lower Sinemurian MFS, and is considered to be equivalent to an intra Semicostatum Zone ammonite chronozone level (see discussion below).

There is evidence of a stratigraphic break in some wells at the base of the J4 sequence, for instance in the 27/4-1 well. Here, is seems that Late Sinemurian J4 sequence section overlies intra Early Sinemurian aged section (J3 sequence), but all within the Hollywood Member of the Meelagh Formation.

The lower part of the LJ3 sequence of Ewins & Shannon (1995) in the Fastnet Basin, equating with the Gara Sandstone Member of the Glenbeg Formation in the new stratigraphy defined herein, correlates with the J4 and J6 sequences as interpreted in the current study.

There is widespread evidence from onshore European sections of a major transgression (candidate MFS) in the Semicostatum Zone. This corresponds closely to the high gamma event (and associated hiatal surface) seen close to the base of the Charmouth Mudstone Formation, Shales-with-Beef/top Blue Lias Formation in Dorset, Southern England, at the same level in the Cleveland Basin, and at the base of the Pabay Shale Formation/top Blue Lias Formation/top Broadford Beds boundary (and associated hiatal surface) in Morvern and the Inner Hebrides (Western Scotland) (Hesselbo & Jenkyns, 1998; Van Buchem & Knox, 1998). De Graciansky, Jacquin *et al*. (1998) place the peak transgression of their Second Order Cycle 4a within the Semicostatum Zone, which they also equate with the boundary between the Blue Lias Formation and the overlying Charmouth Mudstone Formation, Shales-with-Beef in Dorset. Barth *et al*. (2018) recognised the equivalent MFS within the Semicostatum Zone in Germany, Poland and southern Sweden. These authors calculated that during this flooding/transgression, the shoreline advanced for about 500 km in Poland (from Kamień Pomorski to the Holy Cross Mountains area).

Distribution and lithostratigraphical development. The sequence is present within the Glenbeg Formation in the Fastnet and North Celtic Sea basins, falling within the lower part of the Gara Sandstone Member and the Loughbaun Sandstone Member. The sequence is interpreted to fall within the upper part of the Meelagh Formation (upper part of the Hollywood Member) in the Slyne and Erris basins.

J6 SEQUENCE

Age: Early Jurassic, Late Sinemurian.

Well definition of basal boundary: The base of the sequence is placed at a high gamma claystone within the section dated as Late Sinemurian, where there is clear evidence of transgression. This is seen in wells across the offshore Ireland region. In the west of Ireland area, for instance in the Slyne Basin wells (for example 18/20-2, 18/25-1), this flooding level falls at a high gamma ray claystone at the base of the Inniscarra Member (Inagh Formation). This corresponds with the level of significant transgression, with the sediments containing the interpreted MFS being of fully marine origin, transgressing across marginal marine sediments (of the Meelagh Formation) in this region. This high gamma claystone at the base of the sequence contains the *L. variabile* acme (for example in the 27/13-1A and 27/5-1 Slyne Basin wells).

An equivalent high gamma claystone is present at the base of the sequence in the Fastnet, North Celtic Sea and South Celtic Sea basins. In this area, the base of J6 occurs beneath the upper sandstone of the Loughbaun Sandstone Member, as in the 50/3-1 and 50/3-3 wells (see **Figure D.6. 3**).

Remarks: The base J6 MFS equates to the intra Late Sinemurian marine flooding surface of Kessler & Sachs (1995) recognised in the North Celtic Sea Basin, which defines the base of their Sequence 2. Sequence 2 contains the "Upper Sinemurian Sandstone", here named the Loughbaun Sandstone Member, in that area. In this study, the base of J6 is placed at the same level as by Kessler & Sachs (1995), that is below the upper main sandstone of the Loughbaun Sandstone in the 50/3-1 and 50/3-3 wells (see above). The upper part of Kessler & Sachs' Sequence 2 is separated into the J12 sequence in this evaluation.

The upper part of the LJ3 sequence of Ewins & Shannon (1995) in the Fastnet Basin, equating with the Gara Sandstone Member of the Glenbeg Formation in the new stratigraphy defined herein, correlates with the J4 and J6 sequences as interpreted in the current study.

The acme of the dinocyst *L. variabile* is widespread in onshore and offshore Europe (including wells in the North Sea Basin; see Partington, Copestake *et al*., 1993) that can be tied to the Oxynotum and Obtusum Zones. This acme bioevent has been interpreted to correspond to a phase of regional sea level rise associated with a probable climatic change (warming event) (Riding *et al*., 2013), which is consistent with the recognition of the base J6 as a regional flooding event.

The base J6 maximum flooding surface may correlate with that identified at the base of the Oxynotum Zone in onshore UK sections, for example in the Yorkshire and Dorset areas, by Hesselbo & Jenkyns (1998). This regional flooding surface is regarded as being a second order cycle boundary by these authors. Van Buchem & Knox (1998) interpreted a basinwide flooding event at a slightly different level, in the Obtusum Zone in the Cleveland Basin and north Lincolnshire, where deeper water mudstones overlie silty and sandy deposits in the basin and Frodingham Ironstone on the Market Weighton High.

In the Paris Basin, De Graciansky, Jacquin *et al*. (1998) have identified a maximum flooding surface ("peak transgression" within Second Order Cycle 4b, sequence Si3 MFS), based on wireline log data, associated with the development of a shaley bed containing phosphate and glauconite, which is placed in the Obtusum Zone. This is slightly earlier than the apparent MFS in the UK onshore succession which those authors place at the base of the overlying Oxynotum Zone. In northern Germany, Zimmermann *et al.* (2015) place their Sin2 MFS within the Obtusum Zone.

Distribution and lithostratigraphical development: The sequence is present within the upper part of the Glenbeg Formation in the Fastnet and North Celtic Sea basins, representing the upper part of the Gara Sandstone Member and the Loughbaun Sandstone Member. The sequence equates to the Inagh Formation in the Slyne and Erris basins.

J12 SEQUENCE

Age. Early Jurassic, Latest Sinemurian-earliest Early Pliensbachian.

Well definition of basal boundary. The base J12 floods the deposition of the Neaskin Sandstone Member (Inagh Formation) within the basal claystone (Poulnamuck Member) of the Pabay Shale Formation in the Slyne Basin area (as in the 27/4-1Z and 18/25-1 wells). In the North Celtic Sea and Fastnet basins, the flooding surface at the base of the sequence terminated deposition of the Gara Sandstone Member and the coeval Loughbaun Sandstone Member (in the upper part of the Glenbeg Formation) and is represented by a high gamma claystone (for instance in 50/3-1 and 50/3-3 wells; see **Figure D.6. 3**.

The Neaskin Member is interpreted to be of estuarine to shallow marine origin, while the basal claystone of the Pabay Shale Formation is fully marine, representing a significant (maximum) flooding event. The development of a marine flooding surface at this level was also noted by Melvin (2009) and Serica Energy (2009) at the Neaskin Member/Pabay Shale contact in the 27/4-1Z well (Bandon Discovery). This flooding surface provides the effective top seal to the Neaskin Member reservoir sandstone in this discovery. Where the Neaskin Member is absent, as in well 18/20-1, the base J12 MFS is interpreted to fall in the basal Poulnamuck Member claystone that overlies the Adoon Member (of the Inagh Formation). On wireline logs, the boundary is expressed as a gamma-sonic bow boundary, with a high gamma ray log peak and associated trough of lowered sonic velocity, as seen on several wells in **Figure D.6. 3**.

The base J12 MFS occurs within the Late Sinemurian, and is considered to equate to the Raricostatum Zone, Aplanatum Subzone (Partington, Copestake *et al*., 1993). This age dating is confirmed by the association of the base of the sequence with the upper part of the IOJ3c subbiozone and upper part of the IFJ2 biozone in the west of Ireland.

Remarks. The base J12 MFS, in occurring above an unconformity surface in some areas, appears to demonstrate transgressive, onlapping character, and is the first main marine transgression within the Dunlin Group (Amundsen Formation) in the North Viking Graben, North Sea (Partington, Copestake *et al*., 1993). The same event is also present in offshore Denmark (at the MFS12 of Nielsen, 2003) and onshore France (MFS within Si4 sequence of De Graciansky, Dardeau *et al*., 1998). This unconformity appears to be related to the latest Sinemurian major transgression as recognised throughout North West Europe and adjacent areas by Hallam (1961, 1978) and can be recognised in onshore Britain (as in the Witney Borehole, Oxfordshire, Humberside and Warwickshire; see Cope *et al*., 1980a). In southern England sections, the base J12 unconformity is clearly seen around the margin of the London Platform, where Raricostatum Zone sediments onlap and overstep pre-Oxynotum Zone sediments (Donovan *et al.*, 1979). As indicated above, the ammonite calibration from onshore successions suggests that this transgressive event occurs within the Aplanatum Subzone of the Raricostatum Zone.

Distribution and lithostratigraphical development. The lowermost part of the sequence is present within the uppermost part of the Glenbeg Formation in the Fastnet and North Celtic Sea basins and ranges into the lower part of the overlying Pabay Shale Formation. In the Slyne Basin, the sequence falls entirely within the lower part of the Pabay Shale Formation, equating to the Poulnamuck Member and basal part of the Ardra Member.

J13 SEQUENCE

Age. Early Jurassic, earliest Early Pliensbachian-intra Late Pliensbachian.

Well definition of basal boundary. The base J13 is placed at a prominent high gamma ray log marker, and associated increase in sonic interval transit time, which occurs a short distance above the base of the Ardra Member (of the Pabay Shale Formation) in the Slyne and Erris basins (for example in well 18/20-1). In the Fastnet and North Celtic Sea basins, the base of the sequence is taken at an equivalent prominent gamma ray log peak and associated sonic interval transit time increase above the base of the Pabay Shale Formation, as seen in 50/3-1 and 50/3-3 (see **Figure D.6. 3**). This level is associated with an increase in algae (*Tasmanites* and *Pterospermella*) in the 49/9-1 well, a palynological feature often associated with organic rich claystones. It should be noted that the base of the Pabay Shale Formation is taken at a slightly younger level, at the base of the J13 sequence, intra Early Pliensbachian east of Ireland than it is west of Ireland (base J12), intra Late Sinemurian.

The base J13 MFS occurs within the earliest Early Pliensbachian and is interpreted to fall within the Taylori Subzone of the Jamesoni Zone. This age dating is confirmed by the association of the base of the sequence with the IOJ5 ostracod biozone in the Fastnet and North Celtic Sea basins, and the IOJ4 ostracod biozone west of Ireland. On palynology data the surface falls above the FDO of *L. variabile*, defining the DM2C2 subzone in these basins.

Remarks. The sequence was defined by Charnock *et al.* (2001) in the northern North Sea, Dunlin Group. This was a subdivision of the J12 sequence as previously defined by Partington, Copestake *et al.* (1993) in the North Sea Basin.

The base J13 MFS correlates with the "Top Sinemurian Marker" (marine flooding surface), which defines the base of Sequence 3 in the North Celtic Sea Basin, offshore Ireland, and which is developed as a major gamma log peak and sonic low in wells from this area (Kessler & Sachs, 1995, who illustrated the 50/3-1 and 50/3-3 wells). An equivalent wireline log gamma log peak is also recognised in the Llanbedr (Mochras Farm) Borehole (Copestake & Johnson, 2014) and is probably correlative with that in the Celtic Sea Basin.

The equivalent flooding surface has been recorded in the Yorkshire and Hebrides areas (onshore UK) within the Taylori Subzone of the Jamesoni Zone (basal Lower Pliensbachian) by Hesselbo & Jenkyns (1998) and Van Buchem & Knox (1998), based largely on the development of an organic rich shale facies at this level. It correlates with the third order sequence Si5 MFS in Western Europe reported by Jacquin & De Graciansky (1998) and De Graciansky, Dardeau *et al*. (1998).

The basal boundary of the J13 sequence correlates with the base of the JG10 tectonostratigraphic sequence recognised in East Greenland by Surlyk & Nygaard (2000), which is defined by these authors at a major marine flooding of the underlying lacustrine basin at the base of the Pliensbachian.

Seismic expression. The Top Sinemurian (Top Glenbeg) seismic horizon, identified in the North Celtic Sea Basin (as seen in the 49/9-1 well), ties to the base of the J13 sequence.

Distribution and lithostratigraphical development. The sequence equates with the lower part of the Pabay Shale Formation in the Fastnet and North Celtic Sea basins. In the Slyne Basin, the sequence equates to the Ardra Member of the latter formation.

J14 SEQUENCE

Age. Early Jurassic, Late Pliensbachian.

Well definition of basal boundary. The base J14 MFS is taken at the gamma log maximum, with an associated sonic interval transit time maximum, within the mid part of the Pabay Shale Formation in west of Ireland (within the Barnahallia Member) as in well 18/20-1 and 27/13-1A in the Slyne Basin (see **Figure D.6. 3, Figure D.6. 53**) and in south and east of Ireland basins, as in 50/3-1 (see **Figure D.6. 3**). This boundary comprises a well-developed gamma-sonic bow boundary type log feature.

The base J14 maximum flooding surface is coincident with the top of the IOJ7 ostracod biozone and falls within the IFJ8 foraminifera zone. This surface falls within the lower part of the DM3 palynology biozone.

The biostratigraphy data overall from offshore Ireland shows a precisely the same age as for the basal boundary of the sequence in the North Sea and onshore UK, which suggests a level within the lower part of the Margaritatus Zone, within the early part of the Late Pliensbachian.

Remarks. In offshore Ireland there is often an unconformity developed within the Pliensbachian, indicated by missing lithostratigraphic and wireline logs units, and the absence of biostratigraphic zones. This break is frequently of considerable magnitude and is seen over a wide area from the Fastnet and North Celtic Sea basin to the Slyne and Erris basins. In west of Ireland wells the break is seen several wells, such as 27/4-1 (where the J16 sequence unconformably overlies the J12 sequence), 19/8-1 (where the J16 sequence, unconformably overlie the J13 sequence) and 18/25-1 (where the J17 sequence unconformably overlies the J12 sequence). In many wells the magnitude of the break prevents the accurate placement of the unconformity, for instance, in 48/30-1 (North Celtic Sea Basin), Lower Toarcian Whitby Mudstone Formation sits unconformably upon the Glenbeg Formation, of Sinemurian age. It is very difficult to be sure at what level the break occurs, and it is drawn tentatively at the base of the J14 sequence. In the Slyne Basin area, Serica Energy, operator of the 27/4-1 and other wells in this area, termed the intra Pliensbachian unconformity the “Early Pliensbachian Marker”. In the latter well, this break is represented by J16 section occurrinig above J12 sediments, omitting the J14 sequence. Notably, a Pliensbachian unconformity is visible on seismic data evaluated by O’Sullivan *et al*. (pers. comm., in prep) from the central part of the Slyne Basin, although it is less clear in the greater Corrib Field area. Faults are truncated by this surface.

The base J14 MFS correlates with the "Lower Pliensbachian Event, possible sequence boundary (?)" highlighted by Kessler & Sachs (1995) within their Sequence 3 in the North Celtic Sea Basin (as in 50/3-1, that is also illustrated here, see **Figure D.6. 3**).

In some wells the development of one or more unconformities associated with either the base of the J17 sequence or base of the J16 sequence, can completely cut out the J14 sequence (as in the 56/21-1, 27/4-1 and 18/25-1 wells).

The J14 genetic stratigraphic sequence was originally defined by Partington, Copestake *et al*. (1993) in the Northern North Sea Basin where it is well developed within the Dunlin Group. It has since been recognised by many subsequent workers in this basin (for example Charnock *et al*., 2001). This sequence seems to be developed in offshore Ireland in very similar facies, namely offshore marine claystone. The sequence is also present in offshore Denmark and Holland. In addition, Charnock *et al*. (2001) defined a new, J15 sequence in the North Viking Graben area, within the J14 sequence as defined by Partington, Copestake *et al*. (1993), however, there is no clear evidence that this additional sequence can be recognised within the J14 sequence in offshore Ireland.

The base J14 MFS (as defined by Partington, Copestake *et al*., 1993) has been tied by De Graciansky, Jacquin *et al*. (1998) to the peak transgression within their Second Order Cycle 5 in the North Sea. They also state that this event can be identified in mid Norway, to the north of the North Sea Basin.

Distribution and lithostratigraphical development. Preservation of the sequence appears to be related to the magnitude of the intra Pliensbachian break (either base J17 or base J16), or by the downcutting erosional break at the base of the UJ10 sequence (Oxfordian; see below). Where present, the sequence is developed as marine claystones of the Pabay Shale Formation in all basins where preserved, including the Slyne, Erris, Goban Spur, Fastnet and North Celtic Sea basins.

J16 SEQUENCE

Age. Early Jurassic, latest Pliensbachian.

Well definition of basal boundary. The base of the sequence is placed at the base of a gamma-sonic log bow boundary that falls within the upper part of the Pabay Shale Formation, though this is a subtler log feature than that of many other sequence boundaries. This falls one depositional log cycle below the log shoulder that characterises the base of the overlying J17 sequence. In the Slyne Basin wells such as 18/20-1, and Erris Basin wells such as 19/11-1A, this log feature is well displayed and falls within Allua Member of the Pabay Shale Formation (see **Figure D.6. 3).**

The J16 MFS occurs within IOJ8 ostracod biozone and within the DM3A palynology subzone in the Fastnet and North Celtic Sea basins and at the top of the IJO7 ostracod biozone in the Erris and Slyne basin wells. The biostratigraphy data indicates a level within or near the top of the Margaritatus Zone.

Remarks. This sequence, previously named J16a (Partington, Copestake *et al*., 1993), defined in the North Sea Basin, is renamed the J16 sequence by Copestake & Partington (in prep), and the previous J16b (of the former authors) sequence renamed as the J17 sequence.

An intra Late Pliensbachian erosional unconformity is developed onshore UK, at the base of the Spinatum Zone, which often cuts out part or all of the underlying Margaritatus Zone. This break is well developed in the vicinity of the Market Weighton High (Yorkshire, North Humberside, South Humberside, Eastern England), where it has been considered to have been controlled by structural movements on that structure (Howard, 1985). In the Northern North Sea, Viking Graben, an age equivalent unconformity is also identified, at the base of the J16 sequence, at the Cook/Burton formational boundary, within the Dunlin Group (Copestake & Johnson, 1989). In both offshore and onshore regions, the break is onlapped by sediments of the Spinatum Zone. This change is typically marked by an increase in sandstone which may correspond either to a basinward shift of facies or highstand shallowing. The J16 sequence can also be recognised in the Danish Basin, where the basal boundary of the sequence correlates with Nielsen's (2003) MFS14.

It is uncertain precisely where the intra Pliensbachian unconformity as seen in offshore Ireland (see discussion of J14 sequence above) falls stratigraphically. For now it is drawn at the base of the J14 sequence, however, it is possible in some wells that it falls at the base of the J16 sequence.

Distribution and lithostratigraphical development. Preservation of the sequence appears to be related to the magnitude of the intra Pliensbachian break (either base J17 or base J16), or by the downcutting erosional break at the base of the UJ10 sequence (Oxfordian; see below). Where present, the sequence is developed as marine claystones of the Pabay Shale Formation in all basins where preserved, including the Slyne, Erris, Goban Spur, Fastnet and North Celtic Sea basins.

J17 SEQUENCE

Age. Early Jurassic, Early Toarcian.

Chronostratigraphic calibration.

Well definition of basal boundary. In the offshore Ireland area, the base J17 MFS can be recognised regionally as a high gamma ray log peak and associated interval transit time sonic log peak which occurs near the base of the Whitby Mudstone Formation. This is a substantially lesser log feature than that at the base of the overlying J18 sequence. In many cases this log feature occurs a short distance above a prominent wireline log shoulder on the gamma and sonic logs representing the boundary between the Pabay Shale Formation and the overlying Whitby Mudstone Formation. This is well developed in many wells, such as 18/20-1, 19/11-1A (see **Figure D.6. 3**).

The basal boundary of the sequence falls at the base of the IOJ9 ostracod biozone, the base of the IFJ9 foraminiferal biozone and within the DM3A palynology subzone in the Fastnet, North Celtic Sea, Erris and Slyne basins. Correlation with onshore UK ammonite dated sections suggests a position near the base of the Early Toarcian Tenuicostatum Zone for the basal boundary of the sequence.

Remarks. A major unconformity is developed at the base of the sequence in the South Celtic Sea Basin, as seen **in Figure D.6.4,** in the vicinity of the 49/29-1 well. Major onlap above the Top Pliensbachian (Top Pabay) seismic horizon is seen in this area. The magnitude of the break is sufficiently large that it is not entirely clear at which sequence boundary the unconformity should be drawn, however.

This sequence, previously named J16b (Partington, Copestake *et al*., 1993), has been renamed as the J17 sequence (Copestake & Partington, in prep).

The "Top Pliensbachian Limestone Marker" marine flooding surface, defining the base of Sequence 3 in the North Celtic Sea Basin (offshore east of Ireland, Kessler & Sachs, 1995), equates with the base of J17.

The J17 MFS represents a significant deepening event within the earliest Toarcian, within the Cook Formation (Dunlin Group) in the Viking Graben (North Sea), within the Danish Central Graben (within the Fjerritslev Formation) and the uppermost part of the Aalburg Shale Formation in the Dutch Central Graben. In the Danish Basin, Nielsen's (2003) TS15, close to the base of the Spinatum Zone, correlates with the base of J17.

The base J17 maximum flooding surface appears to correlate with the base of a high gamma claystone developed at the base of the Grey Shales, above the Cleveland Ironstone, in the Yorkshire area (onshore Eastern England), at the base of the Tenuicostatum Zone, equating to the Pliensbachian/Toarcian boundary. The base J17 MFS appears to correlate with the transgression represented in the Hebrides Basin (Isles of Skye and Raasay, western Scotland) by the Portree Shale (Early Toarcian, Tenuicostatum Zone) above the Late Pliensbachian Scalpay Sandstone.

Seismic expression. The Top Pliensbachian (Top Pabay) seismic horizon, identified in the Slyne, Erris, Fastnet, North Celtic Sea and South Celtic Sea basins, ties to the base of the J17 sequence (see **Figure D.6. 4, Figure D.6. 5, Figure D.6. 6,** for example).

Distribution and lithostratigraphical development. The sequence is developed as marine claystones of the basal part of the Whitby Mudstone Formation in all basins where preserved, including the Slyne, Erris, Goban Spur, Fastnet and North Celtic Sea basins.

J18 SEQUENCE

Age. Early Jurassic, Early-Late Toarcian.

Well definition of basal boundary. The base of the sequence is placed at the level of maximum gamma ray log values and associated reduction in sonic velocity that is developed in the lower part of the Whitby Mudstone Formation, falling closely above the base of the Derg Member in the Erris Basin and Slyne Basin, and in the upper part of the Whitewood Member in the Fastnet and North Celtic Sea basins. This log feature is well developed in many wells, such as 18/20-1, 19/11-1A and 56/21-1 (see **Figure D.6.3**). This level appears to relate to the peak of organic richness in this claystone, and also with the Early Toarcian carbon isotope excursion (see below).

The base of the J18 sequence MFS falls within the IFJ10 foraminiferal biozone and within the DM3 palynology biozone, approximately at the base of the DM3B subzone.

Remarks. On wireline logs, occasionally, an additional apparent depositional cycle appears to be developed within J18, as seen for instance in 50/3-1 (see **Figure D.6. 3**), which, if proven to correlate regionally may form the basis for a subdivision of the sequence.

The base J18 MFS as defined here is considered to correlate with the Europe-wide, largely isochronous, intra Serpentinum Zone (Exaratum Subzone) anoxic event (Falciferum Ocean Anoxic Event of Fleet *et al*., 1987; Early Toarcian ocean anoxic event, or "T-OAE" of Jenkyns, 1988). The condensed interval around this level (both above and below the actual MFS surface) represents an important hydrocarbon source rock unit across Europe ("Posidonienschiefer" in the offshore Holland area and onshore Germany, Schistes Cartons in France; Fleet *et al*., 1987) which has been related to a major, regional relative sea level rise (Hallam & Bradshaw, 1979; Hallam, 1981). A locally developed source rock facies is developed at this level also in Norway Quadrant 30 (Parkinson & Hines, 1995). In offshore Ireland, source rock facies are present through the lower part of the J18 sequence, and also through the underlying J17 sequence; in the Ree and Derg members of the Whitby Mudstone Formation in the Slyne Basin, and in the Whitewood and Holaun members in the North Celtic Sea, Fastnet and Goban Spur basins (see below for source rock descriptions) (see **Figure D.6. 53**). The development of these Early Toarcian high gamma ray claystones has been previously reported from the North Celtic Sea Basin (Murphy *et al*., 1995) and the Slyne Basin (Trueblood & Morton, 1991).

The "T-OAE" is also associated with a geographically widespread negative carbon-isotope excursion (CIE) of as much as *ca* 7‰ in marine and terrestrial organic matter and a 3 to 6‰ negative excursion in coeval carbonate and biomarker compounds (Hesselbo *et al*., 2000; Jenkyns *et al*., 2002). An equivalent carbon isotope excursion has been identified by Silva *et al*. (2017) from well 18/25-1 in the Slyne Basin, in the Whitby Mudstone. In this well, two carbon isotope peaks are developed, one associated with the base of the J18 sequence as picked in this study, and one slightly higher, within the J18 sequence.

The base of J18 is recognised in the North Sea area and at UK outcrop as a high gamma or condensed shale (associated with oil prone black shales) which onlaps and oversteps basement margins, and which falls at the base of the Drake Formation (Dunlin Group) in the Viking Graben area. This level marks the Peak Transgression of the Ligurian major transgressive/regressive cycle 2 of Western Europe of Jacquin & de Gracianksy (1998), equivalent to the Second Order Cycle 6 peak transgression of De Graciansky, Jacquin *et al*. (1998), expressed both in the Paris Basin and in onshore UK. Zimmermann *et al*. (2015) placed the maximum flooding surface within second order Sequence 6 at the base of the Serpentinum Zone in north Germany, correlating with the deposition of the Posidonienschiefer and associated shoreline shift of over 200km.

The "Top Toarcian Marker" marine flooding surface described from the North Celtic Sea Basin by Kessler & Sachs (1995), which equates to the base of their Sequence 5, falls in various sequences as interpreted in the current study. In several wells, the base Sequence 5 surface of Kessler & Sachs (1995) falls within the J18 sequence as defined herein. In some wells, the surface falls much higher, within J22. The variations are due to differences in interpretation.

Distribution and lithostratigraphical development: The sequence is developed as marine claystones of the upper part of the Whitby Mudstone Formation in all basins, including the Slyne, Erris (as the Derg Member of the formation), Goban Spur, Fastnet Basin and North Celtic Sea basins (as the upper part of the Whitewood Member and all of the Holaun Member). The sequence extends into the overlying Dun Caan Shale Formation in the Erris and Slyne basins.

J22 SEQUENCE

Age. Early Jurassic, Late Toarcian-Middle Jurassic, late Aalenian.

Well definition of basal boundary. The base J22 maximum flooding surface is a condensed shale or gamma maximum/sonic interval transit time maximum recognised regionally within the lower part of Dun Caan Shale Formation (Lias Group), as in the 19/11-1A and 18/20-1 wells, in the Slyne Basin. This gamma peak occurs at the base of a coarsening upwards trend that continues through the overlying part of the J22 sequence, which equates lithostratigraphically to the lower part of the Harrier Formation (Kite Group) in the Slyne Basin. A correlative wireline log trend is seen also in wells from the North Celtic Sea Basin, such as 56/21-1 and 50/3-1, above the basal MFS of the sequence (in the uppermost part of the Whitby Mudstone Formation, uppermost Lias Group (see **Figure D.6. 3** and **Figure D.6. 17**).

Remarks. The basal boundary of the sequence in offshore Ireland lies within an interval often only broadly dated as Late Toarcian-late Aalenian, however, thus precise dating of the base of the sequence is not as yet possible. Elsewhere, for instance the North Sea Basin, the base of the sequence is placed in the latest Toarcian (Levesquei Zone) (Partington, Copestake *et al*., 1993), however, this dating of the basal boundary cannot yet be proven for offshore Ireland.

The sequence spans the Lower/Middle Jurassic boundary. It correlates with the North Sea Basin, North Viking Graben, where the sequence represents the uppermost part of the Dunlin Group and the basal part of the overlying Brent Group. Over much of the Central North Sea, a large stratigraphic gap omits much of the stratigraphy around this level, which has been termed the "Mid Cimmerian Unconformity" (Ziegler, 1990), is recognised at the approximate base of the preserved Middle Jurassic section over a wide area of the North Sea Basin. It is notable that an equivalent break is not seen in offshore Ireland at this level, where the stratigraphy appears largely complete across this boundary. There is evidence in well 18/20-7 of an unconformity at the base of J22, on the basis of apparent sedimentary thinning at this level by correlation with nearby wells, however, this may be related to faulting as no similar break is seen in other wells.

The deposition of the Ollach Sandstone Member (lower unit of the Bearreraig Sandstone Formation) in the Hebrides Basin (western Scotland) above the open marine Dun Caan Shale Member represents shallow marine progradation above a probable flooding surface, in either the Aalensis Zone or Opalinum Zone (as interpreted by Hesselbo & Coe, 2000). This progradation of the Ollach Sandstone Member equates to the upper part of the J22 sequence in offshore Ireland. This is suggested by the correlation of the Upper Glen-1 well (onshore Isle of Skye, Hebrides Basin) with the Slyne Basin 18/20-1 well (see **Figure D.6. 17**). Similarly, Archer *et al*. (2019) also relate the base of the Ollach Sandstone Member to the "Mid Aalenian Unconformity", and with the J22 sequence. The incoming of clastic sedimentation in the Hebrides Basin correlates with the incoming of the Chough Sandstone Member (Sparrowhawk Formation) in the North Celtic Sea Basin correlates with the basinward shift of facies and incoming of clastic sedimentation at the base of the Brent Group, in the northern North Sea.

Seismic expression. The Aalenian (Top Lias) seismic horizon, identified in the North Celtic Sea Basin, ties to the base of the J22 sequence (see **Figure D.6. 5**).

Distribution and lithostratigraphical development. The sequence is developed as marine claystones of the uppermost part of the Dun Caan Shale Formation and extends through the lower part of the Harrier Formation (Dunnock and Robin members and lower part of the Sparrow Member) in the Slyne Basin. In the FB and NCSB, the sequence spans the lower part of the Sparrowhawk Formation (lower part of Eagle Group) and includes the Chough Sandstone Member near the base of the sequence.

J24 SEQUENCE

Age. Middle Jurassic, Late Aalenian-Late Bajocian.

Well definition of basal boundary. The base J24 maximum flooding surface is a gamma maximum/sonic minimum within the lower part of Harrier Formation (mid part of Sparrow Member) in the Erris and Slyne basins. This is well illustrated in the block 18/20 wells, such as 18/20-4 (P4). A correlative wireline log trend is seen also in wells from the NCSB, such as 49/9-1, 50/3-1 and 50/6-1, above the basal MFS of the sequence (within the Sparrowhawk Formation) (see **Figure D.6. 1, Figure D.6. 7**). In wells in which the Chough Sandstone Member is present within the Sparrowhawk Formation, the basal MFS of the sequence is taken at a boundary between two wireline gamma-sonic cycles within the sandstone member; this is well displayed in 41/30-1, 42/21-1 and 50/6-1 (see **Figure D.6. 7)** from the North Celtic Sea Basin.

Good biostratigraphic control on the basal boundary of the sequence is seen in Slyne Basin well 18/20-4 (P4) in which the boundary falls within the DM3 palynology zone, above the DM3D1 subzone. The DM3D3 subzone occurs in the mid part of the J24 sequence, and the DM4 palynology zone occurs in the upper part of the sequence in this well. The sequence contains a succession of foraminiferal zones from IFJ11 to IFJ16, as in the 18/20-4 (P4) well.

Remarks. The marine flooding of the Aalenian Ollach Sandstone Member by the open marine Udairn Shale Member in the Hebrides Basin (isles of Skye and Raasay), in the Discites Zone (Bj1 MFS of Hesselbo & Coe, 2000) appears to correlate with the base J24 MFS in offshore Ireland. This is suggested by the correlation, and sequence interpretation, of the Upper Glen-1 well (onshore Isle of Skye) with the 18/20-1 well (see **Figure D.6. 17**).

In the northern North Sea Basin, the base of the J24 sequence falls at a shale within the Rannoch Formation (of the lower part of the Brent Group) (see Mitchener *et al*., 1992; Partington, Copestake *et al*., 1993).

Seismic expression. In the Slyne Basin, the Lower Bajocian seismic horizon corresponds to the Kingfisher Limestone Member below the Minard Formation, as seen for instance over the Corrib Field area (blocks 18/20, 18/25), as shown in **Figure D.5.3**. This falls within the J24 sequence. In the Goban Spur Basin, this seismic horizon falls below the top of the Sparrowhawk Formation, within the J24 sequence (see **Figure D.8.10**). No obvious unconformity has been seen at this horizon.

Distribution and lithostratigraphical development. The sequence is developed as marine claystones and limestones of the upper part of the Harrier Formation (upper part of the Sparrow Member, plus the overlying Skylark and Wren Members) together with the lower part of the overlying Kestrel Formation in the Erris and Slyne basins. This stratigraphic succession displays a well-developed gamma-sonic bow log profile (as seen in wells such as 18/20-1 and 18/25-1). The "regressive" unit comprising the mid part of this log cycle corresponds to the Kingfisher Limestone Member (limestone-shale interval) of the Kestrel Formation. In the Fastnet and North Celtic Sea basins, the sequence spans the upper part of the Sparrowhawk Formation (mid part of Eagle Group), including the upper part of the Chough Sandstone Member where present.

In some wells in the Slyne Basin area, for example, 18/20-7 and 19/11-1A, the upper part of the sequence is cut out by the unconformity at the base of the Minard Formation. Similarly, the sequence is either absent totally or truncated also in the Fastnet and Celtic Sea basins by one or more younger downcutting unconformities.

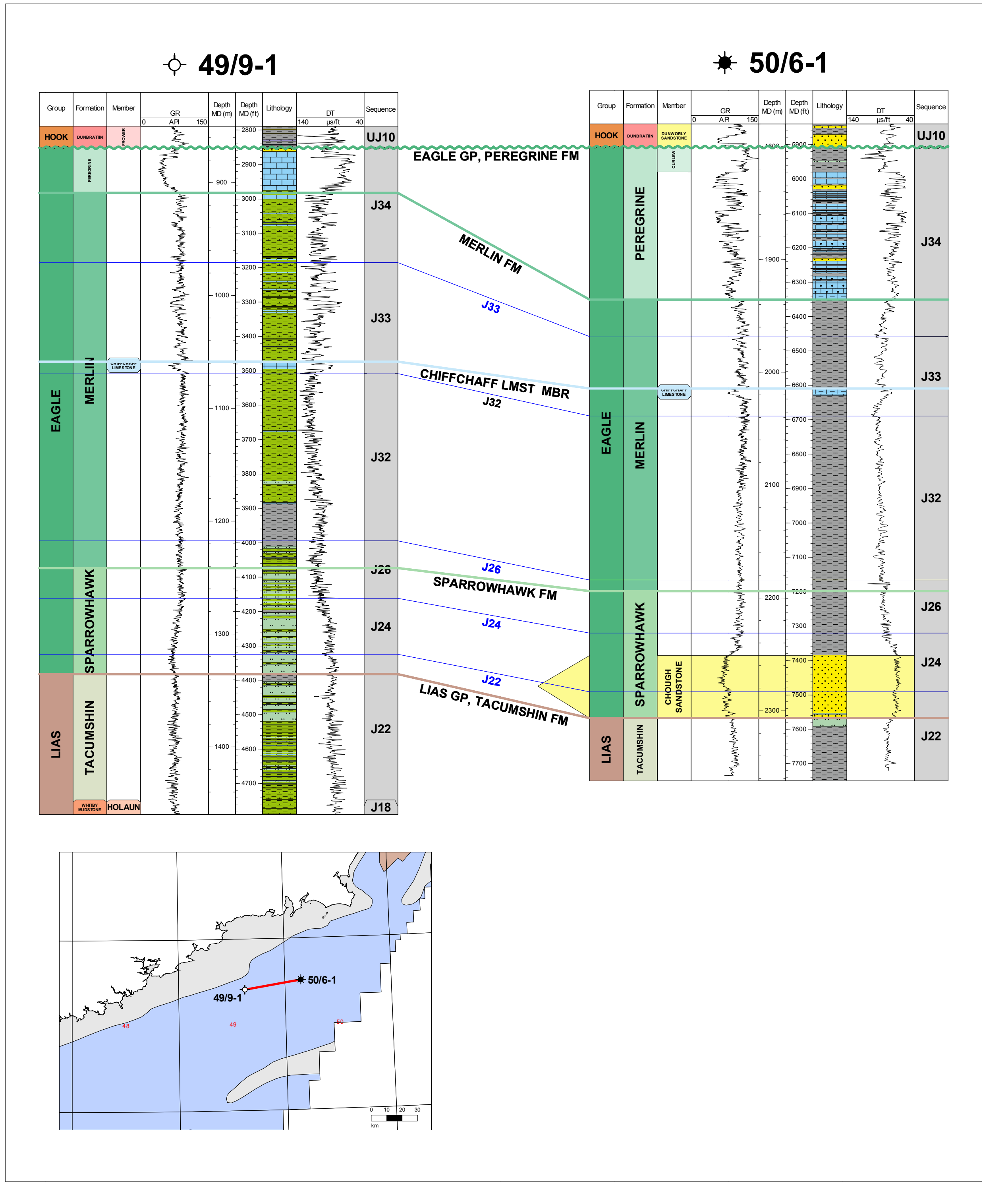


Figure D.6. 7. 49/9-*1, 50/6-1 Bajocian-Bathonian (Eagle Group) lithostratigraphic and sequence stratigraphic subdivisions in the North Celtic Sea Basin.*

J26 SEQUENCE

Age. Middle Jurassic, latest Bajocian-earliest Bathonian.

Well definition of basal boundary. In western offshore Ireland basins, such as the Slyne Basin, the base of the sequence is taken at the base of a gamma-sonic wireline log bow that is present within the Kestrel Formation, above the Kingfisher Limestone Member. This is well displayed in the 18/20-1, 18/20-4 (P4) and 18/25-1 wells, among others. In the North Celtic Sea Basin, the base of the sequence is placed at a wireline log feature (gamma ray log peak) interpreted as the maximum flooding surface that terminated deposition of the uppermost sandstone of the Chough Sandstone Member, a short distance below the top of the Sparrowhawk Formation. This is seen, for example, in wells 41/30-1, 42/21-1 and 50/6-1 (see **Figure D.6. 7**). Biostratigraphically, the basal boundary of the sequence falls within the DM4 palynology zone, DM4B subzone and IFJ17 foraminferal zone and IOJ17 ostracod zone in the west of Ireland area, for instance the Slyne Basin, for instance the 18/20-4 (P4) well.

Remarks. The sequence was originally recognised by Mitchener *et al*. (1992) in the North Sea North Viking Graben region (UK and Norwegian sectors) within the Brent Group, with its base at the Mid Ness Shale transgression, within the Ness Formation.

The base of the sequence correlates with the "Vesulian Unconformity" (Arkell, 1933) that occurs at the base of the Salperton Limestone Formation (formerly Upper Inferior Oolite) in south west and southern England, in the uppermost Garantiana Zone (Late Bajocian). The marine flooding of the Rigg Sandstone Member (of the Bearreraig Sandstone Formation) by the marine Late Bajocian Garantiana Clay Member in Northwest Scotland (isles of Skye and Raasay) correlates with the base J26 MFS. This level is associated with a stratigraphic break and corresponds to the boundary between Sequence D and Sequence E of Morton (1989). This break has also been considered to be recognisable in wells from the Slyne Basin, west of Ireland (for example 27/13-1A, Trueblood & Morton, 1991, figure 13), the same level at which the base of J26 is placed in this study.

Distribution and lithological development. The sequence is widespread in offshore Ireland and is recognised in the Slyne Basin (in the upper part of the Kestrel Formation) and in the North Celtic Sea Basin (in the uppermost Sparrowhawk Formation and lower part of the Merlin Formation). The sequence is absent (either totally or partially) over wide areas due to the erosional effects of one or more major unconformities at either the base Upper Jurassic or Base Cretaceous levels.

J32 SEQUENCE

Age. Middle Jurassic, (?latest Bajocian) Early-Middle Bathonian.

Well definition of basal boundary. In the North Celtic Sea Basin, the base of the sequence is placed at a wireline log feature (gamma ray log peak at the base of a gamma-sonic bow boundary) in the lower part of the Merlin Formation, as North Celtic Sea Basin wells 49/9-1 and 50/6-1 (see **Figure D.6. 7**). In well 41/30-1 the basal boundary of the sequence is interpreted to be represented by a minor unconformity and falls at the base of the Merlin Formation.

Remarks. It is notable that an abundance of planktonic foraminifera (marking the IFJ14 Zone) is seen in the mid part of the sequence (in the Merlin Formation) in some wells (for example, 49/9-1), consistent with deepening and marine flooding at this level.

The base J32 MFS was originally defined by Mitchener *et al*. (1992) in the North Sea Basin, where it falls at the base of the Tarbert Formation, of the uppermost Brent Group.

The J32 sequence correlates approximately with the lower part of the broadly defined Bat-1 sequence of Andsbjerg & Dybkjaer (2003), which these authors recognise in offshore Denmark, in the lower part of the fluvial–lacustrine Bryne Formation.

The unconformity developed close to the base of the Bathonian in onshore UK sections, within the Zigzag Zone, correlates with the base of J32 (for example break in the Mendips-Bath-Cotswolds areas of England at the base of the Great Oolite Series, Fullers Earth Clay Formation/top Upper Inferior Oolite (Clypeus Grit). In the Hebrides Basin, the base J32 MFS is probably expressed as the base of the Cullaidh Shale Formation (formerly known as the Basal Oil Shale, at the base of the Great Estuarine Group), which has also been suggested by Archer *et al*. (2019), which these authors date as latest Bajocian (base Parkinsoni Zone).

The base J32 MFS equates to the maximum flooding surface within sequence Bj5, defined by Jacquin *et al*. (1998), at the base of the Bathonian Zigzag Zone in Western Europe.

Distribution and lithological development. The sequence is developed in the marine Bathonian sediments of the Merlin Formation (lower part of the Eagle Group) in the North Celtic Sea Basin. The sequence is absent from studied wells in western offshore Ireland basins, for example the Slyne and Porcupine basins, due to the large stratigraphic break between the Upper Jurassic (Oxfordian) and Middle Jurassic (Bajocian) sediments in this area. Similarly, the sequence is absent from the Fastnet Basin, due to the large magnitude of the base Upper Jurassic unconformity, which merges with the Berriasian (Intra Pike) unconformity in this area, often cutting down to the Lias Group to cut out the whole of the Middle Jurassic section.

J33 SEQUENCE

Age. Middle Jurassic, Middle Bathonian.

Well definition of basal boundary. The base of the J33 sequence is placed in North Celtic Sea Basin wells (such as 41/30-1, 42/21-1, 49/9-1 and 50/6-1; see **Figure D.6. 7**) at the base of a broad coarsening upwards succession that begins in the mid part of the Merlin Formation, closely below the Chiffchaff Limestone Member. The base of this wireline log profile is interpreted as the base of a progradational succession, with the high gamma log feature at the base of the sequence interpreted as a downlap surface.

Remarks. The J33 was originally defined in the northern North Sea Basin, where it equates to a progradational depositional succession within upper part of the Tarbert Formation (Brent Group) (Partington, Copestake *et al*., 1993).

The sequence correlates with regressive Unit 2 of Wyatt (1996) documented from central England, the base of which falls close to the base of the Fullers Earth Rock Member, with an associated unconformity, tied to the base of the Subcontractus/Progracilis Zone boundary (intra Late Bathonian). This break may correlate with the base of J33. The Fullers Earth Rock Member is considered to probably correlate with the Chiffchaff Limestone Member. The Fullers Earth Rock Member has been correlated within wells across the South Celtic Sea Basin by Tappin *et al*. (1994), in wells close to the median line with offshore Ireland.

Distribution and lithological development. J33 is developed as shallow marine sediments of the upper part of the Merlin Formation (Eagle Group) in the North Celtic Sea Basin; the Chiffchaff Limestone Member falls within the sequence. The upper part of the sequence may contain limestones and sandstones, as in the 42/21-1 well.

J34 SEQUENCE

Age. Middle Jurassic, latest Middle to Late Bathonian.

Well definition of basal boundary. The base of the sequence is placed at a high gamma ray claystone in the uppermost Merlin Formation, in the North Celtic Sea Basin. This represents the base of a coarsening upwards depositional succession that culminates in the deposition of the limestones and interbedded sandstones of the Peregrine Formation (see well 50/6-1, for example, **Figure D.6. 7**).

Remarks. The J34 sequence was defined by Mitchener *et al*. (1992) in the northern North Sea Basin, and amended by Partington, Copestake *et al*. (1993). The sequence represents the upper unit of the Tarbert Formation (Brent Group) in the North Sea North Viking Graben area. In the Horda Platform area, Norwegian sector (Troll Field area), J34 represents the middle cycle of the Krossfjord Member sandstone (within the Heather Formation).

In onshore UK sections, a distinct Late Bathonian flooding event defining the base of Wyatt's (1996) regressive unit 3, at the base of the Frome Clay Formation, equates to the base of J33, within the Hodsoni Zone of the earliest Late Bathonian. This correlates with the base of J33 in the North Sea and offshore Ireland (North Celtic Sea Basin).

Seismic expression. The Bathonian (Top Peregrine) seismic horizon, identified in the North Celtic Sea Basin, ties to the top of the J34 sequence and is a high amplitude event reflecting the presence of carbonates at this level. This horizon has been known as the "Top Bathonian Limestone" marker in the area previously. This is the level of a significant unconformity across the Celtic Sea region, which is more properly described as a base Upper Jurassic unconformity. Because of the downcutting nature of this unconformity, the J34 and older sequences are often missing from well sections. This horizon is shown in **Figure D.6. 5** and Figure D.6. 8.

Distribution and lithological development. The sequence is represented by the uppermost part of the Merlin Formation the overlying Peregrine Formation and, in the most complete sections, by the overlying Curlew Member, of the Eagle Group, in the North Celtic Sea Basin. In other basins of offshore Ireland, Bathonian aged section has not been penetrated in any of the studied wells and boreholes. The upper part of the sequence is often truncated by the unconformity at the base of the Hook Group.

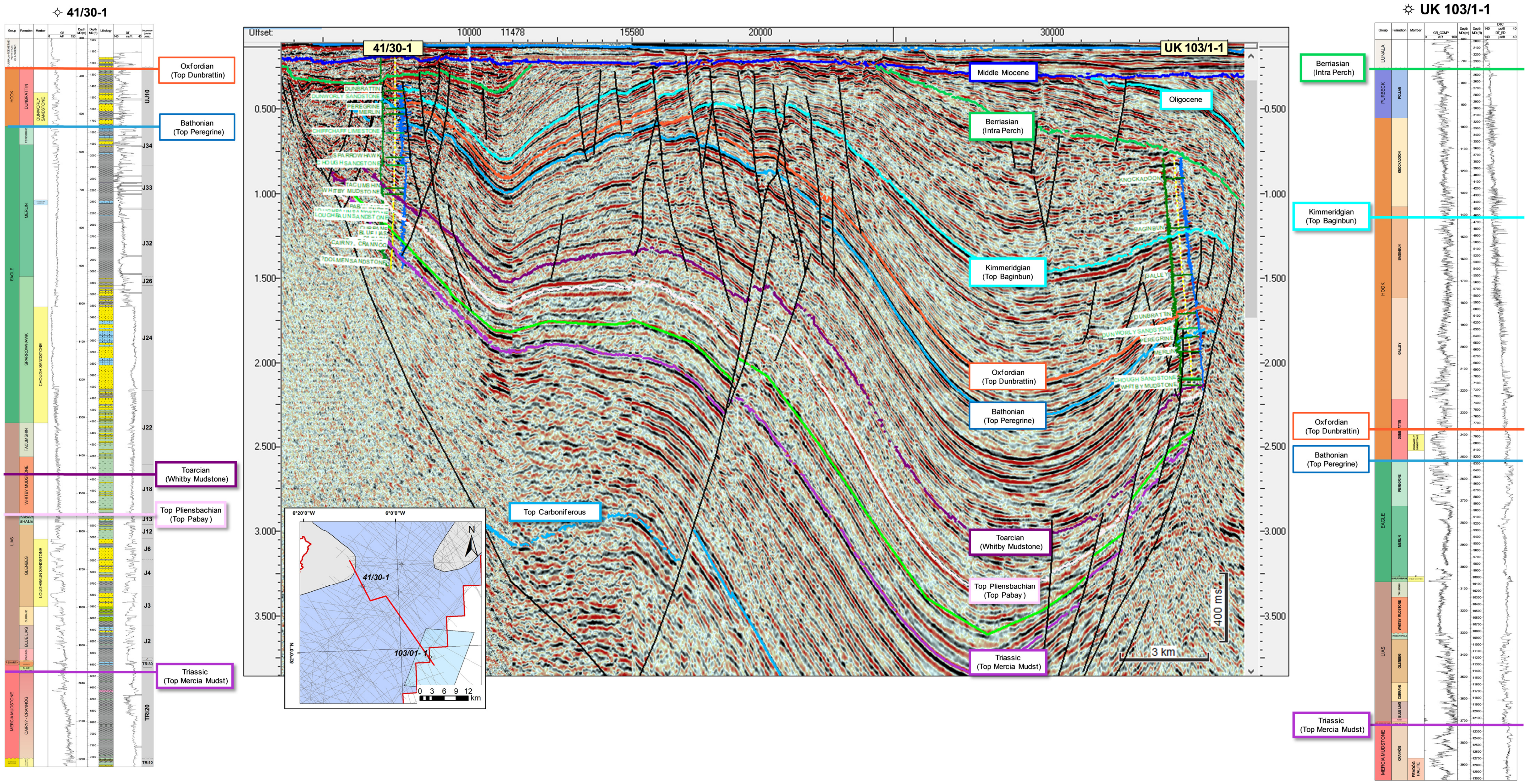


Figure D.6. 8. *Lower-Upper Jurassic seismic sequences, and ties to 41/30-1 and UK 103/1-1 wells, North Celtic Sea Basin. Arbitrary line comprises MIL92-26, MIL93P-21 and SGC06-780528.*

LOWER-MIDDLE JURASSIC PALAEOFACIES DISTRIBUTION

Palaeofacies maps have been created for the Lower to Middle Jurassic of offshore Ireland, for the Hettangian (**Figure D.6. 9**), Sinemurian (**Figure D.6. 10**), Pliensbachian (**Figure D.6. 11**), Early Toarcian (**Figure D.6. 12**), Aalenian-Bajocian (**Figure D.6. 13**) and Late Bathonian (**Figure D.6. 14**) intervals. An occurrence is known also in the Kish Bank Basin (sea bed sample, see Dobson & Whittington, 1979), however, its age is poorly constrained and hence it has not been added as a data point on any of the following Early Jurassic palaeofacies maps.

The Hettangian palaeofacies map focuses on the J2 sequence basal part of the Lias Group, of mid to late Hettangian age, which is represented by a range of depositional environments across the offshore Ireland region. In the Slyne and Erris basins, the interval equates to the lower part of the Meelagh Formation (including the Easky, Emo, Mullagh, Moanmore, Arroo and Lackagh members). These sediments are represented by alternating claystones, sandstones and evaporites reflecting marginal marine setting, interbedded with limestones of marine origin). Hettangian sediments are widespread in the Fastnet, North Celtic Sea, South Celtic Sea basins and across this region display a range of depositional environments, passing from a predominantly non-marine setting (represented by freshwater claystones), with interfingering marine facies (oolitic limestones) in the Fastnet, South Celtic Sea and southern part of the North Celtic Sea basins (represented by the Leane Formation). To the north eastern part of this region, alternating non-marine and marine environments persisted within the Leane Formation, represented by interbedded claystone/limestone lithofacies in the North Celtic Sea Basin and claystone/marl facies in the South Celtic Sea Basin. In this area, however, the various members of the Leane Formation that are differentiated to the south west are not discernible.

To the north east, depositional environments become fully marine, with the deposition of Blue Lias Formation (in the 50/12, 50/3 and 41/30 blocks) alternating limestones and claystones. To the south east of this area, in block 50/10 and passing into the UK sector block 103/2, the fully marine facies is developed entirely in claystones and marls (Gill Formation).

The Sinemurian palaeofacies map focuses on the whole Sinemurian interval and covers a range of depositional environments across the offshore Ireland region. In the Slyne and Erris basins, the interval equates to the upper part of the Meelagh Formation (including the Hollywood and Glennaun members) plus the overlying marine-estuarine Inagh Formation (including the Neaskin Member). These sediments are represented in this area by an interbedded mudrocks, carbonates, sandstones and evaporites, with limestones and dolomite intervals reflecting marine incursions (in the Hollywood Member).

Sinemurian sediments are widespread in the Fastnet, North Celtic Sea, South Celtic Sea basins and across this region and reflect fully marine depositional environments, passing from the Currane Formation (alternating claystones and limestones) in the earliest Sinemurian into the Glenbeg Formation. This formation is predominantly claystone dominated but includes shallow marine sandstones in the south west (Gara Sandstone Member) in the Fastnet Basin, and the correlative Loughbaun Sandstone Member in the northern part of the North Celtic Sea Basin (quadrants 50, 41 and 42).

The Pliensbachian interval is represented by the Pabay Shale Formation, which is in fully marine facies in all areas where penetrated, namely the Slyne, Goban Spur, Fastnet, South Celtic Sea and North Celtic Sea basins. Lithofacies are claystone dominated in all areas, with occasional limestones and are of shallow marine, shelf origin. A shallow marine sandstone (“42/21-1 Lower Sandstone Member”) is developed in the 42/21 block.

The Early Toarcian interval is represented by the Whitby Mudstone Formation which is in fully marine facies in all areas where penetrated, namely the Slyne, Goban Spur, Fastnet, South Celtic Sea and North Celtic Sea basins. Depositional environments are thought to be deeper marine than in the underlying Pliensbachian.

The Middle Jurassic, middle Aalenian-Bajocian interval is represented by the lower part of the Kite and Eagle groups, above the Lias Group. This equates to the Harrier and overlying Kestrel formations (Kite Group) in the Slyne Basin, which are developed as shallow marine, and claystone dominated lithofacies, with interbedded limestones, including the Kingfisher Limestone Member at the base of the Kestrel Formation. In the Goban Spur, Fastnet, South Celtic Sea and North Celtic Sea basins, the age equivalent sediments are referred to the Sparrowhawk Formation, of shallow marine origin. Sediments of this formation are predominantly claystone-dominated, with sandstones (“62/7-1 Sandstone” in the Goban Spur Basin; Chough Sandstone Member in the North Celtic Sea Basin, quadrants 41 and 50 areas) and limestones (for example the “50/3-1 Limestone Member).

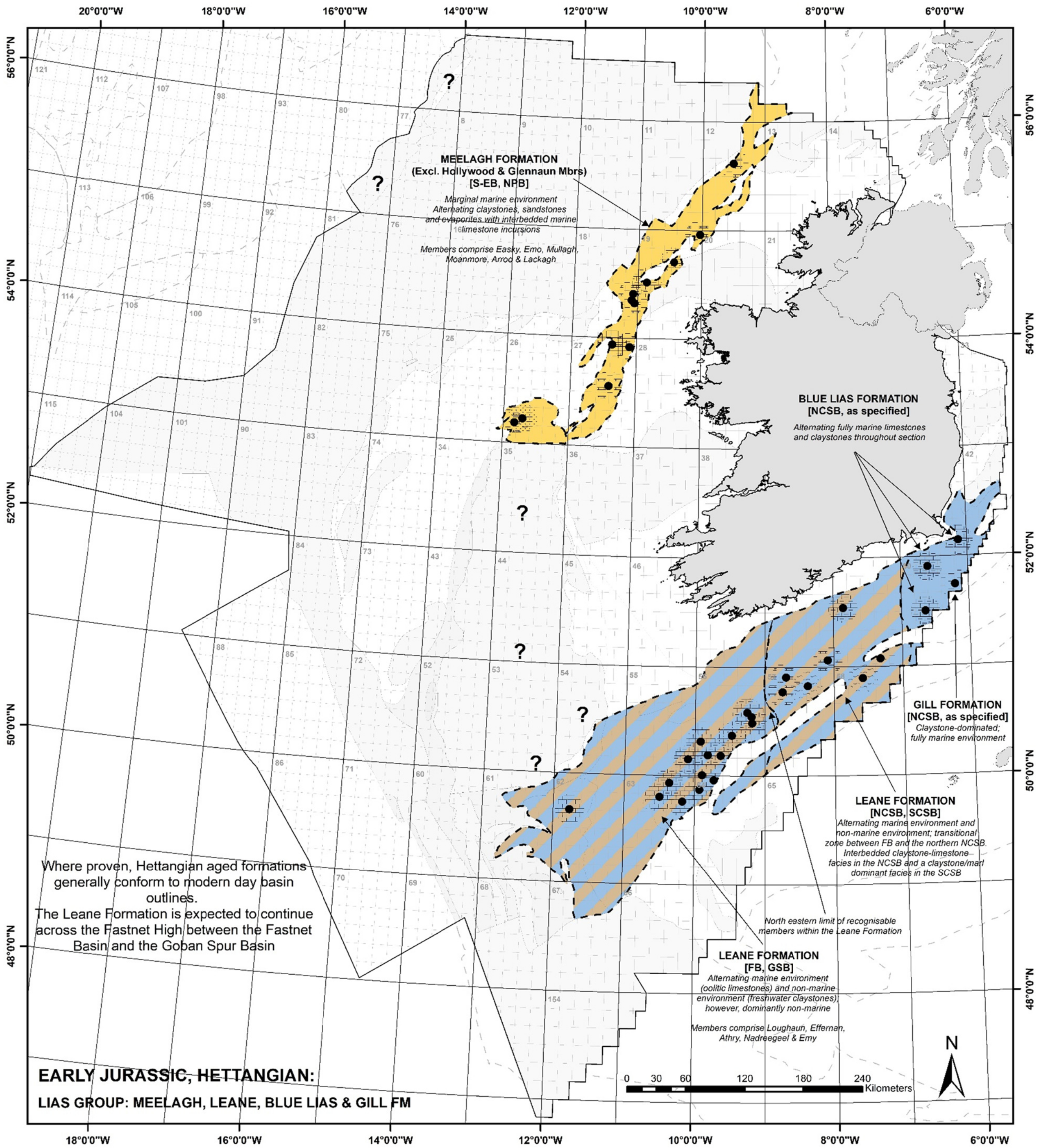


Figure D.6. 9. ***Hettangian palaeofacies map.***

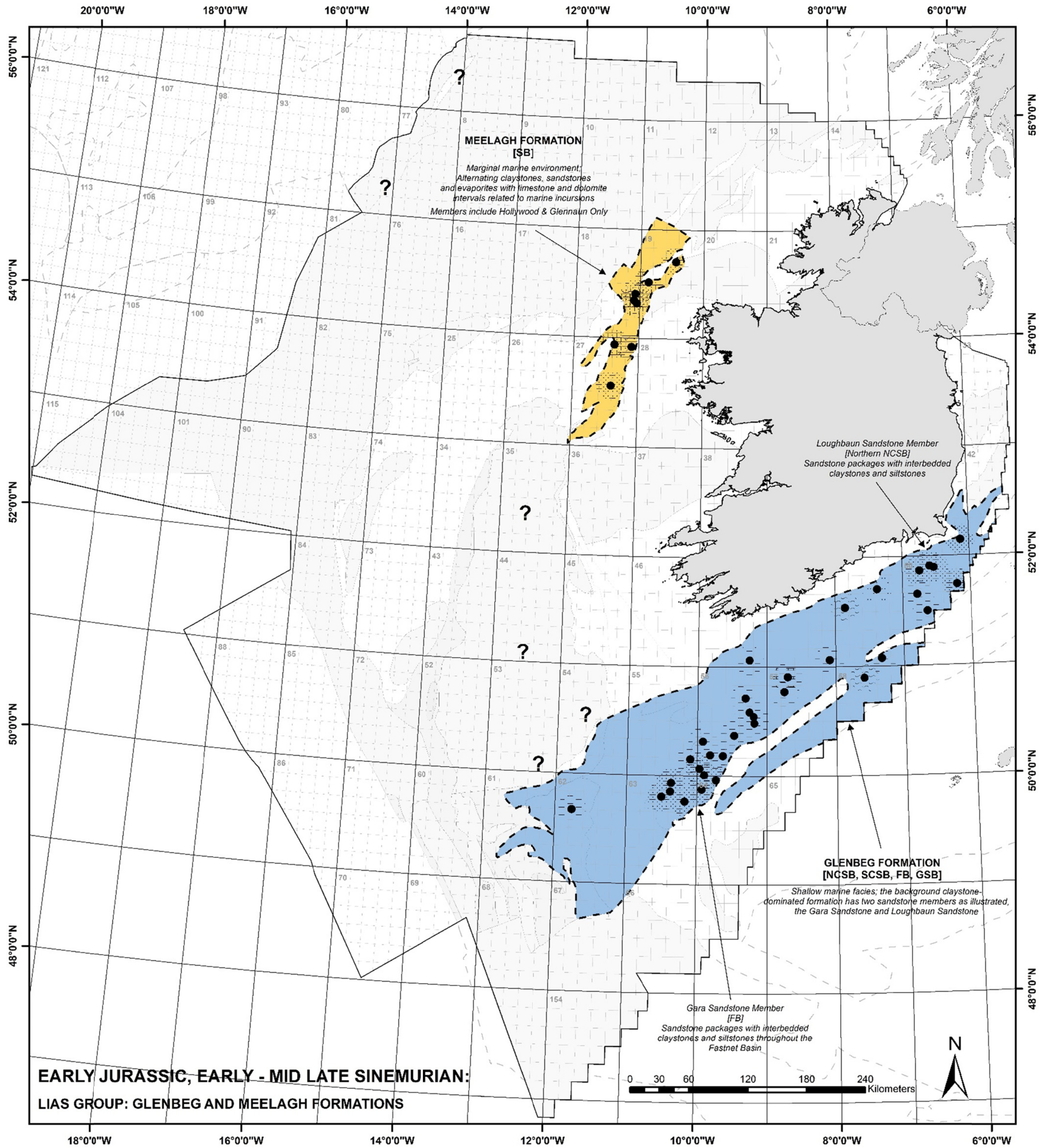


Figure D.6. 10. ***Sinemurian palaeofacies map.***

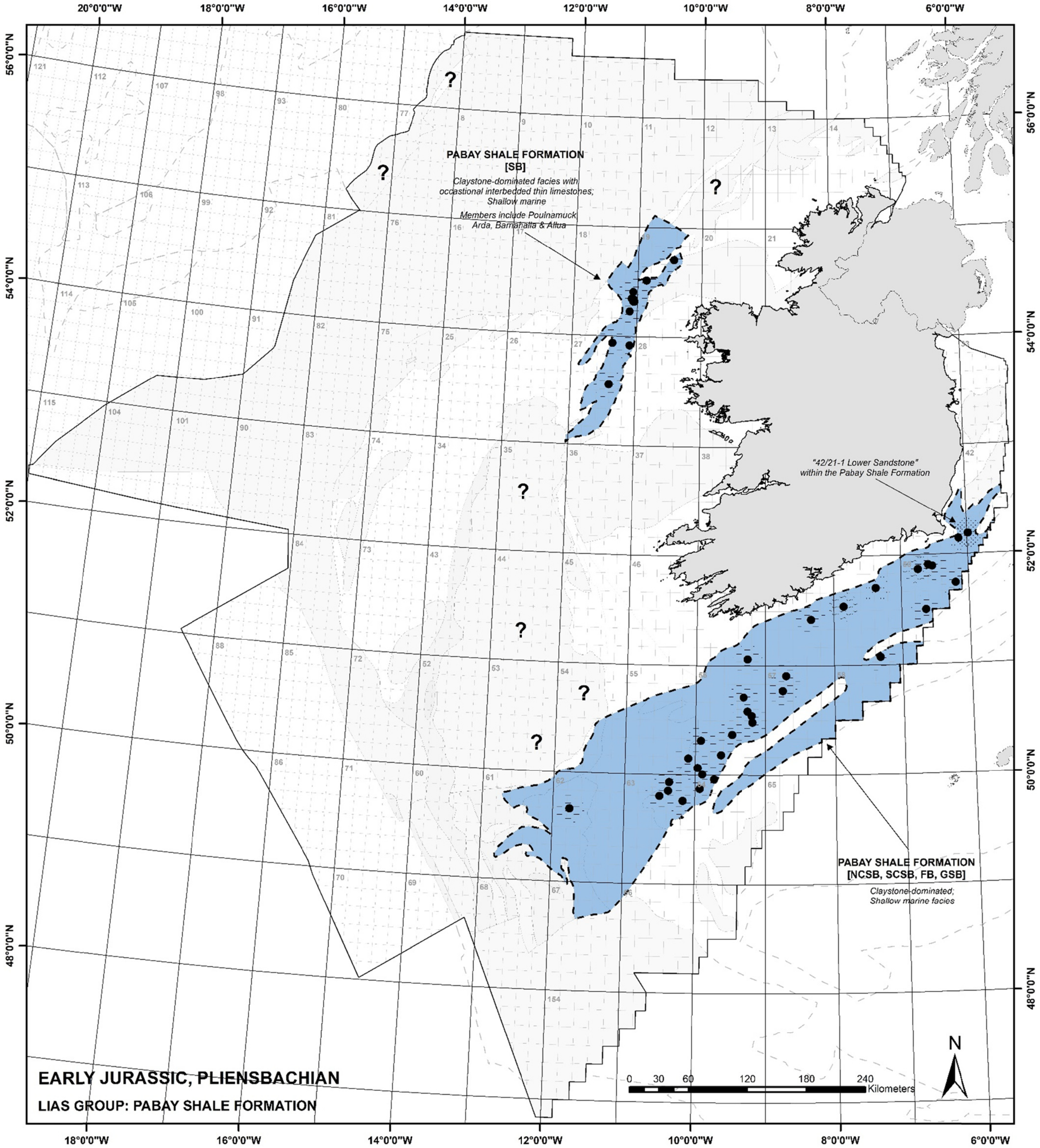


Figure D.6. 11. ***Pliensbachian palaeofacies map.***

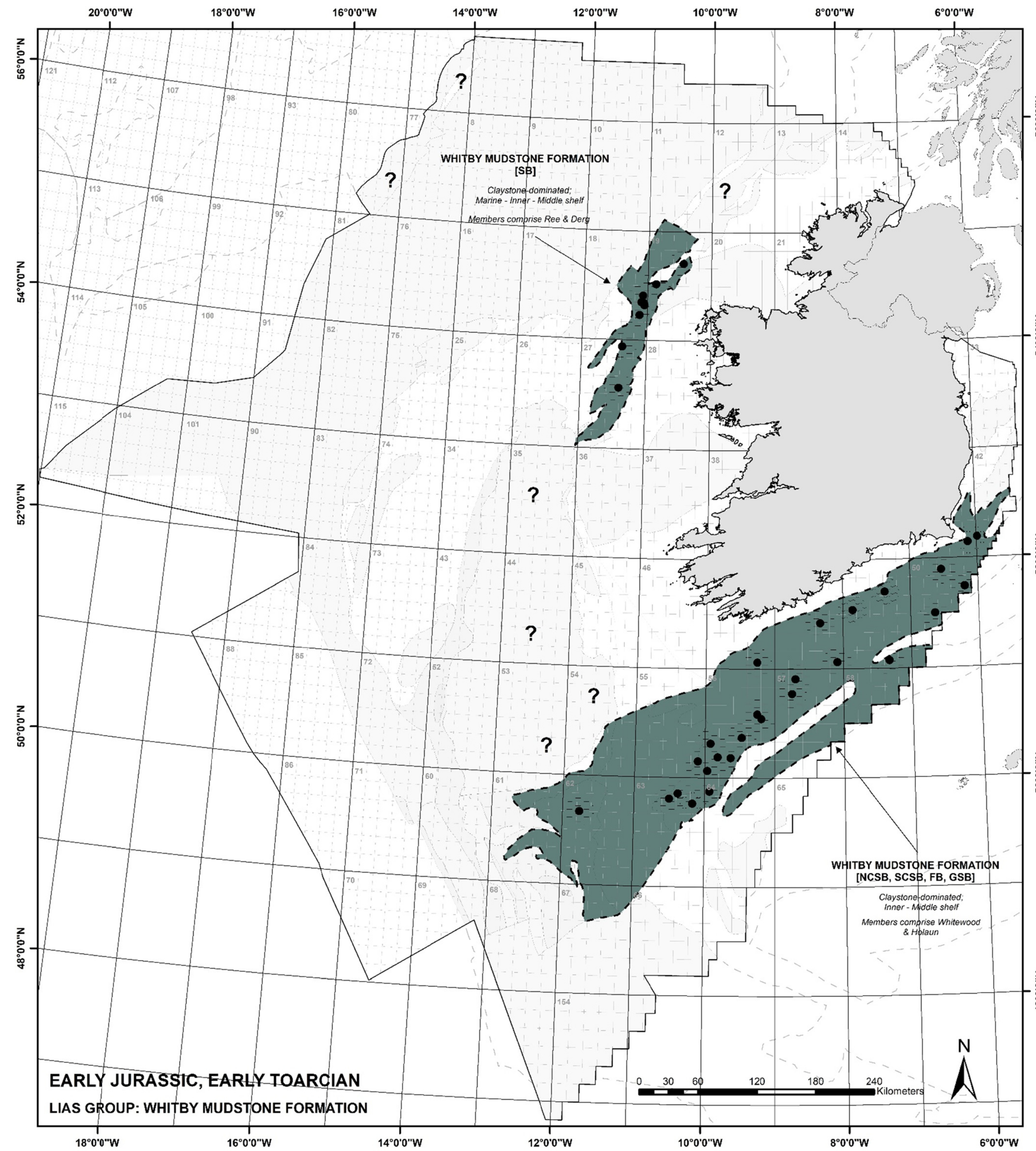


Figure D.6. 12. *Early Toarcian palaeofacies map.*

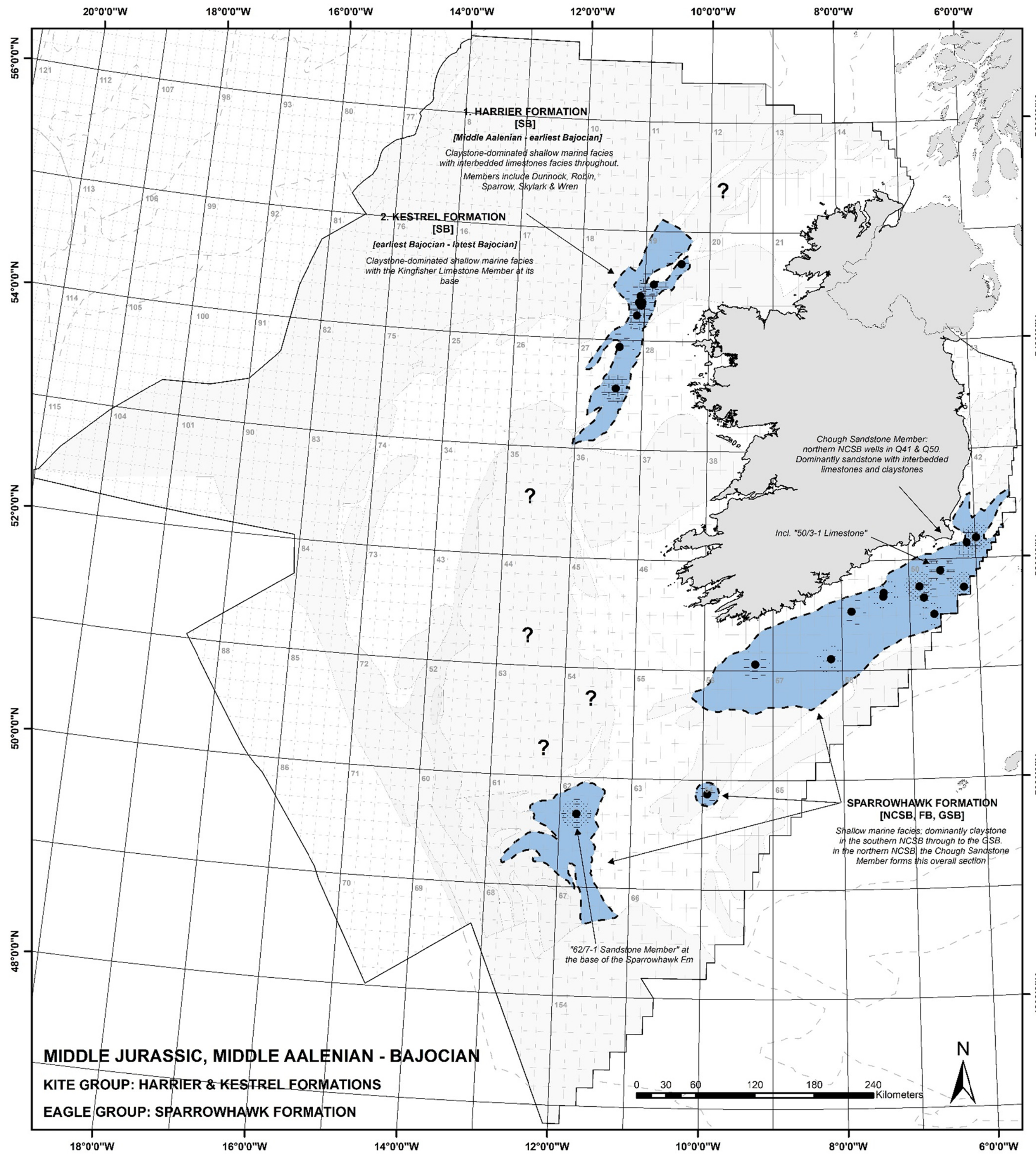


Figure D.6. 13. *Aalenian-Bajocian palaeofacies map.*

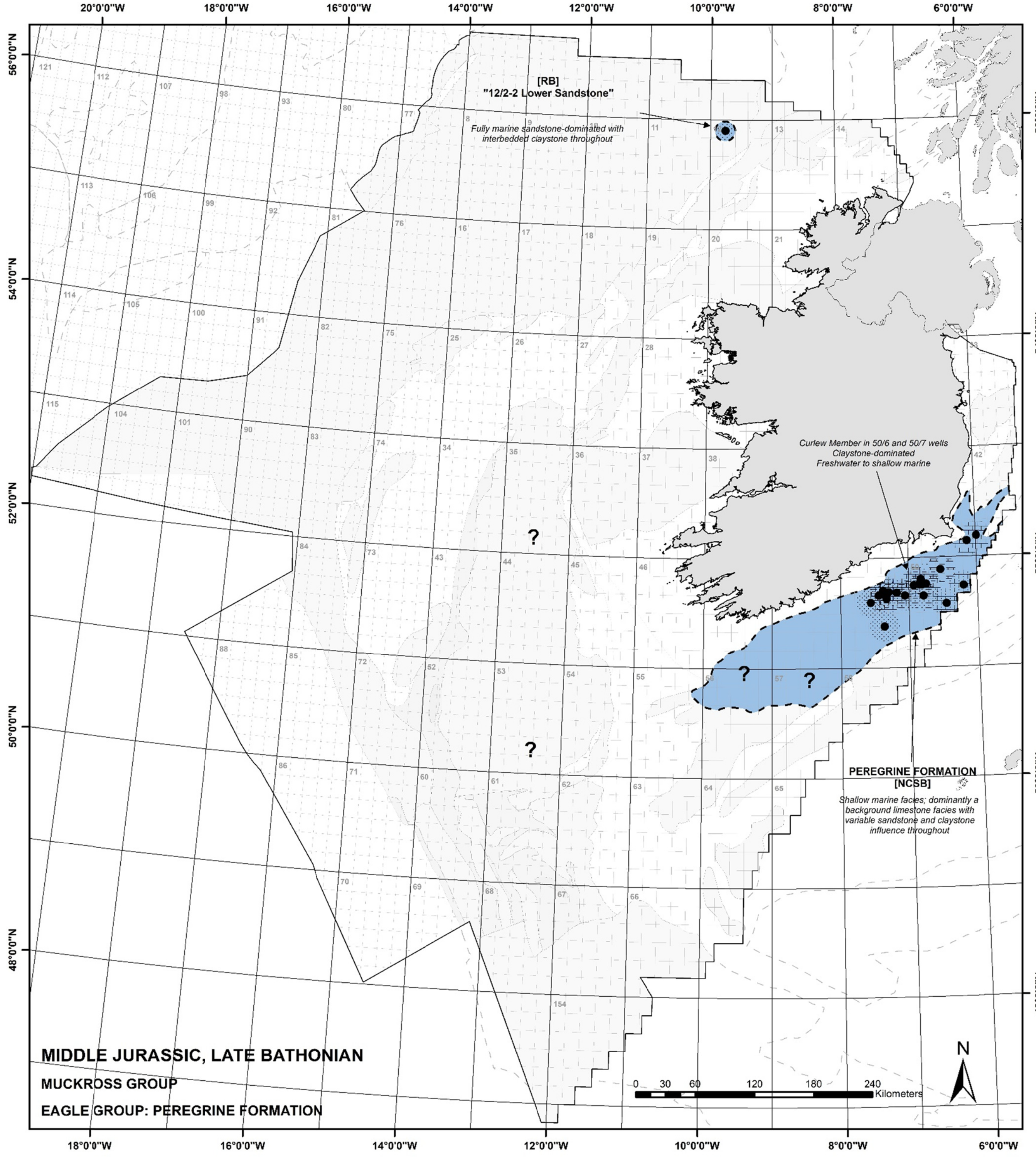


Figure D.6. 14. ***Late Bathonian palaeofacies map.***

The Middle Jurassic, Late Bathonian interval is represented by the Peregrine Formation in the North Celtic Sea Basin. This formation is of shallow marine origin and is developed in carbonate lithofacies, with subordinate sandstone and claystone. The uppermost part of the formation is represented by the Curlew Member, a marine claystone facies developed in wells from the 50/6 block. In a single well, 12/2-2, from the Rockall Basin, the "12/2-2 Lower Sandstone" is considered to be partly of Late Bathonian age, and is developed as a marine lithofacies composed of sandstones and interbedded claystones. Rocks of Late Bathonian age are absent from all other wells and boreholes in the western offshore Ireland basins.

LOWER-MIDDLE JURASSIC LITHOSTRATIGRAPHIC SUBDIVISIONS

Lower-Middle Jurassic rocks are widespread in offshore Ireland and are proven in wells, boreholes and sea bed samples from the Rockall, Erris, Slyne, Porcupine, Goban Spur, Fastnet, South Celtic Sea, North Celtic Sea and Kish Bank basins. Three lithostratigraphic groups are recognised, Eagle Group (Middle Jurassic of the Celtic Sea and Fastnet areas), Kite Group (Middle Jurassic of the Slyne and Porcupine areas) and the Lias Group (Middle to Lower Jurassic of the whole of offshore Ireland) (see **Figure D.6.15**). The presence of Middle Jurassic section is not proven by well penetrations in the Porcupine Basin, though Lower Jurassic sediments are proven in the northern part of the basin. It is considered likely that Middle Jurassic section is present in the basin, as is suggested by seismic interpretations both in this study and by others. The question regarding the presence of Bathonian aged section in this basin is discussed further below.

Lower and Middle Jurassic deposition appears to have been contiguous from UK onshore (Britain and Northern Ireland) to UK offshore areas to offshore Ireland, as shown by data published by, among others, Tappin *et al*. (1994; Cardigan Bay, Bristol Channel areas). In the nearby UK areas, Lower Jurassic rocks are referred to the Lias Group and this name has been applied to rocks of this age across all areas of offshore Ireland in the current scheme. Formation and member subdivisions of the group recognised offshore Ireland are discussed in more detail below.

Some previous authors, for instance, Trueblood & Morton (1991) and Trueblood (1992) considered that the tectonic history of the Slyne and Erris basins was linked to that of the Hebrides Basin (western Scotland) and therefore that it was valid to apply the lithostratigraphic terminology from Scotland to the offshore Ireland area. The application of Hebridean nomenclature in the Slyne-Erris areas has been continued since by all other companies in the area such as Enterprise (including Millennia, 1997), Shell, Statoil (Millennia, 2004) and Serica Energy (2009) and authors such as Dancer *et al.* (2005) and Scotchman & Thomas (1995). In the current project this approach is considered a valid approach for those lithological units that are likely to be widespread, that is background argillaceous sediments, hence terms such as Pabay Shale and Dun Caan Shale are extended from onshore Scotland into western offshore Ireland on the evidence that it appears that the facies and ages of these units are comparable across the region (though the Late Toarcian-Aalenian Dun Caan Shale Formation is allocated to the Lias Group herein; it was originally included as the basal member of the Bearreraig Formation in the Hebrides Basin).

Millson (1987) published a lithostratigraphic scheme for the Jurassic (Lower, Middle and Upper) of Fastnet and Celtic Sea basins (Ireland and UK regions), however, no type or reference wells were cited or illustrated, and the scheme is therefore not workable, and has not been adopted by the industry or academia in offshore Ireland.

Since the work of Trueblood & Morton (1991) the stratigraphy of the Hebridean successions has been revised (for example Morton in Simms *et al*., 2004; Hesselbo *et al*., 1999; Hesselbo & Coe, 2008). One amendment arising from this is that the term Broadford Beds is now discontinued in favour of new name, Breakish Formation, in western Scotland. The term Broadford Beds has been used extensively in western offshore Ireland basins, for example, in the Slyne Basin (Trueblood, 1992, 27/13-1A well; and in the Corrib Field, Dancer *et al*., 2005) and in other wells in the area. The succession formerly allocated to the Broadford Beds west of Ireland is referred here to the newly defined Meelagh Formation; it differs from the section in onshore Skye, around Broadford (now referred to the Breakish Formation) in being non to marginal marine, rather than fully marine in the Breakish Formation.

An important sandstone unit is present in several wells in the Slyne Basin, that has been termed the Suisnish Sandstone by operators and consultants in the area. This comprises the reservoir in the Bandon Discovery well 27/4-1. Biostratigraphic data from western offshore Ireland wells shows that this sandstone does appear to be coeval with the Suisnish Sandstone Member (Pabay Shale Formation) that is developed in onshore western Scotland (see for example, Simms *et al*., 2004, Hesselbo & Coe, 2000). Given the shallow marine-estuarine origin of this sandstone in the Ireland area it is highly unlikely to be contiguous with the Hebridean occurrences, hence a new name, Neaskin Member, is adopted for the offshore Ireland, Slyne Basin occurrences. The term Scalpay Sandstone has also been applied in western offshore Ireland (Trueblood, 1992; Trueblood & Morton, 1991), extending this name from onshore Hebrides outcrops. There is in fact no sandstone present at the level generally interpreted as representing this sandstone in western offshore Ireland (see 27/13-1A well in Trueblood, 1992 and Scotchman & Thomas, 1995). The Scalpay Sandstone Formation would not be expected to be present in offshore Ireland as it is clearly discontinuous in onshore Skye, having nearly totally shaled out over the distance between eastern Skye and the northern Skye well Upper Glen-1 (see **Figure D.6.16**). A similar rapid pinch out of the Suisnish Sandstone Member is also apparent on this correlation, as this sandstone is absent from the Upper Glen-1 well and has pinched out between here (northern Isle of Skye) and the type area of the sandstone, in central Isle of Skye.

Lower Toarcian marine claystones in the Inner Hebrides Basin are referred to the Portree Shale Formation (Morton in Simms *et al*., 2004). The junction between this formation and the overlying Dun Caan Shale Member is known to be unconformable in the onshore Hebrides area, hence the Portree Shale Formation name is not applied in offshore Ireland. In offshore Ireland, an expanded section is present, that is referred to the Whitby Mudstone Formation, by correlation with the North Celtic Sea Basin and Fastnet Basin. The Whitby Mudstone Formation name is extended into offshore Ireland from its use for lithologically similar sediments in onshore UK. Sedimentation is sufficiently different in the Fastnet and Celtic Sea basins during the Late Toarcian-Aalenian from that in the UK to warrant a new name, the Tacumshin Formation.

The Lias Group contains several organic-rich formations that show good to excellent source rock potential. These are, in descending stratigraphic order, the Tacumshin, Whitby Mudstone, Dun Caan Shale, Pabay Shale, Glenbeg, Currane and Leane formations. These formations occur in the North and South Celtic Sea basins, the Fastnet and Goban Spur basins, as well as in the Slyne Basin. In particular, the Whitby Mudstone Formation and the Pabay Shale Formation in the Slyne Basin area show very good to excellent oil-prone source rock potential.

Middle Jurassic (pre-Callovian) rocks onshore Britain are more variable lithologically than the Lower Jurassic, and can be separated out into carbonate-dominated successions, of marine to marginal marine origin (Inferior Oolite Formation and Great Oolite Group) in southern and central Britain, to marginal marine, deltaic clastic successions to the north of the Market Weighton axis (Ravenscar Group in Yorkshire, and Bearreraig Sandstone Formation and Great Estuarine Group in western Scotland) (Barron *et al*., 2012). None of these broad Middle Jurassic facies developments are directly comparable to the nature of the Middle Jurassic in offshore Ireland, which is dominated by fully marine Aalenian to Bathonian, mixed clastic-carbonate successions. While some individual units of the Irish Middle Jurassic successions do compare to those from the UK onshore and offshore area, in overall terms there are sufficient differences to warrant a new nomenclature for Ireland. Further comparisons with the UK successions are provided in the individual lithostratigraphic unit descriptions below.

The question of the presence of Bathonian sediments offshore Ireland warrants some specific consideration. On the basis of the current evaluation, it has been concluded that no firmly dated Bathonian section has yet been identified in any well or borehole drilled west of Ireland (the one exception is the "12/2-2 Lower Sandstone" section in the 12/2-2 well, which is dated as within the Callovian to Bathonian age range). Bathonian sediments have been interpreted to be present, however, by previous authors and operators in the region. Trueblood & Morton (1991) and Trueblood (1992), as stated above, applied Hebridean lithostratigraphic names to the successions in the north Porcupine and Slyne basins, and interpreted the presence of Great Estuarine Group (Bathonian) section in 26/22-1A (north Porcupine Basin) and 27/13-1A (Slyne Basin) wells. The correlation of the Middle Jurassic of the Upper Glen-1 well with the 18/20-1 Ireland well (that is a type well for the Middle Jurassic Kite Group) is shown in **Figure D.6. 17**, whereby the Bathonian Great Estuarine Group of the Hebrides Basin is interpreted to be cut out/absent in the stratigraphic gap (unconformity) that is developed between the base of the Oxfordian Minard Formation (Beara Group) and the top of the Bajocian Kestrel Formation (Kite Group) in offshore Ireland (Slyne Basin). This break is present in all wells in western Ireland that preserve Middle Jurassic section. The correlation also shows the lateral equivalence of the Bearreraig Group of the Hebrides Basin with the more fully marine Kite Group in west of Ireland wells. Further discussion regarding the presence/absence of Bathonian sediments west of Ireland is provided in the relevant sections below.

Note that in the northern Porcupine Basin, only two wells are known which penetrate the pre-Oxfordian Jurassic, 26/22-1A and 26/21-1; in both cases the Minard Formation unconformably overlies the Lower Jurassic, demonstrating the magnitude of the base Upper Jurassic unconformity and its presence in this basin.

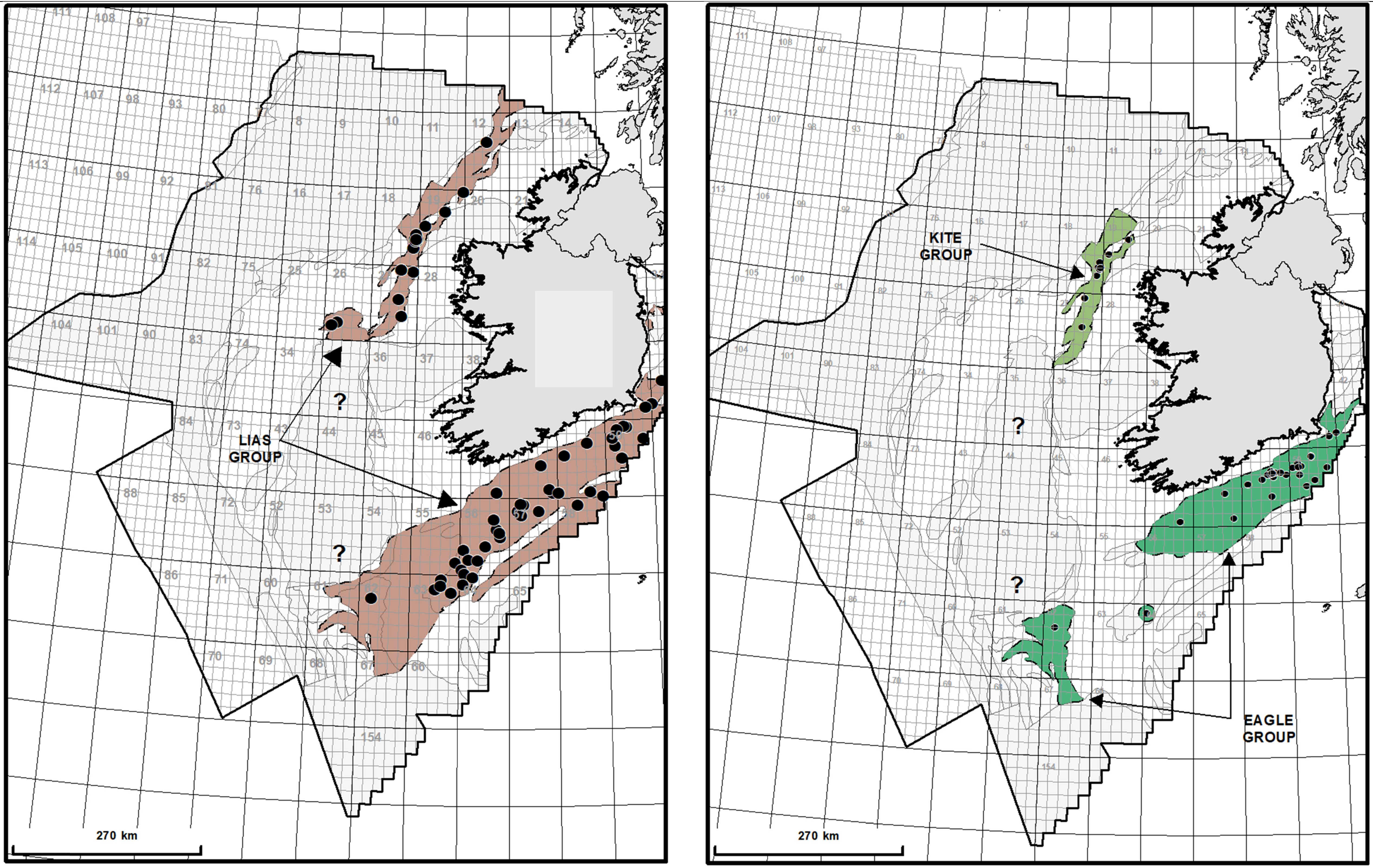


Figure D.6. 15. ***Lower-Middle Jurassic lithostratigraphic group distributions, offshore Ireland. Black dots represent proven well and borehole penetrations.***

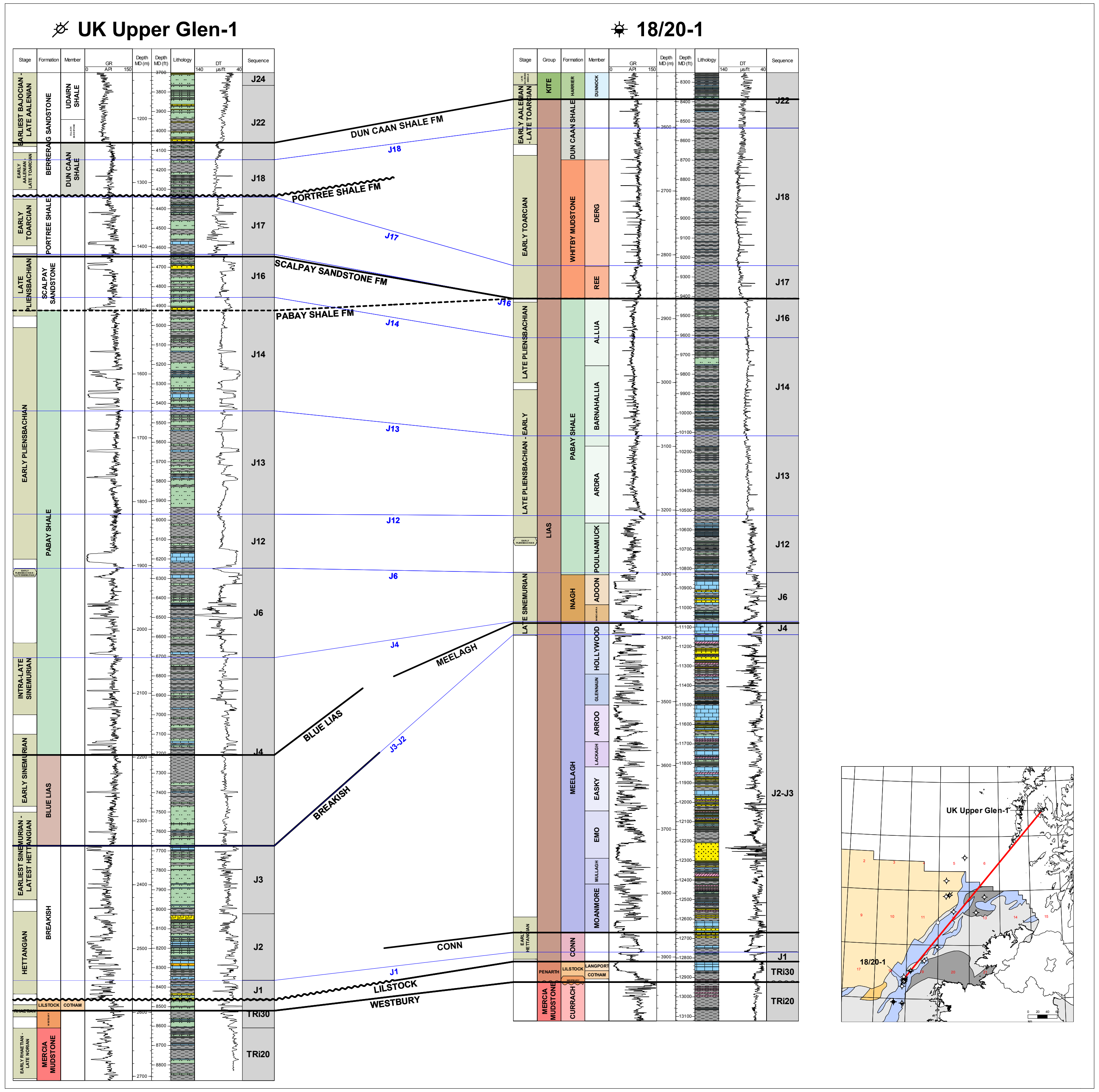


Figure D.6. 16. ***Lower Jurassic correlation of 18/20-1 well (Slyne Basin) with Upper Glen-1 well (onshore northern Isle of Skye, western Scotland)*.**

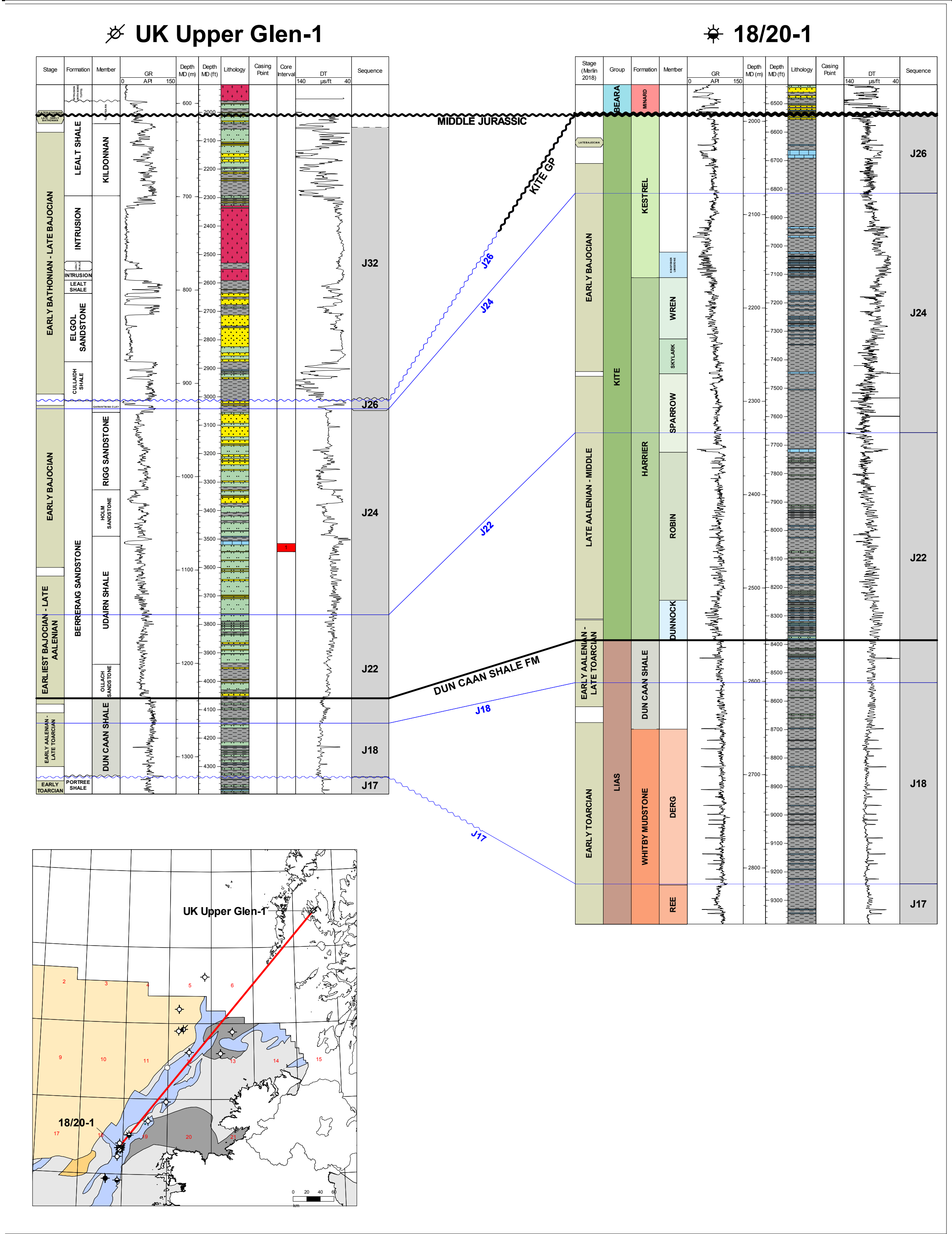


Figure D.6. 17. ***Middle Jurassic correlation of 18/20-1 well (Slyne Basin) with Upper Glen-1 well (onshore northern Isle of Skye, western Scotland)***.

The section formerly considered to be Bathonian age in Porcupine and Slyne-Erris basins (for example by Trueblood & Morton, 1991, for example in the 26/22-1A, 27/13-1A wells) is regarded in this study as Late Jurassic in age and is assigned to the Oxfordian aged Minard Formation (Beara Group).

In addition, in the Porcupine Basin successions, Bathonian aged sediments have been interpreted to be present in areas such as the Connemara Field (block 26/28), incorporating the lower part of the hydrocarbon reservoir section (see BP operator reports and composite logs, also see MacDonald *et al*., 1987; Jones & Underhill, 2011). The reasons for the interpretation of the Minard Formation, and its contained microfaunas and palynofloras, as Oxfordian are as follows: -

- In the northern Porcupine Basin, and to a lesser extent in the Slyne Basin, a number of Oxfordian index taxa have been recorded. These include the marine ostracod taxon *Galliaecytheridea staffinensis*, and the non-marine ostracod species *Theriosynoecum fluxans* and *Theriosynoecum hemigymnon.* In addition, the occurrences of a number of *Klieana* spp., plus *Cetacella armata/inermis* and *Leiria* cf. *striata* would indicate an age no older than Oxfordian for these dominantly red bed successions.
- There are no Bathonian restricted taxa in the palynofloral associations from the formation. While there are Middle Jurassic dinocysts present in the lower part of the formation, these are all typical Bajocian marine forms that are regarded as having been reworked from the underlying *in situ* Bajocian (Kite Group) sediments that typically underlie the Minard Formation.
- Charophytes are present in a number of intervals within the Minard Formation; a selection of these have been studied by a charophyte expert, Dr Carles Martin-Closas, as part of the current study (Closas, 2018). Dr Closas has identified the taxa as being primarily of Late Jurassic age, which include such species as *Aclistochara bransoni, A. polyspirata, Mesochara cancellata, M. harrisii, M. voluta, Porochara fusca* and *P. westerbeckensis.*

Only one well, 12/2-2, penetrated a unit "12/2-2 Lower Sandstone", see below for description) that yields marine Bathonian-Callovian sediments, based on the presence of a dinocyst association that suggests an age within this range.

It is curious that no Bathonian aged sediments have yet been identified offshore western Ireland (with the exception of the broadly dated Callovian-Bathonian interval in the 12/2-2 well, and also notwithstanding those previously interpreted Bathonian occurrences that are considered herein to represent Oxfordian aged sediments). In contrast, marine sediments of Bathonian age (Peregrine and Merlin formations, of the Eagle Group) are well-developed in eastern offshore Ireland area, in the North and South Celtic Sea basins (though are believed to be absent due to the Base Cretaceous or base Upper Jurassic unconformity in the Fastnet Basin wells).

It is further notable that there is no strong evidence for the presence of Callovian sediments in any offshore Ireland wells or boreholes studied. In west of Ireland wells and boreholes, this may be related to the absence of Bathonian strata from all studied sections too. In the Celtic Sea basins, however, marine Bathonian sediments are present, though Callovian sediments have not been recognised. In this project, the basal part of the Upper Jurassic in this area, comprising the Frower Member (Dunbrattin Formation) has been sampled and studied in detail seeking definitive Callovian biostratigraphic assemblages, however, no taxa of this age were found in this interval. This section, which is developed in "red beds" non-marine facies is considered to correlate with the Minard Formation of western offshore Ireland, with both formations being regarded as being of Oxfordian age. It is though likely that Callovian aged sediments will be present to east of offshore Ireland, in areas such as the St George's Channel Basin and Bristol Channel Basin, given that marine Callovian is well-developed in southern and central England (in the Oxford Clay Formation).

The lithostratigraphic subdivision proposed for the Lower and Middle Jurassic of offshore Ireland incorporates a mixture of existing names that appear to extend from the UK offshore area into offshore Ireland and new names applied to units that appear to be restricted to Irish offshore basins.

New Middle Jurassic lithostratigraphic units are named after birds that are native to Ireland. The hierarchy of group, formation and member reflects the order in the food chain. Each new member name begins with the letter C.

New Lower Jurassic lithostratigraphic units are named after Irish lakes. Mnemonics are used for formations, such that the first letters of the members of the Pabay Shale Formation spell "PABA", those of the Meelagh Formation spell the formation name, those of the Inagh Formation spell "INA", those of the Whitby Mudstone Formation spell "WH", those of the Glenbeg Formation spell "GL", those of the Currane Formation spell "CUR" and those of the Leane Formation spell the formation name.

EAGLE GROUP (NEW)

The Eagle Group is defined here for the Middle Jurassic (Bathonian-intra Aalenian) sediments that are developed in the Fastnet and North Celtic Sea basins, offshore eastern Ireland. The group includes the three newly defined formations, formations; in descending stratigraphic order; Peregrine, Merlin and Sparrowhawk formations.

The Eagle Group correlates with the Great Oolite and Inferior Oolite groups that are well developed in central and southern England (see for example, Barron *et al*., 2012). The carbonate dominated Inferior Oolite Group is significantly different lithologically from age equivalent section in offshore Ireland to warrant a new name for the interval. Tappin *et al*. (1994) did extend the Inferior Oolite and Great Oolite Group subdivisions as far west as the UK 103/2-1 well in the North Celtic Sea Basin, even though the carbonate dominated facies seen in southern England in these groups is not apparent. Even in Bristol Channel Basin wells, such as UK 103/18-1 (see Tappin *et al*., 1994, Figure 35), the Middle Jurassic is developed largely in argillaceous lithofacies demonstrating the westwards passage of the carbonate rich Inferior Oolite and Great Oolite groups of western and central England into claystone dominated facies in the near offshore area. The interval in the Celtic Sea area was referred to as the "Bajocian-Aalenian Shale Unit" by Ternan (2006), reflecting this.

The upper part of the Middle Jurassic in the Celtic Sea area is dominated by carbonates, however, which are referred to the Peregrine Formation. This unit was formerly known as the "Bathonian Limestone" by some previous operators in this area, for example, Marathon Oil. This carbonate dominated section (which includes oolitic facies) is quite expanded on the UK part of the North Celtic Sea Basin and achieves a significant thickness in the UK 103/1-1 well. This section was included within the Great Oolite Group of Tappin *et al*. (1994, Figure 34) in the North Celtic Sea Basin.

The group and its constituent formations and members are named after birds of prey that are native to Ireland.

MERLIN FORMATION (NEW)

The Merlin Formation is defined here for a claystone dominated formation of Middle Bathonian-latest Bajocian age which is developed within the Eagle Group, in the North Celtic Sea Basin. The formation is overlain by the Peregrine Formation and underlain by the Sparrowhawk Formation.

One new member is proposed, the Chiffchaff Limestone Member. A single informal sandstone unit is also recognised, the "42/21-1 Upper Sandstone".

Name. Named after the bird of prey that is native to Ireland.

Type section. 49/9-1: 909-1241.5m below KB. See **Figure D.6. 18**.

Reference sections. 42/21-1: 421-931.5m below KB. See **Figure D.6. 19**. 50/6-1: 1935.5-2194m below KB. See **Figure D.6. 18**.

Lithology. This formation is dominated by calcareous claystones and claystones. A thin white limestone (Chiffchaff Limestone Member) is recognised midway throughout the formation. A prominent sandstone unit is locally developed in the 42/21-1 well.

The calcareous claystones and claystones are medium to dark grey, locally greyish brown, medium grey/brownish grey, micromicaceous, rare carbonaceous specks, locally silty or sandy, locally pyritic, and soft to moderately well indurated, and grading to siltstone. Stringers of light to medium grey, yellowish grey, mudstone, microcrystalline to cryptocrystalline, in part bioclastic or oolitic, limestones and argillaceous limestones are present throughout. Off white to light grey, very fine to fine grained, well sorted, slightly glauconitic, calcareous sandstone stringers are recognised, particularly in the 41/30-1 and 42/21-1 wells.

The Chiffchaff Limestone Member is dominated by white, cryptocrystalline, mudstone, locally argillaceous, carbonates. Locally thin interbedded light grey, calcareous claystones are also present.

The "42/21-1 Upper Sandstone" is dominated by off white to yellowish brown, light grey, very fine to medium grained, well sorted, subangular to subrounded, locally iron-stained (limonitic) or argillaceous, sandstones. Interbedded light to dark grey, micromicaceous, rare carbonaceous specks, calcareous claystones and light to medium grey, light olive grey, pyritic argillaceous siltstones and siltstones are also recognised.

Wireline log character. The mudrocks of the Merlin Formation possess slightly serrated, relatively high gamma ray values and high sonic velocities. The formation overall is characterised by a linear to slightly bowed shaped log motifs.

The Chiffchaff Limestone Member exhibits a serrated wireline log motif, denoting interbedded limestones and locally developed calcareous claystones. The "42/21-1 Upper Sandstone" possesses a poorly defined boxcar log motif, with lower gamma ray and higher sonic velocity values compared to the overlying and underlying mudrock units.

Upper boundary. The top of the formation is taken at a downsection lithological change from the limestones and calcareous sandstones of the Peregrine Formation to the claystones of the Merlin Formation. On wireline log criteria, this is expressed as an increase in gamma ray values and a corresponding decrease in sonic velocity.

Lower boundary. The lower boundary displays a downward lithological change from claystones to the slightly more silty, less calcareous claystones of the Sparrowhawk Formation. This is reflected on wireline log criteria by a slight decrease in gamma ray values and corresponding slight increase in sonic velocity.

Subdivision. One new formal member is recognised; the Chiffchaff Limestone Member. A single informal sandstone unit is also recognised; the "42/21-1 Upper Sandstone".

Thickness. The formation ranges in thickness from 120m (49/9-4) to a maximum thickness of 510.5m (42/21-1) in the North Celtic Sea Basin. In many instances where this formation has been encountered the base has not been penetrated.

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is generally good to very good. Towards the base of the interval a decline in microfossil recovery is often noted. Occurring within Ostracod Zones IOJ16 (*pars*) to IOJ13, Foraminiferal Zones IFJ15 to IFJ14 and Palynological Subzones DM5A2 to DM5A1.

Age. Middle Jurassic, Middle Bathonian-latest Bajocian.

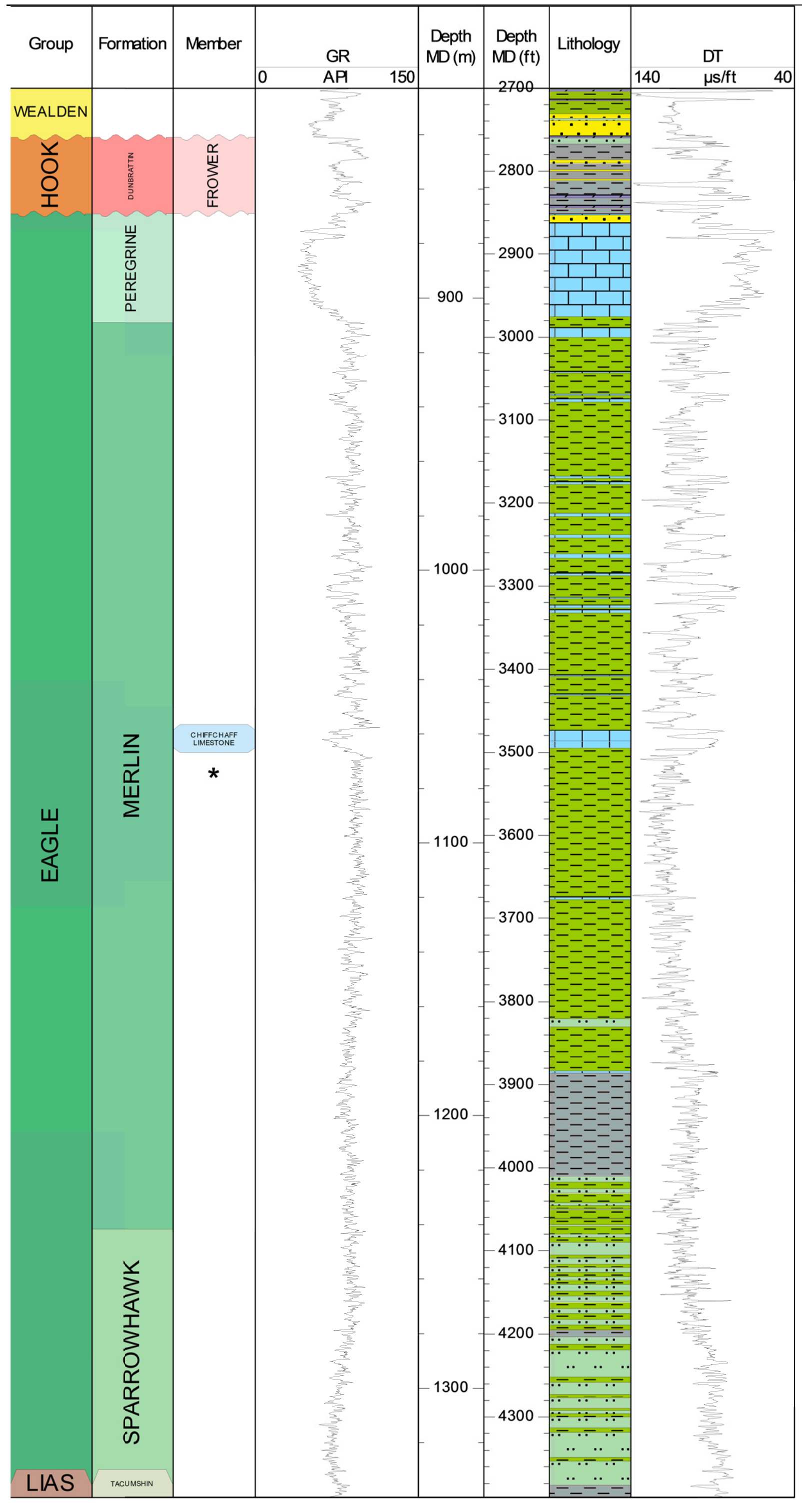
Depositional environment. Marine, inner to middle shelf. The occurrence of often rich and diverse microfaunas (ostracods, foraminifera and macrofossils) is indicative of low energy, well oxygenated, open marine, conditions. The presence of rare to common planktonic foraminifera would support this conclusion, while the presence of echinoderm debris would indicate warm, shallow clear waters. Towards the base of the interval microfaunal recovery declines in abundance and diversity, with the microfaunas often dominated by smooth ostracods (*Cardobairdia, Polycope, Cytherella* spp.) and the foraminiferal genera *Garantella, Reinholdella* and *Epistomina,* suggesting some restriction in the sedimentary environment, with possible locally dysaerobic marine conditions. The occurrence of calcareous sandstones and oolitic limestones in the upper sections of the formation, particularly in the 41/30-1 and 42/21-1 wells, reflects decreasing water depths and localised sand sourcing. It is envisaged that the commencement of Merlin Formation deposition represents a marked transgressive event (interpreted as the base J32 maximum flooding surface).

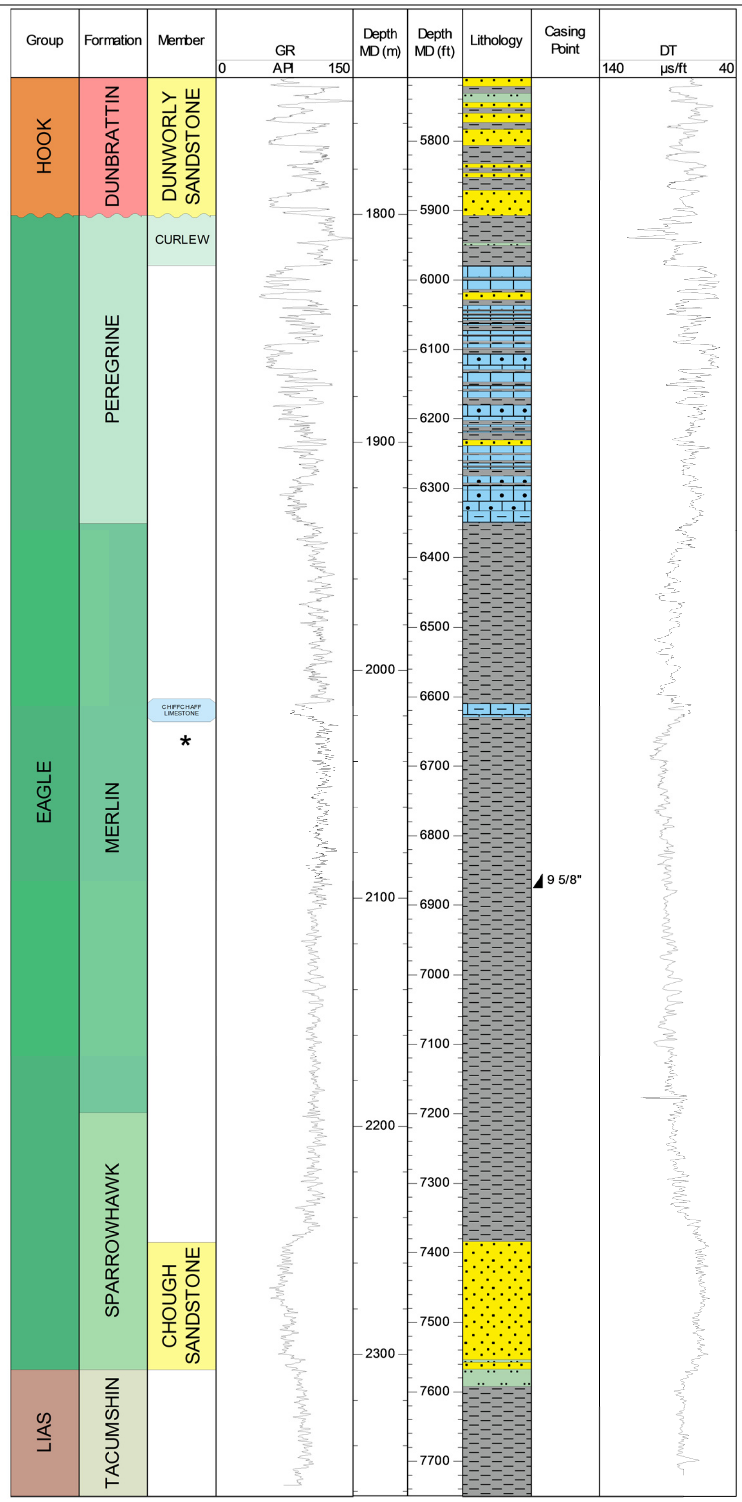
Distribution. The formation has been recorded in wells from the North Celtic Sea Basin and its distribution is extended to the present-day basin limits on the basis of seismic evidence. Its presence in the Fastnet and South Celtic Sea basins are unproven, however, as in the wells drilled to date all penetrate a significant unconformity at the base of the Upper Jurassic that cuts down into the Middle and Lower Jurassic, it is possible that in some undrilled areas of this basin that the formation may be present.

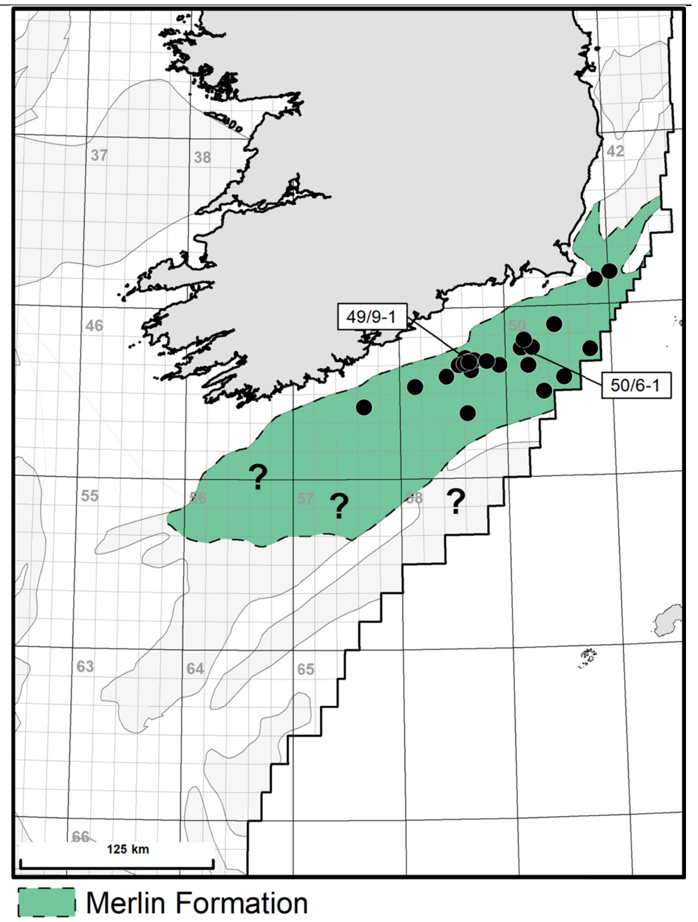
Seismic expression. The formation occurs between the Bathonian (Top Peregrine) and Aalenian (Top Lias)/Toarcian (Whitby Mudstone) seismic horizons in the North Celtic Sea Basin. In many areas, no clear seismic character is discernible, however, in the expanded succession in the northern part of this basin, the formation displays distinctive banded character typified by high amplitude parallel reflectivity (see **Figure D.6.8**), although this character is not particularly evident at the 41/30-1 well location on the latter seismic line.

Regional correlation. The formation is age equivalent to the uppermost Inferior Oolite Group and most of the Fuller's Earth Formation, Great Oolite Group, of southern England (Cox, 2002; Cox & Page, 2002; Barron *et al.*, 2012). In northwest Scotland the formation is equivalent to the lower and middle parts of the Great Estuarine Group (Cox *et al*., 2002).

Comparison with Eastern Canada. The Merlin Formation is age equivalent to the upper part of the Downing Formation (claystones) of the Carson, Horseshoe and Jeanne d'Arc basins, offshore east coast Canada.







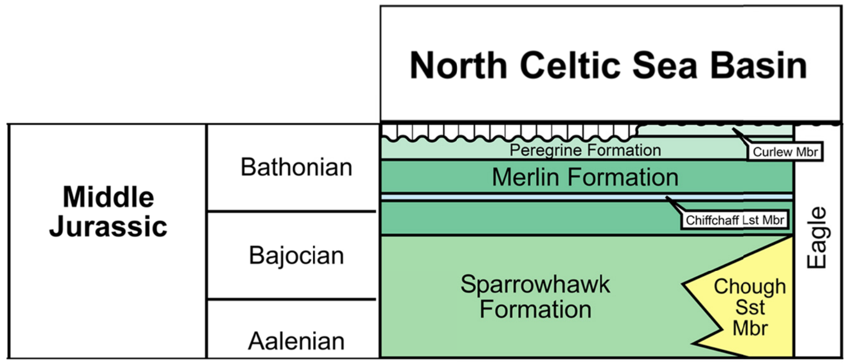


Figure D.6. 18. ***Merlin Formation type and reference wells with location and distribution map.***

Chiffchaff Limestone Member (New)

The Chiffchaff Limestone Member is defined here for a thin dominantly limestone unit of intra Middle Bathonian age that is developed in the middle part of the Sparrowhawk Formation in the North Celtic Sea Basin.

The member is considered to correlate with the Fuller's Earth Rock as interpreted by Tappin *et al*. (1994), for example, in the UK 103/2-1 (St George's Channel Basin) and UK 103/21-1 (South Celtic Sea Basin) wells, adjacent to the offshore Ireland occurrences. The member correlates chronostratigraphically with the Fuller's Earth Rock Member known from onshore UK basins also.

Name. Named after the bird that is native to Ireland.

Type section. 49/9-1: 1058.5-1065m below KB. See **Figure D.6. 19**.

Reference section. 50/6-1: 2014.5-2020.5m below KB. See **Figure D.6. 19**.

Lithology. The Chiffchaff Limestone Member is dominated by white, mudstone, cryptocrystalline, locally argillaceous, limestones. Locally, a thin light grey, calcareous claystone/marl is developed midway through the member.

Wireline log character. This member exhibits a serrated wireline log motif, denoting the interbedded limestones, with a thin calcareous claystone developed in the middle part of the member. This unit exhibits moderately low gamma ray values and moderately high sonic velocities reflecting the limestone lithologies. The locally developed calcareous claystone bed developed midway is reflected by slightly higher gamma ray values and slower sonic velocities.

Upper boundary. The upper boundary is taken at a downsection lithological change from the claystones of the Merlin Formation to the limestones of the Chiffchaff Limestone Member. On wireline log criteria this boundary is taken at a sharp decrease in gamma ray values, coinciding with a sharp increase in sonic velocity.

Lower boundary. The lower boundary displays a downward lithological change from limestone to the claystones of the Merlin Formation. This is reflected on wireline log criteria by a sharp increase in gamma ray values and corresponding sharp decrease in sonic velocity.

Thickness. The member ranges in thickness from 1.5m (42/21-1) to 7.5m (41/30-1).

Biostratigraphic characterization. Occurring within Ostracod Zone IOJ15 (*pars*), Foraminiferal Zone IFJ15 (*pars*) and Palynological Subzone DM5A2.

Age. Middle Jurassic, intra Middle Bathonian.

Depositional environment. Marine, inner shelf. The member was deposited in a well oxygenated marine inner shelf. The high calcareous content possibly reflects a warm carbonate-rich environment.

Distribution. The member is proven by well penetrations in the northern part of the North Celtic Sea Basin, however, it is absent from wells to the immediate south of this area, due to lateral facies changes. The member appears to extend into adjacent areas of western offshore UK St George's Channel and South Celtic Sea basins (where it was referred to as the "Fullers Earth Rock" by Tappin *et al*., 1994).

Regional correlation. Age equivalent section is absent from any other offshore Ireland basin other than the North Celtic Sea Basin. This member is a lateral equivalent to part or all of the Fuller's Earth Rock Member, Fuller's Earth Formation of southern England (see Cox, 2002; Cox & Page, 2002; Barron *et al.,* 2012).

Comparison with Eastern Canada. The member is age equivalent to the upper part of the Downing Formation (claystones) of the Carson, Horseshoe and Jeanne d'Arc basins, offshore east coast Canada.

"42/21-1 Upper Sandstone"

This dominantly arenaceous unit of Middle-Early Bathonian age is present in the lower part of the Merlin Formation within the 42/21-1 well, located in the northern part of the North Celtic Sea Basin.

Type section. 42/21-1: 677-824.5m below KB. See **Figure D.6. 19**.

Lithology. This unit is dominated by off white to yellowish brown, light grey, very fine to medium grained, well sorted, subangular to subrounded, locally iron-stained (limonitic) or micaceous, argillaceous sandstones and sandstones. Interbedded light to dark grey, micromicaceous, rare carbonaceous specks, calcareous claystones and light to medium grey, light olive grey, pyritic argillaceous siltstones and siltstones are also present.

Wireline log character. This unit possesses a slightly serrated boxcar log motif with moderately high gamma values and moderately low sonic velocities reflecting the argillaceous sandstones and sandstones within this member. The gamma ray values within this unit are only slightly lower than the encompassing claystone units, reflecting the high argillaceous and/or micaceous content of the sandstones.

Upper boundary. The top of this unit is taken at a downsection lithological change from the claystones of the Merlin Formation to the sandstones of the "42/21-1 Sandstone". This is expressed on wireline log criteria as a decrease in gamma ray values and a corresponding increase in sonic velocity.

Lower boundary. The base of this unit is indicated by downward lithological change from sandstones to the claystones of the Merlin Formation. On wireline log criteria the boundary is taken as an increase in gamma ray values and a coincident decrease in sonic velocity.

Thickness. This unit attains a thickness of 147.5m in the 42/21-1 well.

Biostratigraphic characterization. Poorly constrained due to an absence of short-ranging microfossil taxa. It occurs within Palynological Subzones DM5A2 to DM5A1.

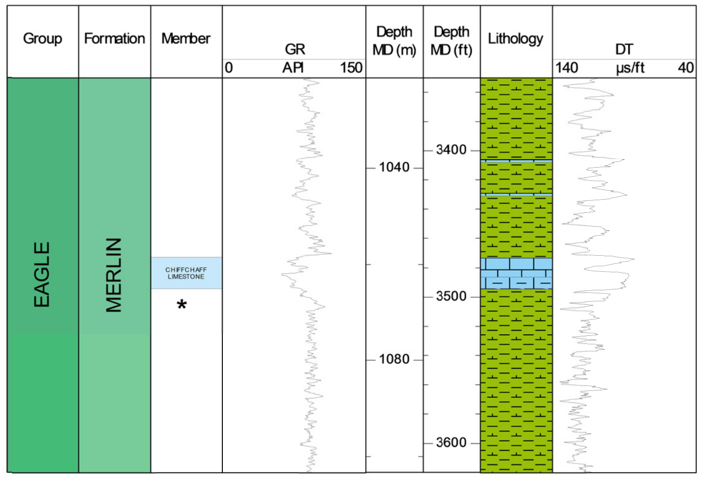
Age. Middle Jurassic, Middle-Early Bathonian.

Depositional environment. Marine, shoreface to inner shelf. These fine to medium grained sands are only recorded in the 42/21-1 well indicating a localised sediment source, possibly from the Irish mainland to the northwest of the well location. The localised presence of iron stained (limonite) sediments may suggest sediment starvation and/or very shallow water deposition.

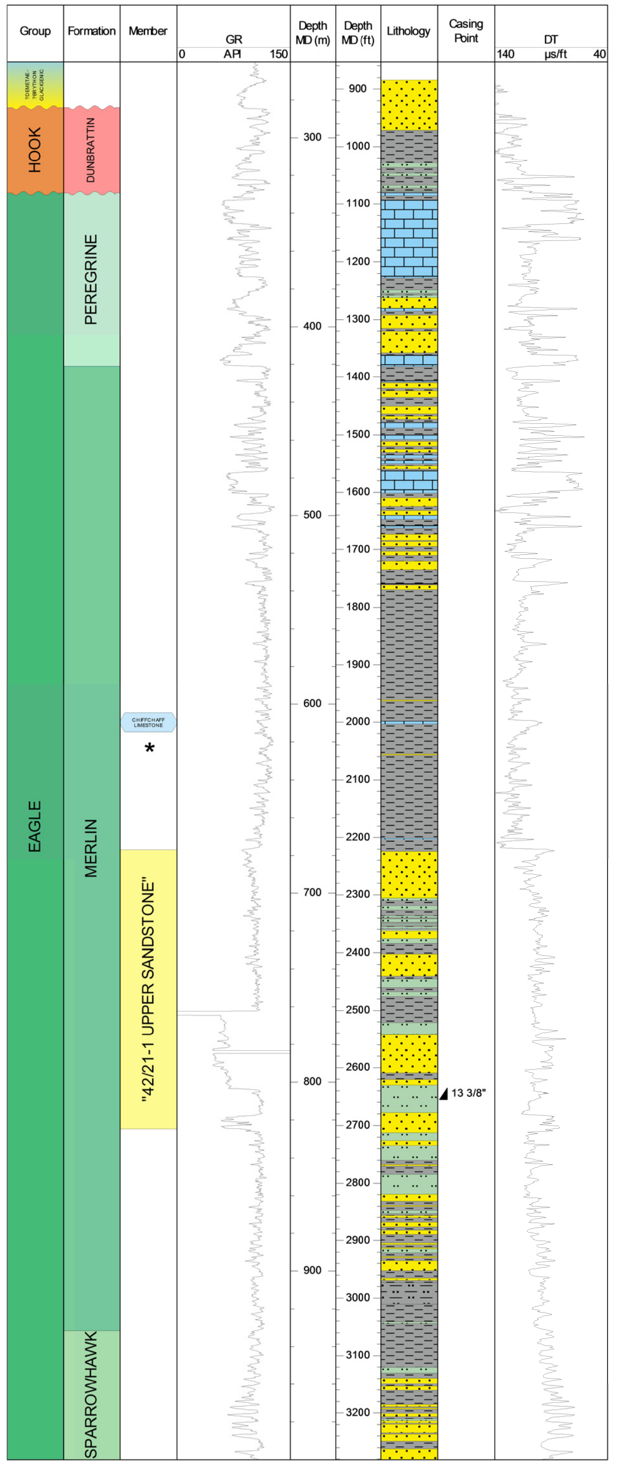
Distribution. The unit is known only from the 42/21-1 well location at the present time.

Regional correlation. This unit appears to be an age equivalent to part of the Lower Fuller's Earth Rock Member, Fuller's Earth Formation, of southern England (see Cox, 2002; Cox & Page, 2002; Barron *et al.,* 2012).

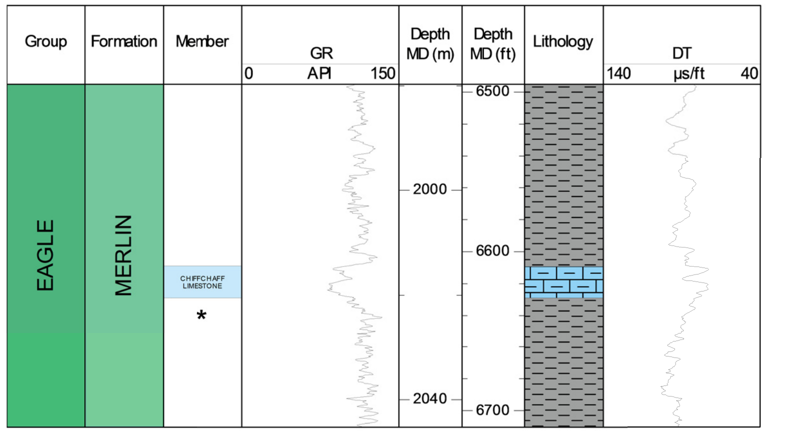
Comparison with Eastern Canada. This unit is a lateral age equivalent to the upper succession of sediments of the Downing Formation (claystones) of the Carson, Horseshoe and Jeanne d'Arc basins, offshore east coast Canada.



49/9-1
Type well; Chiffchaff Limestone Member *

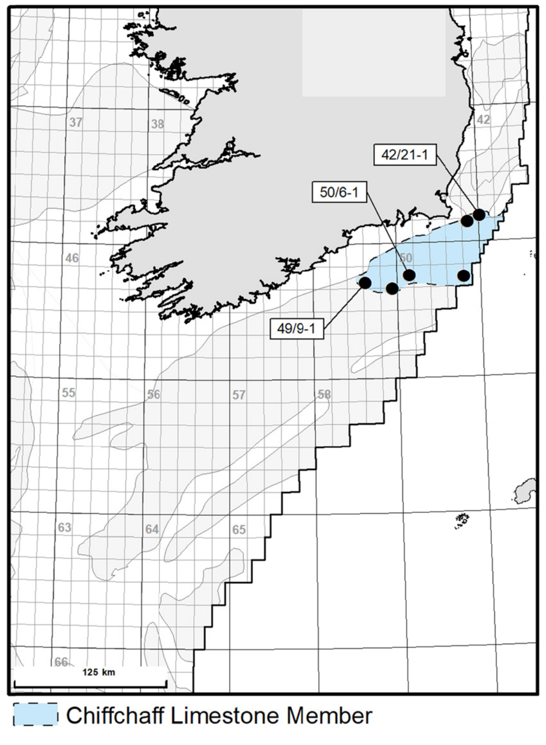


42/21-1
Type well, "42/21-1 Upper Sandstone" Member,
Reference well; Merlin Formation,



50/6-1
Reference well; Chiffchaff Limestone Member *.

*Chiffchaff Limestone Member



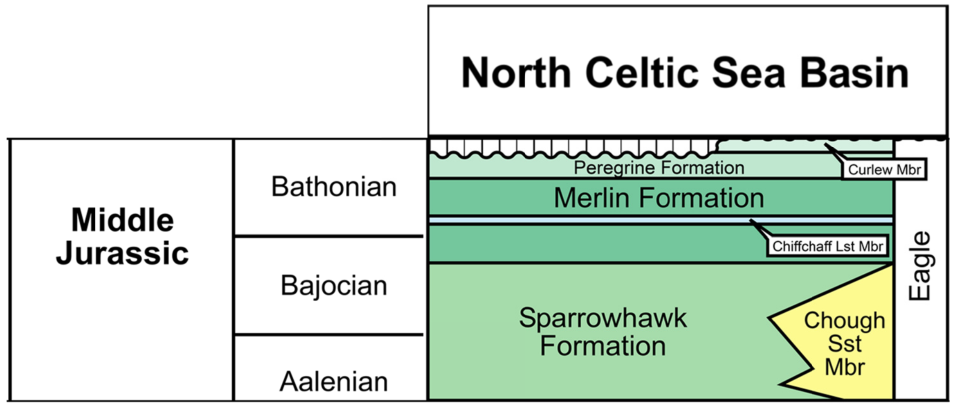


Figure D.6. 19. ***Chiffchaff Limestone Member and "42/21-1 Upper Sandstone" type and reference wells with location and distribution map.***

PEREGRINE FORMATION (NEW)

The Peregrine Formation is defined here for a limestone dominated sedimentary succession of Late-latest Middle Bathonian age, which lies in the upper part of the Eagle Group, which is developed in the middle and northern parts of North Celtic Sea Basin. This formation is unconformably overlain by the red claystones and sandstones of the Hook Group, Dunbrattin Formation.

The formation has previously been known informally as the "Bathonian Limestone" by operators in the North Celtic Sea Basin (for example Marathon Oil), including both offshore Ireland and offshore UK waters (for example UK 103/1-1 well). The British Geological Survey (for example Tappin *et al*., 1994; well UK 103/2-1, Figure 34) referred this formation to the "Great Oolite Group".

One new member is proposed; the Curlew Member, which occurs at the top of the formation.

Name. Named after the bird of prey that is native to Ireland.

Type section. 50/6-1: 1800.5-1935.5m below KB. See **Figure D.6. 20**.

Reference sections. 42/21-1: 329.5-421m below KB. 50/10-1: 1180.5-1279.5m below KB. See **Figure D.6. 20**.

Lithology. This formation is dominated by limestones, in association with sandstones and subsidiary calcareous claystones. Locally a yellowish brown to medium dark grey, claystone unit (Curlew Member) is present at the top of the formation.

The limestones are off white to very pale orange, light to medium grey, light olive grey, pale yellowish brown, wackestones to grainstones, locally lime mudstones, in part oolitic, locally argillaceous or locally sandy, grains clear, very fine grained, locally bioclastic (bivalve, gastropod and echinoderm debris), micritic to cryptocrystalline, and generally well indurated. Locally these limestones grade into mottled argillaceous limestones and sandy limestones. The ooid content varies from rare to highly oolitic. Off white to very pale orange, light grey, very fine to fine grained, well sorted, subangular to subrounded, locally oolitic and/or bioclastic, rarely glauconitic, friable to subrounded sandstones and calcareous sandstones are also present, more especially in the 42/21, 49/10, 49/13 and 50/12 blocks. These arenaceous units are generally more prominent in the lower sections of the formation. They may warrant subdivision and member status with future drilling. Beds of light to medium grey, calcareous claystones, marls and siltstones are also present within the formation.

The Curlew Member is dominated by yellowish brown to medium dark grey, non to slightly calcareous, claystones.

Wireline log character. The Peregrine Formation is characterised often by highly serrated, wireline log motifs, reflecting the interbedded limestone, sandstone and mudrock lithologies. The limestone and sandstone beds exhibit low gamma ray values and high sonic velocities, and often possess boxcar log motifs. The interbedded claystones possess higher gamma ray values and decreased sonic velocities and are often finely serrated.

Upper boundary. The top of the Peregrine Formation is marked everywhere by an unconformity. At this boundary the juxtaposed lithologies and the resulting wireline log responses are varied.

It is generally defined at a downsection lithological change from the interbedded reddened sandstones and mudrocks of the Dunbrattin Formation to the limestones and sandy limestones of the Peregrine Formation. This is reflected on wireline log criteria by a decrease in gamma ray values and a corresponding increase in sonic velocity.

Where the Curlew Member is present in the upper part of the formation, the upper boundary is taken at a downsection lithological change from the red sandstones and mudrocks of the Dunbrattin Formation to the grey claystones of the Peregrine Formation, Curlew Member. On wireline log criteria the boundary is taken at an abrupt increase in gamma ray values and an associated decrease in sonic velocity.

Lower boundary. The base of formation is marked by a downsection lithological change from carbonates and calcareous sandstones to the claystones of the Merlin Formation. On wireline log criteria the boundary is reflected at a generally sharp increase in gamma ray values and coincident sharp decrease in sonic velocity.

Subdivision. One new member is proposed, the Curlew Member.

Thickness. The formation ranges from 17m (49/15-1) to the thickest known section in offshore Ireland of 140.5m (50/6-2), however, this is exceeded by the 208.5m penetrated in UK well 103/1-1 in the UK part of the North Celtic Sea Basin. In all cases, the upper boundary of the formation is an unconformity.

Biostratigraphic characterization. Dating of this formation is by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is poor to good throughout the interval. Occurring within Ostracod Zones IOJ18 to IOJ16 (*pars*) and Foraminiferid Zones IFJ17 to IFJ16 and Palynological Subzones DM5B to DM5C.

Age. Middle Jurassic, Late-latest Middle Bathonian.

Depositional environment. Marine, inner shelf for the main part of the formation. The limestones and sandstones of the Peregrine Formation were deposited on a low to high energy (agitated), shallow, carbonate shelf. The presence of marine microfaunas and macrofaunas (common echinoderm and abundant shell debris) indicate deposition in warm, shallow shelf seas, with the shell debris possibly occurring within interdune channels. Oolitic limestones and oolitic sandstones are often commonly developed within the formation again indicating shallow waters, most likely reflecting mobile complexes of oolitic sand dune developments. The more sandy developments of the Peregrine Formation are noted along the north western edge of the North Celtic Sea Basin (42/21, 49/10, 49/13 and 50/12 blocks) indicating sediment sourcing from the Irish mainland.

The topmost Curlew Member was deposited in a continental to very shallow marine environment. The presence of charophyte oogonia, miospores and non-marine ostracods in the top sediments is indicative of freshwater to ?slightly brackish waters, while in the middle and lower sediments shallow marine ostracods are recorded. These sediments indicate a marked shallowing event at the top of the Bathonian.

Distribution. The formation has been recorded in wells from the North Celtic Sea Basin and its distribution is extended to the present-day basin limits on the basis of seismic evidence. Its presence in the South Celtic Sea Basin is unproven, however, as in the wells drilled to date all penetrate a significant unconformity at the base of the Upper Jurassic that cuts down into the Middle and Lower Jurassic, it is possible that in some undrilled areas of this basin that the formation may be present.

Seismic expression. The top of the Peregrine Formation equates to the Bathonian (Top Peregrine) seismic horizon in the North Celtic Sea Basin, which is a prominent seismic marker in this region (see **Figure D.6. 5** and **Figure D.6.8**). This marker has been previously referred to as the "Top Bathonian Limestone" seismic reflector in the region. This corresponds to a level of significant unconformity across the region, and major onlaps are evident above this horizon in some areas for instance in the 49/9 area as seen in **Figure D.6. 5.** This horizon is often displayed as a single high amplitude seismic event (peak = hard event), reflecting the carbonate development of this formation.

Regional correlation. The formation is laterally equivalent to the Frome Claystone and Forest Marble formations of southern England (see Cox, 2002; Cox & Page, 2002; Barron *et al.,* 2012). Similar limestone lithofacies (Chalfield Oolite Formation) are also recognised in the Cotswolds of central and southern England (Cox, 2002; Barron *et al.,* 2012).

Fields & Discoveries. The Peregrine Formation comprises the lower reservoir unit in the 49/9-2 (Helvick) discovery, and tested oil and gas from the interval.

Comparison with Eastern Canada. The Peregrine Formation limestones are a lateral equivalent to the upper half of the Downing Formation claystones. The Curlew Member is thought to be an age equivalent of the basal sediments of the Voyager Formation from the Jeanne d'Arc Basin, offshore east coast Canada.

Curlew Member (New)

The Curlew Member is defined here for a non-marine to very shallow marine claystone unit of latest Bathonian age that is developed at the top of the Eagle Group, Peregrine Formation, in the northwest part of North Celtic Sea Basin. This unit is unconformably overlain by the red claystones and sandstones of the Hook Group, Dunbrattin Formation, Dunworly Sandstone Member.

Name. Named after the bird that is native to Ireland.

Type section. 50/6-1: 1800.5-1822.5m below KB. See **Figure D.6. 21**.

Reference section. 50/7-1: 1636-1655.5m below KB. See **Figure D.6. 21**.

Lithology. The Curlew Member is dominated by pale yellowish brown to moderate yellowish brown, medium dark grey, non to slightly calcareous, claystones. Locally, rare very thin light grey, siltstone and light grey, microcrystalline, limestone stringers are also present.

Wireline log character. The wireline log motifs for this claystone member are finely serrated and comprise higher gamma ray values and low sonic velocities than the encompassing members above and below.

Upper boundary. The top of the Curlew Member is marked everywhere by an unconformity.

It is generally defined at a downsection lithological change from the interbedded reddened sandstones and mudrocks of the Dunbrattin Formation to the grey claystones of the Peregrine Formation, Curlew Member. This is reflected on wireline log criteria by a marked increase in gamma ray values, in association with a less pronounced decrease in sonic velocity.

Lower boundary. The base of member is marked by a downsection lithological change from claystones to the limestones and calcareous sandstones of the Peregrine Formation. On wireline log criteria, the boundary is reflected by a sharp decrease in gamma ray values and a sharp increase in sonic velocity.

Thickness. The member ranges in thickness from 6m (50/6-4) to 35.5m (50/6-2). It is only recorded in five wells in the northern North Celtic Sea Basin and in all cases their upper surface is an unconformable contact with overlying sediments and as such the true thickness of the member cannot be determined.

Biostratigraphic characterization. Dating of this member is by ostracod faunas only. Charophyte oogonia have also been recorded. Calcareous microfossil recovery is generally good throughout the member. Occurring in Ostracod Zone IOJ18 and Palynological Zone DM5, Subzone DM5C.

Age. Middle Jurassic, latest Bathonian.

Depositional environment. Continental to very shallow marine. A marked regressive episode is recognised within this member. The lower and middle sediments yield shallow marine ostracod faunas, while the top sediments yield charophyte oogonia, miospores and non-marine ostracods, indicating freshwater to possible brackish water environments. These sediments indicate a marked shallowing event at the top of the Bathonian.

Distribution. The member is present in a small number of wells from the northern part of the North Celtic Sea Basin (Quadrant 50). Its preservation is considered to be partly due to the erosional nature of the unconformity at the base of the Upper Jurassic that cuts down into the Middle Jurassic across the basin.

Regional correlation. This unit is a lateral equivalent of the uppermost part of the Forest Marble Formation of southern England (see Cox, 2002; Cox & Page, 2002; Barron *et al.,* 2012).

Comparison with Eastern Canada. The Curlew Member is age equivalent of the basal mudrocks of the Voyager Formation from the Jeanne d'Arc Basin, offshore east coast Canada.

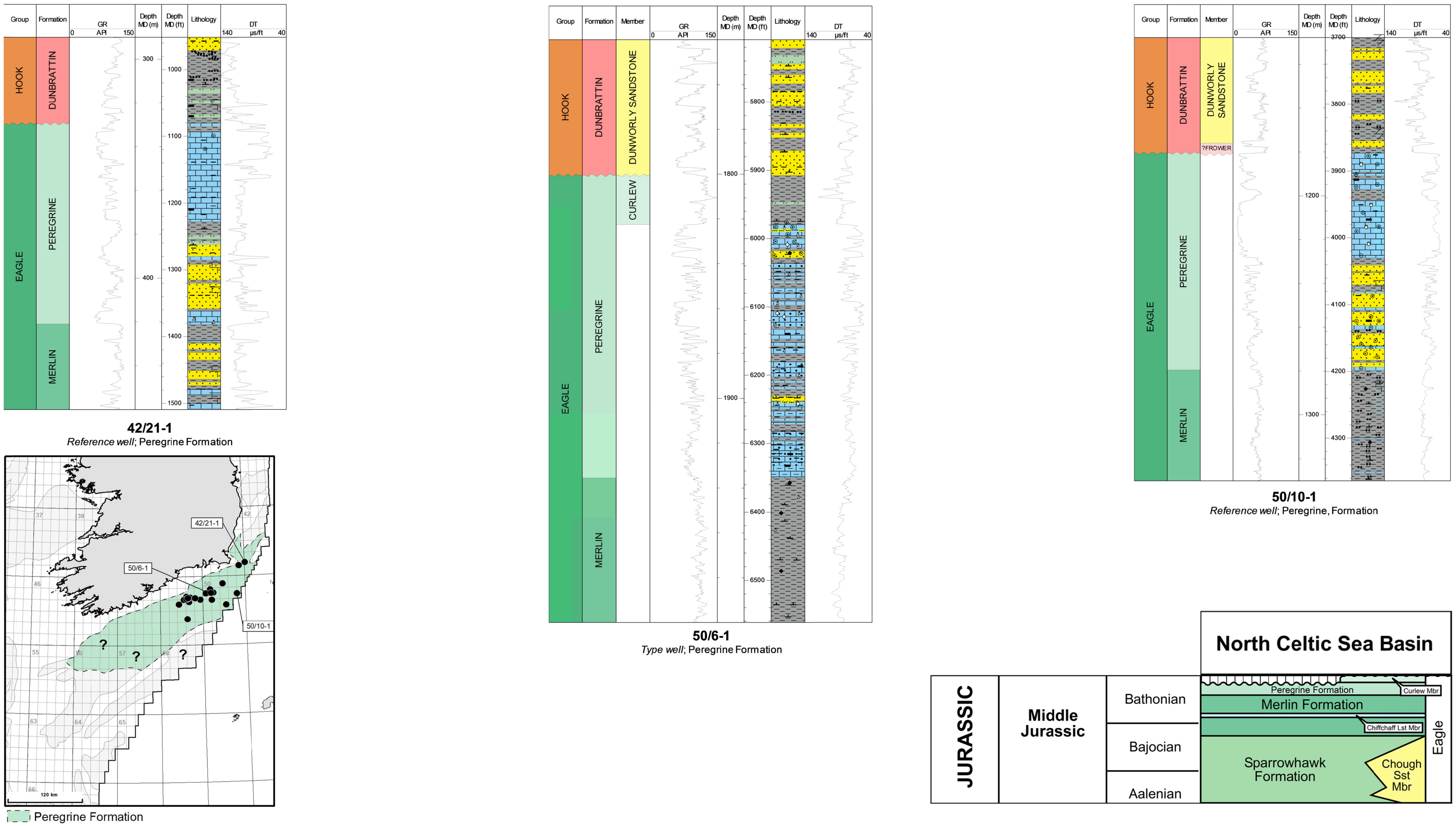


Figure D.6. 20. ***Peregrine Formation type and reference wells with location and distribution map.***

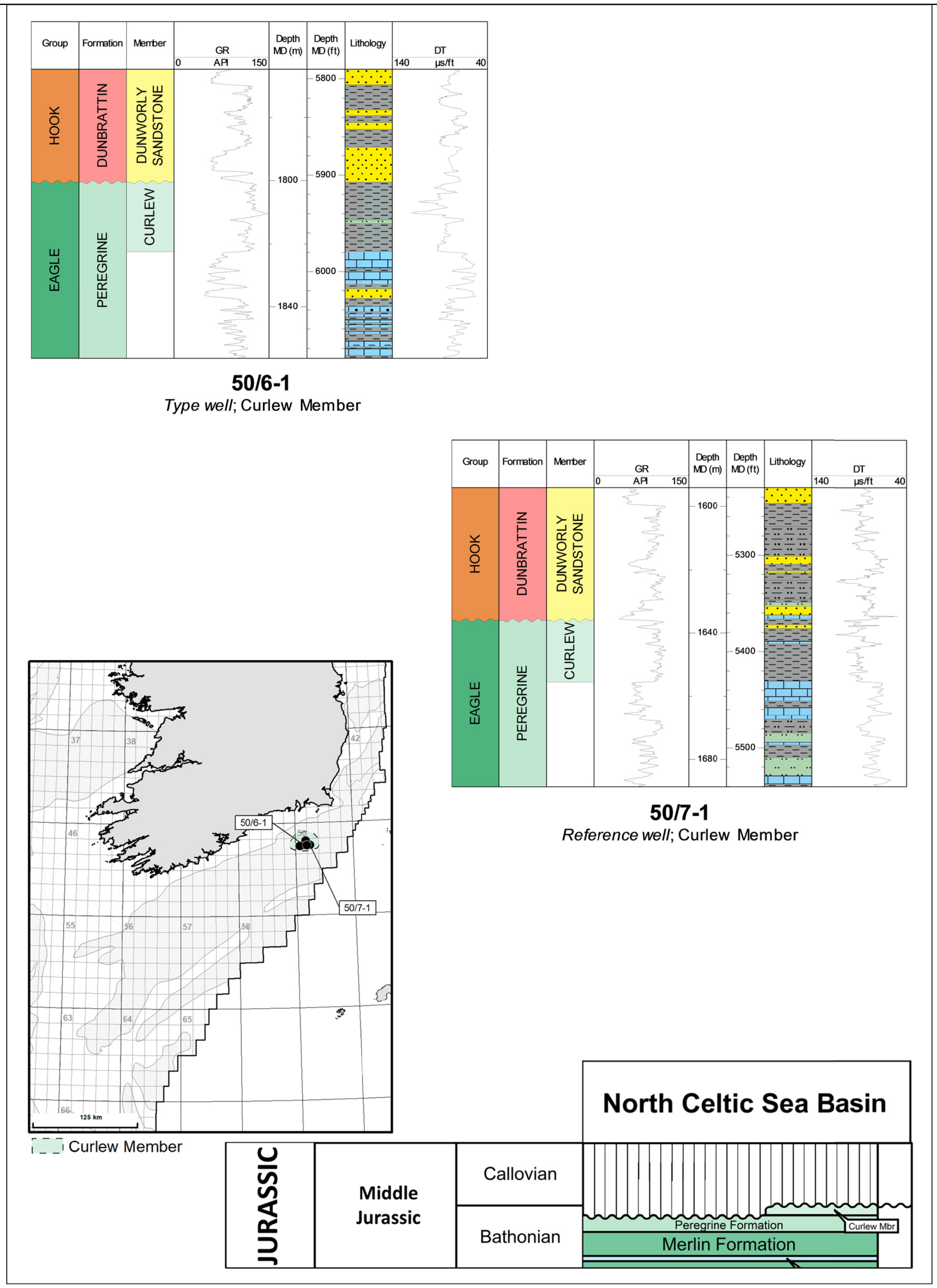


Figure D.6. 21. ***Curlew Member type and reference wells with location and distribution map.***

SPARROWHAWK FORMATION (NEW)

The Sparrowhawk Formation is defined here for a unit of mudrocks and sandstones, in association with subsidiary limestones, of Late Bajocian-Middle Aalenian age, which is developed in North Celtic Sea, Fastnet and Goban Spur basins. This formation is overlain by the Merlin Formation and underlain by the Lias Group, Tacumshin Formation.

One new member is proposed, the Chough Sandstone Member. Two informal units are also recognised in this formation; the "50/3-1 Limestone" and the "62/7-1 Sandstone". Both units occur in the lower half of the formation.

Name. Named after the bird of prey that is native to Ireland.

Type section. 49/9-1: 1241.5-1335.5m below KB. See **Figure D.6. 22**.

Reference sections. 42/21-1: 931.5-1475m below KB. 50/6-1: 2194-2306.5m below KB. 41/30-1: 928-1313.5m below KB. See **Figure D.6. 22**.

Lithology. This formation is dominated by grey claystones and siltstones. Sandstones, and subsidiary limestones, (Chough Sandstone Member) are recognised in the lower half of the formation within the northern half of the North Celtic Sea Basin. A lithologically distinct limestone ("50/3-1 Limestone") is present at the base of the formation in the north western part of the North Celtic Sea Basin.

The claystones are light to dark grey, locally olive grey, often with common carbonaceous specks, locally silty or sandy, non to slightly calcareous and subplaty to subfissile. These claystones grade to argillaceous siltstones downsection. The siltstones are medium to dark grey, light greyish brown, argillaceous in part, and generally calcareous. Stringers of limestone and dolomitic limestone, greyish orange, off white, light to medium grey, brownish grey, mudstone and cryptocrystalline, are present throughout. A number of thin, very pale orange, light to medium grey, very fine to fine grained, well sorted, subangular to subrounded, rare to abundant carbonaceous specks/debris, calcareous, friable, argillaceous sandstones and sandstones are also recognised.

The Chough Member is dominated by off white, light to medium grey, light greyish brown, very fine to medium grained, well sorted, subangular to subrounded, locally pyritic, rarely glauconitic, moderately well indurated, sandstones and calcareous sandstones. Beds of off white to very light grey, mudstone to grainstone, oolitic, sandy, bioclastic (bivalves), micritic to cryptocrystalline, limestones are more commonly developed in the 41/30-1 and 42/21-1 wells. Interbedded within the main arenaceous succession are light to dark grey, calcareous claystones and medium light grey siltstones.

The "50/3-1" limestone is light grey, slightly silty, micritic, mudstone to wackestone, and moderately well indurated.

Wireline log character. The claystones of the overall Sparrowhawk Formation possess serrated, relatively high gamma ray values and low sonic velocities. Downsection the claystones grade to siltstones and silty claystones, leading to a slight decrease in gamma ray values and a slight increase in sonic velocities. This may lead to a poorly developed inverse funnel shaped log motifs or a slightly bow shaped log motifs.

Where the Chough Sandstone Member is developed, the gamma ray values are lower, while sonic velocities are increased. In most wells the wireline log motifs exhibit a bow shaped log profile. A number of wireline log cycles are noted within the unit; however, these could not be correlated with certainty between wells.

Upper boundary. The top of the formation is placed at a downsection lithological change from the claystones of the Merlin Formation to the slightly more silty, less calcareous, mudrocks of the Sparrowhawk Formation. This is reflected on wireline log criteria by a slight decrease in gamma ray values and corresponding slight increase in sonic velocity.

Lower boundary. The base of formation is marked by a downsection lithological change from either the silty poorly calcareous mudrocks of the Sparrowhawk Formation or the sandstones of the Chough Sandstone Member, to the calcareous claystones of the Tacumshin Formation. On wireline log criteria, the boundary is marked by an increase in gamma ray values and a decrease in sonic velocities, both of which are more pronounced where the Chough Sandstone Member is present at the base of the formation.

Subdivision. One new member is proposed, the Chough Sandstone Member. Two informal members are also present in this formation, the "50/3-1 Limestone" and the "62/7-1 Sandstone".

Thickness. The formation has a thickness range of 69.5m (50/12-3) to 543.5m (42/21-1).

Biostratigraphic characterization. Dating of this formation is by foraminifera and dinocysts. The ostracod faunas comprise only long-ranging taxa. Calcareous microfossil recovery is poor to good throughout the interval. Occurring within Ostracod Zone IOJ12, Foraminiferal Zone IFJ13 and Palynological Subzones DM4B to DM3D3.

Age. Middle Jurassic, Late Bajocian-Middle Aalenian.

Depositional environment. Marine, inner to outer shelf. Sediment deposition is envisaged to have occurred mainly in a low energy, inner to outer shelf environment. Throughout the poorly calcareous mudrock intervals, microfaunal recovery varies from poor to good, comprising poorly diverse, rare, smooth ostracods, which often occur in association with pulses of the foraminiferal genera *Garantella* and *Reinholdella.* Periods of marine restriction, locally with dysaerobic and anoxic bottom waters are envisaged. Sandstone deposition (Chough Member) took place in a high energy, shallow shelf, marine environment, with localised sand sources. The presence of oolitic limestone beds within the sand member in the 41/30-1 and 42/21-1 wells is suggestive of a more shallower agitated depositional environment.

Distribution. The formation is proven mainly in the North Celtic Sea Basin and its distribution is extended to the present-day basin limits on the basis of seismic evidence. Its presence in the South Celtic Sea Basin is unproven, however, as in the wells drilled to date all penetrate a significant unconformity at the base of the Upper Jurassic that cuts down into the Middle and Lower Jurassic, it is possible that in some undrilled areas of this basin that the formation may be present.

The formation is also present in one well in the Fastnet Basin (64/1-1) and in the Goban Spur (62/7-1) well; its distribution is extended to the limits of the Goban Spur Basin on this basis, together with extrapolation from seismic data.

Seismic expression. Over most of the depositional area of this formation, no particular seismic character is apparent on the data available. In the major depocentre of the northern part of the North Celtic Sea Basin, however, between UK quadrant 103 and Ireland quadrant 41, the formation appears to correspond to a banded, high amplitude, parallel bedded seismic facies (see **Figure D.6.8**).

Regional correlation. The formation is laterally equivalent to both the Kestrel and Harrier formations within the Slyne Basin. The Sparrowhawk Formation is age equivalent to the Inferior Oolite Group of southern England and the Bearreraig Formation and lowermost part of the Great Estuarine Group of northwest Scotland (see Cox, 2002a, b; Cox & Page, 2002; Barron *et al.,* 2012).

Comparison with Eastern Canada. The dominant mudrock lithologies of the Sparrowhawk Formation are age equivalent to the mid sedimentary succession of the Downing Formation (claystones) of the Carson, Horseshoe and Jeanne d'Arc basins, offshore east coast Canada. Both the Chough Sandstone Member and "62/7-1 Sandstone" are lateral equivalents to the Downing Formation, Whale Member, whilst the "50/3-1 Limestone" is age equivalent to the lower part of the Whale Member.

Chough Sandstone Member (New)

The Chough Sandstone Member is defined here for the sandstone unit of Late Bajocian-Middle Aalenian age, that occurs within the Sparrowhawk Formation, in the lower part of the Eagle Group, in the northern part of the North Celtic Sea Basin.

Lateral siltstone equivalents to the Chough Sandstone Member are recognised in several wells, which display characteristic low gamma ray wireline log profiles, such as the 49/9-1 and 50/12-2A wells.

Name. Named after the bird that is native to Ireland.

Type section. 42/21-1: 1030.5-1474m below KB. See **Figure D.6. 22**.

Reference sections. 41/30-1: 1008-1313.5m below KB. See **Figure D.6. 22**. 50/6-1: 2251-2306.5m below KB. See **Figure D.6. 22**.

Lithology. The Chough Member is dominated by off white, light to medium grey, light greyish brown, very fine to medium grained, well sorted, subangular to subrounded, rare carbonaceous specks/debris, locally pyritic, rarely glauconitic, moderately well indurated, sandstones and calcareous sandstones. Iron staining (chamosite) has been observed in some of the sandstone ditch cuttings. Beds of off white to very light grey, mudstone to grainstone, oolitic or peloidal, sandy, bioclastic (bivalves), micritic to cryptocrystalline, limestones are more commonly developed in the 41/30-1 and 42/21-1 wells. Interbedded within the main arenaceous succession are light to dark grey, calcareous silty claystones and claystones, and medium light grey to light olive grey, locally pyritic, calcareous siltstones.

Wireline log character. This unit possesses lower gamma ray values and higher sonic velocities than the overlying and underlying units. It may display slight serrated wireline log motifs, and these may become more serrated towards the base of the unit as the member becomes a more interbedded mudstone, siltstone and sandstone succession (for example 41/30-1). In most wells the wireline logs exhibit a bow shaped profiles, locally with a number of cycles present. These, however, could not be correlated with certainty between wells.

Upper boundary. The top of the member is marked by a downsection lithological change from the silty mudrocks of the Sparrowhawk Formation, to the sandstones of the Chough Sandstone Member. This is expressed on the wireline log criteria by a sharp decrease in gamma ray values and corresponding sharp increase in sonic velocity.

Lower boundary. The base of the member displays a downward lithological change from sandstones to the calcareous claystones of the Tacumshin Formation. This is reflected on wireline log criteria as an increase in gamma ray values and a coincident decrease in sonic velocity. In a small number of wells (for instance 41/30-1) both the lithological and the wireline log criteria definitions may be less pronounced due to the presence of thin interbeds of mudrocks at the base of the Chough Sandstone Member.

Thickness. The member ranges in thickness from 52m (50/10-1) to 444.5m (42/21-1).

Biostratigraphic characterization. Dating of this member is by dinocysts. Occurring within Palynological Subzones DM4A1 to DM4A2 (42/21-1 well) DM4B to DM3D3 (43/30-1 well).

Age. Middle Jurassic, Late Bajocian-Middle Aalenian.

Depositional environment. Marine, inner shelf. This fine to medium grained sandstone member was deposited in a high energy, inner shelf, marine environment. The sand sources are likely to be localised with much of the sand derived from the Irish Mainland to the north and northwest. The presence of iron staining (chamosite) sediments, plus the occurrence of oolitic limestone beds within the sand member in the 41/30-1 and 42/21-1 wells, indicates a shallower depositional environment compared to other wells which possess this sandstone member.

Distribution. The member is proven to be present by well penetrations in the northern part of the North Celtic Sea Basin. Its southern extent is limited by nearby wells from which the member is absent. This absence is due to lateral facies change, not unconformity.

Regional correlation. The unit is a lateral equivalent to the Kestrel and Harrier formations of the Slyne Basin, the Inferior Oolite Group of southern England and the Bearreraig Formation of northwest Scotland (Cox, 2002a, b; Cox & Page, 2002; Barron *et al.,* 2012).

Comparison with Eastern Canada. The Chough Sandstone Member is thought to be a lateral equivalent to the limestones of the Downing Formation, Whale Member, from the Carson, Horseshoe and Jeanne d'Arc basins, offshore east coast of Canada.

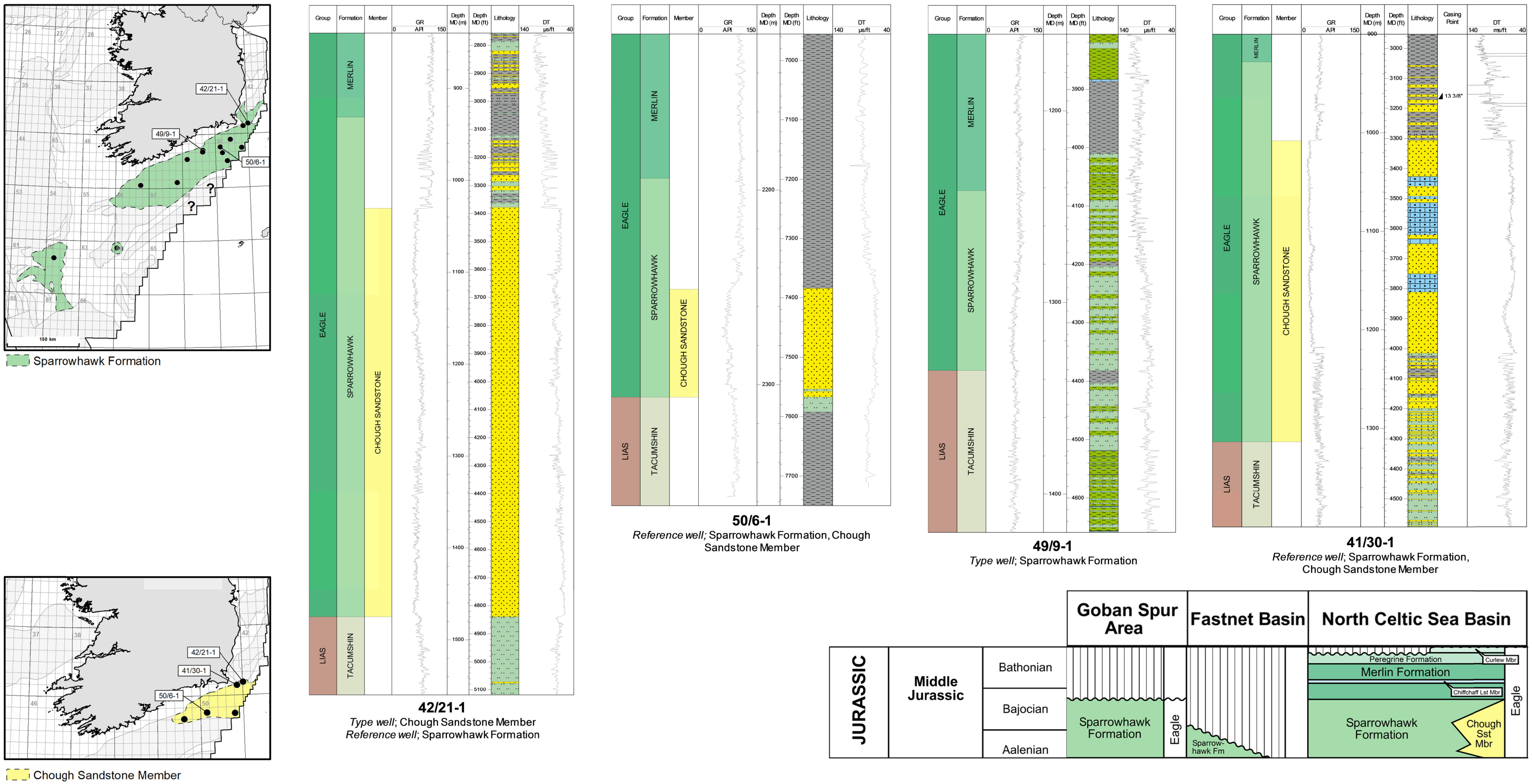


Figure D.6. 22. ***Sparrowhawk Formation (including Chough Sandstone Member) type and reference wells with location and distribution maps.***

"50/3-1 Limestone"

This limestone unit of earliest Bajocian age is present at the base of the Sparrowhawk Formation in the 50/3-1 well located in the northern part of the North Celtic Sea Basin. It is probably laterally equivalent to the lower part of the Inferior Oolite Group of onshore England.

Type section. 50/3-1: 1228-1243.5m below KB. See **Figure D.6. 23**.

Lithology. This limestone is light grey, slightly silty, micritic, mudstone to wackestone, and well indurated.

Wireline log character. The limestone unit exhibits low gamma ray values and high sonic velocities, forming a boxcar wireline log motif.

Upper boundary. The top of the unit is denoted by a downsection lithological change from the silty mudrocks of the Sparrowhawk Formation, to the limestones of the "50/3-1 Limestone". This denoted on wireline log criteria by a decrease in gamma ray values and corresponding increase in sonic velocity.

Lower boundary. The base of this unit is unconformable and is denoted by a downsection lithological change from limestones to the calcareous claystones of the Tacumshin Formation. This is expressed on wireline log criteria by an increase in gamma ray values and corresponding decrease in sonic velocity.

Thickness. This unit attains a thickness of 15.5m in the 50/3-1 well.

Biostratigraphic characterization. No *in situ* microfossils are recorded, due to the well indurated nature of the limestone lithologies. The limestone occurs stratigraphically beneath ?DM3D4 palynological subzone and above the top of the Tacumshin Formation.

Age. Middle Jurassic, earliest Bajocian, based primarily on stratigraphic position.

Depositional environment. Marine, inner shelf. The unit was laid down in a warm, carbonate-rich, shallow, marine environment. The absence of mudrocks and sands may be indicative of surrounding low topographies.

Distribution. This limestone unit is only known from the 50/3-1 well located in the northern part of the North Celtic Sea Basin.

Regional correlation. The unit appears to a lateral equivalent to the lower part of the Inferior Oolite Group in southern England (see Cox, 2002a; Cox & Page, 2002; Barron *et al.,* 2012).

Comparison with Eastern Canada. The "50/3-1 Limestone" is a lateral equivalent of the Downing Formation, Whale Member (limestones) from the Carson, Horseshoe and Jeanne d'Arc basins, offshore east coast Canada.

"62/7-1 Sandstone"

This Aalenian aged interbedded sandstone/mudstone unit is present at the base of the Sparrowhawk Formation in the 62/7-1 well located in the Goban Spur Basin.

Type section. 62/7-1: 3387.5-3453m below KB. See **Figure D.6. 23**.

Lithology. This unit comprises an interbedded succession of thin sandstones and silty claystones. The sandstones are very pale orange, very fine to fine grained, well sorted, subangular to subrounded, calcareous, and moderately well indurated. The silty claystones are medium to locally dark grey, with rare carbonaceous specks, and slightly calcareous.

Wireline log character. The thin sandstones within this unit possess low gamma ray values and higher sonic velocities than the encompassing mudrocks which exhibit high gamma ray values and lower sonic velocities.

Upper boundary. The top of the unit is denoted by a downward lithological change from the silty mudrocks of the Sparrowhawk Formation, to the sandstones of the "62/7-1 Sandstone". This is expressed on wireline log criteria by a sharp decrease in gamma ray values and corresponding sharp increase in sonic velocity.

Lower boundary. The base of the unit displays a downsection lithological change from sandstones to the calcareous claystones of the Tacumshin Formation. This is reflected on wireline log criteria by a sharp increase in gamma ray values and a coincident sharp decrease in sonic velocity.

Thickness. This unit displays a thickness of 65.5m in the one well in which it is recorded.

Biostratigraphic characterization. Dated by foraminifera and dinocysts. Occurring within Foraminiferal Zone IFJ13 and Palynological Subzones DM3D3 to DM3D2.

Age. Middle Jurassic, Aalenian.

Depositional environment. Marine, inner to middle shelf. This unit was deposited in a generally low energy, well oxygenated, inner to middle shelf marine environment as denoted by the microfaunas. The thin localised sand pulses indicate higher energy levels.

Distribution. Recorded from only a single well (62/7-1) in the Goban Spur Basin.

Regional correlation. The unit is a lateral equivalent of the basal part of the Chough Sandstone Member, Sparrowhawk Formation, that is developed in the northern North Celtic Sea Basin. It is likely that the sandstone is separate depositionally from the latter. The unit is age equivalent to the Robin Member, Harrier Formation, located in the Slyne Basin.

Comparison with Eastern Canada. The "62/7-1 Sandstone" is a lateral equivalent to the Downing Formation, Whale Member (limestones) from the Carson, Horseshoe and Jeanne d'Arc basins, offshore east coast Canada.

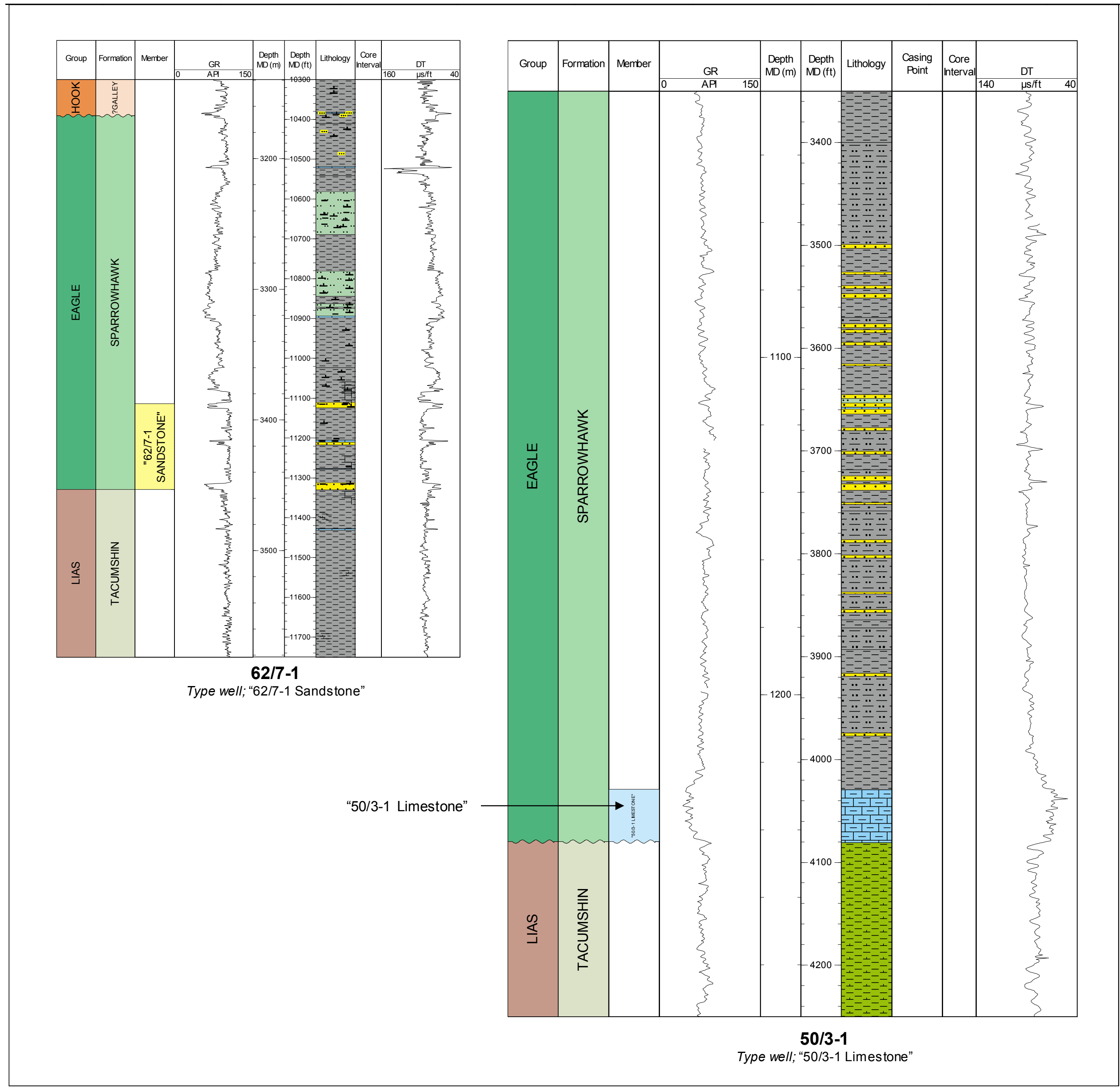


Figure D.6. 23. ***"50/3-1 Limestone" and "62/7-1 Sandstone" type wells.***

KITE GROUP (NEW)

The Kite Group is defined here for the Middle Jurassic (Bajocian-Aalenian) sediments that are developed in the Slyne Basin, offshore western Ireland. Sediments of this group are considered likely to be present in the Erris and Porcupine basins, from seismic evidence, but have not yet been penetrated by any wells drilled to date in these basins.

The Kite Group correlates with the Inferior Oolite Group shallow marine carbonate succession that is well developed in central and southern England (see for example, Barron *et al*., 2012). The Inferior Oolite Group is significantly different lithologically from the age equivalent section in the Slyne Basin (which is dominated by argillaceous sediments, with interbedded limestones) to warrant a new name for the interval in the latter area. The lithological succession in the Kite Group is also sufficiently different lithologically from that of the Eagle Group as developed in the North Celtic Sea Basin, to warrant a new group in this area. In addition, contiguous deposition between both these regions of Ireland during the Bajocian cannot be demonstrated.

Some previous workers have utilised Hebrides Basin (western Scotland) nomenclature for the Bajocian succession in the Slyne Basin, for example, Trueblood (1992) and Millennia (1997, 2004). These authors applied the name Bearreraig Sandstone Formation (with component Ollach Sandstone, Udairn Shale, Holm Sandstone, Rigg Sandstone and Garantiana Clay members) to the interval now referred to the Kite Group. These names have not been applied in the new offshore Ireland nomenclature proposed in this project. A correlation between the new terminology (as typified by the 18/20-1 succession) and the Hebridean names (as developed in the Upper Glen-1 well) is shown in **Figure D.6. 17**.

Ternan (2006) used the informal term Middle Jurassic B Unit, following operators (including Enterprise and Statoil) in the Slyne Basin area, for the Aalenian to mid Bajocian interval, that equates to the Kite Group as defined herein. Ternan's (2006) "Bajocian Limestone", within their Middle Jurassic B Unit, is renamed the Kingfisher Limestone Member in this report.

The upper boundary of the Kite Group is truncated by a major unconformity omitting Bathonian aged rocks (see **Figure D.6. 2).** This unconformity cuts down into the older parts of the group in some areas. This unconformity/sequence boundary is marked seismically by the Base Upper Jurassic (Top Kestrel) seismic horizon.

Two new formations are proposed, in descending stratigraphic order; the Kestrel Formation and the Harrier Formation.

The group and its constituent formations and members are named after birds that are native to Ireland and reflect the order in the food chain.

HARRIER FORMATION (NEW)

The Harrier Formation is defined here for a dominantly claystone succession of Middle Jurassic, earliest Bajocian-late Early Aalenian, age that is developed in the Slyne Basin. At the base of the formation there is a prominent calcareous unit (Dunnock Member). This formation lies between an overlying Kestrel Formation and an underlying Lias Group, Dun Caan Shale Formation.

Ternan (2006) used the informal term Middle Jurassic B Unit, following operators (Enterprise and Statoil) in the Slyne Basin area, for the Aalenian to mid Bajocian interval. The lower part of the Middle Jurassic B Unit equates to the Harrier Formation.

Five new members are proposed, in descending stratigraphic order; Wren Member, Skylark Member, Sparrow Member, Robin Member and the Dunnock Member.

Name. Named after the bird of prey that is native to Ireland.

Type section. 18/20-1: 2167.5-2556m below KB. See **Figure D.6. 24**.

Reference sections. 18/25-1: 2245-2531m below KB. 19/11-1A: 3102-3330m below KB. 27/13-1A: 1848-2000m below KB. See **Figure D.6. 24**.

Lithology. This unit comprises a dominantly claystone succession, in association with generally thin ratty limestone stringers. The basal unit (Dunnock Member), however, comprises an interbedded calcareous claystone/limestone succession. The claystones are generally medium light to dark grey, dark olive grey, slightly micromicaceous, locally silty or pyritic, and calcareous. Locally these sediments grade into argillaceous siltstones and siltstones. The thin limestones and argillaceous limestones are light grey, light brownish grey, micritic to microcrystalline, lime mudstones. Two prominent light grey to light brown, microcrystalline, well indurated, limestone markers are present at the base of Skylark and Sparrow members.

Wireline log character. This formation displays slightly serrated, bow shaped wireline log profiles, with moderately high to high gamma ray values and moderately slow sonic velocities. Towards both the top and base of the units the calcareous content of the sediments increases. The basal member (Dunnock Member) is distinct, denoted by a decrease in gamma ray values and an increase in sonic velocity, reflecting the interbedded limestones and calcareous claystones. Two distinct gamma ray/sonic velocity spikes are recognised reflecting limestone beds at the bases of the Skylark and Sparrow members.

Upper boundary. The top of the formation is placed at a downsection lithological change from the limestones of the Kestrel Formation, Kingfisher Limestone Member, to the claystones of the Harrier Formation. On wireline log criteria, this boundary is denoted by an increase in gamma ray values, in association with a decrease in sonic velocity.

Lower boundary. The lower boundary is denoted by a downward lithological change from the interbedded claystones and thin limestones to the more homogeneous claystones of the Dun Caan Shale Formation. This is marked on wireline log criteria by an increase in gamma ray values and a corresponding decrease in sonic velocity.

Subdivision. A five-fold subdivision of this formation is proposed. In descending stratigraphic order, these are; Wren Member, Skylark Member, Sparrow Member, Robin Member and the Dunnock Member.

Thickness. The formation ranges in thickness from 152m (27/13-1A) to 388.5m (18/20-1).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil and dinocyst recovery is good through the studied interval. Occurring within Ostracod Zones IJO13 to IOJ10, Foraminiferal Zones IJF13 to IJF10 and Palynological Subzones DM3D2 (*pars*) to DM3D5 (*pars*).

Age. Middle Jurassic, earliest Bajocian-late Early Aalenian.

Depositional environment. Marine, inner shelf. The Harrier Formation was deposited in a marine, well oxygenated, low energy, inner shelf environment, denoted by the abundant and diverse ostracod and foraminiferal faunas. The latter is often dominated by *Epistomina* and *Reinholdella* spp.

The basal unit (Dunnock Member) is more carbonate dominated compared to both the underlying and overlying rock units, and yields common to abundant crinoid and echinoderm debris, possibly suggesting a shallower water depositional environment.

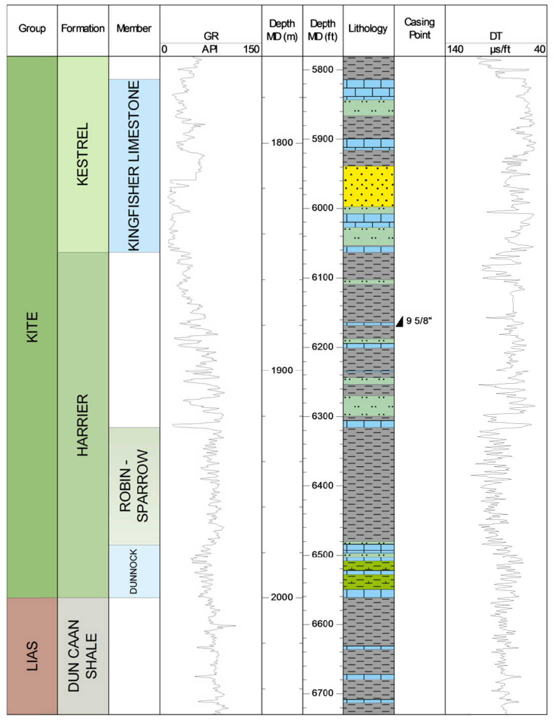
Distribution. The formation is proven only by well penetrations in the Slyne Basin, west of Ireland and its limits are extended to the limits of this basin on the basis of seismic evidence (see **Figure D.6. 25**). It is likely that the formation is also present in the Porcupine Basin, however, this is uncertain due to the lack of Middle Jurassic well penetrations in this basin to date.

Seismic expression. No particular seismic character is evident for this formation. The formation occurs between the Lower Bajocian and Toarcian (Whitby Mudstone) seismic horizons in the Slyne Basin, for instance over the Corrib Field area (blocks 18/20, 18/25), as shown in **Figure D.5.3**. In the Slyne Basin, the Lower Bajocian horizon corresponds to a hard seismic event reflecting the incoming of carbonate dominated lithologies (Kingfisher Limestone Member) below the Minard Formation.

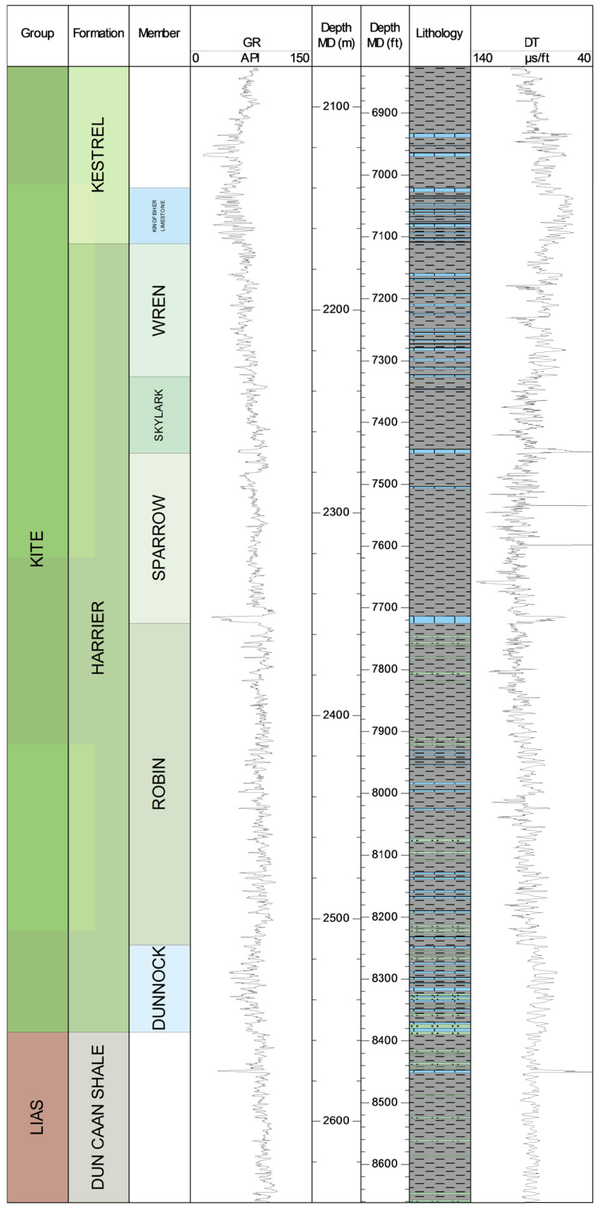
Regional correlation. The Harrier Formation correlates with the lower half of the Sparrowhawk Formation in the Goban Spur, Fastnet and North Celtic Sea basins to the south and east of Ireland. This formation is age equivalent to the lower and mid sections of the Inferior Oolite Group of southern England and the lower and mid sections of the Bearreraig Formation of northwest Scotland (see Cox, 2002a, b; Cox & Page, 2002; Barron *et al.,* 2012).

Source rock characterisation. The Harrier Formation in the Slyne Basin includes a few samples with TOC contents greater than 1%, but the source rock potential is mainly poor (**Appendix E, Figure A.E.6**). Only some samples from well 18/20-7 show elevated HI values and a Type II kerogen composition, indicating some hydrocarbon generation potential.

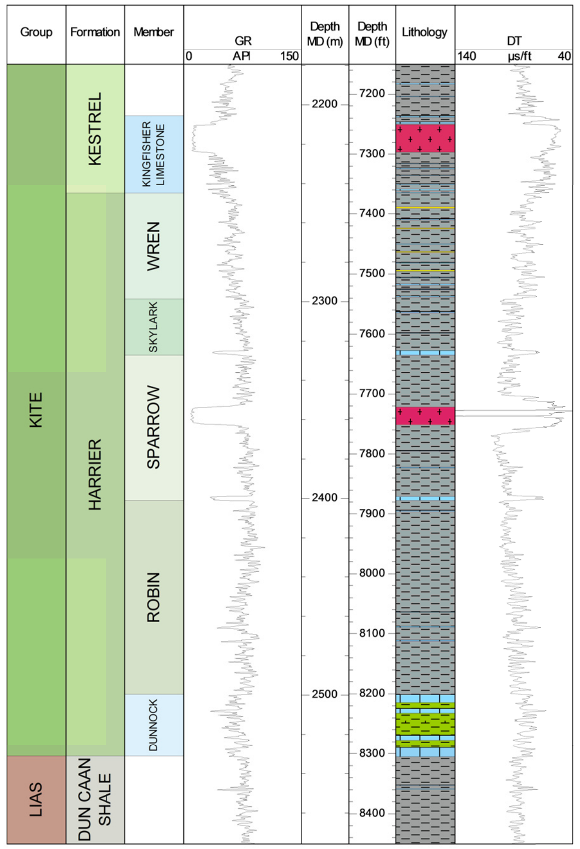
Comparison with Eastern Canada. The Harrier Formation is age equivalent to the middle part of the Downing Formation (claystones) of the Carson, Horseshoe and Jeanne d'Arc basins, offshore east coast Canada.



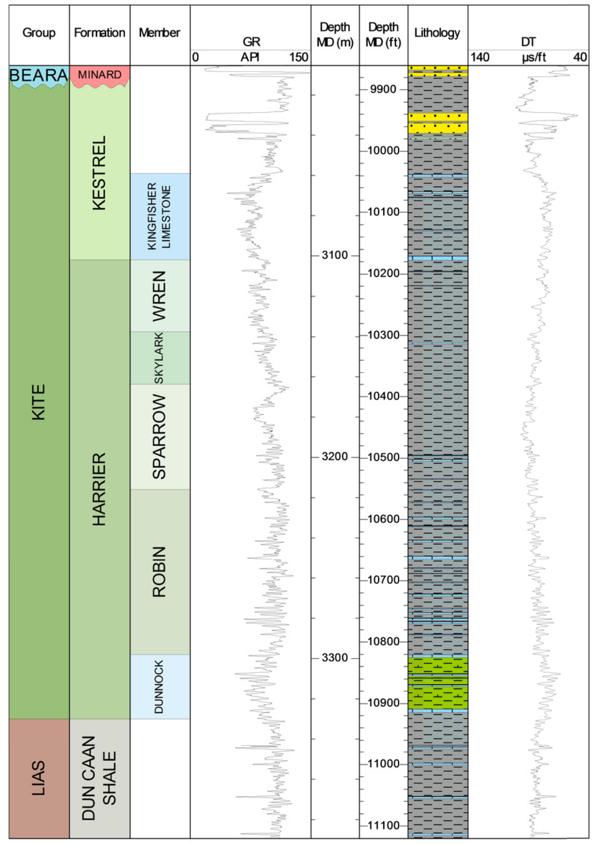
27/13-1A
Reference well; Harrier Formation, Dunnock Member



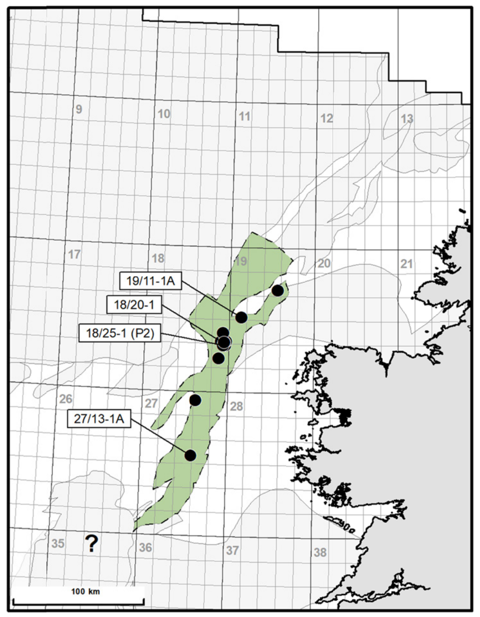
18/20-1
Type well; Harrier Formation, Dunnock, Robin, Skylark, Sparrow, Wren Members



18/25-1 (P2)
Reference well; Harrier Formation, Dunnock, Robin, Skylark, Sparrow, Wren Members



19/11-1A
Reference well; Harrier Formation, Dunnock, Robin, Skylark, Sparrow, Wren Members



Harrier Formation

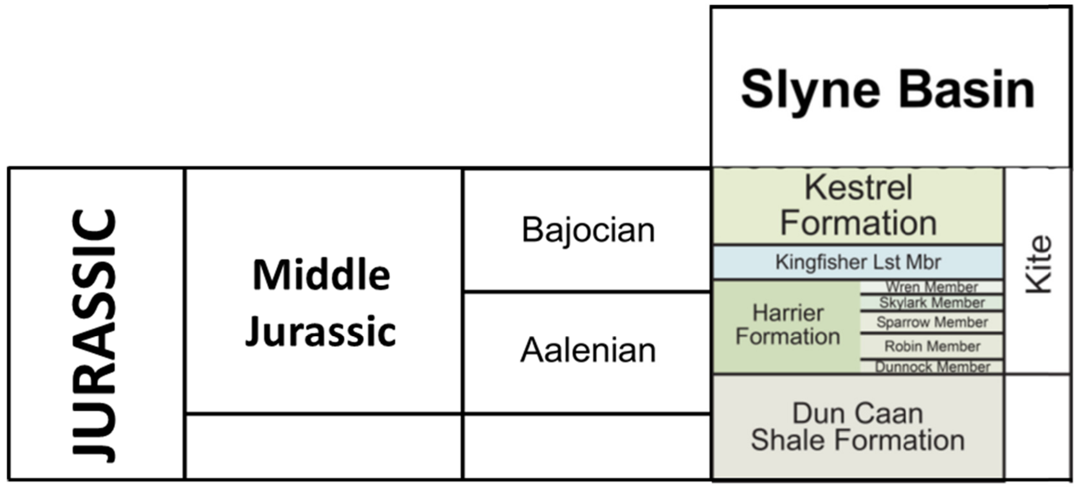


Figure D.6. 24. ***Harrier Formation and constituent members type and reference wells with location and distribution map.***

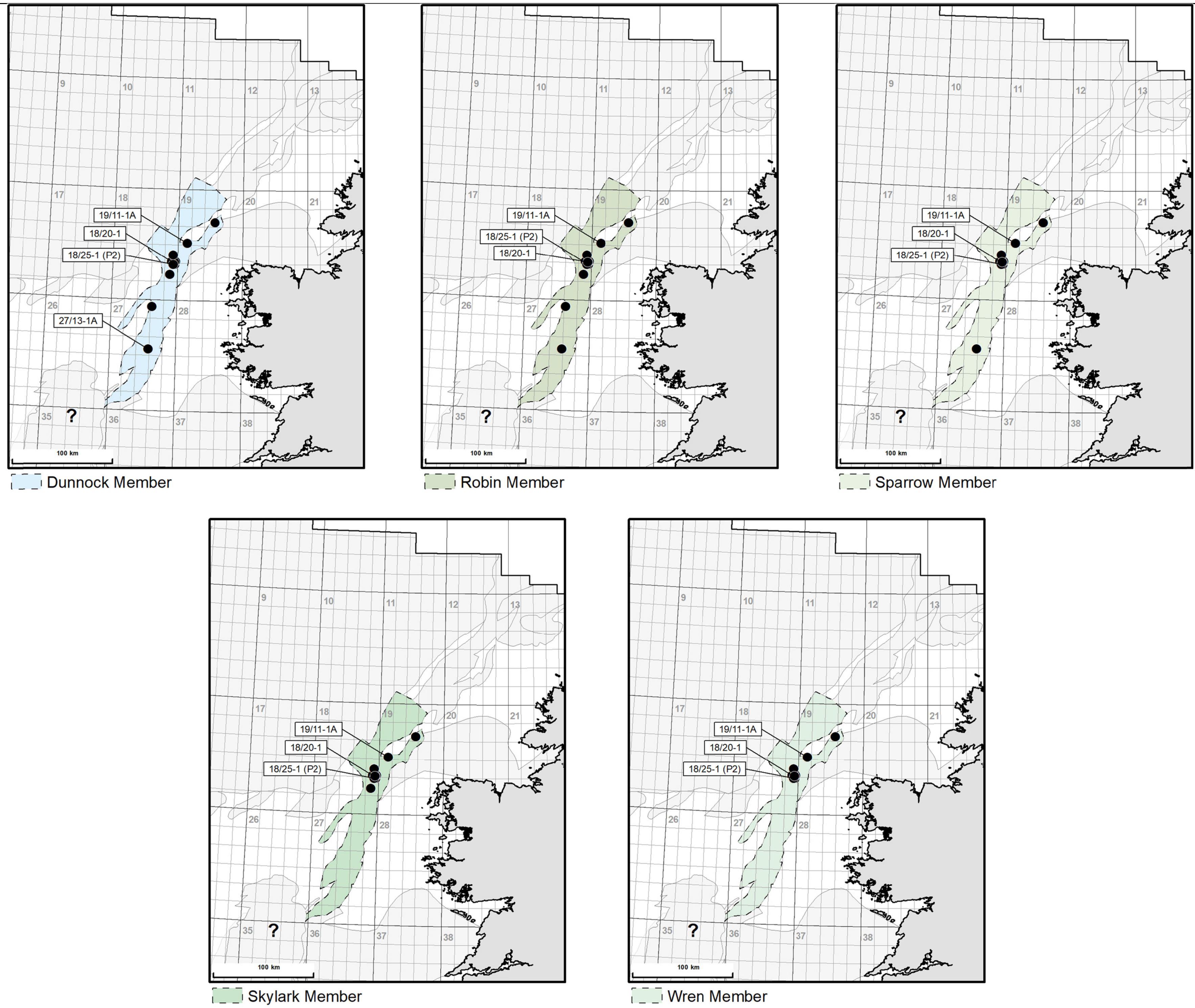


Figure D.6. 25. ***Harrier Formation constituent members distribution maps.***

Dunnock Member (New)

The Dunnock Member is defined here for an interbedded limestone/claystone unit of late Early Aalenian age, that occurs at the base of the Harrier Formation, Kite Group, in the Slyne Basin. This unit lies between an overlying Robin Member of the Harrier Formation and the underlying Dun Caan Shale Formation.

Name. Named after the bird that is native to Ireland.

Type section. 18/20-1: 2513-2556m below KB. See **Figure D.6. 24**.

Reference sections. 18/25-1: 2499.5-2531m below KB. 19/11-1A: 3298-3330m below KB. 27/13-1A: 1976.5-2000m below KB. See **Figure D.6. 24**.

Lithology. This member comprises an interbedded succession of limestones and claystones. The thinly bedded limestones are off white to light brownish grey, mudstone, cryptocrystalline and well indurated, while the claystones are medium to dark grey, slightly micromicaceous, locally silty and calcareous.

Wireline log character. The interbedded claystones and limestones of the Dunnock Member possess serrated lower gamma ray values and higher sonic velocities than the overlying and underlying units. A bow shaped wireline log motif is recognised within the member.

Upper boundary. The upper boundary is taken at a downward lithological change from the claystones of the Robin Member to the interbedded limestones and claystones of Dunnock Limestone Member. This is indicated on wireline log criteria by a decrease in gamma ray values and a coincident increase in sonic velocity.

Lower boundary. The lower boundary is denoted by a downsection lithological change from the interbedded limestones and claystones to the homogenous claystones of the Dun Caan Shale Formation. On wireline log criteria this boundary is taken at an increase in gamma ray values, in association with a decrease in sonic velocity.

Thickness. The member ranges in thickness from 18m (18/25-2) to a maximum of 47m (27/4-1Z) and in most of the 12 wells where it is encountered the upper and lower boundaries are conformable, except in 18/25-3 (P5), where the lower boundary is an unconformity.

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil and dinocyst recovery is good throughout the unit. Occurring within Ostracod Zone IJO10, Foraminiferal Zone IFJ10 and Palynological Subzone DM3D1.

Age. Middle Jurassic, late Early Aalenian.

Depositional environment. Marine, inner shelf. This member was deposited in a marine, well oxygenated, quiet, inner shelf environment. The increase in carbonate development within this member may possibly indicate a shallower water, ?regressive interval, compared to both the overlying and underlying mudrock members. The occurrence of common to abundant crinoid and echinoderm debris would suggest a shallow, warm carbonate rich, marine environment.

Distribution. The member is proven only by well penetrations in the Slyne Basin, west of Ireland and its limits are extended to the limits of this basin on the basis of seismic evidence (see **Figure D.6. 25**). It is possible that the member is also present in the Porcupine Basin, however, this is uncertain due to the lack of Middle Jurassic well penetrations in this basin to date.

Regional correlation. The unit correlates with the uppermost part of the Tacumshin Formation in the Goban Spur, Fastnet and North Celtic Sea basins to the south and east of Ireland. This member is laterally equivalent to the lower section of the Inferior Oolite Group of southern England and the lowermost part of the Bearreraig Formation of northwest Scotland (see Cox, 2002a, b; Cox & Page, 2002; Barron *et al.,* 2012).

Comparison with Eastern Canada. The Dunnock Member is age equivalent to the middle part of the Downing Formation (claystones) of the Horseshoe, Carson and Jeanne d'Arc basins, offshore east coast Canada.

Robin Member (New)

The Robin Member is defined here for a dominantly claystone unit, in association with thin limestone interbeds of Middle Aalenian age, which occurs in the lower half of the Harrier Formation in the Slyne Basin. This unit lies between an overlying Sparrow Member and an underlying Dunnock Member.

Name. Named after the bird that is native to Ireland.

Type section. 18/20-1: 2354.5-2513m below KB. See **Figure D.6. 24**.

Reference sections. 18/25-1: 2401-2499.5m below KB. 19/11-1A: 3216-3298m below KB. See **Figure D.6. 24**.

Lithology. This unit dominantly comprises claystones, in association with a small number of thin ratty limestone stringers or beds. The argillaceous sediments comprise medium to dark grey, dark greenish grey, slightly micromicaceous, non to calcareous claystones. The thin limestones and argillaceous limestones are light grey, micritic to microcrystalline, lime mudstones.

Wireline log character. The dominantly claystones of the Robin Member possess serrated, relatively high gamma ray values and low sonic velocities compared to the overlying and underlying units. The gamma ray and sonic velocity logs can be sub-linear to slightly inverse funnel shaped. In the latter case this is envisaged to be due to an increase in calcareous content of the claystones. A number of cycles are recognised, these, however, could not be correlated with certainty between wells.

Upper boundary. The upper boundary is denoted by a downsection lithological change from the basal limestone of the Sparrow Member to the claystones of the Robin Member. This is reflected on wireline log criteria by a marked increase in gamma ray values, in association with a clear decrease in sonic velocity.

Lower boundary. The lower boundary is taken at a downward change from claystones to the more interbedded limestones and claystones of the Dunnock Limestone Member. On wireline log criteria, this is denoted by a decrease in gamma ray values and a coincident increase in sonic velocity.

Thickness. The member ranges in thickness from 81.5m (18/20-3 (P3)) to 158.5m (18/20-1).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil and dinocyst recovery is good throughout the unit. Occurring within Ostracod Zones IJO12 (*pars*) to IJO11 (*pars*), Foraminiferal Zone IFJ11 and Palynological Subzones DM3D1 (*pars*) to DM3D3 (*pars*).

Age. Middle Jurassic, Middle Aalenian.

Depositional environment. Marine, inner shelf. This member was deposited in a marine, well oxygenated, low energy, inner shelf environment, as indicated by the presence of often abundant and diverse ostracod and foraminiferal microfaunas.

Distribution. The member is proven only by well penetrations in the Slyne Basin, west of Ireland and its limits are extended to the bounds of this basin on the basis of seismic evidence (see **Figure D.6. 25**). It is possible that the member is also present in the Porcupine Basin, however, this is uncertain due to the lack of Middle Jurassic well penetrations in this basin to date.

Regional correlation. This member is laterally equivalent to the lower sediments of the Sparrowhawk Formation in the Goban Spur, Fastnet and North Celtic Sea basins. In southern England this unit is an age equivalent to the lower sedimentary succession of the Inferior Oolite Group, while in northwest Scotland the Robin Member is equivalent to in the lower sediments of the Bearreraig Formation (Cox, 2002a, b; Cox & Page, 2002; Barron *et al.,* 2012).

Comparison with Eastern Canada. The Robin Member is age equivalent to the middle part of the Downing Formation (claystones) of the Horseshoe, Carson and Jeanne d'Arc basins, offshore east coast Canada.

Skylark Member (New)

The Skylark Member is defined here for a dominantly claystone unit of Late Aalenian age, which occurs in the upper half of the Harrier Formation, in the Slyne Basin. This unit lies between an overlying Wren Member and an underlying Sparrow Member.

Name. Named after the bird that is native to Ireland.

Type section. 18/20-1: 2233-2270.5m below KB. See **Figure D.6. 24**.

Reference sections. 18/25-1: 2298.5-2327m below KB. 19/11-1A: 3137.5-3163.5m below KB. See **Figure D.6. 24**.

Lithology. This unit dominantly comprises claystone, in association with a small number of thin ratty limestone stringers. The claystones are medium light to dark grey, slightly micromicaceous, locally silty and calcareous. Locally these sediments grade into argillaceous siltstones and siltstones. The thin limestones and argillaceous limestones are light grey, micritic to microcrystalline, lime mudstones. A distinct light grey, microcrystalline, well indurated, limestone is present at the base of the unit.

Wireline log character. The wireline log motifs are serrated and exhibit a gradual downsection increase in gamma ray values and a corresponding decrease in sonic velocity leading to a slight funnel shaped wireline log motif. At the base of the member there is a prominent gamma ray and sonic velocity spike reflecting the presence of a well indurated limestone bed.

Upper boundary. The top of this member is taken on the downsection lithological change from the calcareous claystones of the Wren Member to the claystones of the Skylark Member. This is reflected on wireline log criteria by an increase in gamma ray values, in association with a decrease in sonic velocity.

Lower boundary. The lower boundary is denoted by the downsection lithological change from a basal limestone to the claystones of the Sparrow Member. This is expressed on wireline log criteria by a sharp increase in gamma ray values and a corresponding sharp decrease in sonic velocity.

Thickness. The member ranges in thickness from 20m (18/20-2) to a maximum of 42m (19/8-1), with all ten wells where it is recorded having conformable contacts at the top and base of the member. The thickest development of the member is seen at the northern end of the Slyne Basin.

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil and dinocyst recovery is good throughout the member. Occurring within Ostracod Zone IJO12 (*pars*), Foraminiferal Zone IJF12 (*pars*) and Palynological Subzone DM3D4.

Age. Middle Jurassic, Late Aalenian.

Depositional environment. Marine, inner shelf. The Skylark Member was laid down in a marine inner shelf environment. The rich microfaunas so dominated by the foraminiferal genera *Epistomina* and *Reinholdella* spp. indicate well oxygenated, quiet, shallow marine conditions.

Distribution. The member is proven only by well penetrations in the central part of the Slyne Basin, west of Ireland and its limits are extended to the limits of this basin on the basis of seismic evidence (see **Figure D.6. 25**). It is possible that the member is also present in the Porcupine Basin, however, this is uncertain due to the lack of Middle Jurassic well penetrations in this basin to date.

Regional correlation. The Skylark Member correlates to the middle sedimentary succession of the Sparrowhawk Formation in the Goban Spur, Fastnet and North Celtic Sea basins to the south and east of Ireland. In southern England this unit is laterally equivalent to the middle section of the Inferior Oolite Group, while in northwest Scotland to the middle part of the Bearreraig Formation (see Cox, 2002a, b; Cox & Page, 2002; Barron *et al.,* 2012).

Comparison with Eastern Canada. The Skylark Member is age equivalent to the middle part of the Downing Formation (claystones) of the Horseshoe, Carson and Jeanne d'Arc basins, offshore east coast Canada.

Sparrow Member (New)

The Sparrow Member is defined here for a dominantly claystone unit of intra Late Aalenian age, that occurs as the middle unit of the Harrier Formation, in the Slyne Basin. This unit lies between an overlying Skylark Member and an underlying Robin Member.

Name. Named after the bird that is native to Ireland.

Type section. 18/20-1: 2270.5-2354.5m below KB. See **Figure D.6. 24**.

Reference sections. 18/25-1: 2327-2401m below KB. 19/11-1A: 3163.5-3216m below KB. See **Figure D.6. 24**.

Lithology. This unit is dominantly claystone, in association with a small number of thin ratty limestone stringers. The claystones are medium dark to dark grey, dark olive grey, slightly micromicaceous, locally silty and calcareous. Locally these sediments grade into argillaceous siltstones and siltstones. The thin limestones and argillaceous limestones are light grey, micritic to microcrystalline, lime mudstones. A prominent light grey to light brown, microcrystalline, well indurated limestone is present at the base of the unit.

Wireline log character. The dominantly claystone unit possesses slightly higher gamma ray values and lower sonic velocities than the overlying and underlying members. The overall wireline log motifs are either sublinear to slightly bow shaped.

Upper boundary. The upper boundary is taken at a downsection lithological change from the basal limestone bed of the Skylark Member to the claystones of the Sparrow Member. This is expressed on wireline log criteria by a sharp increase in the gamma ray values and a corresponding sharp decrease in sonic velocity.

Lower boundary. The base of this unit is placed at a marked downsection lithological change from a basal limestone to the claystones of the Robin Member. This is reflected on wireline log criteria by a sharp increase in gamma ray values and a corresponding sharp decrease in sonic velocity.

Thickness. The member ranges from 38m (18/25-3 (P5)) to a maximum thickness of 84m (18/20-1), with both upper and lower surfaces being conformable in all nine wells where it has been recorded.

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil and dinocyst recovery is good throughout the unit. Occurring within Ostracod Zone IJO12 (*pars*), Foraminiferal Zone IJF12 (*pars*) and Palynological Subzone DM3D3.

Age. Middle Jurassic, intra Late Aalenian.

Depositional environment. Marine, inner shelf. This member was deposited in a marine, well oxygenated, low energy, inner shelf environment. The sediments contain large numbers of ostracods and foraminifera faunas which provide support for this depositional environment.

Distribution. The member is proven only by well penetrations in the Slyne Basin, west of Ireland and its limits are extended to the limits of this basin on the basis of seismic evidence (see **Figure D.6. 25**). It is possible that the member is also present in the Porcupine Basin, however, this is uncertain due to the lack of Middle Jurassic well penetrations in this basin to date.

Regional correlation. The unit is laterally equivalent to the middle sedimentary succession of the Sparrowhawk Formation in the Goban Spur, Fastnet and North Celtic Sea basins. In both southern England and in northwest Scotland this member is age equivalent to the middle section of the Inferior Oolite Group and Bearreraig Formation respectively (Cox, 2002a, b; Cox & Page, 2002; Barron *et al.,* 2012).

Comparison with Eastern Canada. The Sparrow Member is age equivalent to the middle part of the Downing Formation (claystones) of the Horseshoe, Carson and Jeanne d'Arc basins, offshore east coast Canada.

Wren Member (New)

The Wren Member is defined here for a dominantly calcareous claystone/claystone unit of earliest Bajocian age, which occurs at the top of the Harrier Formation, in the Slyne Basin. This unit lies between an overlying Kingfisher Limestone Member of the Kestrel Formation and an underlying Skylark Member.

Name. Named after the bird that is native to Ireland.

Type section. 18/20-1: 2167.5-2233m below KB. See **Figure D.6. 24**.

Reference sections. 18/25-1: 2245-2298.5m below KB. 19/11-1A: 3102-3137.5m below KB. See **Figure D.6. 24**.

Lithology. This unit is dominated by calcareous claystones and claystones, with a small number of thin limestone stringers. The claystones are medium dark to dark grey, slightly micromicaceous, locally silty, and/or pyritic, and slightly to very calcareous. The calcareous content of these argillaceous sediments increases slightly upsection. Locally these sediments grade into argillaceous siltstones, siltstones and more rarely very fine-grained sandstones. The thin limestones comprise off white to light grey, light brownish grey, cryptocrystalline, lime mudstones.

Wireline log character. The gamma ray and sonic velocity logs of the Skylark Member are slightly serrated indicating the local interbedded limestones within the dominantly argillaceous sediments. The overall wireline log motif is funnel shaped, denoting the slightly decreasing downhole calcareous content of the sediments.

Upper boundary. The top of the member is taken at a downsection lithological change from the carbonates of the Kestrel formation, Kingfisher Limestone Member, to the calcareous claystones of the Wren Member. This is denoted on wireline log criteria by an increase in gamma ray values and a corresponding decrease in sonic velocity.

Lower boundary. The lower boundary is denoted by a downward lithological change from calcareous claystones to claystones of the Skylark Member. On wireline log criteria, the boundary is taken at an increase in gamma ray values, with an associated decrease in sonic velocity.

Thickness. The member ranges in thickness from 35m (19/11-1A) to 65.5m (18/20-1).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil and dinocyst recovery is good throughout the member. Occurring within Ostracod Zone IJO13, Foraminiferal Zone IJF13 and Palynological Subzone DM3D5.

Age. Middle Jurassic, earliest Bajocian.

Depositional environment. Marine, inner shelf. This member was laid down in a marine, well oxygenated, low energy, inner shelf environment. The sediments contain abundant and diverse ostracod and foraminiferal (dominated by *Epistomina* and *Reinholdella* spp.) faunas, which provide support for this depositional environment.

Distribution. The member is proven only by well penetrations in the central part of the Slyne Basin, west of Ireland and its limits are extended to the limits of this basin on the basis of seismic evidence (see **Figure D.6. 25**). It is possible that the member is also present in the Porcupine Basin, however, this is uncertain due to the lack of Middle Jurassic well penetrations in this basin to date.

Regional correlation. The member correlates to the middle sedimentary succession of the Sparrowhawk Formation in the Goban Spur, Fastnet and North Celtic Sea basins to the south and east of Ireland. In southern England this unit is laterally equivalent to the middle/upper section of the Inferior Oolite Group, while in northwest Scotland to the upper part of the Bearreraig Formation (Cox, 2002a, b; Cox & Page, 2002; Barron *et al.,* 2012).

Comparison with Eastern Canada. The Wren Member is age equivalent to the middle part of the Downing Formation (claystones) of the Horseshoe, Carson and Jeanne d'Arc basins offshore, east coast Canada.

KESTREL FORMATION (NEW)

The Kestrel Formation is defined here for a mudrock dominated sedimentary succession of Late-Early Bajocian age, which is developed in the Slyne Basin, offshore western Ireland. This formation is unconformably overlain by the Beara Group, Minard Formation. The formation conformably overlies the Harrier Formation.

Ternan (2006) used the informal term Middle Jurassic B Unit, following operators (for example Enterprise and Statoil) in the Slyne Basin area, for the Aalenian to mid Bajocian interval. The upper part of the Middle Jurassic B Unit equates to the Kestrel Formation, and the "Bajocian Limestone", within Ternan's (2006) Middle Jurassic B Unit, is renamed the Kingfisher Limestone Member, of the Kestrel Formation, herein. In a number of operator (Enterprise, Shell) reports this unit has been referred to as the Bearreraig Limestone or the Bajocian Limestone.

One new member is proposed; the Kingfisher Limestone Member, which lies at the base of the Kestrel Formation.

Name. Named after the bird of prey that is native to Ireland.

Type section. 18/20-1: 1991.5-2167.5m below KB. See **Figure D.6. 26**.

Reference sections. 18/25-1: 2111.5-2245m below KB. 19/11-1A: 3011-3102m below KB. 27/13-1A: 1699.5-1848m below KB. See **Figure D.6. 26**.

Lithology. This formation is dominated by grey mudrocks. Interbedded carbonates and claystones (Kingfisher Limestone Member) are recognised in the basal section of the formation.

The mudrocks are light greenish grey, medium dark to dark grey, greyish black, locally silty or pyritic, locally carbonaceous, rarely bioclastic (shell debris), and non to calcareous. Medium grey, sandy, calcareous siltstones are locally present. A number of white to very light grey, mudstone to wackestone, microcrystalline, well indurated, limestone beds are noted within the formation.

The Kingfisher Limestone Member mainly comprises an interbedded limestone and calcareous claystone succession. The limestones are off white, light to medium grey, mudstone to packstone, locally silty to sandy, locally peloidal, in part argillaceous, microcrystalline, and well indurated. Prominent limestone beds are present in the 27/13-1A well. The calcareous claystones and marls are light to medium dark grey, slightly micromicaceous and locally silty. Local off white, very fine to fine grained, well sorted, subrounded, calcareous sandstone laminae or beds are noted in the 27/13-1A well.

Wireline log character. The overall claystones of the Kestrel Formation possesses higher gamma ray values and lower sonic velocities than the overlying and underlying formations. The argillaceous part of this formation exhibits a slight funnel shaped log motif, with decreasing gamma ray values and increasing sonic velocities downsection. Two tentative cycles can be recognised within the claystone interval.

The Kingfisher Limestone Member possesses a slightly to moderately serrated bow shaped wireline log motif, mainly reflecting the interbedded limestones and marls/calcareous claystones. Locally boxcar log profiles are noted where the limestone beds are thicker and well indurated (for example 27/13-1A). This member possesses lower gamma ray values and higher sonic velocities than the overlying and underlying sediments.

Upper boundary. The top of this formation is marked by an unconformity at the junction with the overlying Minard Formation. The top of the formation is marked by a downsection lithological change from the red mudrocks and sandstones of the Minard Formation, to the grey claystones of the Kestrel Formation. On wireline log criteria, this is denoted by a sharp increase in gamma ray values and corresponding sharp decrease in sonic velocity.

Lower boundary. The base of this formation is marked by a downward lithological change from the interbedded limestones, marls and calcareous claystones, to the calcareous mudrocks of the Harrier Formation. This is denoted on wireline log criteria by a marked increase in gamma ray values, associated with a marked decrease in sonic velocity.

Subdivision. One new member is recognised, the Kingfisher Limestone Member.

Thickness. No complete section of this formation has been encountered due to the unconformable nature of the upper surface in all wells where it occurs. The formation ranges from 82.5m (18/20-3 (P3)) to 188m (18/25-3 (P5)), however, several of the well penetrations, including those cited here, are deviated and these values are not true vertical thicknesses. The formation attains a thickness of 148.5m in the 27/13-1A reference well.

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Rich calcareous microfossil and dinocyst assemblages are present throughout the unit. Occurring within Ostracod Zones IJO17 to IJO14, Foraminiferal Zones IJF16 to IFJ14 and Palynological Subzones DM3D5 (*pars*) to DM4B.

Age. Middle Jurassic, Late-Early Bajocian.

Depositional environment. Marine, inner shelf. The main argillaceous sediments within the Kestrel Formation were laid down in a marine, well oxygenated, low energy, inner shelf environment. The sediments yield rich and moderately diverse ostracod and foraminiferal (often dominated by *Epistomina* and *Reinholdella* spp.) assemblages confirming the depositional environment.

The Kingfisher Member is more limestone dominated, and contains common to abundant crinoid and echinoderm debris, indicating a warm, carbonate-rich, shallower marine environment compared to the main overlying argillaceous section of the Kestrel Formation.

Distribution. The formation is proven by well penetrations in the Slyne Basin, west of Ireland and its limits are extended to the limits of this basin on the basis of seismic evidence. It is possible that the formation is also present in the Porcupine Basin, however, this is uncertain due to the lack of Middle Jurassic well penetrations in this basin to date.

Seismic expression. . In the Slyne Basin, the Bajocian seismic horizon ties to the top of the Kingfisher Limestone Member, in the basal part of the Kestrel Formation. for instance, over the Corrib Field area (blocks 18/20, 18/25), as shown in **Figure D.5.3**. This horizon has been recognised in this area previously, as the "Bajocian Limestone" seismic marker (Dancer *et al*., 2005).

Regional correlation. The Kestrel Formation directly correlates to the upper sedimentary succession of the Sparrowhawk Formation in the Goban Spur, Fastnet and North Celtic Sea basins to the south and east of Ireland. In southern England this formation is laterally equivalent to the upper part of the Inferior Oolite Group, and to the upper part of the Bearreraig Formation and the lowermost part of the Great Estuarine Group in northwest Scotland (see Cox, 2002a, b; Cox & Page, 2002; Barron *et al.,* 2012).

Source rock characterisation. Data availability for the Kestrel Formation of the Slyne Basin is very limited but includes a range of organic-rich samples with TOC contents greater than 1% (**Appendix E**). A Type II kerogen composition and elevated hydrocarbon yields (S2) suggest some source rock potential.

In well 18/20-1, located in the Slyne Basin, samples of the Kestrel Formation correspond to the source rock interval Mid J1 that was identified in project IS16/01 (BeicipFranlab, 2017).

Comparison with Eastern Canada. The Kestrel Formation is age equivalent to the upper succession of the Downing Formation (claystones) of the Horseshoe, Carson and Jeanne d'Arc basins, offshore east coast Canada.

Kingfisher Limestone Member (New)

The Kingfisher Limestone Member is defined here for a basal interbedded limestone, marl/calcareous claystone succession of intra Early Bajocian age, which is developed in the Slyne Basin, offshore western Ireland. The member overlies the Harrier Formation, Wren Member.

Ternan's (2006) "Bajocian Limestone", within their Middle Jurassic B Unit, is renamed the Kingfisher Limestone Member in this report. The operators (Enterprise, Shell) name this unit the Bearreraig Limestone and the Bajocian Limestone respectively

Name. Named after the bird that is native to Ireland.

Type section. 18/20-1: 2140-2167.5m below KB. See **Figure D.6. 26**.

Reference sections. 19/11-1A: 3059-3102m below KB. 27/13-1A: 1722-1848m below KB. See **Figure D.6. 26**.

Lithology. This member comprises an interbedded limestone and marl/calcareous claystone succession. The limestones are off white, light to medium grey, mudstone to packstone, locally silty to sandy, locally peloidal, in part argillaceous, microcrystalline, and well indurated. The more prominent well indurated limestone beds are present in the 27/13-1A well. The calcareous claystones and marls are light to medium dark grey, slightly micromicaceous, locally silty, which grade locally to siltstones. Local off white, very fine to fine grained, well sorted, subrounded, calcareous sandstone laminae or beds are recognised in the 27/13-1A well.

Wireline log character. The wireline log motifs are slightly to moderately serrated, mainly reflecting the interbedded limestones and marls/calcareous claystones. This member possesses lower gamma ray values and higher sonic velocities than the overlying and underlying sediments. Generally, a bow shaped wireline log motif is recognised within the member. Locally boxcar log profiles are noted where the limestone beds are well indurated and thicker (for example 27/13-1A).

Upper boundary. The top of the unit is placed at a marked downsection lithological change from the claystones of the Kestrel Formation to the carbonates of the Kingfisher Limestone Member. This is reflected on wireline log criteria by a sharp decrease in gamma ray values, coincident with a sharp increase in sonic velocity.

Lower boundary. The base of the member is denoted by a downward lithological change from the interbedded limestones, marls and calcareous claystones, to the calcareous claystones of the Harrier Formation, Wren Member. On wireline log criteria, the boundary is taken at a marked increase in gamma ray values, in association with corresponding marked decrease in sonic velocity.

Thickness. The member has a thickness range of 23.5m (18/20-2) to 76m (27/13-1A).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil and dinocyst recovery is moderately good through the limestone member. Occurring within Ostracod Zone IJO14 (*pars*), Foraminiferal Zone IJF14 and Palynological Subzone DM3D5 (*pars*).

Age. Middle Jurassic, intra Early Bajocian.

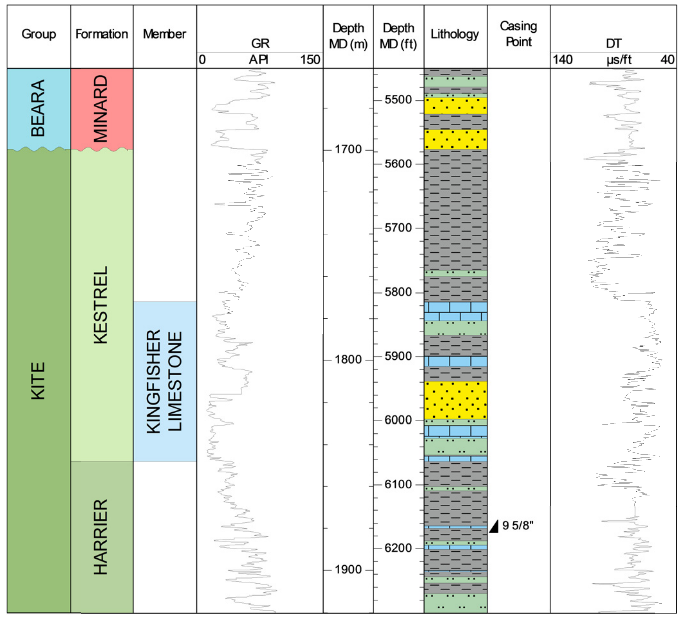
Depositional environment. Marine, inner shelf. The limestones/marls of the Kingfisher Member yield common to abundant crinoid and echinoderm debris, suggesting deposition in a warm, carbonate-rich, inner shelf, marine environment. This carbonate dominated section is envisaged to have been laid down in a shallower marine environment compared to the main overlying argillaceous section of the Kestrel Formation.

Distribution. The member is proven only by well penetrations in the Slyne Basin, west of Ireland and its limits are extended to the limits of this basin on the basis of seismic evidence. It is possible that the member is also present in the Porcupine Basin, however, this is uncertain due to the lack of Middle Jurassic well penetrations in this basin to date.

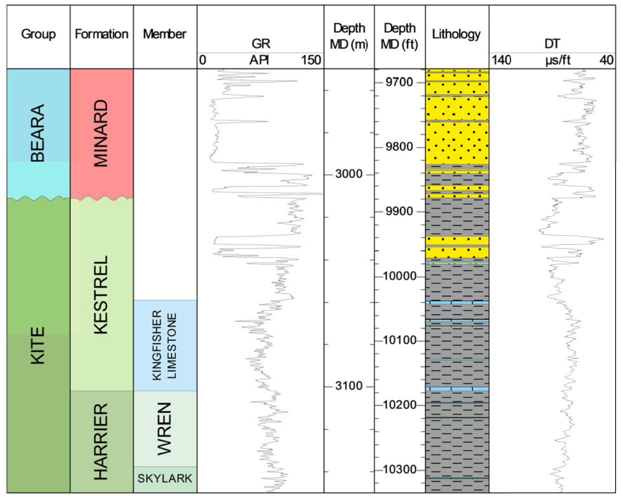
Seismic expression. In the Slyne Basin, the Lower Bajocian seismic horizon corresponds to a hard seismic event reflecting the incoming of carbonate dominated lithologies equating to the Kingfisher Limestone Member below the Minard Formation, as seen for instance over the Corrib Field area (blocks 18/20, 18/25), as shown in **Figure D.5.3**.

Regional correlation. The Kingfisher Member correlates to the middle sedimentary succession of the Sparrowhawk Formation in the Goban Spur, Fastnet and North Celtic Sea basins to the south and east of Ireland. In northwest Scotland this unit is age equivalent to the middle/upper part of the Bearreraig Formation, while in southern England it appears to be laterally equivalent to the middle section of the Inferior Oolite Group (Cox, 2002a, b; Cox & Page, 2002; Barron *et al.,* 2012).

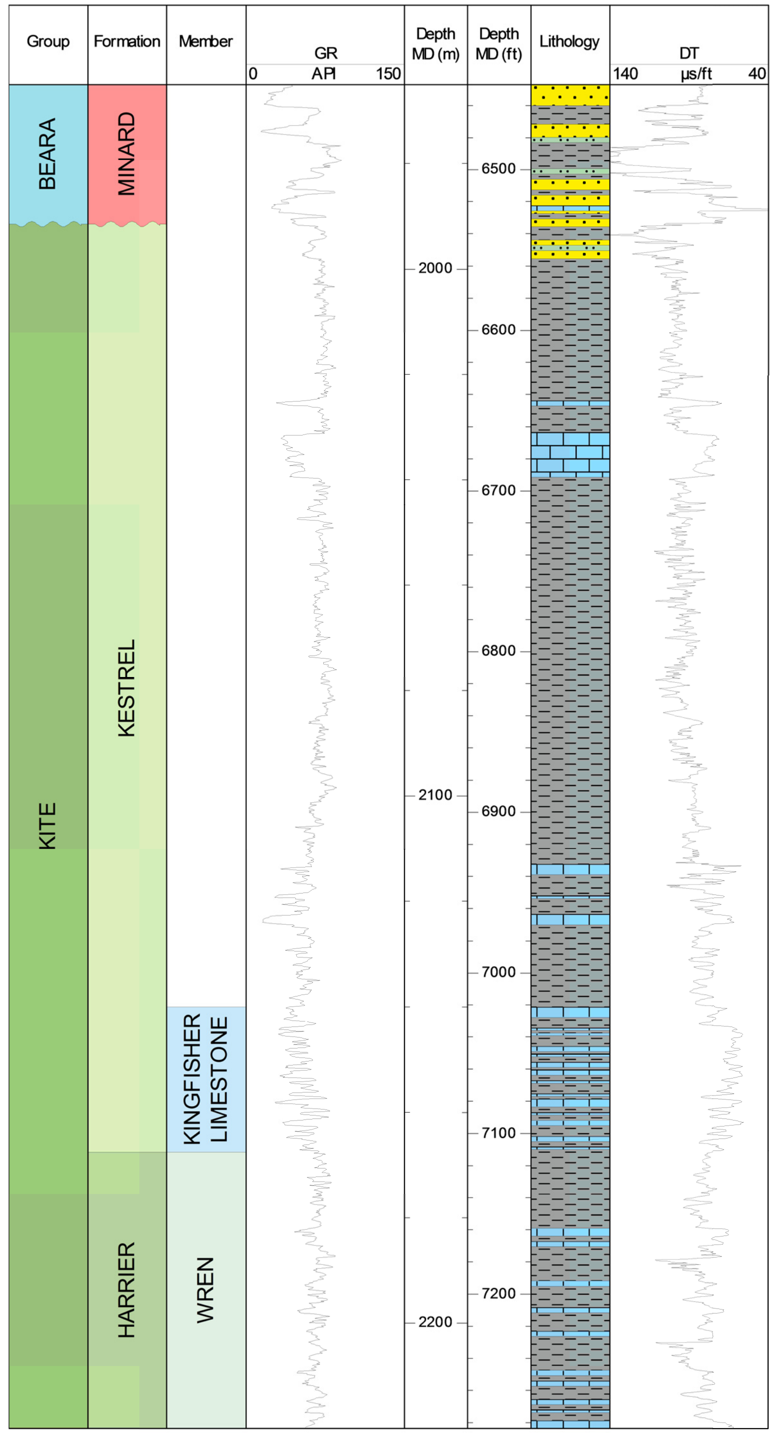
Comparison with Eastern Canada. The Kingfisher Member is laterally equivalent to the upper part of the Downing Formation (claystones) and also part of the Whale Member (limestones) of the Horseshoe, Carson and Jeanne d'Arc basins, offshore east coast Canada.



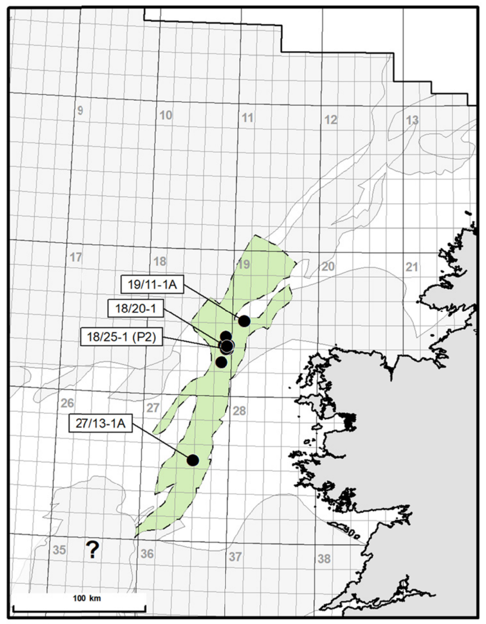
27/13-1A
Reference well; Kestrel Formation, Kingfisher Limestone Member



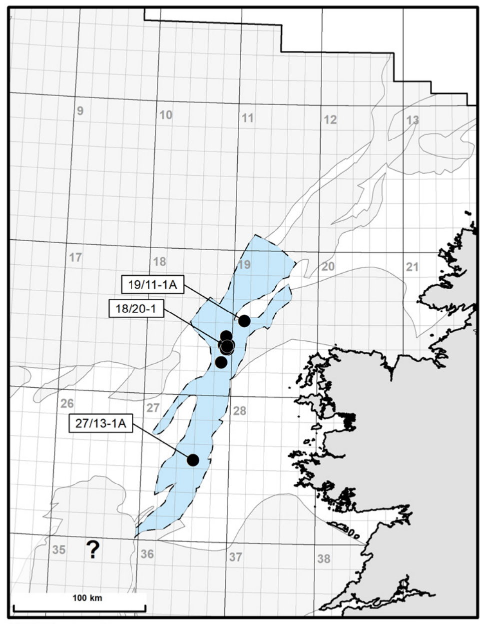
19/11-1A
Reference well; Kestrel Formation, Kingfisher Limestone Member



18/20-1
Type well; Kestrel Formation, Kingfisher Limestone Member



Kestrel Formation



Kingfisher Limestone Member

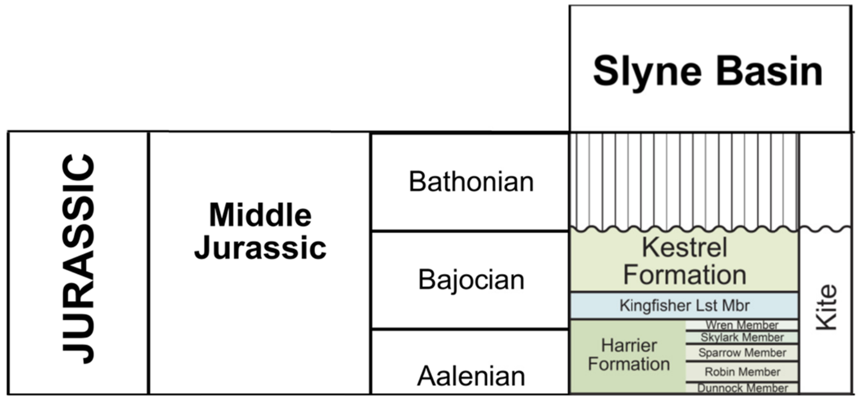


Figure D.6. 26. ***Kestrel Formation (including Kingfisher Limestone Member) type and reference wells with location and distribution maps.***

LIAS GROUP

The Lias Group includes all Lower Jurassic and lower Middle Jurassic (Aalenian) sediments in offshore Ireland, and the term is applied here following UK onshore usage. The sedimentary succession appears to be contiguous between offshore western British basins, such as the Bristol Channel, South Celtic Sea and St George's Channel basins, passing without apparent break into offshore Ireland. The group is widespread offshore Ireland and the name is also applied to western offshore Ireland basins (see **Figure D.6.15**). The group is proven in wells, boreholes and sea bed samples from the Erris, Slyne, Porcupine, Goban Spur, Fastnet, South Celtic Sea, North Celtic Sea and Kish Bank basins. The latter record is from a sea bed sample (Dobson & Whittington, 1979), but cannot be assigned to a formation.

The name Lias has been in usage for many years since the term was first coined by William Smith in 1813 (as "Lyas"), and later as Lias (Buckland *in* Phillips, 1818), and was formalised as a group by Cox *et al*. (1999). Cox *et al*. (1999) formalised the large number of informal subdivisions within the Lias Group in onshore Britain that were previously in use. Simms *et al*. (2004) described further revisions of formations in the Hebrides area of western Scotland, that are pertinent to the usage that can be applied in western offshore Ireland.

Ternan (2006) applied the term Lias Group to the Lower Jurassic rocks of offshore Ireland but restricted the group to Pliensbachian-Hettangian only. This differs from the traditional usage in Britain where Lias Group equates to whole Lower Jurassic (formalised in Cox *et al*., 1999).

Murphy & Ainsworth (1991) defined a scheme of five lithostratigraphic units for the Lower to Middle Jurassic (Aalenian) of the Fastnet Basin. These units are valid subdivisions of the Lower Jurassic of the area but were not named in accordance with the stratigraphic code guidelines, therefore new names are applied in the current scheme, namely the Caragh, Currane, Leane formations. In addition, the use of the formations is extended northwards to apply to the North Celtic Sea and Central Irish Sea Basins.

Millson (1987) coined the name Mochras Group for the Lower Jurassic of the Fastnet and Celtic Sea basins (Ireland and UK regions). This was part of a scheme (group, three formations, four members) he established for the whole Jurassic, however, this scheme has not been adopted by subsequent workers or operating companies and has not been used in the current evaluation, but reference is made to his terms and the likely equivalence to the newly defined units.

Within the Lias Group of offshore Ireland, a variety of formations and members is recognised. These comprise some units that appear to be of regional extent, extending from onshore and offshore UK areas into Irish waters, for instance the Blue Lias Formation (Hettangian-Sinemurian), the Pabay Shale Formation (Pliensbachian) and the Whitby Mudstone Formation (Toarcian). Between these formations occur units that are of more localized origin, such as the shallow marine to non-marine carbonate successions of Fastnet Basin (Leane Formation, Hettangian) and the Slyne-Erris basins (Meelagh Formation, Hettangian-Early Sinemurian). Sandstone units occur in certain areas and are recognised as members (for example Gara and Loughbaun Sandstone Members in the Fastnet and North Celtic Sea basins, and Neaskin Sandstone Member in the Slyne Basin) within formations that are dominated by argillaceous background sediments.

The lower boundary of the group is placed at the top of the Penarth Group, marked by the top of the Lilstock Formation (Langport Member) limestone. This is usually a sharp lithological contact passing from a massive limestone into the claystone of the basal formation of the Lias Group (Caragh Formation in the Fastnet-North Celtic Sea basins and Conn Formation in the Slyne and Erris basins). As far as can be ascertained, the basal boundary of the group appears conformable in offshore Ireland.

In onshore UK areas, the top of the Lias is difficult to define, as it falls at various levels from the base of the Aalenian to intra Aalenian. In southern Britain, the top of the Lias Group is marked by the base of the Inferior Oolite Group carbonate succession. In Dorset, the boundary between the Lias (Bridport Sandstone Formation) and Inferior Oolite Group falls within the Aalenian (top of Opalinum Zone; see Hesselbo & Jenkyns, 1995). In Central England (for example Cotswolds, Lincolnshire) the Lias/Inferior Oolite group junction falls at the Toarcian/Aalenian boundary. In Yorkshire the sections are affected by the presence of sandstone in the Upper Toarcian and Aalenian. In offshore Ireland, the Middle Jurassic overlying the Lias Group differs from that seen in the UK in displaying a development of a thick Aalenian to Bajocian claystone-sandstone succession. In the North Celtic Sea Basin, an upper limit to the shale-dominated Tacumshin Formation (uppermost formation of the Lias Group) is defined at a level within the Aalenian (dated by biostratigraphy data in this study), for example in the 49/9-1, 41/30-1, 42/21-1 wells. In the Slyne-Erris basins wells, a correlative, equivalent boundary (the upper limit of Toarcian-Aalenian Dun Caan Shale Formation) also falls within the Aalenian, based on biostratigraphic data in this study (as seen in well 18/20-1). This level correlates with the top of the Dun Caan Shale Member in the Isle of Skye, where this level is dated as intra Aalenian (Murchisonae Zone) age (see Cope *et al*., 1980; Morton & Hudson, 1995).

The Lias Group in offshore Ireland contains several organic-rich formations that show good to excellent source rock potential (**Figure D.6. 27**). These are, in descending stratigraphic order; the Tacumshin, Whitby Mudstone, Dun Caan Shale, Pabay Shale, Glenbeg, Currane and Leane formations. These formations occur in the North and South Celtic Sea basins, the Fastnet and Goban Spur basins, as well as in the Slyne Basin. In particular, the Whitby Mudstone Formation and the Pabay Shale Formation in the Slyne Basin area show very good to excellent oil-prone source rock potential. In the North Celtic Sea Basin, the Glenbeg Formation, in addition, shows good hydrocarbon generation potential. Other formations, including the Meelagh and Caragh, contain very limited numbers of samples with elevated TOC values, but are not considered to have significant source rock potential. Data for these formations are shown in **Appendix E**.

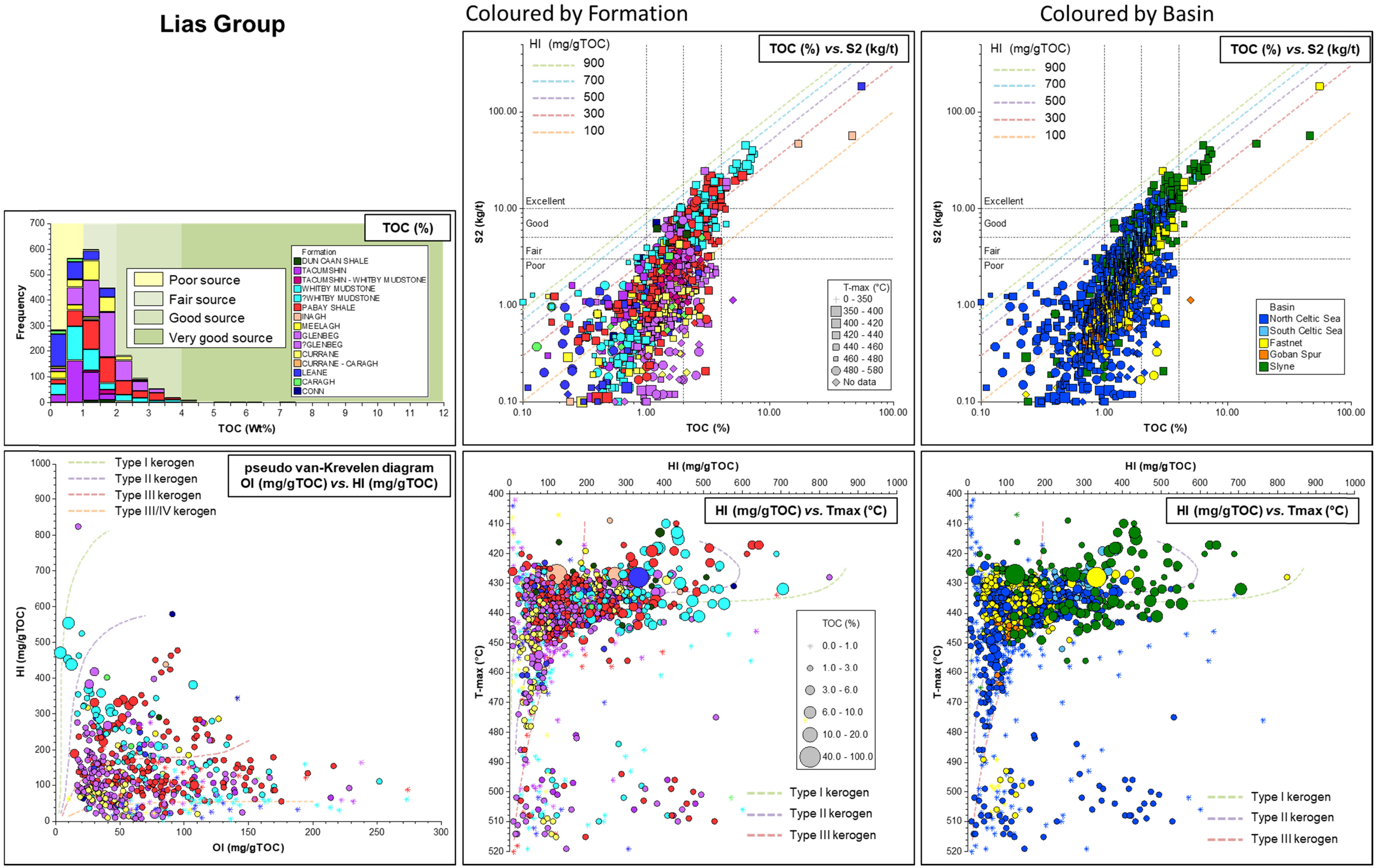


Figure D.6. 27. *Lias Group source rock characteristics, offshore Ireland.*

BLUE LIAS FORMATION

The Blue Lias Formation was formally defined by Cox *et al*. (1999), though the term has been in use for many years since it was first coined by William Smith in 1799 for the rocks of the lowermost Lower Jurassic in Britain.

The type section for the formation is the Saltford railway cutting, near Keynsham, Somerset, western England, with reference sections in the cliffs west of Lyme Regis, Dorset and on the north Somerset coast around Watchet, together with several BGS boreholes (Cox *et al*., 1999). The formation is present in Britain throughout England, south Wales, Yorkshire, north west Scotland (Morvern, Highland), as well as the offshore Bristol Channel Basin and South Celtic Sea Basin. Notably, the formation is not typically developed in the Llanbedr (Mochras Farm) Borehole, Gwynedd, west Wales, where the lithofacies is more typical of the Gill Formation, that is defined herein. The formation is present in onshore Northern Ireland.

The formation is characterised by its development of alternating limestones and mudrocks. The latter are sometimes laminated and organic rich or bituminous ("paper shale"). Individual limestones are typically 0.10 m to 0.30 m thick, and intervening claystones, which may contain limestone nodules, are typically less than 1m thick (Cox *et al*., 1999). In UK onshore successions, substantial units of mudstone with relatively few limestone beds occur in some areas. While these mudstone units have been given informal names in many areas (for example Saltford Shales, Aldergrove Beds, Lavernock Shales), these remain part of the Blue Lias Formation as conceived by Cox *et al*. (1999) and were not formalised as members by them. In offshore Ireland, the equivalent mudstone units are present but are separated out as the Caragh and Conn formations, hence the lower limit of the Blue Lias Formation as applied in offshore Ireland is taken at a higher stratigraphical level, within the Hettangian, than it is in the UK area (base of the Hettangian).

In onshore British sections, the top of the formation falls within the Lower Sinemurian, where it is overlain by the claystones and shales of the Charmouth Mudstone, as on the Dorset coast. This upper boundary is markedly diachronous across Britain, however, occurring at various levels from Bucklandi, Semicostatum, Turneri, Obtusum or Oxynotum Zones (Cox *et al*., 1999). The upper boundary is difficult to pinpoint as there typically occurs an upwards transition from interbedded limestones and claystones to a section above with a reduced limestone content, but with thin limestones still present. Placement of the upper boundary is often therefore very interpretative and differs between authors. In offshore Ireland, the upper boundary of the formation is placed in the uppermost Hettangian.

The Blue Lias is of fully marine origin. In offshore Ireland, non-marine to shallow marine facies are developed as lateral equivalents of the formation, namely the Leane Formation in the Fastnet Basin and the Meelagh Formation in Slyne and Erris basins. A further formation, the Gill Formation, is a lateral equivalent of the Blue Lias, and is of marine origin, but is distinguished from the Blue Lias Formation by the absence of well-developed limestones.

Reference sections in offshore Ireland. 41/30-1: 1847.5-1909m below KB. 50/3-3: 1037-1124m below KB. Present in 50/12-3: 2940-2945m below KB, though highly truncated. See Figure D.6. 28.

Lithology. The Blue Lias Formation is characterised by alternations of light to dark grey, slightly micromicaceous, marls and claystones, in association with off white, light to medium grey, light brownish grey, mudstone to locally wackestone, locally silty, bioclastic, micritic to microcrystalline, limestones and argillaceous limestones. Locally the mudrocks are dark grey, non-calcareous and fissile, indicating "paper shales" developments.

Wireline log character. The wireline log motifs are moderately to highly serrated, reflecting the interbedded carbonates and claystones. Locally the thicker limestone exhibit blocky wireline log motifs.

Upper boundary. The upper boundary is taken at a downsection lithological change from the marls/calcareous claystones of the Currane Formation, Corfad Member, to the interbedded marls, claystones and limestones of the Blue Lias Formation. This change is expressed on wireline log criteria by a decrease in gamma ray values and a corresponding increase in sonic velocity.

Lower boundary. The lower boundary of this unit is taken at a downsection lithological change from the marls/calcareous claystones to the claystones of the Caragh Formation. On wireline log criteria, this boundary is represented by an increase in gamma ray values and a corresponding decrease in sonic velocity.

Subdivision. No subdivision is recognised in offshore Ireland.

Thickness. The formation is recorded in two Irish wells where it ranges in thickness from 61.5m (41/30-1) to 87m (50/3-3). In contrast, a thickness of 142.3m is developed in UK onshore (Isle of Skye) well Upper Glen-1.

Biostratigraphic characterization. Dated by ostracods, foraminifera and rare dinocysts. Calcareous microfossil and dinocyst recovery varies from poor to good throughout the formation. Occurring within Ostracod Zone IOJ2, Foraminiferal Zone IFJ2 and Palynological Subzone DM2A1.

Age. Early Jurassic, Hettangian in offshore Ireland. In this area, the upper boundary of the formation falls in the uppermost part of the Hettangian.

Depositional environment. Marine, inner to outer shelf. The Blue Lias Formation was laid down in a low energy, muddy bottomed, marine shelfal environment. The absence of clastic input is indicative of a low relief topography. Bottom water conditions varied from well oxygenated (denoted by rich microfaunas), through dysaerobic (restricted microfaunas) to anoxic (denoted by an absence of microfaunas). Onshore and offshore UK, the formation exhibits small scale rhythms/alternations of limestones and claystones (Hallam, 1975), which are thought to reflect climatic cyclicity (House, 1985, 1987). In the Irish offshore area these depositional patterns are expected to be present.

Distribution. The formation is proven in three wells in the northern part of the North Celtic Sea Basin (quadrants 50 and 41). To the south and east of this area, the formation passes laterally into the Gill and Leane formations.

Seismic expression. The formation cannot be resolved on the available seismic data.

Regional correlation. The formation as developed in offshore Ireland (northern North Celtic Sea Basin) correlates with the mid part of the formation as developed in onshore Britain (England, south Wales, parts of the Hebrides Basin, western Scotland, see Cox *et al*., 1999). The Blue Lias Formation as recognised offshore Ireland correlates with the lower part of the Waterloo Mudstone Formation in Northern Ireland, into which all the Lower Jurassic rocks in the province are placed (see Mitchell, 2004).

The formation correlates with the lower and middle parts of the Meelagh Formation as developed in the Porcupine, Slyne and Erris basins, and with the Gill and Leane formations that are present in the Fastnet and Celtic Sea basins. The Breakish Formation of northwest Scotland is lateral equivalent to the Blue Lias Formation (Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The Blue Lias Formation is age equivalent to the lower part of the Iroquois Formation (dominantly limestones and dolomites) and the Argo Formation (dominantly halites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

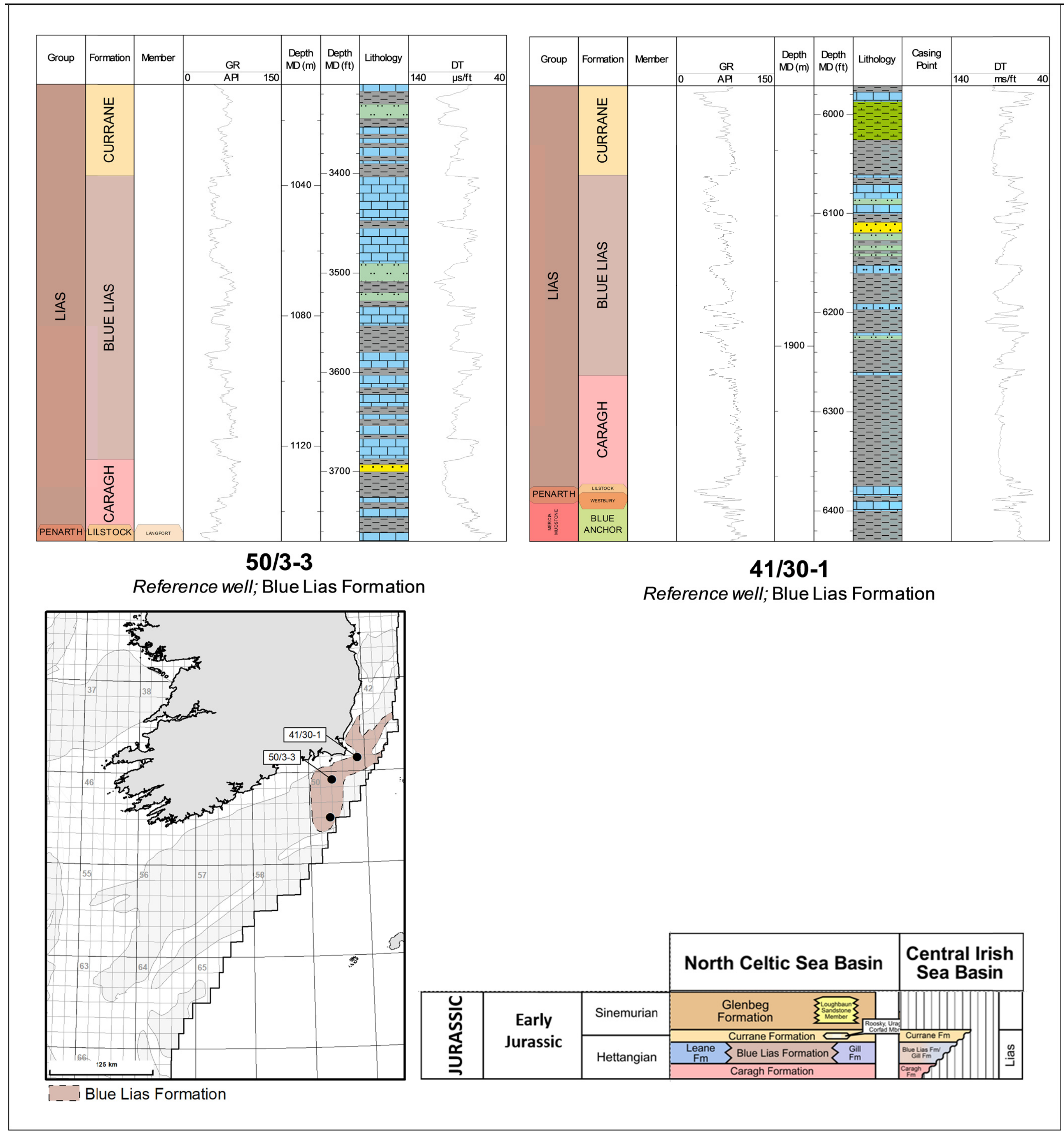


Figure D.6. 28. *Blue Lias Formation reference wells with location and distribution map.*

CARAGH FORMATION (NEW)

The Caragh Formation is defined here as a succession of dominantly claystones, in association with a small number of limestone interbeds, of early Hettangian age. This sedimentary succession comprises the basal part of the Lias Group, that is developed through the Fastnet, South Celtic Sea and North Celtic Sea basins. It is overlain by either the Leanne, Gill or Blue Lias formations. The formation overlies the Penarth Group, Lilstock Formation, Langport Member.

Rocks now allocated to this formation in the Fastnet Basin were previously referred to as Jurassic Basal Liassic Claystone Unit (J-1) by Murphy & Ainsworth (1991). The type well for this unit proposed by these authors, 56/21-2, is here nominated as the type well for the Caragh Formation in offshore Ireland. This unit was originally part of the Liassic Limestone of Robinson *et al.,* 1981; Ainsworth, 1989; Ainsworth *et al*.,1989 and Rutherford & Ainsworth, 1989.

Name. After Lough Caragh in County Kerry.

Type section. 56/21-2: 3205.5-3252.5m below KB. See **Figure D.6. 29**.

Reference sections. 41/30-1: 1909-1944m below KB. 50/3-3: 1124-1146m below KB. See **Figure D.6. 29**.

Lithology. The formation is mainly represented by claystones. A number of limestone beds are also present. Rare sandstone stringers are also present in two wells.

The claystones are medium to dark grey, locally light greenish grey/medium grey, micromicaceous, locally silty, and variably calcareous. The carbonates comprise off white to light grey, medium to dark brown, mudstone, micritic to cryptocrystalline, well indurated, argillaceous limestones and limestones. These limestones beds are more prominent in the lower third of the formation.

Rare light grey to light brown, very fine to fine grained, well sorted, subrounded, calcareous sandstone stringers are recognised in both the 63/4-1 and 56/18-1 Fastnet Basin wells.

Wireline log character. This unit displays a slightly serrated, bow shaped wireline log profiles, with high gamma ray values and slow sonic velocities, reflecting the dominantly claystone lithological succession. Towards the base of the unit, a more serrated wireline log motif is recognised, denoting the presence of prominent limestone beds.

Upper boundary. The top of this formation is placed at a downsection lithological change from the carbonates of the Blue Lias, Gill and Leane formations to the claystones of the Caragh Formation. This is reflected on wireline log criteria by an increase in gamma ray values and a decrease in sonic velocity.

Lower boundary. The base of this unit is taken at a downward lithological change from claystones to the limestones of the Penarth Group, Lilstock Formation, Langport Member. On wireline log criteria, this boundary is taken by an abrupt decrease in gamma ray values and a corresponding sharp increase in sonic velocity.

Subdivision. No subdivision is recognised.

Thickness. The formation varies in thickness from 20.5m (50/12-3) to 47m (56/21-2). The formation appears to be restricted to the Central Irish Sea, Fastnet, North Celtic Sea and South Celtic Sea basins and in many instances has a questionable unconformity at its upper boundary but is of a fairly consistent thickness (30m-40m) when not bounded by unconformities. The thickest section recorded is 47m (56/21-2), but the lower boundary is a questionable unconformity in this well.

Biostratigraphic characterization. Dated by ostracods and foraminifera. Rich calcareous microfaunas are present within this unit. Occurring within Ostracod Zone IOJ1, Foraminiferal Zone IFJ1 and Palynological Subzone DM2A1.

Age. Early Jurassic, early Hettangian.

Depositional environment. Marine, inner shelf. The Caragh Formation was laid down in a low energy, inner shelf, marine environment. The presence of rich microfaunas is indicative of well oxygenated bottom waters. The absence of sands is suggestive of a subdued topography.

Distribution. The formation is proven by wells to be present in the Central Irish Sea, North Celtic Sea, South Celtic Sea and Fastnet basins. On the basis of seismic correlation and extrapolation, the formation is considered to extend to the north western and south eastern limits of these basins. To the south west, the formation is extended from the Fastnet Basin through the Celtic Platform into the Goban Spur Basin on the basis of seismic interpretation.

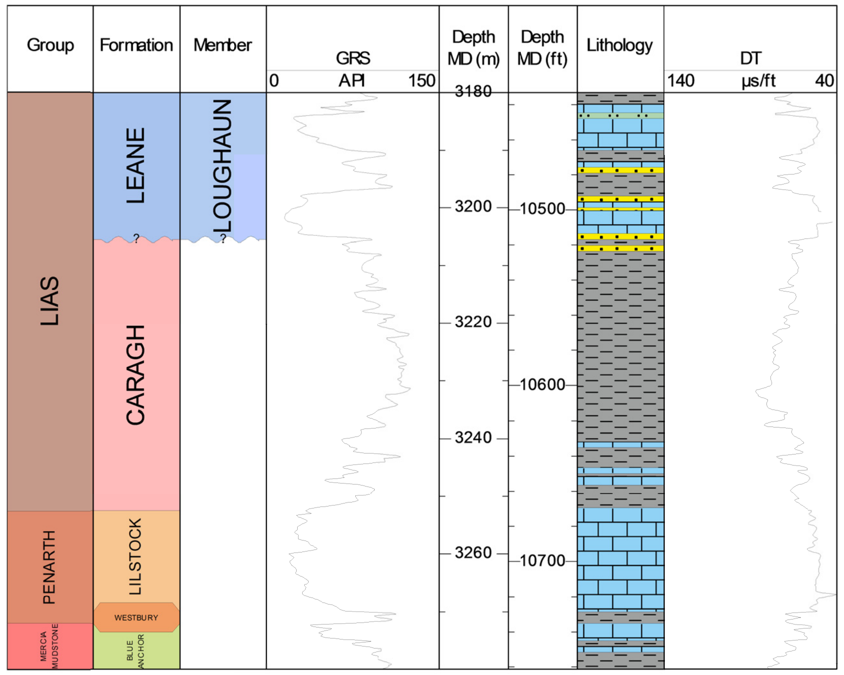
Seismic expression. The formation cannot be resolved on the available seismic data.

Regional correlation. The formation is a direct equivalent to the Conn Formation from the Porcupine, Slyne and Erris basins. The formation correlates with the basal part of the Blue Lias Formation of onshore UK (formalised by Cox *et al*., 1999). The Caragh Formation correlates with the basal part of the Breakish Formation of northwest Scotland (see Morton, 2004; Simms *et al.*, 2004). Over this region, this claystone contains the base J2 maximum flooding surface.

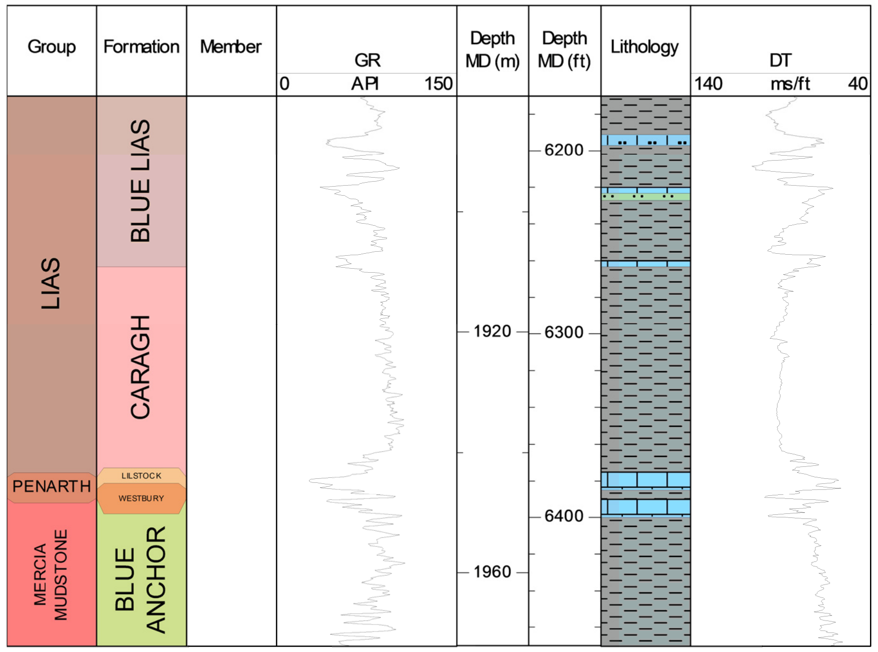
Source rock characterisation. In the South and North Celtic Sea basins the Caragh Formation contains few organic-rich samples with TOC contents greater than 1% (**Appendix E**). Elevated HI values and Type II to Type II/III kerogen composition indicate some source potential, but limited data makes it difficult to define.

The Caragh Formation does not directly correspond to a source rock interval identified in project IS16/01 (BeicipFranlab, 2017).

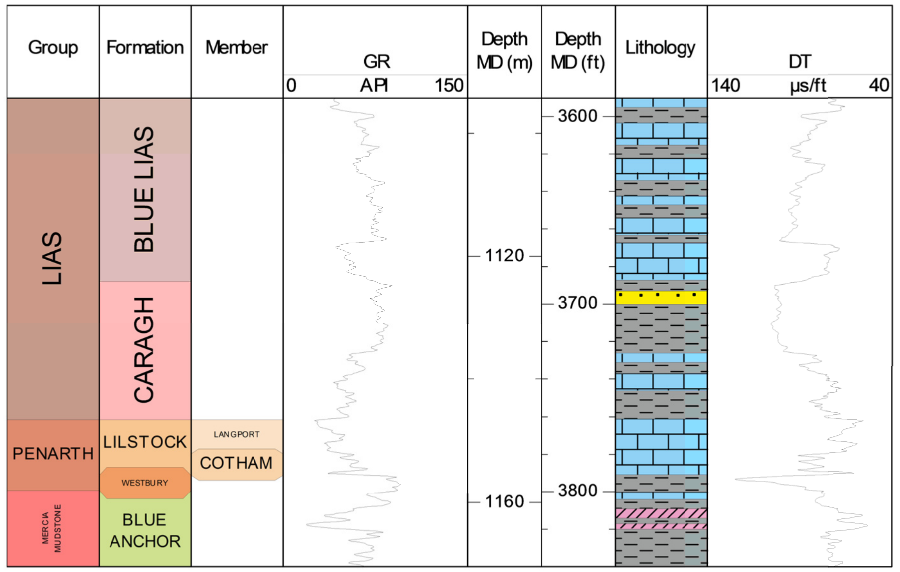
Comparison with Eastern Canada. The Caragh Formation is age equivalent to part of the Argo Formation (dominantly halites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.



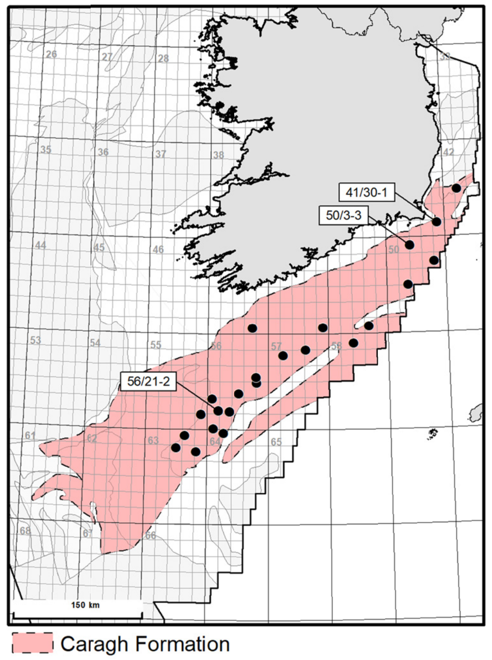
56/21-2
Type well; Caragh Formation



41/30-1
Reference well; Caragh Formation



50/3-3
Reference well; Caragh Formation



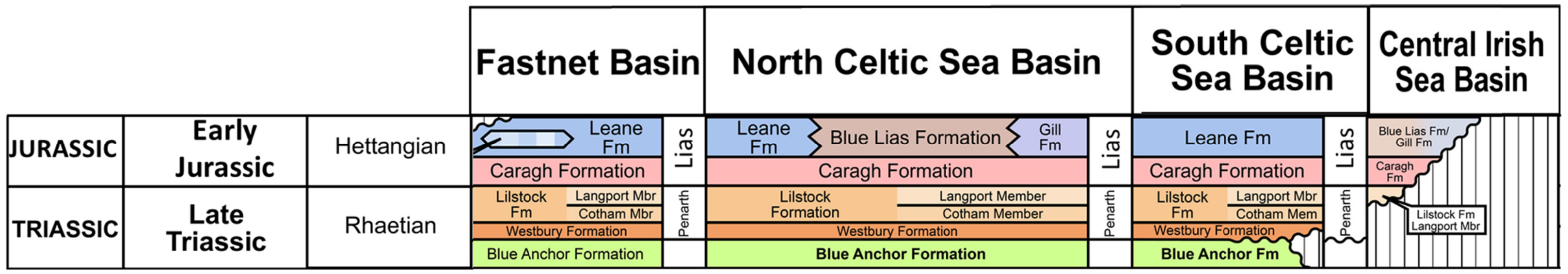


Figure D.6. 29. ***Caragh Formation type and reference wells with location and distribution map.***

CONN FORMATION (NEW)

The Conn Formation is defined here for a claystone dominated unit of early Hettangian age that occurs in western offshore Ireland basins. This unit occurs at base of the Lias Group, and is present in the Erris, Slyne and northern Porcupine basins. This unit lies between Meelagh Formation, Moanmore Member and the Penarth Group, Lilstock Formation, Langport Member.

The Conn Formation was previously included as the basal part of the Broadford Beds by Trueblood & Morton (1991) and Dancer *et al*. (2005), and in the Broadford Beds Equivalent by Dancer *et al*. (1999).

Name. After Lough Conn in County Mayo.

Type section. 18/20-1: 3861.5-3907m below KB. See **Figure D.6. 30**.

Reference sections. 12/13-1A: 2097-2114m below KB. 26/22-1A: 2266-2286.5m below KB. See **Figure D.6. 30**.

Lithology. The unit is claystone dominated. Two prominent limestone beds are often present in the middle part of the formation.

The claystones are light to medium dark grey, light greenish grey/medium light grey, micromicaceous, rare carbonaceous specks and variably calcareous. The limestones are light grey, mudstone, micritic to microcrystalline and well indurated. Locally these carbonates grade to greyish brown, dolomitic limestones.

Wireline log character. This unit displays slightly to moderately serrated, bow shaped wireline log profiles, with high gamma ray values and decreased sonic velocities reflecting the dominantly claystone lithologies, whereas the low gamma ray values and high sonic velocities reflecting the localised limestone beds.

Upper boundary. The top of this unit is denoted by a downsection lithological change from the carbonates and sandstones of the Meelagh Formation to the claystones of the Conn Formation. This change is expressed on wireline log criteria by a sharp increase in gamma ray values and a coincident abrupt decrease in sonic velocity.

Lower boundary. The base of this unit is taken at a downward lithological change from claystones to the limestones of the Penarth Group, Lilstock Formation, Langport Member. This is reflected on wireline log criteria by a sharp decrease in gamma ray values and corresponding sharp increase in sonic velocity.

Subdivision. No subdivision is recognised.

Thickness. The formation varies in thickness from 8m (27/5-1) to a maximum of 45.5m (18/20-1) and in all eleven wells where it has been encountered the upper and lower boundaries of the formation are interpreted as conformable with the overlying and underlying strata.

Biostratigraphic characterization. Dated by ostracods and foraminifera. The recovered calcareous microfaunas are rare to abundant. Occurring within Ostracod Zone IJO1*,* Foraminiferal Zone IJF1 and Palynological Subzone DM2A1.

Age. Early Jurassic, early Hettangian.

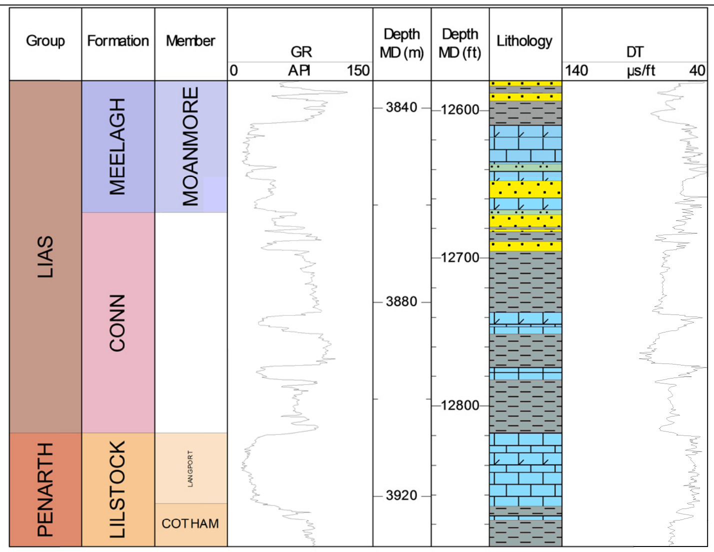
Depositional environment. Marine, inner shelf. This formation was deposited in a low energy, inner shelf, marine environment. The presence of often rich microfaunas is indicative of well oxygenated bottom waters. The absence of arenaceous lithologies is suggestive of a subdued topography.

Distribution. The formation is proven to be present in wells from the Erris, Slyne and northern part of the Porcupine basins. It is considered likely to extend further south into the main part of the Porcupine Basin, though this cannot be proven on the basis of the lack of Lower Jurassic well penetrations in this region.

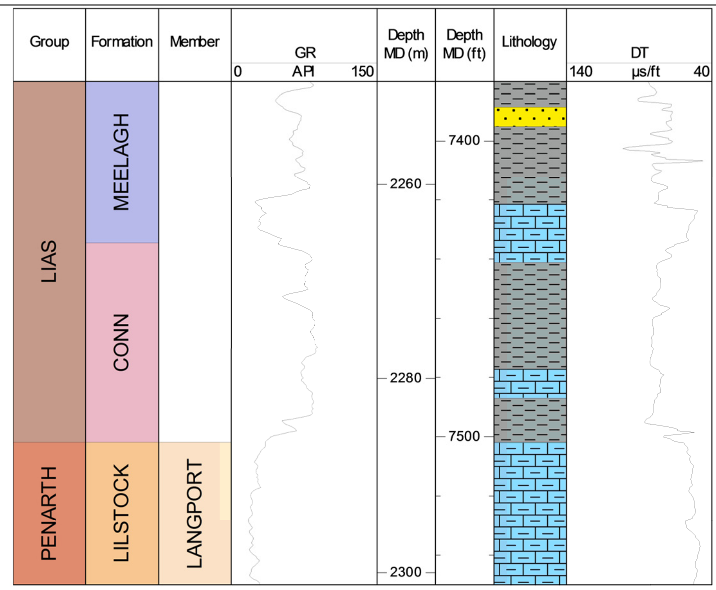
Seismic expression. The formation is too thin to be resolved on seismic data.

Regional correlation. The unit is directly equivalent to the Caragh Formation of the Fastnet, North and South Celtic Sea and Central Irish Sea basins. The formation correlates with the basal part of the Blue Lias Formation of onshore UK (formalised by Cox *et al*., 1999). The Caragh Formation correlates with the basal part of the Breakish Formation of northwest Scotland (see Morton, 2004; Simms *et al.* , 2004). Over this region, this claystone contains the base J2 maximum flooding surface.

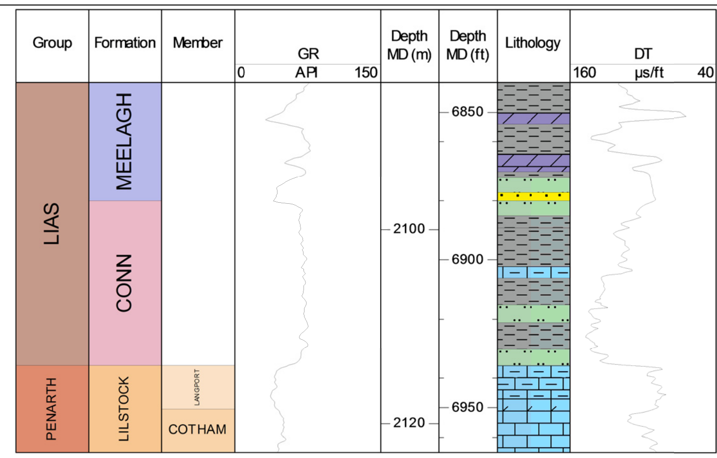
Comparison with Eastern Canada. The Conn Formation is age equivalent to part of the Argo Formation (dominantly halites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.



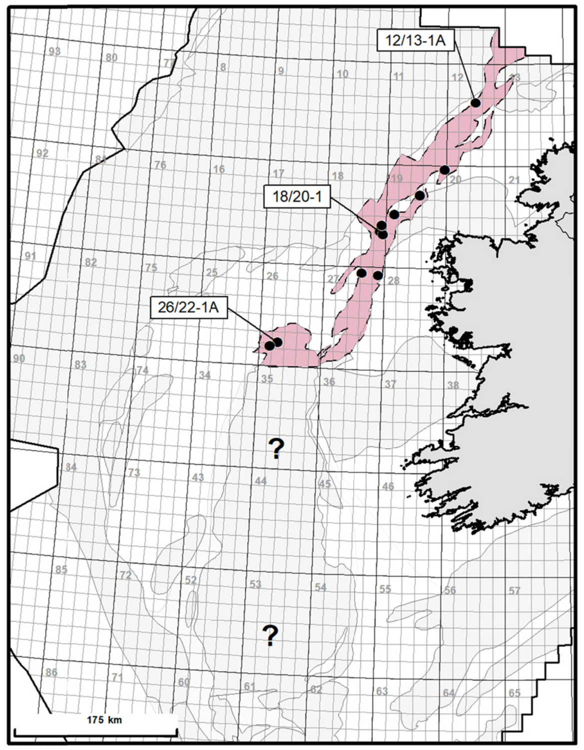
18/20-1
Type well; Conn Formation



26/22-1A
Reference well; Conn Formation



12/13-1A
Reference well; Conn Formation



Conn Formation

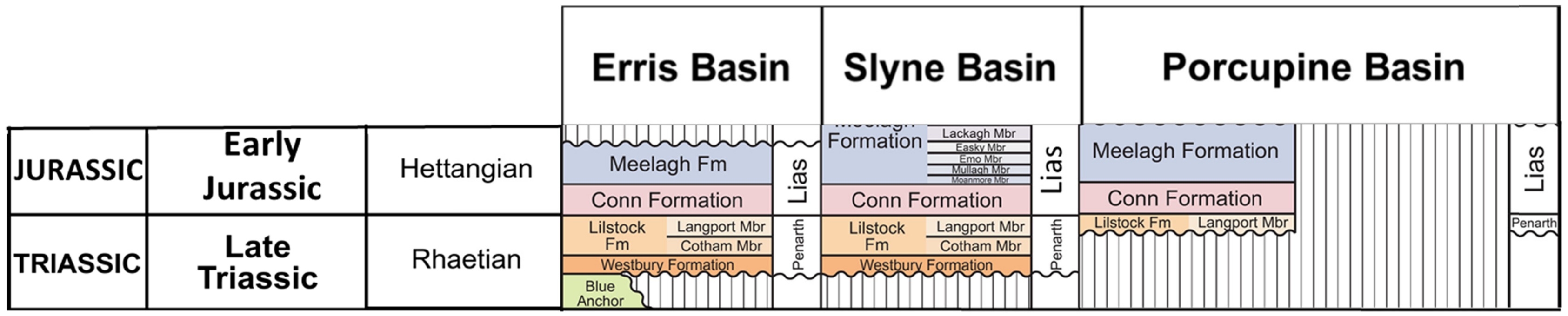


Figure D.6. 30. ***Conn Formation type and reference wells with location and distribution map.***

CURRANE FORMATION (NEW)

The Currane Formation is defined here for a cyclic sedimentary succession of marls, variably calcareous claystones and limestones of earliest Sinemurian to latest Hettangian age. Four distinctive cycles can be recognised. This unit is developed throughout the Fastnet, South Celtic Sea and North Celtic Sea basins. This unit lies between an overlying Glenbeg Formation and the underlying Leanne, Gill and Blue Lias formations.

This formation can be distinguished from the overlying Glenbeg Formation by the more calcareous content of the sediments, the cyclicity of the sedimentary succession and by its very distinctive microfaunal assemblages. The underlying Leanne Formation is a more limestone and claystone-dominated succession, with the lower and middle sections yielding non-marine ostracod faunas. Both the Gill and Blue Lias formations possess more interbedded limestones and argillaceous limestones within their respective sections compared to the Currane Formation.

Three new members are proposed, in descending stratigraphic order; Roosky Member, Uragh Member and Corfad Member. (spelling 'CUR' from first the letter of each Member in ascending stratigraphic order). These three members can only be recognised with certainty within the Fastnet Basin and south-central parts of the North Celtic Sea Basin. A correlation of four wells (56/21-1, 48/30-1, 58/3-1, 49/29-1) in the Fastnet and South Celtic Sea basins is shown in **Figure D.6.48**, illustrating the development of the Currane Formation, and the wireline and lithological characteristics of its member subdivision in this region, together with its boundaries with underlying and overlying formations.

Rocks now referred to this formation in the Fastnet Basin were previously referred to as Jurassic Liassic Marl Unit (J-9 to J-7) by Murphy & Ainsworth (1991). The type well for this unit proposed by these authors was 56/21-1, however, the type well chosen here (56/21-2) displays a slightly thicker section. This unit was informally described as the Liassic Marl (Ainsworth *et al*., 1987; Ainsworth, 1989; Ainsworth *et al*.,1989 and Rutherford & Ainsworth, 1989).

Name. After Lough Currane in County Kerry.

Type section. 56/21-2: 2782.5-2893m below KB. See Figure D.6. 31.

Reference sections. 41/30-1: 1798-1847.5m below KB. 63/10-1: 2957-3020.5m below KB. See Figure D.6. 31.

Lithology. This unit comprises a cyclic sedimentary succession, of marls, with interbedded variably calcareous claystones and limestones. The top of each cycle is capped by an argillaceous limestone.

The marls are light to medium light grey and subblocky. The claystones are to medium to dark grey, micromicaceous, variably calcareous and subplaty. These sediments locally grade to medium light grey argillaceous siltstones. The generally thinly bedded limestones and argillaceous limestones are off white to medium light grey, tan, mudstone, and micritic to microcrystalline, which locally grade to dolomitic limestones. A distinct limestone bed is developed towards the base of the formation (within the Corfad Member). This mud carbonate is usually off white to tan, microcrystalline and well indurated.

Wireline log character. The formation displays a cyclic wireline log motif, with up to four recognisable cycles, some of which display distinct coarsening upwards trends (as in the 41/30-1 well). Each cycle possesses slightly lower gamma values and slightly increased sonic velocities at the top and base of each unit, reflecting marls or argillaceous limestones, while the mid part of each cycle exhibits higher gamma ray values and slower sonic velocities indicating claystone lithologies. The base of the Corfad Member exhibits low gamma ray values and high sonic velocity values indicating a prominent limestone bed.

Upper boundary. The top of this formation is taken at a downsection lithological change from the mudrocks of the Glenbeg Formation (or sandstone where the Loughbaun Sandstone Member is present, as in 41/30-1 well) to the marls/calcareous claystones of the Currane Formation. On wireline log criteria, this boundary is taken as a marked decrease in gamma ray values and an associated increase in sonic velocity.

Lower boundary. The base of this unit is placed at a downsection lithological change from marls/calcareous claystones to the limestones of the Leanne Formation, Emy Member, the interbedded limestones/mudrocks of the Blue Lias formation or to the mudrocks of the Gill Formation. This change is denoted on wireline log criteria by a decrease in gamma ray values and a corresponding increase in sonic velocity. The Currane/Leanne wireline log contact is very distinct, due to presence of well indurated limestones (Emy Member) at the top of the Leanne Formation.

Subdivision. Three new members are recognised, in descending stratigraphic order; Roosky Member, Uragh Member and Corfad Member. These members are not recognisable within the formation in the north eastern part of the North Celtic Sea Basin (quadrant 50).

Thickness. The formation varies in thickness from 59m (56/21-1) to a maximum of 217.5m (49/29-1).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. A number of calcareous microfaunal taxa (*Involutina liassica, Ogmoconchella aspinata, O. michelseni* and *Ogmoconcha hagenowi*) typically occur in flood abundances. Occurring within Ostracod Zone IOJ3, Foraminiferal Zone IFJ3 and Palynological Subzones DM2A2 and DM2A1 (*pars*).

Age. Early Jurassic, earliest Sinemurian-latest Hettangian.

Depositional environment. Marine, inner shelf. The Currane Formation was laid down in a marine, low energy, inner shelf environment. The lower/middle sections (Corfad and lower part of the Uragh members) yield very rich and moderately diverse micro- and macrofaunas indicating well oxygenated bottom waters. The overlying upper part of the Uragh and Roosky members may be barren or yield impoverished faunas implying dysaerobic or anoxic conditions, due to poor water circulation. This may suggest a slight increase in water depth during this time (Murphy & Ainsworth, 1991).

Distribution. The formation is proven to be present in the Central Irish Sea, North Celtic Sea, South Celtic Sea and Fastnet basins and its extent is taken to the current limits of these basins based on seismic extrapolation. It is absent through unconformity from the Goban Spur 62/7-1 well, hence its presence in the Goban Spur Basin is uncertain.

Seismic expression. The Lower Sinemurian (Top Currane) seismic horizon, identified in the Fastnet, South Celtic Sea and North Celtic Sea basins, correlates approximately to the top of the Currane Formation. Beneath this seismic marker, the formation displays a distinctly banded, high amplitude seismic facies (see **Figure D.6.4** and **Figure D.6.8**).

Regional correlation. The formation appears to be a lateral equivalent to the Lackagh and the lower part of the Arroo members of the Meelagh Formation in the Slyne Basin. In onshore and offshore Britain, the formation correlates with the upper parts of the Breakish and Blue Lias formations (Cox *et al*., 1999; Morton, 2004; Simms *et al*., 2004).

Source rock characterisation. The Currane Formation is a fairly organic-rich interval with a significant proportion of available samples showing TOC contents larger 1% (**Figure D.6. 32**). In the Fastnet Basin hydrocarbon yields are low, however, and with a Type III to Type IV kerogen composition this formation shows only poor source rock potential in this area. In the North and South Celtic Sea basins it shows quite heterogenous characteristics. Increased source potential is especially seen in wells 49/29-1, 56/20-1, and 58/3-1 where it shows a Type II to Type II/III kerogen composition. Hydrocarbon yields are lower in other wells from these basins, but higher Tmax values also suggest higher maturities. Increased maturity would tend to reduce the measured present-day source rock potential, and samples are likely to have originally had higher TOC and particularly HI values and thus better hydrocarbon generation potential than indicated on the plots in **Figure D.6. 32**.

The Currane Formation is part of source rock interval Low J1 that was identified in project IS16/01.

Comparison with Eastern Canada. The Currane Formation is age equivalent to the lower part of the Iroquois Formation (mainly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

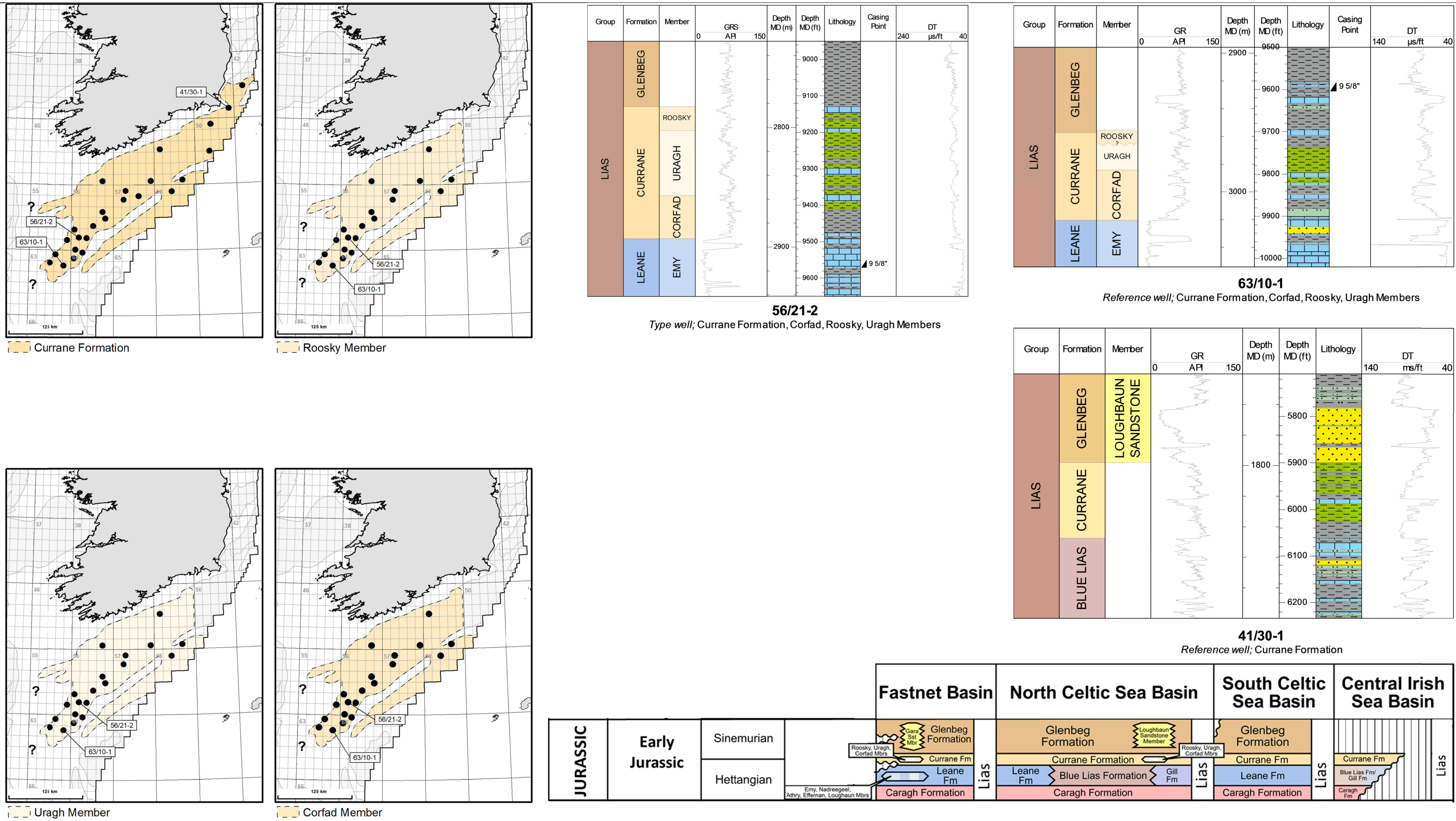


Figure D.6. 31. *Currane Formation and constituent members type and reference wells with location and distribution maps.*

Corfad Member (New)

The Corfad Member is defined here for the lower claystone/marl unit of latest Hettangian age, that occurs within the Currane Formation in the Fastnet, South Celtic Sea and North Celtic Sea basins. This unit lies between an overlying Uragh Member of the Currane Formation and the underlying Leanne, Gill and Blue Lias formations.

Rocks now referred to this member in the Fastnet Basin were previously referred to as the Jurassic Liassic Marl Unit (J-7) by Murphy & Ainsworth (1991). The type well for this unit proposed by these authors was 56/21-1, however, the type well chosen here (56/21-2) displays a slightly thicker development of the unit.

Name. After Corfad Lake, County Monaghan.

Type section. 56/21-2: 2857-2893m below KB. See Figure D.6. 31.

Reference section. 63/10-1: 2984-3020.5m below KB. See Figure D.6. 31.

Lithology. This unit comprises a cyclic sedimentary succession, dominated by marls, with interbedded variably calcareous claystones and thin argillaceous limestones. A distinct limestone bed is often developed towards the base of the member

The marls are light to medium light grey and subblocky, while the claystones are to medium to dark grey, micromicaceous, variably calcareous and subplaty. These latter sediments locally grade to medium light grey, argillaceous siltstones. The generally thinly bedded argillaceous limestones are light to medium light grey, tan, mudstone, micritic, and locally grade to dolomitic limestones. The top of the unit is capped by a marl/argillaceous limestone. The distinct limestone bed which often developed towards the base of the member comprises an off white to tan, microcrystalline, well indurated carbonate.

Wireline log character. This unit displays a slightly serrated, bow shaped wireline log motif, with moderately high to high gamma ray values and moderately slow sonic velocities. The top of the unit displays slightly lower gamma ray values and slightly increased sonic velocities reflecting a marl/argillaceous limestone bed. The base of this member exhibits low gamma ray values and high sonic velocities indicating a prominent limestone bed.

Upper boundary. The upper boundary is denoted by a downward lithological change from the claystones of the Uragh Member to the limestones of the Corfad Member. On wireline log criteria, this boundary is taken as a decrease in gamma ray values, coinciding with an increase in sonic velocity.

Lower boundary. The base of this member is placed at a downsection lithological change from marls/calcareous claystones to the limestones of the Leanne Formation, Emy Member, the interbedded limestones/mudrocks of the Blue Lias Formation or to the mudrocks of the Gill Formation. This change is expressed on wireline log criteria by a decrease in gamma ray values and a corresponding increase in sonic velocity. The Currane Formation, Corfad Member/Leanne Formation, Emy Member wireline log contact is very distinct, due to presence of well indurated limestones (Emy Member) at the top of the Leanne Formation.

Thickness. The member varies in thickness from 19.5m (63/4-1) to 75m (49/29-1).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. A number calcareous microfaunal taxa often occur in flood abundances. Occurring within Ostracod Subzone IOJ3a, Foraminiferal Subzone IFJ3a and Palynological Subzone DM2A1 (*pars*).

Age. Early Jurassic, latest Hettangian.

Depositional environment. Marine, inner shelf. This member was deposited in a marine, low energy, inner shelf environment. The sediments yield very rich and moderately diverse microfaunas (ostracods and foraminifera) and macrofaunas (gastropods and echinoderm debris) indicating well oxygenated bottom waters. The often profuse occurrences of some these taxa may indicate opportunistic taxa.

Distribution. The member is proven to be present in the North Celtic Sea (central part), South Celtic Sea and Fastnet basins and its extent is taken to the current limits of these basins based on seismic extrapolation (though is not identified in quadrant 50 though age equivalent undivided Currane Formation is present). It is absent through unconformity from the Goban Spur 62/7-1 well hence its presence in the Goban Spur Basin is uncertain.

Regional correlation. The Corfad Member appears to be a lateral equivalent to the lower part of the Lackagh Member of the Meelagh Formation in the Slyne Basin. In both the onshore and offshore Britain, this member is an age equivalent to the upper parts of the Breakish and Blue Lias formations (see Cox *et al.,* 1999; Morton, 2004; Simms *et al.* , 2004).

Comparison with Eastern Canada. The Corfad Member is age equivalent to the basal part of the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Roosky Member (New)

The Roosky Member is defined here for an upper claystone/marl/argillaceous unit that occurs within the Currane Formation, of earliest Sinemurian age, in the Fastnet, South Celtic Sea and North Celtic Sea basins. This unit lies between an overlying Glenbeg Formation and an underlying Uragh Member of the Currane Formation.

Rocks now referred to this member in the Fastnet Basin were previously referred to as Jurassic Liassic Marl Unit (J-9) by Murphy & Ainsworth (1991). The type well for this unit proposed by these authors was 56/21-1, however, the type well chosen here (56/21-2) displays a slightly thicker development of the unit.

Name. After Roosky Lough, County Donegal.

Type section. 56/21-2: 2782.5-2802.5m below KB. See Figure D.6. 31.

Reference section. 63/10-1: 2957-2963.5m below KB. See Figure D.6. 31.

Lithology. The marls are light to medium light grey and subblocky. The claystones are to medium to dark grey, micromicaeous, variably calcareous and subplaty. The generally thinly bedded argillaceous limestones are off white to medium light grey, tan, mudstones, which locally grade to dolomitic limestones or marls.

In a small number of wells (for instance 63/10-1) the lowermost part of this unit is absent.

Wireline log character. This member exhibits a serrated wireline log motif. The higher gamma ray values and slower sonic velocities (claystones) are developed midway through the unit. The top and bases of the unit displays slightly lower gamma ray values and slightly increased sonic velocities reflecting the marl/argillaceous limestone sediments.

Upper boundary. The top of this unit is placed at a downsection lithological change from the mudrocks of the Glenbeg Formation to the marls/calcareous claystones of the Currane Formation, Roosky Member. This boundary is taken on wireline log criteria, by a marked decrease in gamma ray values and an associated increase in sonic velocity.

Lower boundary. In the Fastnet Basin the base of the Roosky Member may be marked by a small localised unconformity. The base of this member is denoted by a downsection lithological change from claystones to the marls/calcareous claystones of the Uragh Member. This is reflected on wireline log criteria by a decrease in gamma ray values, with a corresponding increase in sonic velocity.

Thickness. The member varies in thickness from 5m (63/8-1) to a maximum of 38m (56/14-1). In the latter case the lower boundary is an unconformity.

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. A number calcareous microfaunal taxa may occur in large numbers. Occurring within Ostracod Zone IOJ3, Foraminiferal Zone IFJ3 and Palynological Subzone DM2A2 (*pars*).

Age. Early Jurassic, earliest Sinemurian.

Depositional environment. Marine, inner shelf. The Roosky Member was deposited in a marine, low energy, inner shelf environment. Many of the well sections are either barren or yield impoverished faunas indicating dysaerobic or anoxic bottom waters, due to poor water circulation. This may imply a slight increase in water depth during this time (Murphy & Ainsworth, 1991).

Distribution. The member is proven to be present in the North Celtic Sea (central part), South Celtic Sea and Fastnet basins and its extent is taken to the current limits of these basins based on seismic extrapolation (though is not identified in quadrant

50 though age equivalent undivided Currane Formation is present). It is absent through unconformity from the Goban Spur 62/7-1 well, hence its presence in the Goban Spur Basin is uncertain.

Regional correlation. The unit appears to be a lateral equivalent to the lower part of the Arroo Member of the Meelagh Formation within the Slyne Basin. This member is an age equivalent to the upper parts of the Breakish and Blue Lias formations of onshore and offshore UK (see Cox *et al.,* 1999; Morton, 2004; Simms *et al.*, 2004).

Comparison with Eastern Canada. The Roosky Member is age equivalent to the lower part of the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Uragh Member (New)

The Uragh Member is defined here for a cyclic couplet comprising a claystone/marl dominated unit of earliest Sinemurian-latest Hettangian age, which occurs within the Currane Formation in the Fastnet, South Celtic Sea and North Celtic Sea basins. This unit is present between an overlying Roosky Member and an underlying Corfad Member.

Rocks now referred to this member in the Fastnet Basin were previously referred to as Jurassic Liassic Marl Unit (J-8) by Murphy & Ainsworth (1991). The type well for this unit proposed by these authors was 56/21-1, however, the type well (56/21-2) displays a slightly thicker development of the unit.

Name. After Uragh Lough, County Kerry.

Type section. 56/21-2: 2802.5-2857m below KB. See Figure D.6. 31.

Reference section. 63/10-1: 2963.5-2984m below KB. See Figure D.6. 31.

Lithology. This unit comprises two distinct sedimentary cycles, dominated by marls, with interbedded variably calcareous claystones and limestones. In a small number of wells (for instance 63/10-1) part or all of the upper cycle is absent.

The marls are light to medium light grey and subblocky, whereas the claystones are to medium to dark grey, micromicaceous, variably calcareous and subplaty. These latter sediments locally grade to medium light grey argillaceous siltstones. The generally thinly bedded limestones and argillaceous limestones are off white to medium light grey, tan, mudstone, and micritic to microcrystalline, which locally grading to dolomitic limestones.

Wireline log character. This unit comprises a cyclic couplet, exhibiting a serrated wireline log motif. The higher gamma ray values and slower sonic velocities reflect the claystones developed midway, while the top and bases of each the couplets denoted by the lower gamma ray values and increased sonic velocities indicate the marl/argillaceous limestone sediments. The overall shape comprises both waisted and bow shaped wireline log motifs.

Upper boundary. The top of the Corfad Member may be marked by a small localised unconformity, within the Fastnet Basin. The top of this unit is denoted by a downward lithological change from the claystones of the Roosky Member to the marls/calcareous claystones of the Uragh Member. On wireline log criteria, this boundary is indicated by a decrease in gamma ray values, in association with a corresponding increase in sonic velocity.

Lower boundary. The base of this member is indicated by a downward lithological change from claystones to the limestones of the Corfad Member. This is reflected on wireline log criteria as a decrease in gamma ray values, coinciding with an increase in sonic velocity.

Thickness. The member varies in thickness from 27.5m (56/22-1) to a maximum of 107.5m (49/29-1).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. A number calcareous microfaunal taxa occur in very flood abundances. Occurring within Ostracod Subzone IOJ3b, Foraminiferal Subzone IFJ3b (*pars*) and Palynological Subzones DM2A2 (*pars*) to DM2A1 (*pars*).

Age. Early Jurassic, earliest Sinemurian-latest Hettangian.

Depositional environment. Marine, inner shelf. This member was laid down in a marine, low energy, inner shelf environment. The lower part of the Uragh Member yields very rich and moderately diverse micro- and macrofaunas implying well oxygenated bottom waters, while upper part of this member is either barren or yields impoverished faunas implying dysaerobic or anoxic conditions due to poor water circulation. This may suggest a slight increase in water depth during this time (Murphy & Ainsworth, 1991).

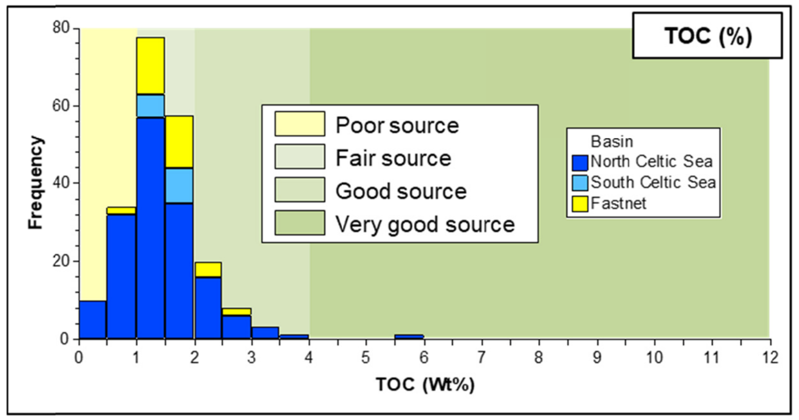
Distribution. The member is proven to be present in the North Celtic Sea (central part), South Celtic Sea and Fastnet basins and its extent is taken to the current limits of these basins based on seismic extrapolation (though is not identified in quadrant 50 though age equivalent undivided Currane Formation is present). It is absent through unconformity from the Goban Spur 62/7-1 well, hence its presence in the Goban Spur Basin is uncertain.

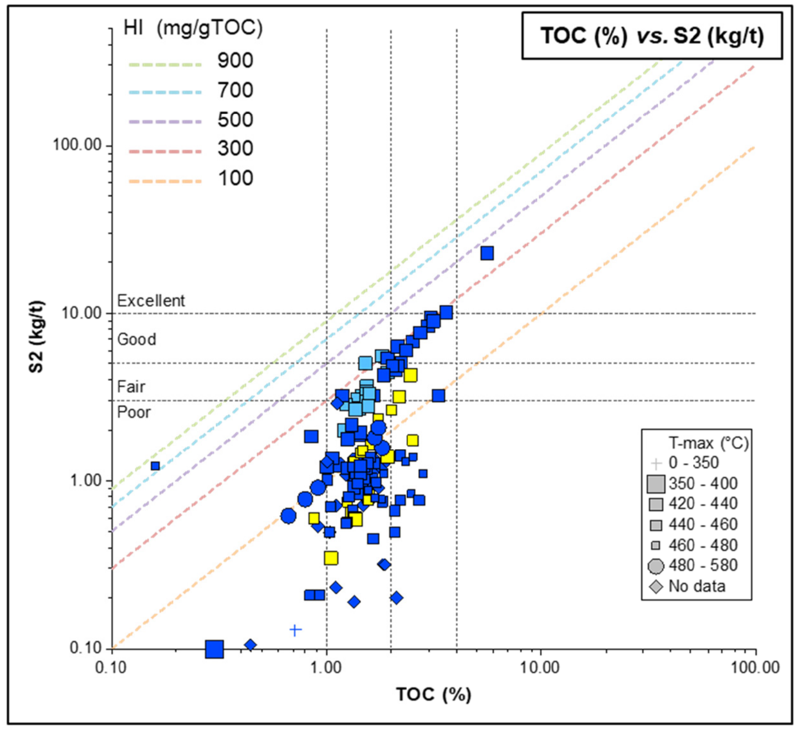
Regional correlation. The Uragh Member appears to be a lateral equivalent to the upper part of the Lackagh Member of the Meelagh Formation in the Slyne Basin. In both the onshore and offshore Britain, this member is an age equivalent to the upper parts of the Breakish and Blue Lias formations (see Cox *et al.,* 1999; Morton, 2004; Simms *et al.*, 2004).

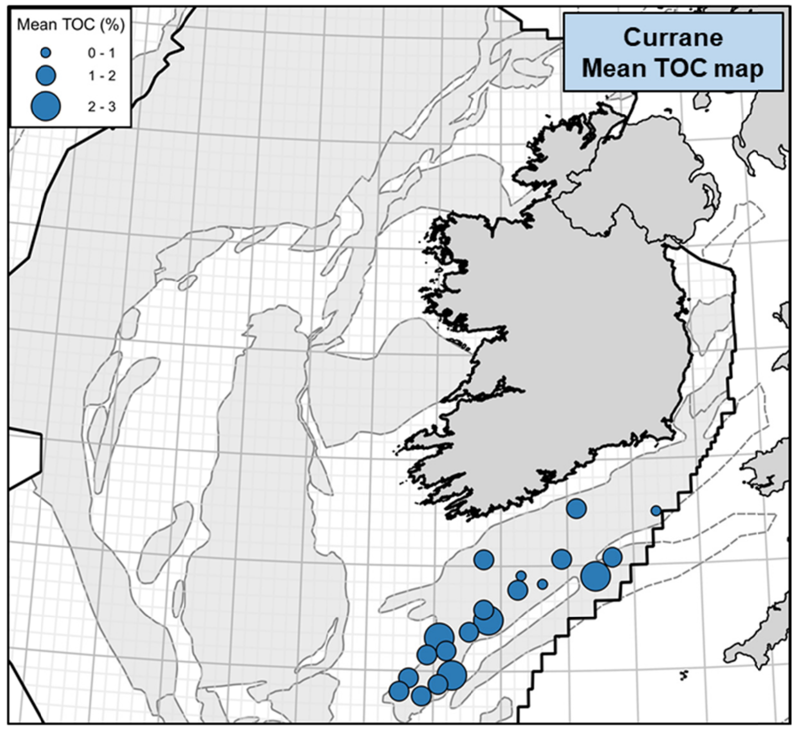
Comparison with Eastern Canada. The Uragh Member is age equivalent to the lower part of the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

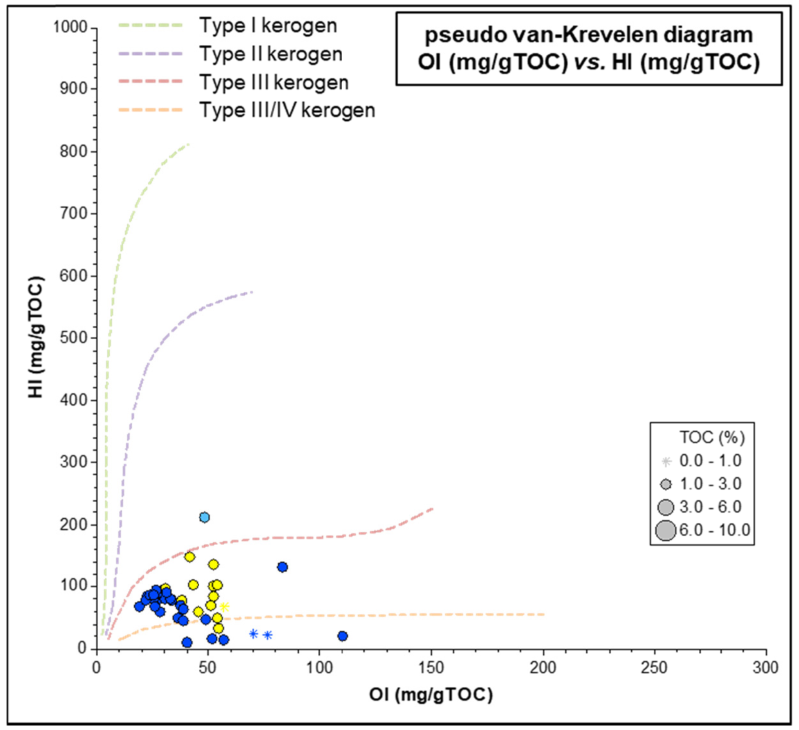
Currane Formation

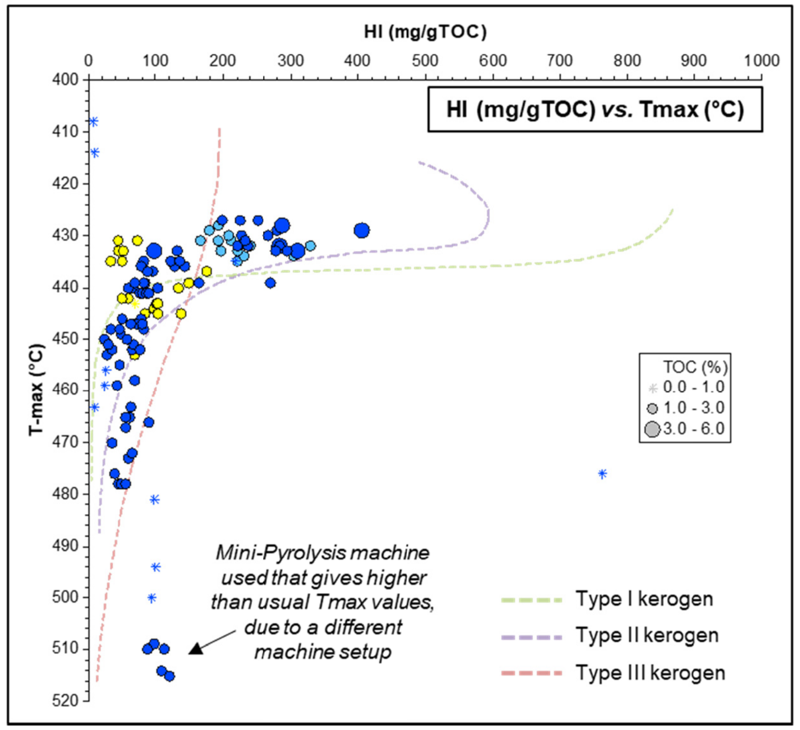
Basin	TOC (%)					HI (mg/gTOC)				
	No. Wells	No. Samples	Min	Max	Avrg.	No. Wells	No. Samples	Min	Max	Avrg.
North Celtic Sea	11	161	0.08	5.6	1.41	11	123	1	763	103
South Celtic Sea	1	15	1.21	1.92	1.51	1	15	166	330	223
Fastnet	8	37	0.88	2.61	1.58	6	21	33	175	86











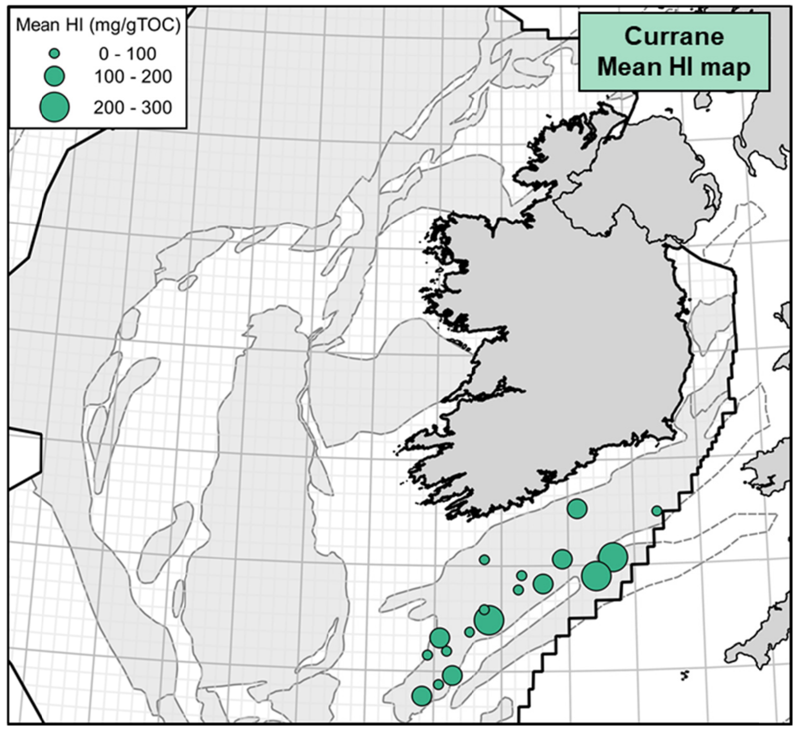


Figure D.6. 32. *Currane Formation source rock characteristics, offshore Ireland.*

DUN CAAN SHALE FORMATION

The Dun Caan Shale was first described by Morton (1965), from the Isle of Skye, western Scotland, with a type section at Bearreraig Bay where it attains a thickness of 12m (though the base of the unit is not exposed at this locality). The formation was named after Dun Caan, a distinctive flat-topped hill on the Isle of Raasay. Morton & Hudson (1995) referred to this unit as the Dun Caan Shale Member, of the Bearreraig Sandstone Formation. The formation lies between the overlying Kite Group, Harrier Formation, Dunnock Member and the underlying Whitby Mudstone Formation, Derg Member.

The Bearreraig Sandstone Formation falls largely in the Middle Jurassic series, but the Dun Caan Shale Member is of latest Toarcian age in its type area (Morton & Hudson, 1995). In the current offshore Ireland study, the unit is regarded more properly as belonging to the Lias Group, to which it is transferred, and it is also elevated here to formational status. Offshore Ireland the Dun Caan Shale Formation has an extended stratigraphic range (intra Early Aalenian-Late Toarcian) compared to the type area.

As discussed above, the Dun Caan Shale Formation name is applied to western offshore Ireland basins following the proposals of previous authors (Trueblood & Morton, 1991; Trueblood, 1992) to extend western Scotland, Hebridean lithostratigraphic nomenclature into western offshore Ireland area, for example the Slyne Basin. It is considered possible that the formation extends also into the Erris and Porcupine basins, though it has not yet been penetrated in any wells in these basins.

Reference sections in offshore Ireland. 18/20-1: 2556-2651m below KB. 27/4-1: 887.5-935m below KB. 27/13-1A: 2000-2092m below KB. See Figure D.6. 33.

Lithology. This unit is dominated by claystones, with localised thin limestone beds and stringers. The claystones are medium to dark grey, micromicaeous, with rare carbonaceous specks, and variably calcareous. Locally the claystones grade to argillaceous siltstones and siltstones. The thinly bedded limestones are light grey to light brown, mudstone, micritic to microcrystalline, and generally well indurated.

Wireline log character. This formation exhibits a finely serrated wireline log motif, with high gamma ray values and slow sonic velocities. The gamma ray and sonic velocity log spikes reflect well indurated limestone beds/stringers. The wireline log profiles vary from subparallel gamma ray and sonic velocities curves to slight funnel shaped log motifs.

Upper boundary. The upper boundary is taken at a downsection lithological change from the interbedded limestones and claystones of the Harrier Formation, Dunnock Member, to the mudrocks of the Dun Caan Shale Formation. On wireline log criteria this boundary is taken at an increase in gamma ray values, in association with a decrease in sonic velocity.

Lower boundary. The lower boundary is denoted by a downward lithological change from medium to dark grey claystones, to the dark grey or greyish black, poorly calcareous, subfissile, claystones of the Whitby Mudstone Formation, Derg Member. This change is expressed on wireline log criteria as a slight increase in the gamma ray values, with a corresponding slight decrease in sonic velocity.

Subdivision. No subdivision is recognised.

Thickness. The thickness of the formation varies from 21m (27/4-1Z) to a maximum of 95m (18/20-1).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is very good. Occurring within Ostracod Subzone IJO9b, Foraminiferal Zone IJF9 and Palynological Subzones DM3C to DM3D2 (*pars*).

Age. Middle-Early Jurassic, intra Early Aalenian-Late Toarcian.

Depositional environment. Marine, inner shelf. The dominantly argillaceous sediments of the Dun Caan Shale Formation were deposited in a low energy, marine, inner shelf environment. Well oxygenated conditions are suggested by the profuse microfaunas recovered from the formation.

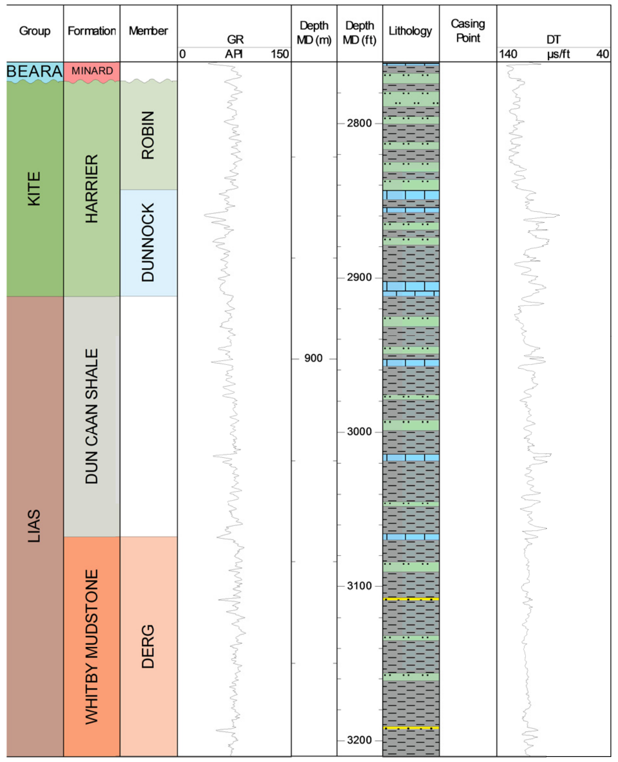
Distribution. The formation is proven to be present in the Slyne Basin on the basis of well penetrations. Its presence in the Porcupine Basin and Erris Basin is uncertain due to lack of well penetrations in these areas, however, the formation most likely extends into these basins given that the Lias Group is proven in the basin, and the interpretation of possible intra Lias Group seismic horizons (Upper Sinemurian, Top Meelagh) in the Porcupine Basin.

Regional correlation. The Dun Caan Shale Formation was originally defined in the Hebrides Basin, western Scotland and its distribution is considered to extend to the west of offshore Ireland (Trueblood & Morton, 1991; Trueblood, 1992). The formation is a lateral equivalent to the Tacumshin Formation and upper part of the Whitby Mudstone Formation of the Fastnet and North Celtic Sea basins. The Dun Caan Shale Formation is a lateral equivalent to the upper part of the Eype Mouth Limestone Member, Beacon Limestone Formation and Bridport Sand Formation in southern England (see Cox *et al*., 1999; Morton, 2004; Simms *et al.* , 2004).

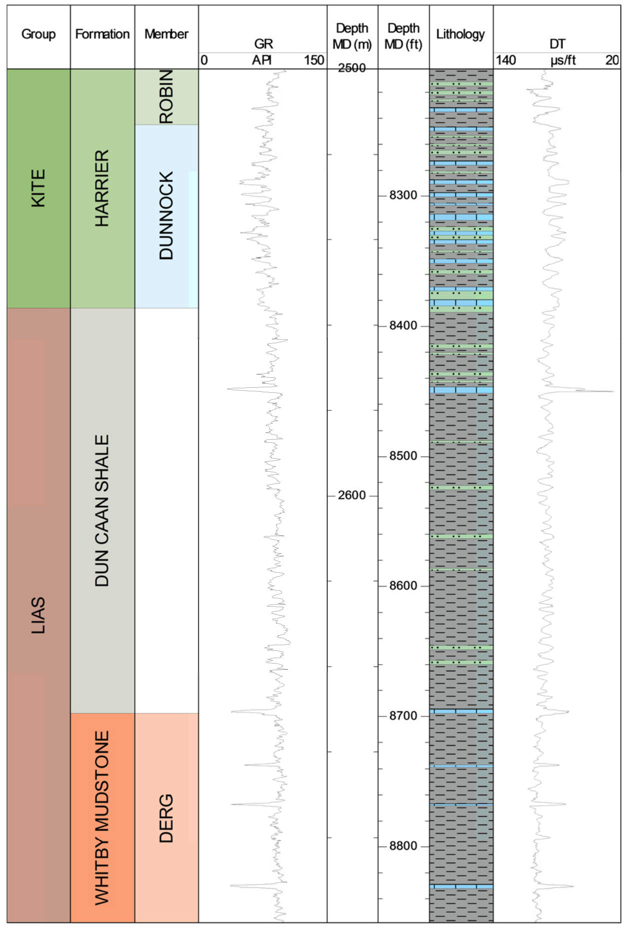
Source rock characterisation. Data availability for the Dun Caan Shale Formation is limited but includes some organic-rich intervals in wells in the Slyne Basin, for example the 27/13-1A well (**Figure D.6. 34**, **Figure D.6. 56**). The formation shows a heterogenous kerogen composition varying from Type III, especially in wells 27/4-1 and 27/4-1Z, to a more Type II kerogen composition, for example in well 19/11-1A. Like the kerogen composition, the source rock potential is also variable, with the Type III samples being gas prone, whereas the more Type II samples show some oil generative potential.

No equivalent source rock was identified by in project IS16/01 (BeicipFranlab, 2017).

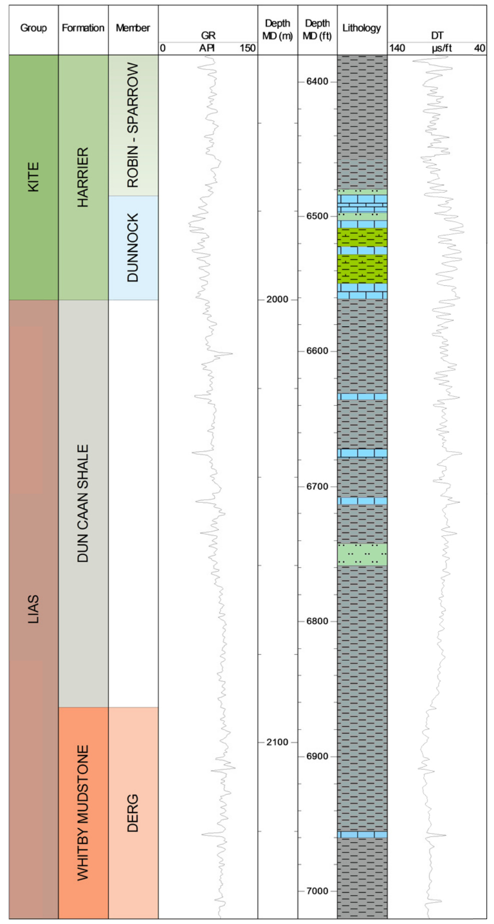
Comparison with Eastern Canada. The Dun Caan Shale Formation is age equivalent to the middle part of the Downing Formation (claystones) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.



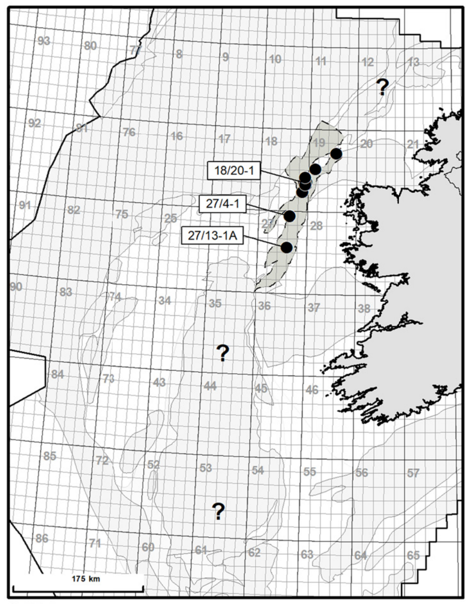
27/4-1
Reference well; Dun Caan Shale Formation



18/20-1
Reference well; Dun Caan Shale Formation



27/13-1A
Reference well; Dun Caan Shale Formation



Dun Caan Shale Formation

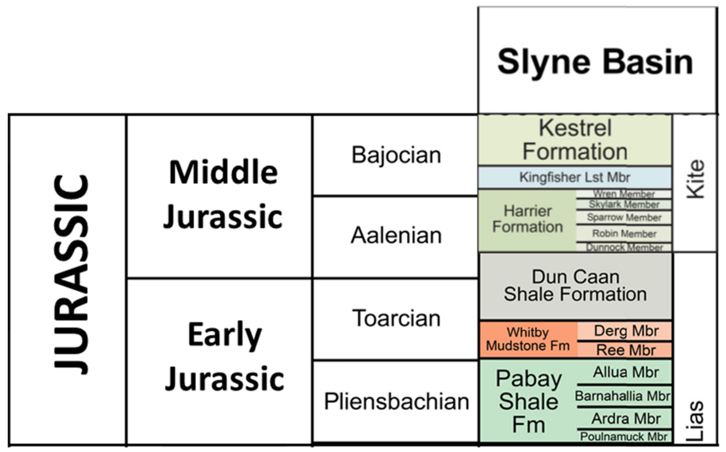


Figure D.6. 33. ***Dun Caan Shale Formation type and reference wells with location and distribution map.***

Dun Caan Shale Formation

Basin	TOC (%) No. Wells	No. Samples	Min	Max	Avrg.	HI (mg/gTOC) No. Wells	No. Samples	Min	Max	Avrg.
Slyne	6	20	0.9	3.6	1.68	6	19	68	508	224

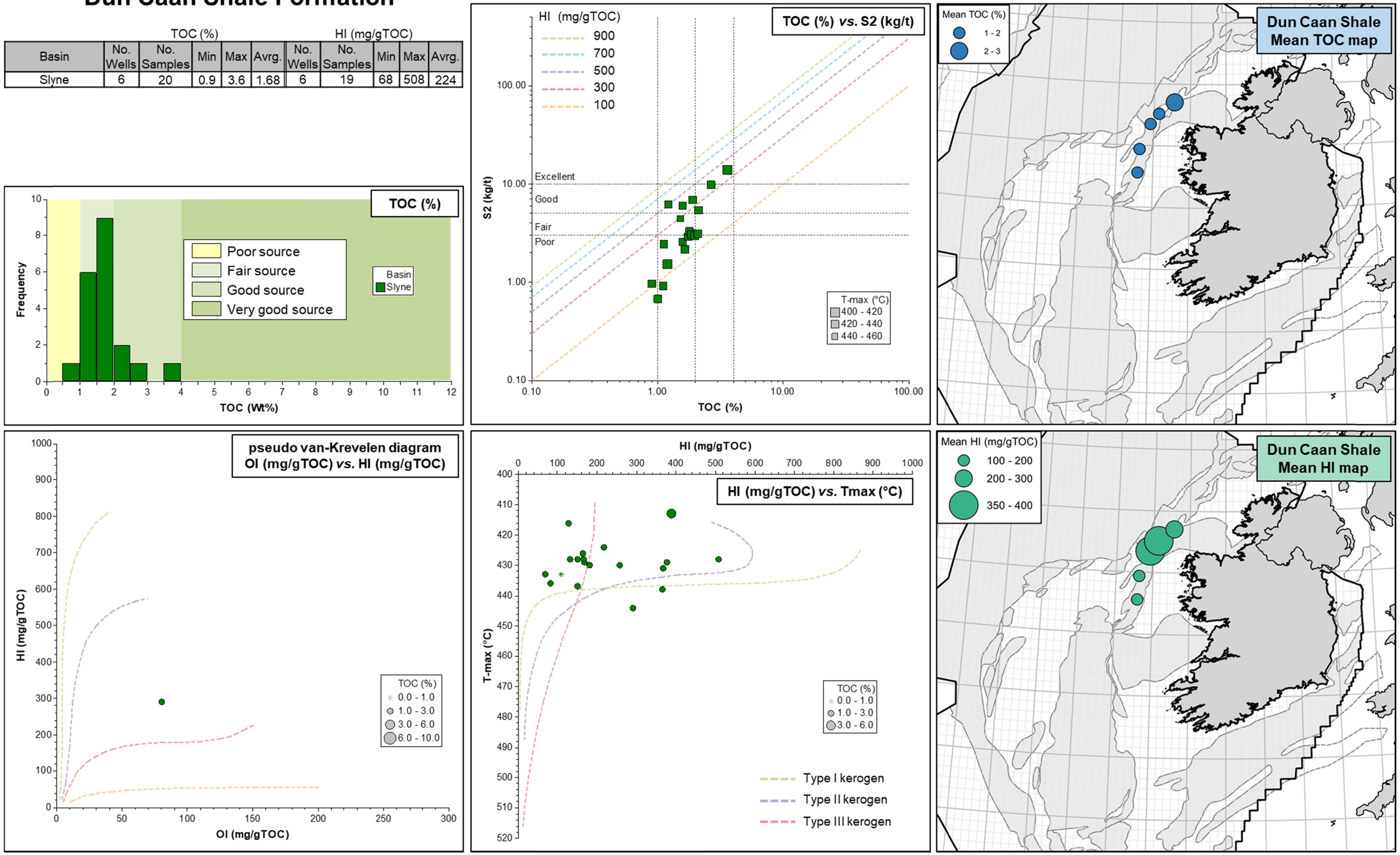


Figure D.6. 34. ***Dun Caan Shale Formation source rock characteristics, offshore Ireland.***

GILL FORMATION (NEW)

The Gill Formation is here defined for a marine, dominantly claystone unit, of Hettangian age, that is developed in the northern part of the North Celtic Sea Basin and the UK sector St George's Channel and Cardigan Bay basins. The formation represents a claystone dominated lateral equivalent of the marine Blue Lias Formation and of the non-marine to shallow marine Leane Formation to the south of the area. This unit lies between the overlying Currane Formation and the underlying Curagh Formation.

In the Irish offshore wells, the formation is incomplete, as in the 50/10-1 well, as it is cut by an unconformity between the Upper Sinemurian sediments (Glenbeg Formation) and the Gill Formation, as indicated by biostratigraphic data and wireline log correlations. More complete sections of the formation are present in the UK sector of the Celtic Sea and Cardigan Bay basins. The Llanbedr (Mochras Farm) Borehole (onshore west Wales, UK) succession appears to be a good example of this[2], as are several other wells from this area (see data in Tappin *et al*., 1994). The nearest apparently stratigraphically complete section to the median line is UK 103/2-1, located in the UK part of the North Celtic Sea Basin, which is therefore chosen as the type well. A correlation of the 50/10-1 and UK 103/2-1 wells, over the relevant interval, is shown in **Figure D.6. 36**.

Name. After Lough Gill, located mainly in County Sligo.

Type section. UK 103/2-1: 893-927m below KB. See **Figure D.6. 35**.

Reference section. 50/10-1: 1868.5-1895m below KB. See **Figure D.6. 35**.

Lithology. This formation is dominated by mudrocks, with subsidiary thin interbedded limestone beds and stringers. The mudrocks comprise medium to dark grey, micromicaceous, rare carbonaceous specks, locally silty, marls and variably calcareous claystones. Stringers of limestone, light to medium grey, light olive grey, light brown, mudstone, micritic cryptocrystalline, soft to well indurated, are present throughout the unit.

Wireline log character. This formation is distinguished by its slightly lower gamma ray values and increased sonic velocities than the overlying and underlying sediments. The wireline log curves are slightly serrated, reflecting the dominantly mudrock lithologies. Localised gamma ray and sonic velocity spikes reflect limestone beds/stringers.

Upper boundary. The top of the Gill Formation may be marked by an unconformity. The upper boundary is placed at a downsection lithological change from the marls and calcareous claystones of the Currane Formation, Corfad Member, to the mudrocks of the Gill Formation. This change is indicated on wireline log criteria by a decrease in gamma ray values and a corresponding increase in sonic velocity.

Lower boundary. The lower boundary displays a downward lithological change from variably calcareous mudrocks to the claystones of the Caragh Formation. This is reflected on wireline log criteria by an increase in gamma ray values and a slight decrease in sonic velocity.

Subdivision. No subdivision is recognised.

Thickness. This formation is only recorded in one Irish well (50/10-1) where it achieves a thickness of 26.5m, although the upper boundary is an unconformity. However, it is also seen in UK well 103/2-1 where it achieves a thickness of 34.1m, where both the upper and lower boundaries are conformable with the overlying and underlying formations.

Biostratigraphic characterization. Dated by ostracods, foraminifera and rare dinocysts. Calcareous microfossil and dinocyst recovery varies from poor to good throughout the formation. Occurring within Ostracod Zone Equivalent IOJ2, Foraminiferal Zone IFJ2 and Palynological Subzone DM2A1.

Age. Early Jurassic, Hettangian.

Depositional environment. Marine, inner to outer shelf. The Gill Formation was deposited in a low energy, muddy bottomed, marine shelfal, environment. The absence of clastics suggests a subdued topography. Bottom waters conditions varied from well oxygenated, denoted by the abundant microfaunas to dysaerobic, suggested by the restricted microfaunas.

Distribution. The formation is proven by two wells in the northern part of the North Celtic Sea Basin, Ireland and UK, 50/10-1 and UK 103/2-1. The formation is likely to extend into the St George's Channel Basin (UK) and the Cardigan Bay Basin (UK).

Well 42/17-1A in the Central Irish Sea Basin appears to contain a section similar to the Gill Formation, of Hettangian-earliest Sinemurian age, however, the wireline log signatures do not readily allow the separation of the Gill from the overlying and underlying formations in this well, where the section is allocated to the undivided Caragh-Currane formations.

Seismic expression. The formation cannot be resolved on the available seismic data.

Regional correlation. The Gill Formation as developed in the northern North Celtic Sea Basin correlates to the Blue Lias and Leane formations in the North Celtic Sea, South Celtic Sea, Fastnet and Goban Spur basins. Onshore UK, the Gill Formation equates to the lower and middle sections of the Blue Lias Formation (Cox *et al*., 2004). The Gill Formation is a lateral equivalent to the lower and middle parts of the Meelagh Formation in the Porcupine, Slyne and Erris basins, while in northwest Scotland the lower and middle parts of the Breakish Formation is laterally equivalent to the Gill Formation (see Morton, 2004; Simms *et al.*, 2004).

The Gill Formation as recognised offshore Ireland correlates with the lower part of the Waterloo Mudstone Formation in Northern Ireland, into which all the Lower Jurassic rocks in the province are placed (see Mitchell, 2004).

Comparison with Eastern Canada. The Gill Formation is age equivalent to the lower part of the Iroquois Formation (dominantly limestones and dolomites) and the Argo Formation (dominantly halites) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

[2] Note that no lithostratigraphic units have been formally defined in the Lower Jurassic of the Llanbedr (Mochras Farm) Borehole (Cox *et al*., 1999). The succession in this borehole is dominated by claystone deposition throughout the Lower Jurassic succession and as such is atypical of any known onshore Lower Jurassic section in Britain.

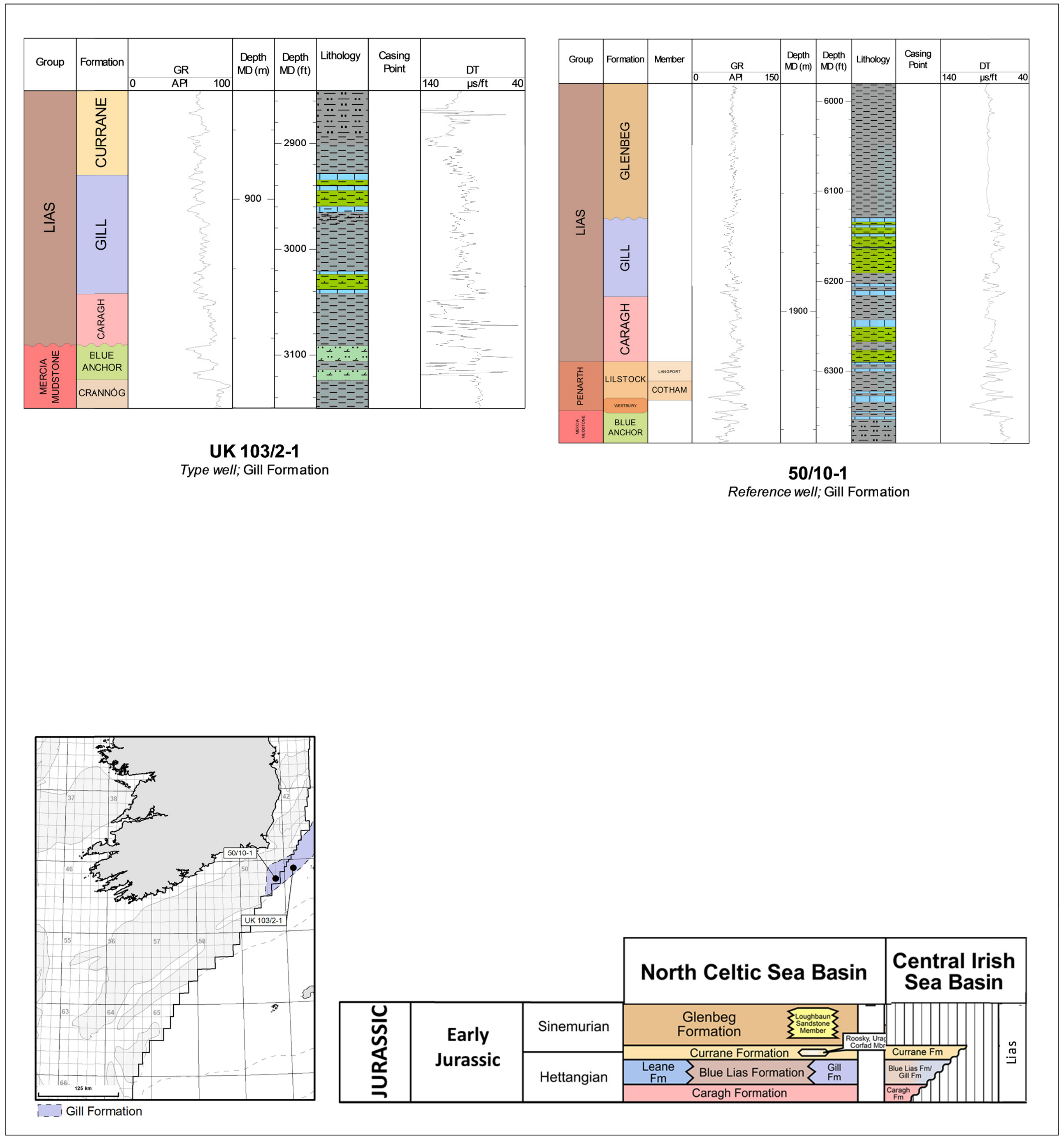


Figure D.6. 35. ***Gill Formation type and reference wells, with location and distribution map.***

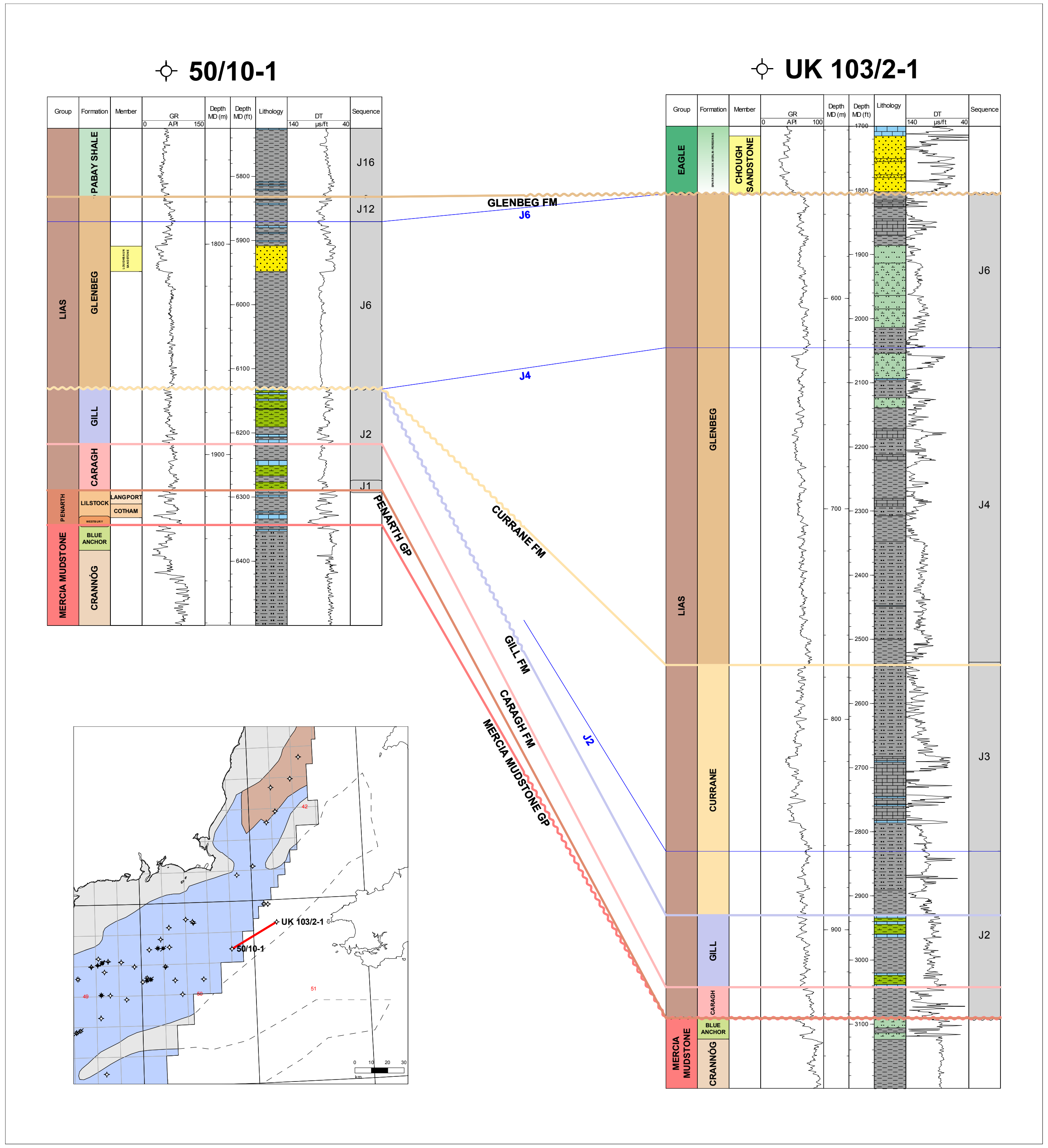


Figure D.6. 36. ***UK 103/2-1 type well for Gill Formation, correlated with Ireland reference well 50/10-1, also showing sequences.***

GLENBEG FORMATION (NEW)

The Glenbeg Formation is here defined for a marine claystone-sandstone succession, of Late-Early Sinemurian age, that is developed in the Goban Spur, Fastnet, North Celtic Sea and South Celtic Sea basins. This formation occurs between the overlying Pabay Shale Formation and the underlying Curanne Formation.

The formation was formerly known as the Liassic Sandstone Unit (J-10) (Murphy & Ainsworth, 1991), part of an overall scheme of five lithostratigraphic units spanning the Lower to lower Middle Jurassic of the Fastnet Basin. These units are valid subdivisions but were not originally named in accordance with the stratigraphic code guidelines, therefore new names are applied in the current scheme. In addition, the use of the formation is here extended northwards to the North Celtic Sea Basin. The type log of 63/10-1 defined for the Liassic Sandstone Unit of Murphy & Ainsworth (1991) is also utilised as the type well for the Gara Sandstone Member, of the Glenbeg Formation, in the current scheme.

Two new members are proposed; the Gara Sandstone Member located in the Fastnet Basin and the Loughbaun Sandstone Member located in the northern North Celtic Sea Basin

Name. After Lough Glenbeg, County Cork.

Type section. 63/4-1: 794.5-1067m below KB. See **Figure D.6. 37.**

Reference sections. 49/9-1: 2942-2816m (T.D.) below KB. 49/11-1: 3181.5-3529.5m below KB. 57/2-1: 3168.5-3475m below KB. 62/7-1: 4599.5-4633m below KB. See **Figure D.6. 37.**

Lithology. This formation is dominated by claystones and siltstones, with localised limestone beds. Two sandstone members are present; the Gara Sandstone Member in the Fastnet Basin and the Lougbaun Sandstone Member in the northern part of the North Celtic Sea Basin.

The claystones are medium to dark grey, greyish black, micromicaceous, with rare carbonaceous specks, locally organic-rich, locally silty or sandy, locally pyritic, non to slightly calcareous, which grade to siltstones. The siltstones are light grey to medium dark grey, locally argillaceous, and variably calcareous. The interbedded limestones are light to medium dark grey, light brownish grey, mudstone to wackestone, locally silty or sandy, micritic to microcrystalline, and well indurated. A number of off white, light brown, light grey, very fine to fine grained, well sorted, subangular to subrounded, locally argillaceous, non to calcareous, sandstone stringers are also present. These arenaceous units are more prevalent in the 49/9, 50/2 and 41/30 block wells. Calcite veins are noted in some of the sections.

A localised dolomite unit is present midway through this formation in the 62/7-1 well.

The Gara Sandstone and Loughbaun Sandstone members are dominated by white to very pale orange, light to medium grey, generally very fine to fine grained, moderately well to well sorted, subangular to subrounded, rare to common carbonaceous specks/debris, locally bioclastic (shell debris), non to calcareous, sandstones. Thick claystone and siltstone beds, in association with thin limestone stringers are also present. These are very similar to those described above.

Wireline log character. The mudrocks of the overall Glenbeg Formation possess finely serrated, moderately high to local high gamma ray values and moderately low sonic velocities values. The argillaceous successions often exhibit both funnel shaped and low bow shaped log profiles. A number of high gamma ray/low sonic velocity claystones are recognised within the formation. These are envisaged to represent organic-rich claystone beds.

The arenaceous members of the Glenbeg Formation are characterised by highly serrated wireline log motifs, reflecting the interbedded sandstone, siltstone and claystone lithologies. The sandstones exhibit boxcar, fining up and coarsening up log motifs, with up to six complete cycles have been recognised in the Gara Sandstone Member from core and wireline log data (Ewins & Shannon, 1995). In the 50/3 block the topmost thick clean sandstone of the Loughbaun Sandstone Member possess subblocky wireline log motifs.

Upper boundary. The top of the formation may be marked by an unconformity. In the central and northern parts of the Celtic Sea Basin, the top of this formation is placed at downsection lithological change from the claystones of the Pabay Shale Formation, to the more non-calcareous, claystones and siltstones of the Glenbeg Formation. This change is reflected on wireline log criteria by a decrease in gamma ray values and a corresponding increase in sonic velocity. In the Fastnet Basin and also the southern part of the North Celtic Sea Basin, this boundary is recognised by downward lithological change from medium to dark grey claystones of the Pabay Shale Formation, to either the non-calcareous, dark grey to greyish black mudrocks or the sandstones of the Glenbeg Formation. On wireline log criteria, this change is reflected either by an increase in gamma ray values and a coincident decrease in sonic velocity where the boundary is a mudrock/mudrock contact, or by a marked decrease in gamma ray values, coinciding with an increase in sonic velocity, where the boundary is a mudrock/sandstone contact.

Lower boundary. The base of this member is generally placed at a downsection lithological change from mudrocks to the marls/calcareous claystones of the Currane Formation. This is expressed on wireline log criteria as a marked decrease in gamma ray values and an associated increase in sonic velocity.

Subdivision. Two sandstone members are recognised, the Gara Sandstone Member and the Loughbaun Sandstone Member.

Thickness. The formation varies in thickness from 160.5m (63/8-1) to a maximum thickness of 659.5m (56/18-1).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery within the claystone dominated sections is poor to moderate. In those sections where the arenaceous members are developed calcareous microfaunal recovery is generally good. Occurring within Ostracod Zone IOJ4, Foraminiferal Zones IFJ6 to IFJ4 and Palynological Subzones DM2C3 to DM2A2.

Age. Early Jurassic, Late-Early Sinemurian.

Depositional environment. Marine, inner to outer shelf. The main argillaceous sedimentary successions of the Glenbeg Formation were deposited in a marine, low energy, inner to outer shelf environment. Bottom waters range from anoxic (absence of microfaunas through dysaerobic (common opportunistic foraminiferal faunas-pulses of *Reinholdella* spp.) through to well oxygenated (common micro- and macrofaunas (shell, gastropod and echinoderm debris). The two main sand members (Gara Sandstone and Loughbaun Sandstone members) located in the Fastnet Basin and northern North Celtic Sea Basin respectively were deposited in low to high energy, inner shelfal, conditions.

The Gara Sandstone Member was laid down mainly as delta fringe deposits, with their sedimentary source areas situated to the west, southwest and southeast of the Fastnet Basin with a clear north-eastern pinch out of the sands (Robinson *et al.,* 1981; Naylor & Shannon, 1982; Murphy & Ainsworth, 1991). Core data, in association with wireline logs indicate coarsening upwards cycles and thinner fining upwards cycles (Ewins & Shannon, 1995). Locally the mudrocks are developed as barren dark grey to black laminates, with deposition in a low energy marine setting, with anoxic bottom waters. Many of the other mudrock units are bioturbated and yield microfaunas indicating well oxygenated bottom waters. The fine to medium grained sandstones exhibit rippled bedding, cross-bedding, rare to common bioturbation and rare to common carbonaceous debris. These have been interpreted as delta front/slope sediments, distal and proximal mouth bar sands within a deltaic setting, through to distributary channel fill deposits (Ewins & Shannon, 1995). The coals and carbonaceous claystones are envisaged to have been laid down due to the emergence of the mouth bars and the establishment of vegetation (Ewins & Shannon, 1995). The presence of large numbers of miospores and carbonaceous debris is indicative of a proximity to a low lying source area, with the palynomorphs washed into a low energy environment (Murphy & Ainsworth, 1991).

The Loughbaun Sandstone Member was deposited in an inner shelf marine environment. The presence of both marine micro- and macrofaunas (shell and echinoderm debris) indicates generally well oxygenated marine conditions. The limited core data from the 50/3-1 well, show burrowing, wavy bedding, cross bedding and reactivation surfaces confirming the inner shelf deposition for the sands (Kessler & Sachs, 1995). Kessler & Sachs (1995) interpret the sands as single and complex coalescing shelf sand ridges, formed during storm driven geostrophic and tidal currents. The sand ridges are situated in a northeast-southwest direction, subparallel to the North Celtic Sea Basin, with a sediment source from the Irish Massif to the northwest of the basin.

Distribution. The formation is proven to be present by well penetrations in the North Celtic Sea, South Celtic Sea, Fastnet and Goban Spur basins. Its depositional extent is generally taken to the limits of these basins but is continued across the Celtic Platform between the Fastnet and Goban Spur basins on the basis of seismic interpretation.

Seismic expression. The Top Sinemurian (Top Glenbeg) seismic horizon can be recognised in some parts of the Fastnet and South Celtic Sea basins, which ties to the top of the formation. It can be tied to the top of the formation in the 63/10-1 well, however, it is a somewhat weak, low amplitude event. It has also been recognised in the 49/9-1 area (see **Figure D.6. 5**).

Regional correlation. This formation is a lateral equivalent of upper part of the Meelagh Formation (Arroo, Glennaun, Hollywood members) and the Inagh Formation in the Slyne and Erris basins. Onshore southern England, this unit is equivalent to uppermost part of the Blue Lias Formation and the Charmouth Mudstone Formation (Shales-with-Beef and

Black Ven Marl members) (see Simms *et al.*, 2004; Cox *et al*., 2004). In northwest Scotland lateral equivalents to this formation comprise the Ardnish Formation and the lower section of the Pabay Shale Formation, which contain both the Hallaig Sandstone and Torosay Sandstone members (see Morton, 2004).

Source rock characterisation. The Glenbeg Formation is an organic-rich interval occurring in the Fastnet, South Celtic Sea and North Celtic Sea basins (**Figure D.6. 38**). It shows a mainly Type III kerogen composition in the Fastnet Basin, except for a few samples, mainly from well 64/2-1, that show a more Type II/III kerogen composition. The source potential of the Glenbeg Formation is limited in this area, mainly showing gas generative potential, with samples with greater Type II kerogen character showing mixed oil and gas potential. It shows similar kerogen characteristics in the North and South Celtic Sea basins, although hydrocarbon yields appear slightly higher. Samples with a more Type II/III kerogen composition show mixed oil and gas potential.

The Glenbeg Formation is partly equivalent to the source rock intervals Low J2a and Low J1 that were identified in project IS16/01 (BeicipFranlab, 2017). TOC and HI data are shown in **Figure D.6. 56** for the 49/9-1 from the North Celtic Sea Basin where the BeicipFranlab identified Low J1 source rock interval is shown, falling at the top of the penetrated Glenbeg Formation.

Comparison with Eastern Canada. The Glenbeg Formation is age equivalent to the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

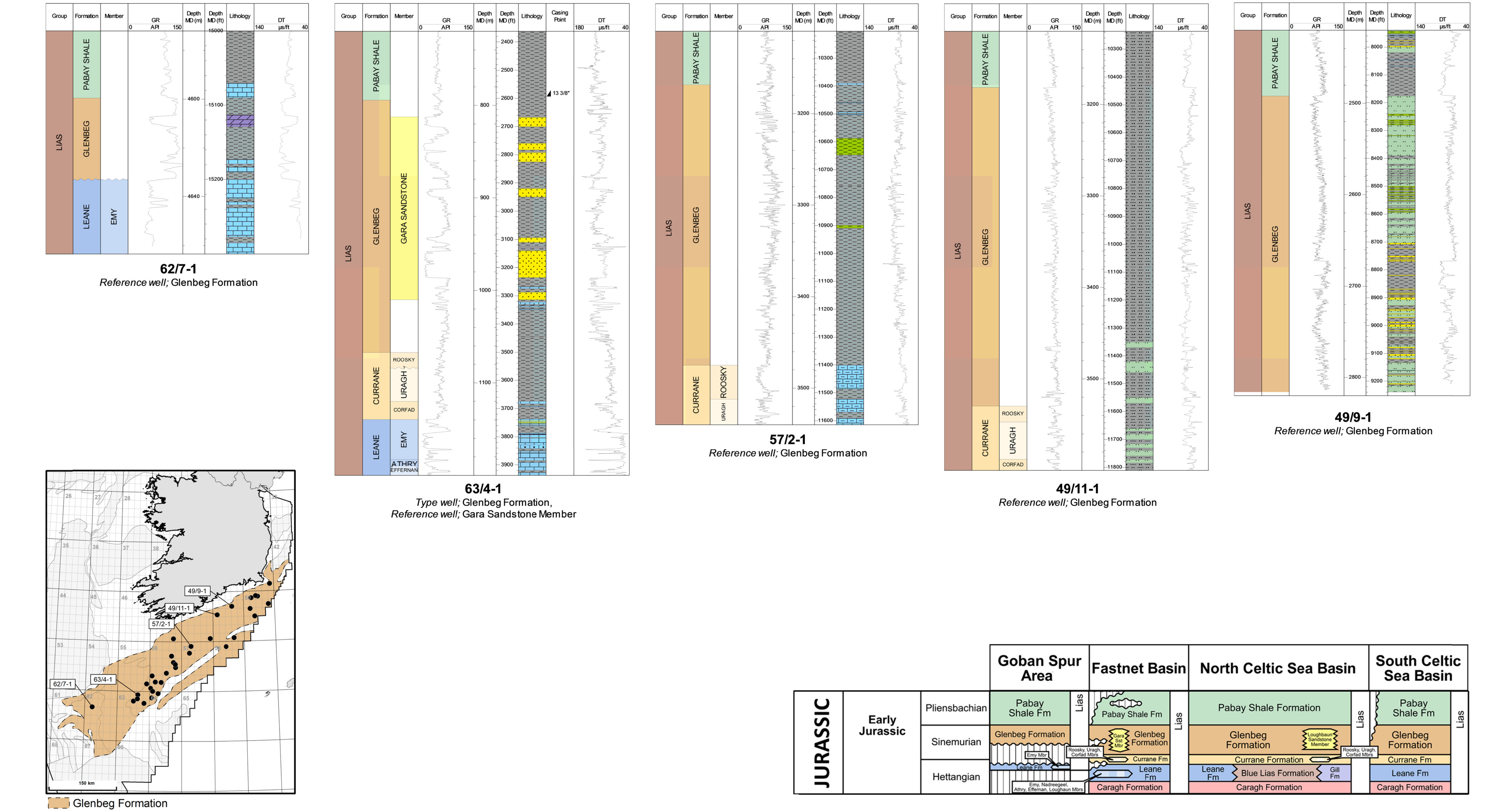
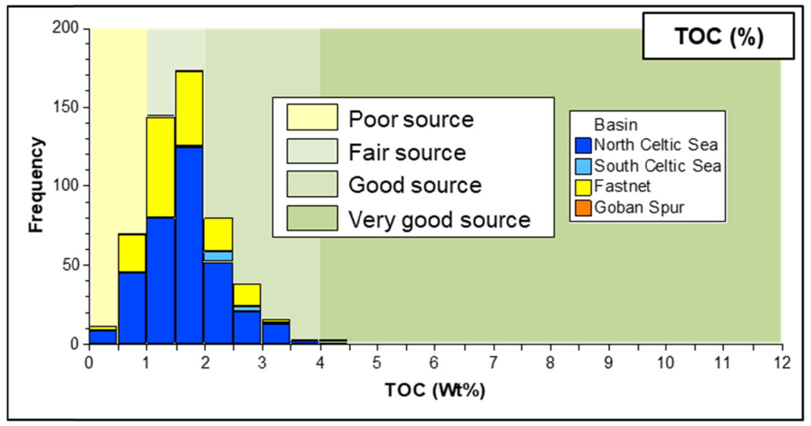
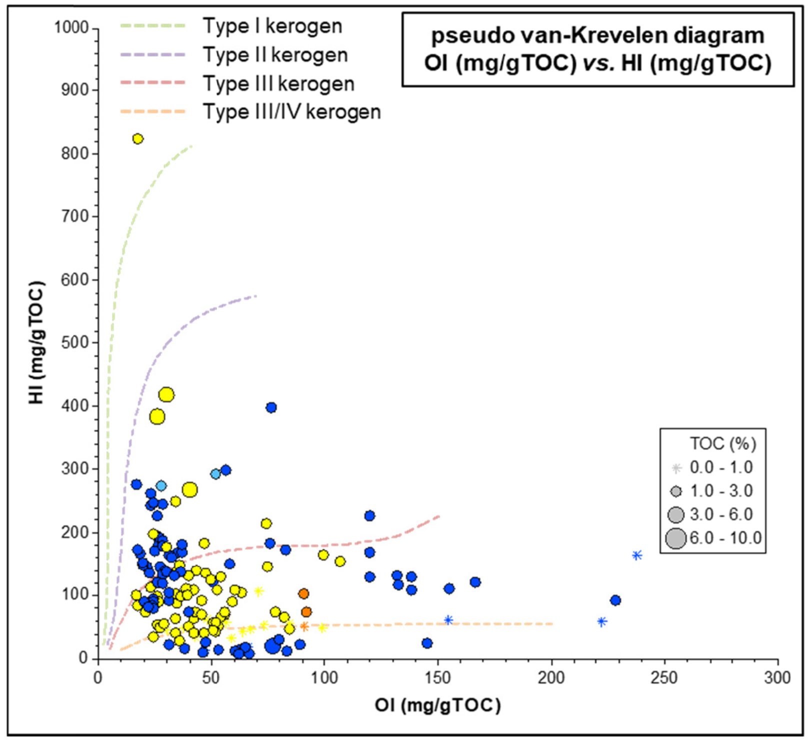


Figure D.6. 37. ***Glenbeg Formation type and reference wells, with location and distribution map.***

Glenbeg Formation

Basin	TOC (%) No. Wells	No. Samples	Min	Max	Avrg.	HI (mg/gTOC) No. Wells	No. Samples	Min	Max	Avrg.
North Celtic Sea	13	349	0.09	4.00	1.7	13	255	7	533	137
South Celtic Sea	1	13	1.96	3.18	2.4	1	13	225	336	288
Fastnet	11	183	0.10	4.46	1.6	9	125	8	825	102
Goban Spur	1	3	0.95	1.90	1.4	1	3	52	102	76





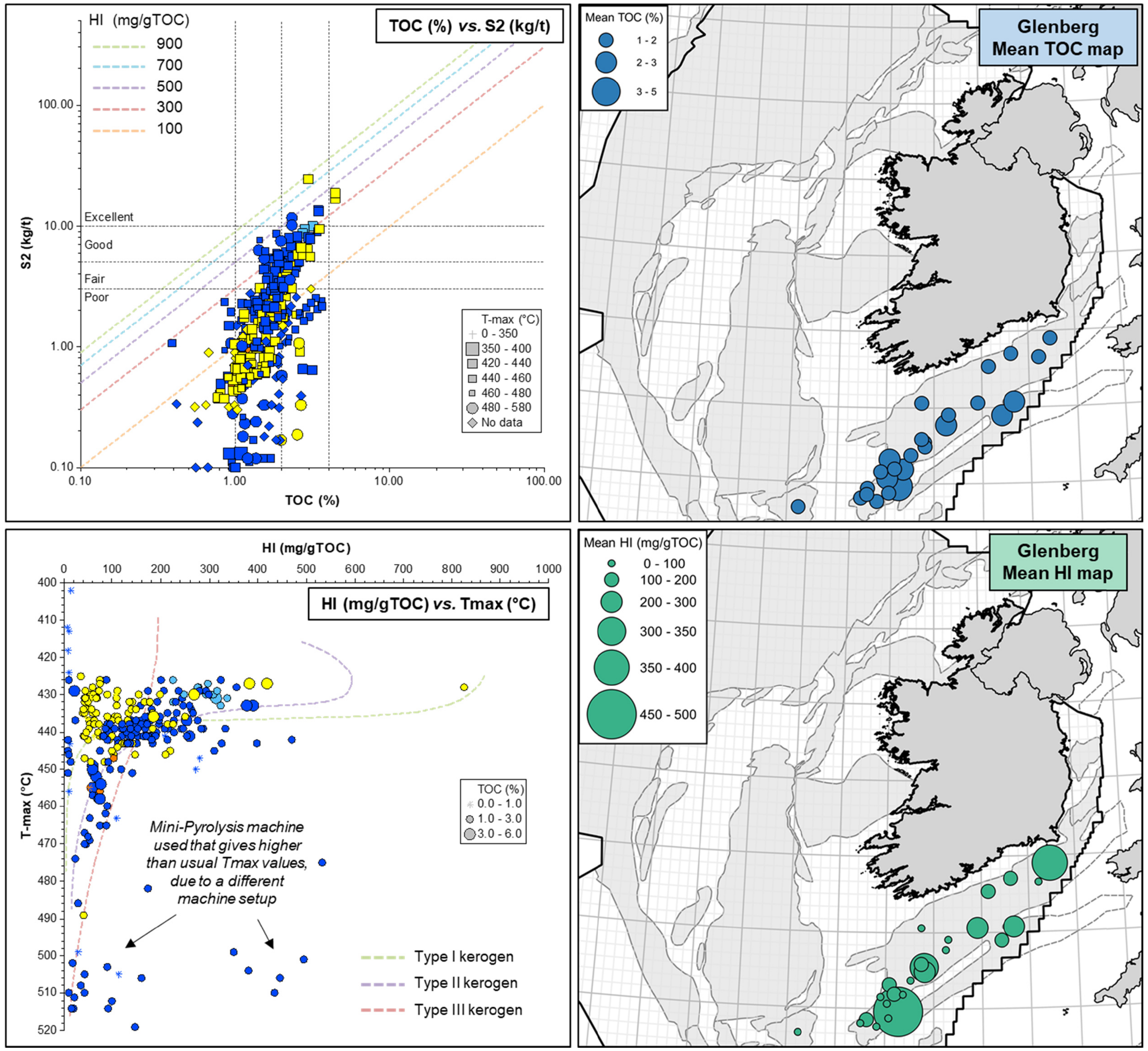


Figure D.6. 38. ***Glenbeg Formation source rock characteristics, offshore Ireland.***

Gara Sandstone Member (New)

The Gara Sandstone Member is here defined for a sandstone/claystone succession, of Late-Early Sinemurian age, that is developed in the Fastnet Basin.

The member was formerly known as the Liassic Sandstone Unit (J-10) (Murphy & Ainsworth, 1991). The type log of 63/10-1 defined by Murphy & Ainsworth (1991) is also utilised as the type well for the Gara Sandstone Member. The sandstone member equates with part of the "Lias Sandstone" of Ewins & Shannon (1995), though the latter was considered to be more widespread than the Gara Sandstone Member as recognised here. The latter authors considered the sandstone to be of non-marine origin, whereas the depositional setting is considered here to be shallow marine.

The sandstone member typically comprises a succession of interbedded sandstones and claystones within which several coarsening upwards wireline log cycles can be recognised. Detailed well correlations based upon biostratigraphically calibrated sequence stratigraphic subdivisions allow the recognition of three subdivisions that fall into the upper part of the J3 sequence plus the overlying J4 and J6 sequences. In some wells the lowermost sandstone subdivision (of the J3 sequence) is absent, for example, from Fastnet Basin wells 63/8-1, 64/1-1 and 64/2-1. In the 55/30-1 well, only the uppermost, J6 sequence, sandstone unit is present.

Name. After Lough Gara in County Sligo.

Type section. 63/10-1: 2540-2878.5m below KB. See **Figure D.6.39**.

Reference sections. 56/26-2: 2259.5-2374.5m below KB. 63/8-1: 1691-1795.5m below KB. 63/4-1: 812.5-1010m below KB. See **Figure D.6.39**.

Lithology. This unit comprises an interbedded sandstone/siltstone/claystone succession. The sandstone are very light to medium grey, very fine to fine grained, locally medium grained in the 63/4-1 well, moderately well to well sorted, subangular to subrounded, rare to common carbonaceous specks/debris, locally bioclastic (shell debris), and generally non-calcareous. The claystones are medium to dark grey, greyish black, micromicaceous, with rare carbonaceous specks, locally silty or finely sandy, and non to calcareous. The siltstones are light grey to medium grey, locally argillaceous, and variably calcareous. Limestone stringers are also present. These are white, light to medium dark grey, light brown, mudstone, micritic to microcrystalline, and moderately well to well indurated. Thin coal beds and greyish black, carbonaceous, non-calcareous claystones are also recognised.

Core data from mudrocks and sandstones from the 56/26-2 and 63/10-1 wells located in the Fastnet Basin exhibit cyclic sedimentation, with fining and coarsening upwards cycles, cross bedding, rippled and bioturbated sediments (Ewins & Shannon, 1995).

Wireline log character. The member is characterised by highly serrated wireline log motifs, reflecting the interbedded nature of the sandstone, siltstone and claystone lithologies. The high gamma ray and low sonic velocities denote the mudrocks, while the low gamma ray values and high sonic velocities reflect the sandstones. The sandstones may exhibit boxcar, fining up and coarsening up log motifs. Up to six complete cycles have been recognised from core and wireline log data (Ewins & Shannon, 1995).

Upper boundary. The top of this member is recognised by downsection lithological change from the claystones and siltstones of the Glenbeg Formation to the sandstones of the Gara Sandstone Member. On wireline log criteria, this is expressed by a marked decrease in gamma ray values, coincident with an increase in sonic velocity.

Lower boundary. The base of this unit is denoted by a downward lithological change from sandstones to mudrocks of the Glenbeg Formation. This is expressed on wireline log criteria by a marked increase in gamma ray values, in association with a corresponding decrease in sonic velocity.

Thickness. The member varies in thickness from 23.5m (64/2-1) to a maximum thickness of 338.5m (63/10-1), but in the latter instance the upper boundary is an unconformity.

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is generally good throughout the studied sections. The dinocyst index taxon *Liasidium variable* is rarely recorded in these sections. Occurring within Ostracod Zone IOJ4, Foraminiferal Zones IFJ6 to IFJ4 and Palynological Subzones DM2C3 to DM2A2.

Age. Early Jurassic, Late-Early Sinemurian.

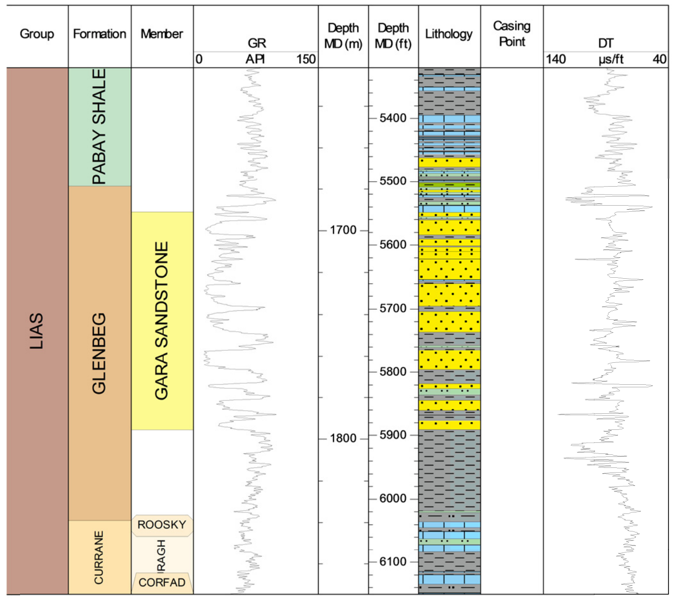
Depositional environment. Marine, inner shelf. The sandstones are envisaged to have been deposited mainly as delta fringe deposits, with their sedimentary source areas located to the west, southwest and southeast of the Fastnet Basin (Robinson *et al.,* 1981; Naylor & Shannon, 1982). Facies maps clearly indicate the north-eastern pinch out of the sands (Murphy & Ainsworth, 1991). Data from both core and wireline logs show coarsening upwards cycles, which are locally capped by thinner fining upwards cycles (Ewins & Shannon, 1995). A number of the mudrocks comprise dark grey to black laminates, which possess no bioturbation, and are barren of microfaunas. These sediments were laid down in a low energy marine setting, with anoxic bottom waters. Many of the other mudrock units are bioturbated and yield microfaunas indicating well oxygenated bottom waters. The fine to medium grained sandstones display rippled bedding, cross-bedding, rare to common bioturbation and rare to common carbonaceous debris. These have been inferred to be delta front/slope sediments, distal and proximal mouth bar sands within a deltaic setting, through to distributary channel fill deposits (Ewins & Shannon, 1995). The coals and carbonaceous claystones may reflect deposition due to the emergence of the mouth bars and the establishment of vegetation (Ewins & Shannon, 1995). The occurrence of abundant miospores and carbonaceous debris is suggestive of proximity to a subdued source area, with the palynomorphs washed into a low energy environment (Murphy & Ainsworth, 1991).

Distribution. The member appears to be restricted to the Fastnet Basin.

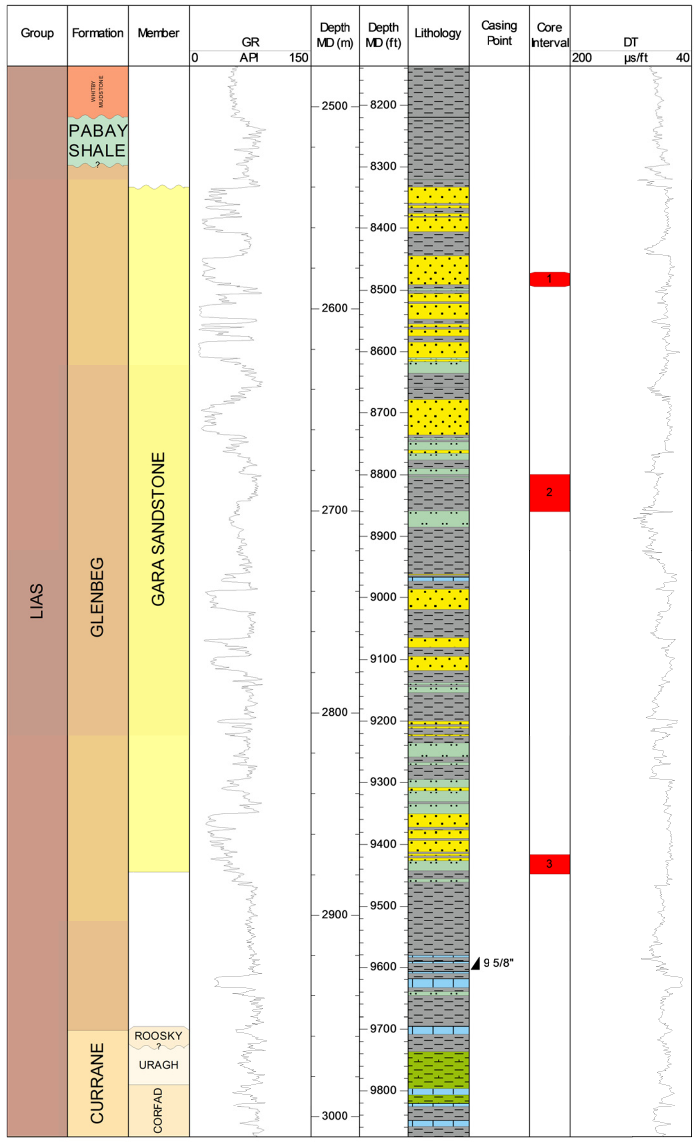
Regional correlation. The sandstone member directly correlates with the Loughbaun Sandstone Member that is developed in the north eastern part of the North Celtic Sea Basin. Other notable laterally equivalent arenaceous units include the Inagh Formation, Neaskin Member of the Slyne Basin, and the Ardnish Formation and the lower section of the Pabay Shale Formation, Hallaig Sandstone and Torosay Sandstone members of the Hebrides Basin, northwest Scotland (Morton, 2004).

This member is laterally equivalent to upper part of the Meelagh Formation (Arroo, Glennaun, Hollywood members) and the Inagh Formation in the Slyne and Erris basins. In southern England, this arenaceous unit is equivalent to uppermost part of the Blue Lias Formation and the Charmouth Mudstone Formation (Shales-with-Beef and Black Ven Marl members) (Simms *et al.*, 2004; Cox *et al*., 2004).

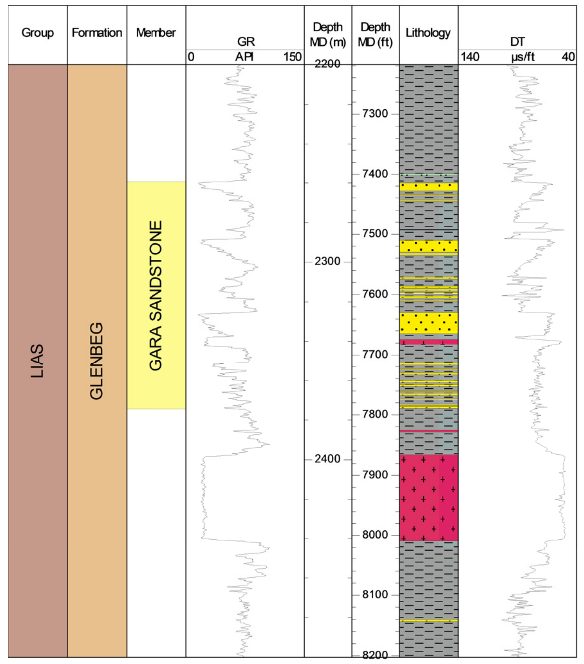
Comparison with Eastern Canada. The Gara Sandstone Member is a lateral equivalent to the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.



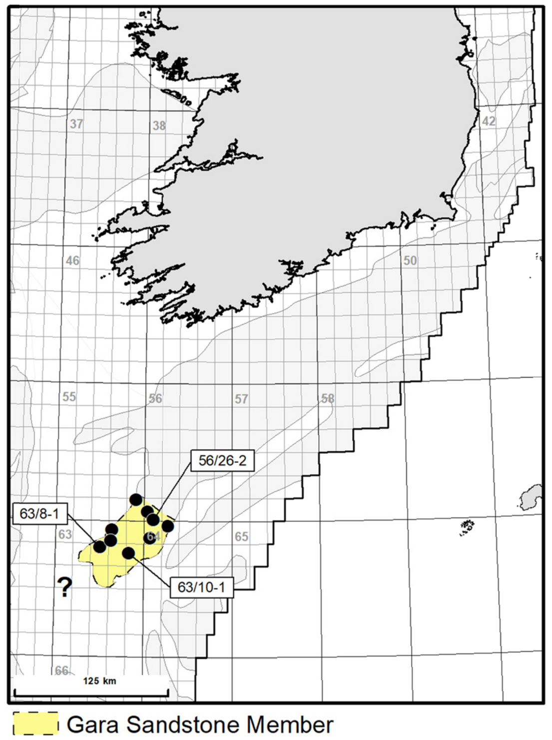
63/8-1
Reference well; Gara Sandstone Member



63/10-1
Type well; Gara Sandstone Member



56/26-2
Reference well; Gara Sandstone Member



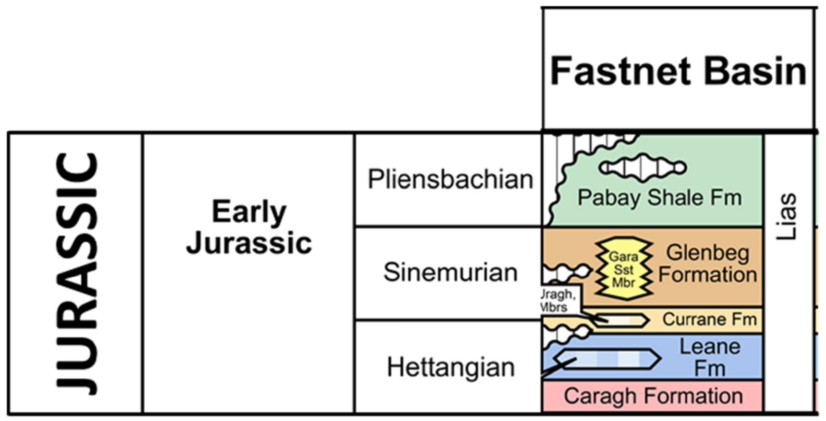


Figure D.6. 39. ***Gara Sandstone Member type and reference wells, with location and distribution map.***

Loughbaun Sandstone Member (New)

The Loughbaun Sandstone Member is defined here for an interbedded sandstone/claystone succession, of Late-Early Sinemurian age, that is developed in the northern part of the North Celtic Sea Basin.

This sandstone member was described as the "Upper Sinemurian Sandstone" by Kessler & Sachs (1995). The two wells 50/3-1 and 50/3-3, described and illustrated by these authors, have been chosen as the type and reference wells, respectively, for the Loughbaun Sandstone Member.

Name. After Lough Baun, County Mayo.

Type section. 50/3-1: 2540-2612.5m below KB. See **Figure D.6. 40**.

Reference section. 50/3-3: 446-899.5m below KB. See **Figure D.6. 40.**

Lithology. This unit comprises an interbedded sandstone and claystone succession. The sandstone are white to buff, very light to medium grey, very fine to fine grained, locally medium to coarse grained, well sorted, subangular to subrounded, locally bioclastic, locally argillaceous, bioclastic (shell debris), and non to calcareous. The claystones are medium to medium dark grey, micromicaceous, with rare carbonaceous specks, locally silty or finely sandy, and non to calcareous. The siltstones are light grey to medium grey, locally argillaceous, and variably calcareous. The limestone and sandy limestone stringers are white to light grey, pale yellowish brown, mudstone to grainstone, micritic to microcrystalline, and moderately well to well indurated.

The upper sandstones in the 50/3-1 and 50/3-3 wells comprise very clean sands, which are tight and very hard. The limited core data from the 50/3-1 well shows extensive burrowing, cross-bedding and wavy cross-bedding (Kessler & Sachs, 1995).

Wireline log character. The member is denoted by highly serrated wireline log motifs, reflecting the interbedded nature of the sandstone, siltstone and claystone lithologies. The high gamma ray and low sonic velocities reflect the mudrocks, while the low gamma ray values and high sonic velocities indicate the sandstones. The sandstones exhibit boxcar, fining up and coarsening up log motifs. In the 50/3 block the topmost thick clean sandstone units are denoted by subblocky wireline log motifs.

Upper boundary. The top of this unit is placed at a downsection lithological change from the claystones and siltstones of the Glenbeg Formation to the sandstones of the Loughbaun Sandstone Member. On wireline log criteria, this is recognised by a marked decrease in gamma ray values, in association with an increase in sonic velocity.

Lower boundary. The base of this member is denoted by a downsection lithological change from sandstones to the mudrocks of the Glenbeg Formation. This corresponds on wireline log criteria by a marked increase in gamma ray values and a corresponding decrease in sonic velocity.

Thickness. The member varies in thickness from 12m (50/10-1) to a maximum thickness of 543.5m (50/3-3). The thickest developments of the member are present along the north western flanks of the North Celtic Sea Basin.

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is generally good throughout the studied sections. Occurring within Ostracod Zone IOJ4, Foraminiferal Zones IFJ6 to IFJ4 and Palynological Subzones DM2C3 to DM2A2.

Age. Early Jurassic, Late-Early Sinemurian.

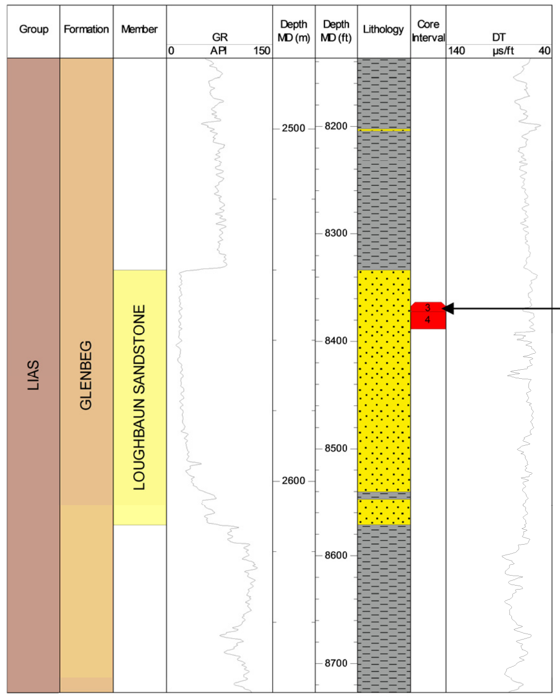
Depositional environment. The Loughbaun Sandstone Member was deposited in an inner shelf marine environment. The occurrence of marine microfaunas and macrofaunas (shell and echinoderm debris) suggests generally well oxygenated marine conditions. From the limited core data in the 50/3-1 well, burrowing, wavy bedding, cross bedding and reactivation surfaces would confirm an inner shelf depositional setting for the sandstone (Kessler & Sachs, 1995). These authors interpreted the sandstone as representing complex, coalescing shelf sand ridges, formed during storm driven geostrophic and tidal currents.

Distribution. The member is proven to be present in a restricted number of wells in the north eastern part of the North Celtic Sea Basin and its south westerly limit is defined by wells in which the member is absent from the Glenbeg Formation, such as in 49/9, and 50/12-2A and 50/12-3. Kessler & Sachs (1995, figure 3) restricted the occurrence of the sandstone unit to the 50/3 to 42/21 area, subparallel to the north western margin of the North Celtic Sea Basin, with a sediment source from the Irish Massif to the northwest of the basin. The presence of the sandstone member in the 50/10-1 well, however, indicates that the sandstones extend further out into the North Celtic Sea Basin than was shown by Kessler & Sachs (1995); see interpreted distribution map in **Figure D.6. 40**.

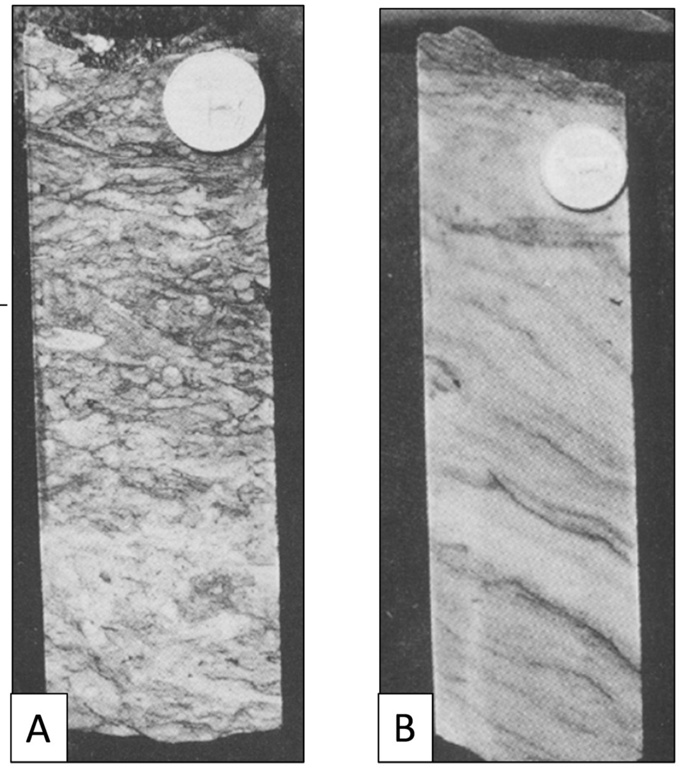
Regional correlation. The sandstone member correlates with the Gara Sandstone Member that is developed in the Fastnet Basin. The uppermost sandstone unit of the Loughbaun Sandstone Member, of the J6 sequence (Late Sinemurian), correlates with the Neaskin Member (Inagh Formation) in the Slyne Basin. The lower part of this member is laterally equivalent to upper part of the Meelagh Formation (Arroo, Glennaun and Hollywood members) in the Slyne and Erris basins.

The Ardnish Formation and the lower section of the Pabay Shale Formation, Hallaig Sandstone and Torosay Sandstone members of northwest Scotland (Morton, 2004) are laterally equivalent to the Loughbaun Sandstone Member. In southern England, the Loughbaun Sandstone Member is equivalent to uppermost part of the Blue Lias Formation and the Charmouth Mudstone Formation (Shales-with-Beef and Black Ven Marl members) (Simms *et al.*, 2004; Cox *et al*., 2004).

Comparison with Eastern Canada. The Loughbaun Sandstone Member is laterally equivalent to the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

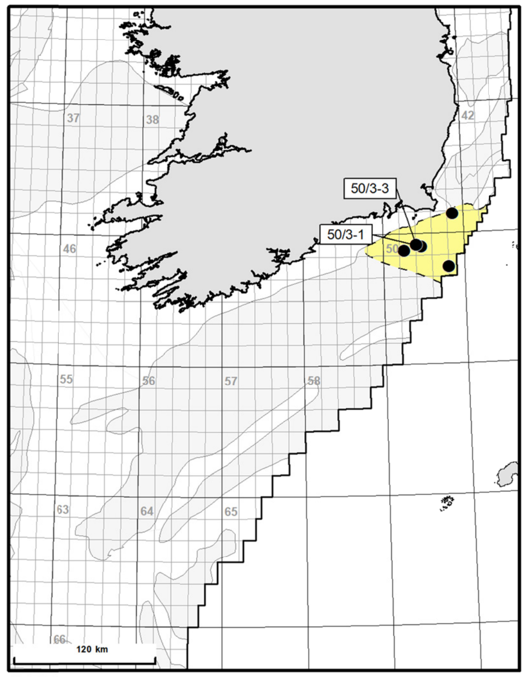


50/3-1
Type well; Loughbaun Sandstone Member

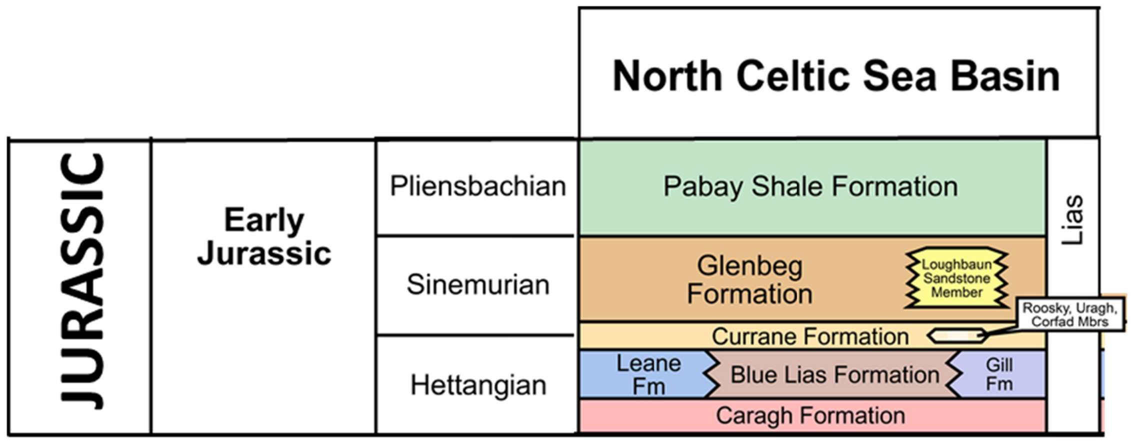


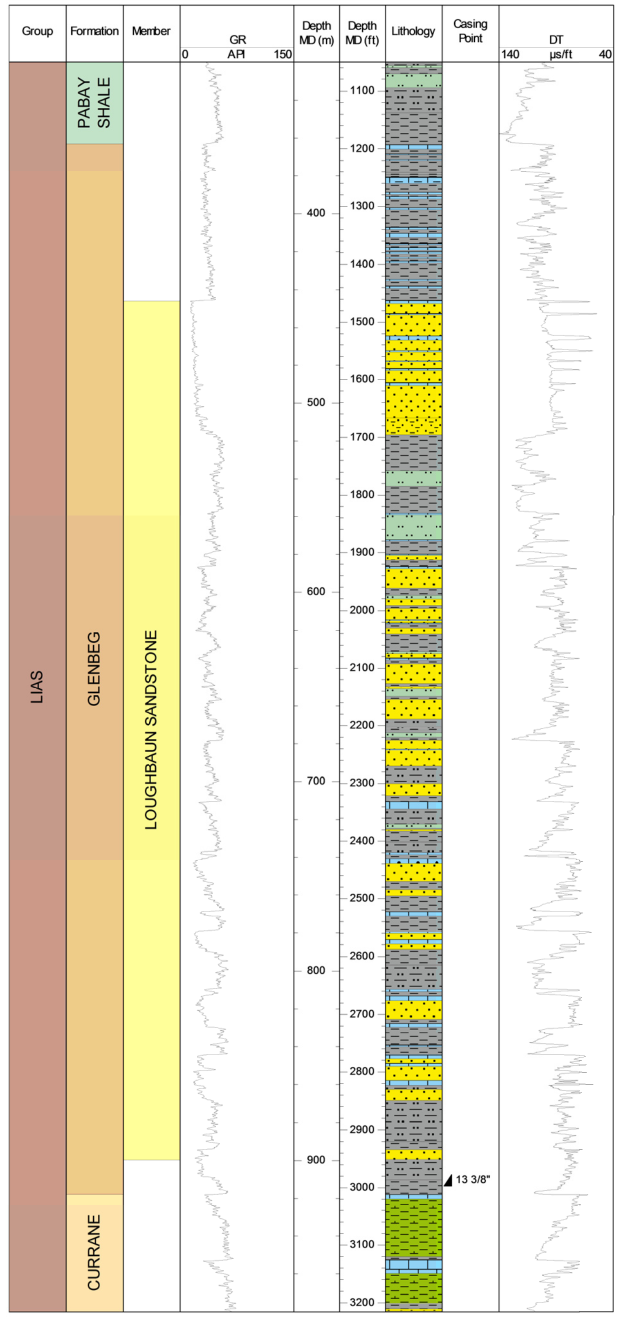
A. Highly burrowed sandstone from 2553.4m; *Planolites*, *Teichichnus*, *Zoophycus* and *Asterosoma* present.
B. Wavy and planar cross bedding with bedding truncation and reactivation surface; from 2552.9m. Old Irish £1 coin for scale.

Core 4 photos of member in 50/3-1, from Kessler & Sachs (1995)



Loughbaun Sandstone Member





50/3-3
Reference well; Loughbaun Sandstone Member

Figure D.6. 40. ***Loughbaun Sandstone Member type and reference wells, with location and distribution map.***

INAGH FORMATION (NEW)

The Inagh Formation is defined here for an estuarine? to marine interbedded claystone/limestone/sandstone succession, of Late Sinemurian age, which is developed in Slyne Basin. This unit is present between an overlying Pabay Shale Formation, Poulnamuck Member and the underlying Meelagh Formation, Hollywood Member.

Three new members are proposed; the Adoon Member, the Neaskin Member and the Inniscarra Member (spelling 'INA' from first the letter of each Member in ascending stratigraphic order).

Name. After Lough Inagh, County Galway.

Type section. 18/20-1: 3301-3376.5m below KB. See **Figure D.6. 41**, **Figure D.6. 42**, **Figure D.6. 43**.

Reference section. 27/13-1A: 2519-2596m below KB. See **Figure D.6. 41**.

Lithology. This formation comprises an interbedded claystone/limestone/sandstone succession. The most arenaceous succession of the three units is the Neaskin Member.

The claystones are medium to dark grey, slightly micromicaceous, locally silty, slightly to non-calcareous, and grade into argillaceous siltstones or siltstones. Locally brownish red or greenish grey claystones are also recognised in the Neaskin Member. The limestones are off white, buff, medium to medium dark grey, mudstone to packstone, locally with greyish black peloids, microcrystalline to cryptocrystalline, locally sandy, and grading to either calcareous sandstones or dolomitic limestones. The sandstones are off white, light brownish grey, light to medium grey, very fine to fine grained, well sorted, subangular to subrounded, and non to calcareous.

A distinct claystone couplet is recognised in the lower Inniscarra Member.

Wireline log character. The formation comprises a highly serrated wireline log profile, reflecting the interbedded nature of the sandstone, limestone and mudrock lithologies. The high gamma ray and low sonic velocities indicate mudrocks, while the low gamma ray values and high sonic velocities reflect the carbonates and sandstones. Both the thickened sandstone and limestone beds possess boxcar wireline log motifs.

The lower member (Inniscarra Member) is denoted by a claystone couplet displaying high gamma ray values and low sonic velocities.

Upper boundary. The upper boundary is taken at a downsection lithological change from the claystones of the Pabay Shale Formation, Poulnamuck Member, to either the limestones or the sandstones of the Inagh Formation, Neaskin or Adoon members respectively. This change is reflected on wireline log criteria by a decrease in gamma ray values, with a corresponding increase in sonic velocity.

Lower boundary. The base of the formation is placed at a downward lithological change from claystones to the limestones of the Meelagh Formation, Hollywood Member. This is expressed on wireline log criteria as an abrupt decrease in gamma ray values, in association with a sharp increase in sonic velocity.

Subdivision. Three new members are recognised; the Adoon Member, the Neaskin Member and the Inniscarra Member.

Thickness. The formation varies in thickness from 36.5m (19/8-1) to 77m (27/13-1A).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is poor to good. Occurring within Ostracod Zone IJO3 (*pars*), Foraminiferal Subzone IJF2b (*pars*) and Palynological Subzones DM2C3 to DM2C2 (*pars*).

Age. Early Jurassic, Late Sinemurian.

Depositional environment. Marine, possibly estuarine to inner shelf. The Inagh Formation is envisaged to have been deposited in an ?estuarine to inner shelf, marine environment.

The claystones of the Adoon Member yield both micro- and macrofaunas indicating low energy, oxygenated, bottom waters, with little or no restriction. The presence of limestones containing peloids and thin sandstones are envisaged to represent slightly higher energy shallower waters.

The Neaskin Member was laid down in a possible estuarine to shallow, marine environment. The thinner interbedded claystones yield poorly diverse, possibly ?opportunistic ostracod faunas, in association with macrofaunas and dinocysts. These ostracod assemblages may suggest some marine restriction at the sediment/water interface. The thicker sand beds are envisaged to have been deposited in a higher energy, estuarine to marine environment. Melvin (2009 unpublished report) considers that this member was laid down in an estuarine depositional setting with a transgressive aspect, due to the restricted fossil assemblages and ichnofauna, plus the strong tidal signature from the core data.

The underlying Inniscarra Member is envisaged to have been deposited in a low energy, inner shelf environment, denoted by the presence of common to abundant marine ostracods, dinocysts, plus crinoid and echinoderm debris.

Distribution. The formation is proven in the Slyne Basin and its depositional extent is taken to the mapped limits of this basin based on seismic interpretation. Seismic correlation from the 19/5-1 well to the 12/13-1A well, across the Erris Basin, suggests that the formation may be present in the south western part of this basin, particularly as truncated Lower Jurassic section (Meelagh Formation) is present in the latter well. The formation may be present in the Porcupine Basin but is not proven in currently drilled wells. Erosionally truncated Lower Jurassic section is present in the northern part of the Porcupine Basin and therefore the formation may be present to the south of this area where more complete Lower Jurassic sections are likely to occur.

Regional correlation. The formation is a lateral equivalent to upper part of the Glenbeg Formation in the Goban Spur, Fastnet, North Celtic and South Celtic Sea basins. Onshore southern England, this unit is equivalent to the middle part of the Charmouth Mudstone Formation (Black Ven Marl Member) (Simms *et al.*, 2004; Cox *et al.*, 2004). In northwest Scotland the lateral equivalent of this formation comprises the lower section of the Pabay Shale Formation, upper part of the Torosay Sandstone Member (Morton, 2004).

Source rock characterisation. The Inagh Formation includes some samples from the Slyne Basin with elevated TOC contents (**Appendix E**). With a mainly Type III kerogen composition and low hydrocarbon yields, the formation has poor source rock potential.

Comparison with Eastern Canada. The Inagh Formation is age equivalent to the upper part of the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

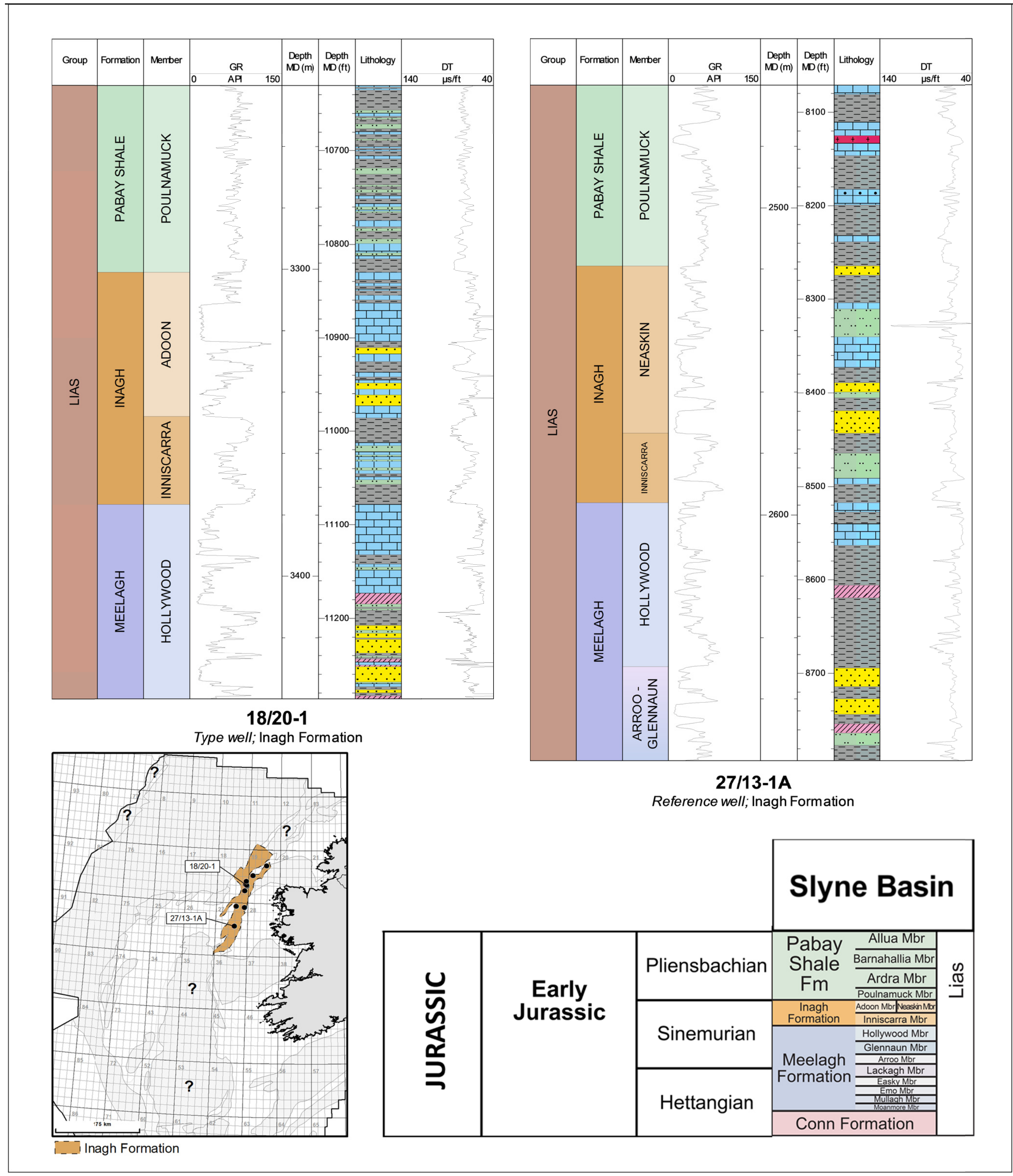


Figure D.6. 41. ***Inagh Formation type and reference well, with location and distribution map.***

Adoon Member (New)

The Adoon Member is defined here for a dominantly interbedded claystone and limestone unit, of latest Late Sinemurian age, that occurs within the Inagh Formation in the Slyne Basin. It lies between the Pabay Shale Formation, Poulnamuck Member and the Inniscarra Member.

Name. After Lough Adoon, County Kerry.

Type section. 18/20-1: 3301-3348m below KB. See **Figure D.6. 42**.

Reference section. 18/20-5: 3299.5-3330m below KB. See **Figure D.6. 42**.

Lithology. This member dominantly comprises an interbedded claystone and limestone unit, in association with localised sandstone beds.

The claystones are medium to dark grey, micromicaceous, with rare carbonaceous specks, slightly to non-calcareous, and grade into argillaceous siltstones or siltstones. The limestones are off white, buff, medium to medium dark grey, mudstone to wackestone, locally with greyish black peloids, microcrystalline to cryptocrystalline, and locally grade into dolomitic limestones. A number of sandstones, off white, very fine to fine grained, well sorted, subangular to subrounded, non to calcareous, are also present.

Wireline log character. The member is characterised by highly serrated wireline log motifs, reflecting the interbedded nature of the lithologies. The high gamma ray and low sonic velocities denote the mudrocks, while the low gamma ray values and high sonic velocities reflect the carbonates and localised sandstones. The thickened limestone beds often exhibit boxcar wireline log profiles.

Upper boundary. The top of the member is taken at a downsection lithological change from the claystones of the Pabay Shale Formation, Poulnamuck Member, to the limestones of the Inagh Formation, Adoon Member. This change is expressed on wireline log criteria by a decrease in gamma ray values and a coincident increase in sonic velocity.

Lower boundary. The base of the unit is placed at a downsection lithological change from limestones to the claystones of the Inniscarra Member. On wireline log criteria, this boundary is denoted as a sharp increase in gamma ray values and an associated decrease in sonic velocity.

Thickness. The member varies in thickness from 31m (19/8-1) to 47m (18/20-1).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is poor to good. Occurring within Ostracod Subzone IJO3c, Foraminiferal Subzone IJF2b (*pars*) and Palynological Subzone DM2C3 (*pars*).

Age. Early Jurassic, latest Late Sinemurian.

Depositional environment. Marine, inner shelf. The Adoon Member was deposited in an inner shelf marine environment. The claystones yield both micro- and macrofaunas indicating low energy, oxygenated, bottom waters, with little or no restriction. The presence of limestones containing peloids and thin sandstones are envisaged to represent slightly higher energy shallower waters.

Distribution. The member is proven in the central and northern parts of the Slyne Basin and its depositional extent is taken to the mapped limits of this basin based on seismic interpretation. Seismic correlation from the 19/5-1 well to the 12/13-1A well, across the Erris Basin, suggests that the Inagh Formation may be present in the south western part of this basin, though whether this includes the Adoon Member is uncertain. The Inagh Formation (and the Adoon Member) may be present in the Porcupine Basin but is not proven in currently drilled wells. Erosionally truncated Lower Jurassic section is present in the northern part of the Porcupine Basin and therefore the member may be present to the south of this area where more complete Lower Jurassic sections are likely to occur.

Regional correlation. This member is a lateral equivalent to the Neaskin Member of the Inagh Formation in the Slyne Basin and the uppermost sediments of the Glenbeg Formation in the Goban Spur, Fastnet and North Celtic Sea basins. This unit appears to be laterally equivalent to the upper part of the Black Ven Marl Member, Charmouth Mudstone Formation, within the basins on and offshore southern England (see Simms *et al.* , 2004; Cox *et al*., 2004). Its lateral equivalent in northwest Scotland comprises the lower sediments of the Pabay Shale Formation (Morton, 2004).

Comparison with Eastern Canada. The Adoon Member is age equivalent to the upper sediments of the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Inniscarra Member (New)

The Inniscarra Member is defined here for a lower unit comprising a claystone couplet, with thinly interbedded limestones located mid-section, of Late Sinemurian age, that occurs within the Inagh Formation in the Slyne Basin. It occurs between the Neaskin or Adoon members and the Meelagh Formation, Hollywood Member.

Name. After Inniscarra Lake, County Cork.

Type section. 18/20-1: 3348-3376.5m below KB. See **Figure D.6. 43**.

Reference section. 18/25-1: 2782.5-2805.5m below KB. See **Figure D.6. 43**.

Lithology. This member comprises a claystone couplet, with thinly bedded limestones developed midway through the unit.

The claystones are medium to dark grey, micromicaceous, with rare carbonaceous specks, slightly to non-calcareous, and grade locally to argillaceous siltstones. The limestones are off white, medium to medium dark grey, mudstone to packstone, locally peloidal, and microcrystalline to cryptocrystalline.

Wireline log character. This member comprises a claystone couplet displaying high gamma ray values and low sonic velocities at the top and bottom, with a midsection denoted by lower gamma ray values and an increase in sonic velocities indicating the presence of interbedded limestones; this signature forms an overall gamma-sonic bow that is very distinctive.

Upper boundary. The top of the member is placed at a downsection lithological change from the sandstones of the Neaskin Member or the carbonates of the Adoon Member, to the claystones of the Inniscarra Member. This change is expressed on wireline log criteria by an increase in gamma ray values and a coincident decrease in sonic velocity.

Lower boundary. The base of the formation is indicated by a downward lithological change from claystones to the limestones of the Meelagh Formation, Hollywood Member. This is expressed on wireline log criteria as an abrupt decrease in gamma ray values, in association with a sharp increase in sonic velocity.

Thickness. The member ranges from 5.5m (19/8-1) to a maximum thickness of 28.5m (18/20-1). The thickest developments of the member are seen towards the centre of the Slyne Basin.

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is poor to good. Occurring within Ostracod Subzone IJO3b, Foraminiferal Subzone IJF2b (*pars*) and Palynological Subzones DM2B to DM2C2.

Age. Early Jurassic, Late Sinemurian.

Depositional environment. Marine, inner shelf. This member is envisaged to have been deposited in a low energy, inner shelf environment, denoted by the presence of common to abundant marine ostracods, dinocysts, plus crinoid and echinoderm debris.

Distribution. The member is proven in the Slyne Basin and its depositional extent is taken to the mapped limits of this basin based on seismic interpretation. Seismic correlation from the 19/5-1 well to the 12/13-1A well, across the Erris Basin, suggests that the Inagh Formation may be present in the south western part of this basin, though whether this includes the Inniscarra Member is uncertain. The Inagh Formation (and the Inniscarra Member) may be present in the Porcupine Basin but is not proven in currently drilled wells. Erosionally truncated Lower Jurassic section is present in the northern part of the Porcupine Basin and therefore the member may be present to the south of this area where more complete Lower Jurassic sections are likely to occur.

Regional correlation. This member appears to be a lateral equivalent to the upper sediments of the Glenbeg Formation in the Fastnet and North Celtic Sea basins. This unit is equivalent to the middle sedimentary succession of the Black Ven Marl

Member, Charmouth Mudstone Formation, in the basins of southern England (Simms *et al.* , 2004; Cox *et al*., 2004). Its lateral equivalent in northwest Scotland comprises the lower sediments of the Pabay Shale Formation and upper part of the Torosay Sandstone Member (Morton, 2004).

Comparison with Eastern Canada. The Inniscarra Member is age equivalent to the upper part of the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Neaskin Member (New)

The Neaskin Member is defined here for a dominantly sandstone unit, with interbedded claystones and limestones, of latest Late Sinemurian age, that occurs within the Inagh Formation in the Slyne Basin. It lies between the Pabay Shale Formation, Poulnamuck Member and the Inagh Formation, Inniscarra Member.

The sandstone included herein within the Neaskin Member has been previously termed the Suisnish Sandstone by operators and consultants, for instance Serica Energy in the 27/4 area, and placed by them within the "Pabba Shales Formation" (Serica Energy, 2009). This sandstone comprises the reservoir in the Bandon Discovery well 27/4-1 and 27/4-1z. Biostratigraphic data from western offshore Ireland wells shows that this sandstone is coeval with the Suisnish Sandstone that is developed in onshore western Scotland (see for example, Simms *et al*., 2004; Hesselbo & Coe, 2000). Given the shallow marine-?estuarine origin of this sandstone in the Slyne Basin area it is highly unlikely to be contiguous with the Hebridean occurrences, hence a new name, Neaskin Member, is adopted for the offshore Ireland unit. This approach is underlined by the absence of the Suisnish Sandstone Member from the Upper Glen-1 well, drilled in northern Isle of Skye (see **Figure D.6.16**), showing that the sandstone has passed laterally into claystone over a relatively short distance from its type area in the southern part of that island.

Name. After Neaskin Lough, County Galway.

Type section. 27/4-1: 1079.5-1135m below KB. See **Figure D.6.44**.

Reference sections. 18/25-1: 2733.5-2782.5m below KB. 27/4-1z: 1128-1188.5m below KB. See **Figure D.6.44.**

Lithology. This member dominantly comprises sandstones, with interbedded claystones and limestones.

The sandstones are off white, light brownish grey, light to medium grey, very fine to fine grained, well sorted, subangular to subrounded, and non- to calcareous. The interbedded claystones are medium to dark grey, locally brownish red, greenish grey, slightly micromicaceous, locally silty, slightly to non-calcareous, and grade into argillaceous siltstones or siltstones. The limestone beds are off white, buff, mudstone to packstone, microcrystalline to cryptocrystalline, locally sandy, and locally grade into calcareous sandstones.

Cores from the 27/4-1z well show a number of sedimentological features, including parallel lamination, flaser bedding, flaser ripples, cross-bedding, minor bioturbation, both fining and coarsening up cycles, and localised carbonaceous drapes (Melvin, 2009).

Wireline log character. The unit is denoted by highly serrated wireline log profiles, reflecting the interbedded nature of the sandstone, limestone and mudrock lithologies. The high gamma ray and low sonic velocities are indicative of the mudrocks, while the low gamma ray values and high sonic velocities denote the carbonates and localised sandstones. The thickened sandstone beds exhibit boxcar wireline log motifs.

Upper boundary. The top of the unit is taken at a downsection lithological change from the claystones of the Pabay Shale Formation, Poulnamuck Member, to the sandstones of the Inagh Formation, Neaskin Member. This change is denoted on wireline log criteria by a sharp decrease in gamma ray values, with an associated increase in sonic velocity.

Lower boundary. The base of the member is placed at a downsection lithological change from sandstones to the claystones of the Inniscarra Member. This change is reflected on wireline log criteria by a sharp increase in gamma ray values and an associated decrease in sonic velocity.

Thickness. The member varies in thickness from 44m (18/20-7) to 60.5m (27/4-1z).

Biostratigraphic characterization. Dated solely by dinocysts. Occurring within Palynological Subzone DM2C3 (*pars*).

Age. Early Jurassic, latest Late Sinemurian.

Depositional environment. Marine, estuarine? to inner shelf. The Neaskin Member was deposited in a possible estuarine to shallow, marine environment. The thinner interbedded claystones yield marine ostracod faunas, macrofaunas and dinocysts. The ostracod faunas are poorly diverse, possibly ?opportunistic, and may indicate some marine restriction at the sediment/water interface. The sands are envisaged to have been deposited in a higher energy estuarine to marine environment. Melvin (2009), however, considers that in the 27/4-1z well, in which the unit is cored, the member was laid down in an estuarine depositional setting with a transgressive aspect, due to the restricted fossil assemblages and ichnofauna, plus the strong tidal signature from the core data.

Distribution. The member is proven in six wells in the Slyne Basin and its depositional extent is taken to the mapped limits of this basin based on seismic interpretation. Seismic correlation from the 19/5-1 well to the 12/13-1A well, across the Erris Basin, suggests that the Inagh Formation may be present in the south western part of this basin, though whether this includes the Neaskin Member is uncertain. The Inagh Formation (and the Neaskin Member) may be present in the Porcupine Basin but is not proven in currently drilled wells. Erosionally truncated Lower Jurassic section is present in the northern part of the Porcupine Basin and therefore the member may be present to the south of this area where more complete Lower Jurassic sections are likely to occur.

Fields & Discoveries. Sandstones within the Neaskin Member comprises the reservoir in the 27/4-1 and 27/4-1z wells, in the Bandon Discovery.

Regional correlation. The Neaskin Member is laterally equivalent to the upper sandstones of the Gara Sandstone and Lougbaun Sandstone members of the Glenbeg Formation in the Goban Spur, Fastnet and North Celtic Sea basins. This unit appears to be laterally equivalent to the upper part of the Black Ven Marl Member, Charmouth Mudstone Formation (see Simms *et al.*, 2004; Cox *et al*., 2004) of onshore southern England. Its lateral equivalent in northwest Scotland comprises the lower sediments of the Pabay Shale Formation, including the Suisnish Sandstone Member, in the Isles of Skye and Raasay (see Morton, 2004; Hesselbo & Coe, 2008).

Comparison with Eastern Canada. The Neaskin Member is laterally equivalent to the upper part of the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

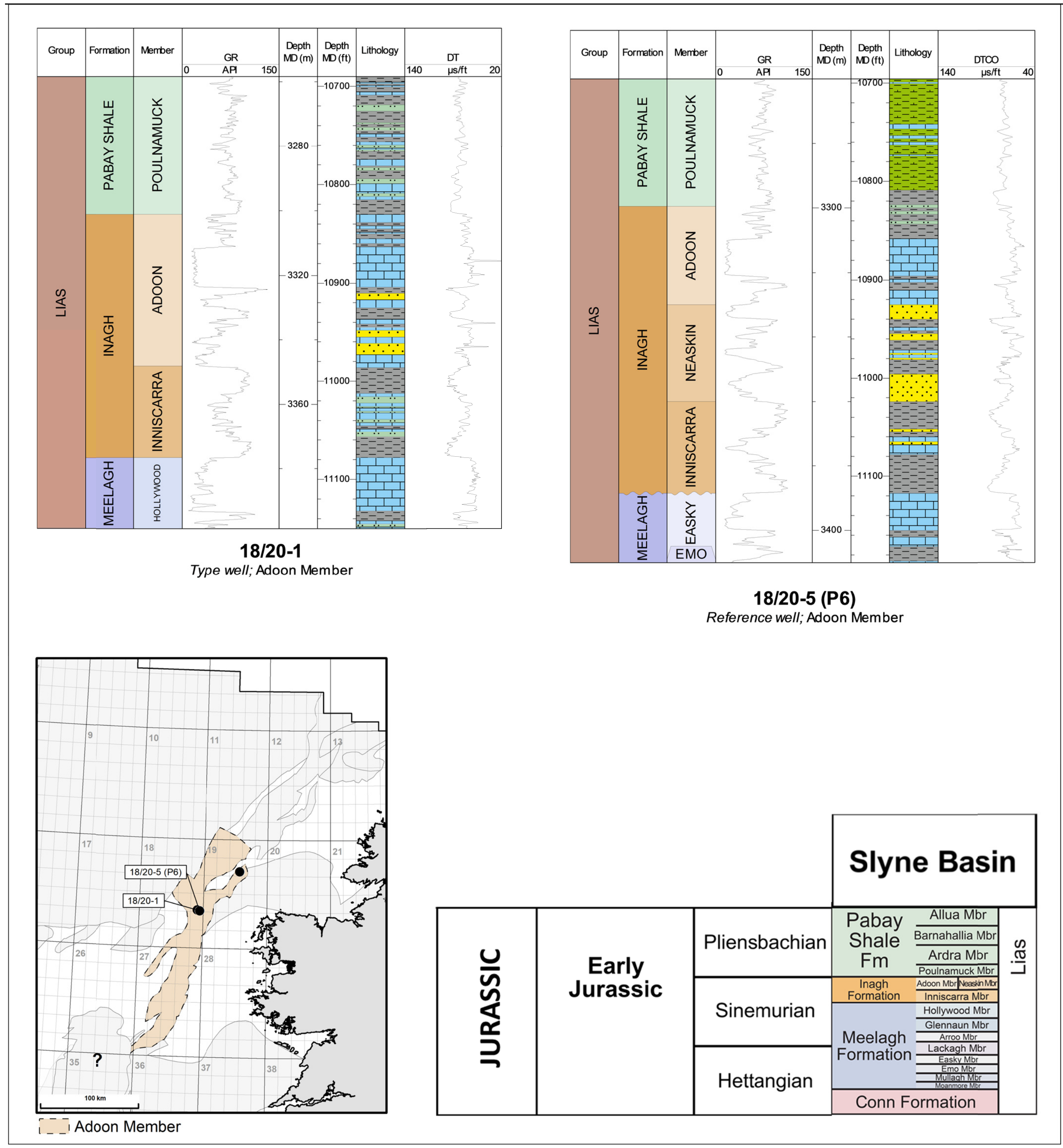


Figure D.6. 42. ***Inagh Formation, Adoon Member type and reference wells, with location and distribution map.***

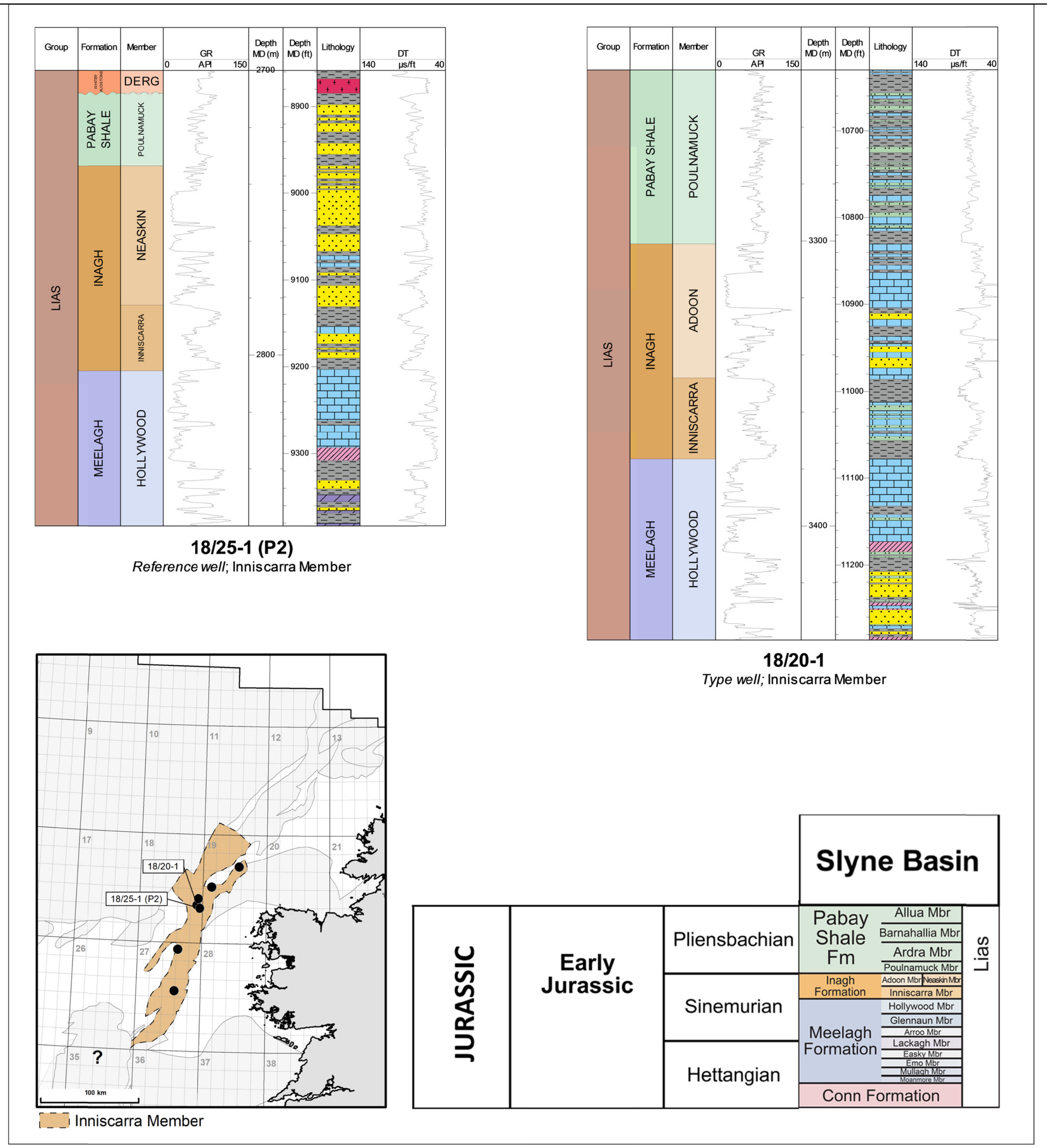
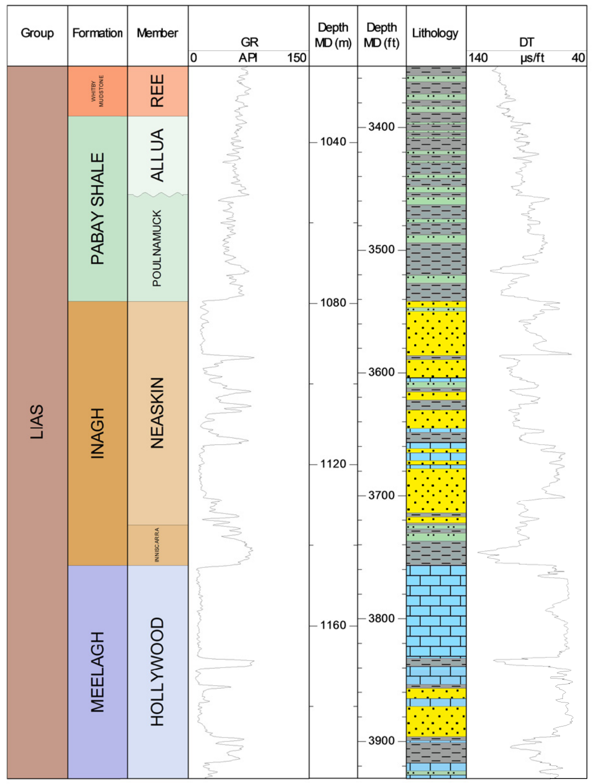
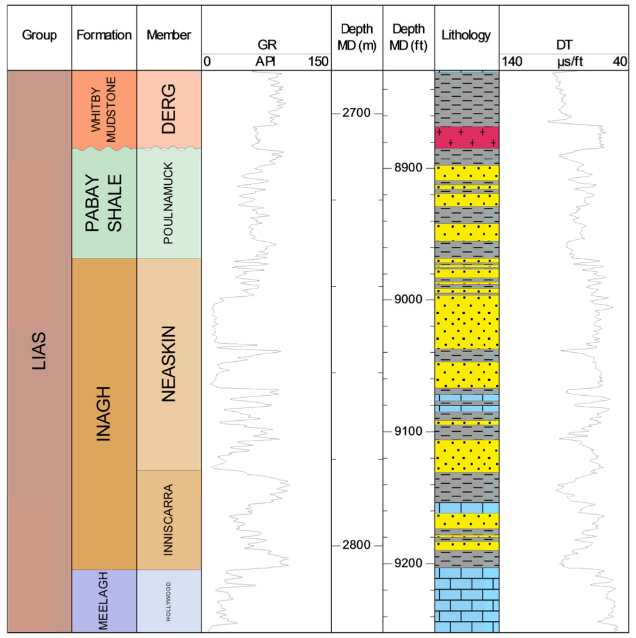


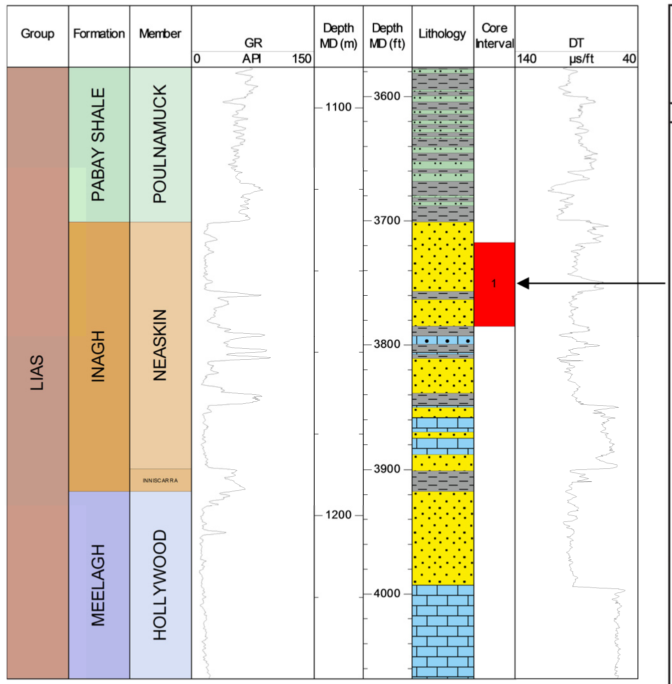
Figure D.6. 43. ***Inagh Formation, Inniscarra Member type and reference well, with location and distribution map.***



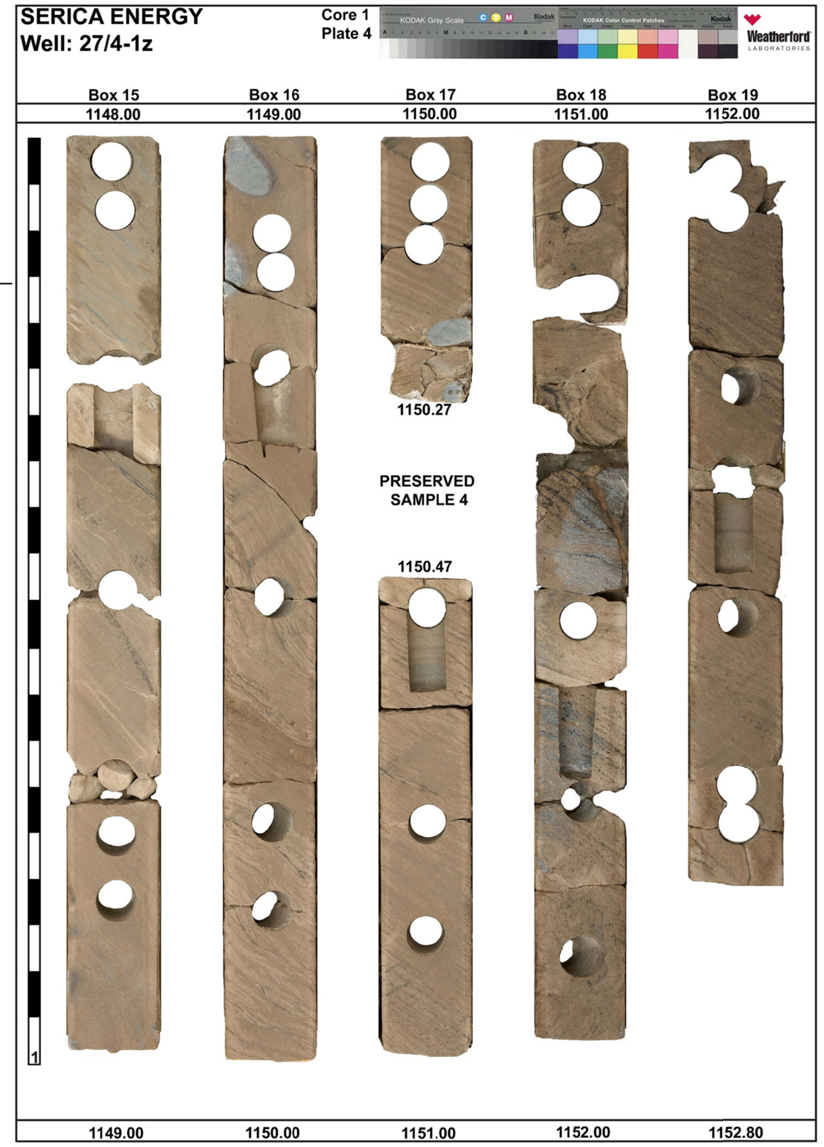
27/4-1
Type well; Neaskin Member



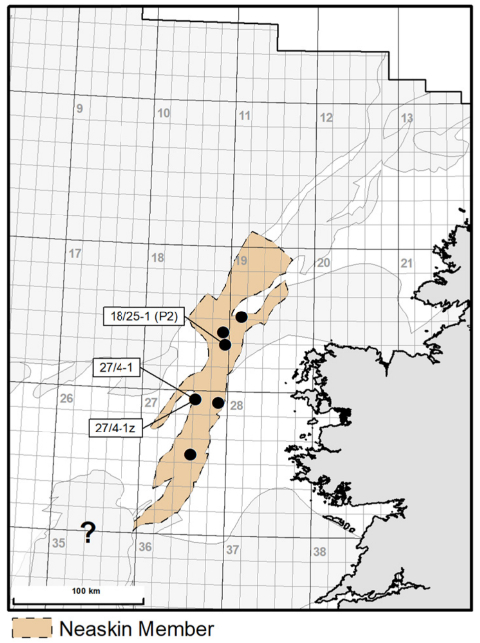
18/25-1 (P2)
Reference well; Neaskin Member



27/4-1z
Reference well; Neaskin Member



Photographs illustrate interpreted tidal channel and mouthbar facies, in estuarine bayhead setting. Source of photographs; Serica Energy (released well data)



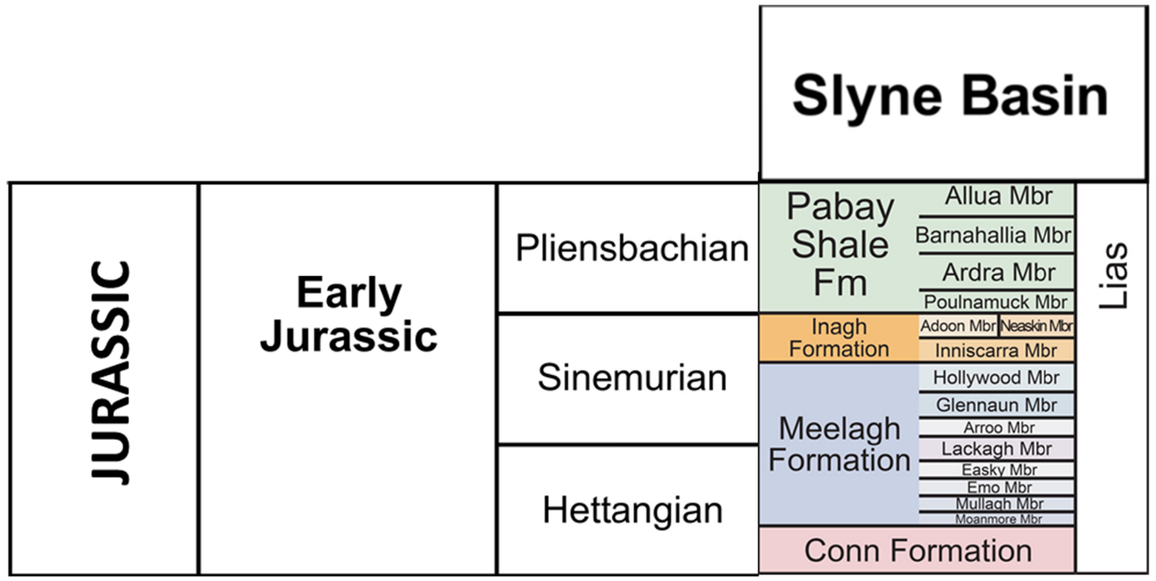


Figure D.6. 44. ***Inagh Formation, Neaskin Member type and reference wells, with location and distribution map. Core photographs from 27/4-1z, Slyne Basin.***

LEANE FORMATION (NEW)

The Leane Formation is defined here for a freshwater to shallow marine cyclic sedimentary succession of Hettangian age, that is developed through the Goban Spur and Fastnet basins, and also the south and central areas of the South Celtic Sea and North Celtic Sea basins. The various members are well-defined in the Fastnet Basin. Away from this basin, the members cannot be defined, due to the lateral shale out of the limestones which define the members. This formation lies between the overlying Currane Formation and the Caragh Formation.

The Leane Formation can be differentiated from both the Gill and Blue Lias formations by the presence of the more thickly developed well indurated limestones which are interbedded with the mudrocks. The lower and middle parts of the Leane formation comprise an interbedded non-marine/marine sedimentary succession, with only the upper third being shallow marine. Both the Gill and Blue Lias formations are fully marine throughout their sedimentary successions. Where the Leane Formation shales out within the North Celtic Sea Basin, the formation can be differentiated from both the Blue Lias and Gill formations by the more marginal marine facies (localised non-marine microfaunas and abundant miospores). No marine microfaunas have been recognised in this more “argillaceous” facies of the Leane Formation.

The Leane Formation is somewhat similar to the Meelagh Formation which is present in the Slyne Basin to the west of Ireland. Both formations possess non-marine to very shallow marine sedimentary facies, often comprising interbedded well indurated limestones and mudrocks. The Leane Formation can be differentiated from the Meelagh Formation by an absence of anhydrite beds/laminae, or reddened sediments, plus the marked decrease in sandstone beds. It is considered that the Meelagh Formation is a more non-marine sedimentary succession than the Leane Formation. Although both formations have been subdivided into a number of members, none of these could be correlated across the basins from the south and east of Ireland to the west of Ireland, further supporting the differentiation of the Leane and Meelagh formations.

Five new members are proposed, in descending stratigraphic order; Emy Member, Nadreegeel Member, Athry Member, Effernan Member and Loughaun Member (spelling ‘LEANE’ from first the letter of each Member in ascending stratigraphic order). The dominantly interbedded carbonate/claystone beds of this formation can be subdivided into five members based on their lithological, wireline and microfossil content. Definitions of the various members have been based on a number of lithological markers; the occurrence of the more thickly developed limestones (for example in the Effernan, Nadreegeel and Emy members) or the more highly interbedded claystone and limestones sections (Loughaun and Athry members). At the same time, it is recognised that the more continental successions occur in the lower two-thirds of the formation, while the continental to very shallow marine sediments are present in only the top third of the succession.

A correlation of four wells (56/21-1, 48/30-1, 58/3-1, 49/29-1) in the Fastnet, North Celtic Sea and South Celtic Sea basins is shown in **Figure D.6.46**, illustrating the development of the Leane Formation, and the wireline and lithological characteristics of its member subdivision in this region, together with its boundaries with underlying and overlying formations. This correlation panel also shows the lateral variation seen within the formation whereby the alternating limestone/claystone succession in the Fastnet Basin (as in the 56/21-1 well) passes laterally into a more claystone dominated succession in the southern part of the North Celtic Sea Basin and the South Celtic Sea Basin.

Rocks now referred to this formation in the Fastnet Basin were previously referred to as Jurassic Liassic Limestone Unit (J-6 to J-2) by Murphy & Ainsworth (1991). The type well for this unit proposed by these authors, 56/21-2, is here nominated as the type well for the formation in offshore Ireland. This unit was informally described as the Liassic Limestone (Ainsworth *et al*.,1987; Ainsworth, 1989; Ainsworth *et al*.,1989; Rutherford & Ainsworth, 1989).

Name. After Lough Leane, County Kerry.

Type section. 56/21-2: 2893-3205.5m below KB. See Figure D.6. 45.

Reference sections. 48/30-1: 2200-2338m below KB. 63/10-1: 3020.5-3277.5m below KB. See Figure D.6. 45.

Lithology. This formation comprises an interbedded succession of limestones, claystones, and sandstones, in association with rare dolomites. The more interbedded successions are recognised in the Fastnet Basin. A rapid lithological change occurs within this formation within the southern part of North Celtic Sea Basin and also in the South Celtic Sea Basin, with the thick limestone developments shaling out. In the more northerly wells, the limestone units are poorly developed, with the main part of the formation developed as claystones.

In the Fastnet Basin the limestones are off white to cream, light to dark grey, light to dark brown, mudstone, locally wackestone to packstone, micritic to cryptocrystalline, locally oolitic, locally silty/sandy, grains clear, subrounded, generally well indurated, and locally grade to argillaceous limestones or dolomitic limestones. The claystones are light to dark grey, greenish grey, olive grey, light brown, rarely reddish brown, non to calcareous, and grade locally to marls. The thin sandstone units are white to light grey, very fine to fine grained, well sorted, subangular to subrounded, friable to moderately well indurated, and often very calcareous. The thicker sandstone units are white to light grey, locally greyish orange pink to pale red, very fine to fine grained, well sorted, subangular to subrounded, friable to moderately well indurated, often calcareous, and grade locally to siltstones. Rare light tan, microcrystalline dolomites are locally developed.

In the North Celtic Sea and South Celtic Sea basins, the claystones are medium light to dark grey, non to calcareous, and grade locally to marls. The limestones are light grey, buff, medium to dark grey, light to dark brownish grey, mudstone, micritic to cryptocrystalline, generally well indurated, and grade to argillaceous limestones or dolomitic limestones.

Wireline log character. The wireline characteristics of the Leanne Formation are highly variable within the Irish offshore wells due to the heterogeneous nature of the constituent lithologies. Where the sandstones and limestones are developed, the wireline logs exhibit blocky profiles, with low gamma ray values and corresponding high sonic velocities. The claystones and siltstones possess slightly serrated high gamma ray values and low sonic velocities.

Within the Fastnet Basin, the wireline logs exhibit far greater variability in their motifs compared to those wells situated in the North Celtic Sea and South Celtic Sea basins. This is due to the more heterogenous nature (marls, limestones, sandstones, claystones) of the sedimentary successions within the Fastnet Basin compared to their counterparts (dominantly mudrocks, with thin limestones and argillaceous limestones) in the Celtic Sea basins.

Upper boundary. The upper boundary is placed at a downsection lithological change from the marls or calcareous claystones of the Currane Formation, Corfad Member, to the limestones of the Leane Formation, Emy Member. This change is expressed on wireline log criteria by a sharp decrease in gamma ray values and a corresponding sharp increase in sonic velocity.

Lower boundary. The base of this unit is placed at a downsection lithological change from limestones to the claystones of the Caragh Formation. This is reflected on wireline log criteria by an increase in gamma ray values and a decrease in sonic velocity.

Subdivision. In the Fastnet Basin, five new members are proposed, in descending stratigraphic order; Emy Member, Nadreegeel Member, Athry Member, Effernan Member and Loughaun Member. In both the North Celtic Sea and South Celtic Sea basins these members cannot be recognised, due to lateral lithofacies changes within the formation. The member subdivision and the lateral lithofacies changes are shown in **Figure D.6.46**.

Thickness. The formation varies in thickness from 138m (48/30-1) to a maximum of 346.5m (64/2-1) where the lower boundary is a possible unconformity. Although the formation is present in the southern part of the North Celtic Sea Basin, it would appear that the thickest developments of the formation occur within the Fastnet Basin.

Biostratigraphic characterization. Dated by ostracods and dinocysts. Calcareous ostracod recovery is poor to very good. Occurring within Ostracod Zone IOJ2 and Palynological Subzone DM2A1 (*pars*).

Age. Early Jurassic, Hettangian.

Depositional environment. The Leane Formation within the Fastnet Basin was deposited in alternating continental (freshwater to brackish water) to marine, inner shelf environments. This has been interpreted to represent a transgressing/regressing shoreline which was associated with a very subdued topography, due to the continuing unstable environment during the Rhaetian/Hettangian marine transgression (Robinson *et al.* 1981; Naylor & Shannon, 1982; Murphy & Ainsworth, 1991). Freshwater and brackish water conditions are denoted by the often abundant ostracod faunas and large numbers of *Classopollis* pollen recorded from the mudrocks and marls. This pollen type occurs in semi-arid and arid conditions, with the parent plant occurring in lowland areas bordering lagoons (Vakhrameev, 1970; Sladen & Batten, 1984). The limestone developments are considered to be largely marine in origin. The presence of rare micro- and common macrofaunas (echinoderm debris), in association with localised developments of oolitic limestones is indicative of carbonate rich, warm, low to locally high energy, inner shelf conditions. The freshwater and brackish sedimentary facies are more persistent in the lower and mid intervals of the formation, while the marine facies are dominant the upper intervals, implying an increase in water depths upsection. The more arenaceous and reddened sediments occurring in the 63/4-1 well are suggestive of subaerial exposure or erosion of the underlying Triassic sediments (Murphy & Ainsworth, 1991).

The more argillaceous successions of the Leane Formation recognised within the Celtic basin are generally devoid of both micro and macrofaunas. This may possibly indicate highly restricted bottom waters. It is considered that these sediments are probably more marine in origin compared to the sediments within the Fastnet Basin.

Distribution. The formation is proven by wells to be present in the North Celtic Sea Basin (quadrant 49 southwards), South Celtic Sea Basin, Fastnet Basin and Goban Spur Basin. Its presence is extended through the Celtic Platform, based on seismic interpretation across this area from the Goban Spur Basin to the Fastnet Basin. The formation passes laterally into the Blue Lias and Gill formations to the north east of quadrant 49. The distributions of the component members of the Leane Formation are shown in **Figure D.6. 47**.

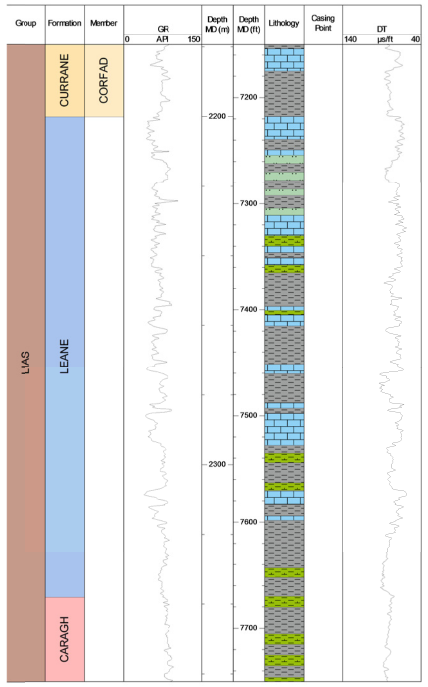
Seismic expression. The top of the formation ties approximately to the Hettangian (Top Leane) seismic horizon, that is recognised in the Fastnet and South Celtic Sea basins (see **Figure D.6.4**, **Figure D.6. 6**). This horizon, which is expressed as a peak (hard event) corresponds to the downward passage into limestone-claystone succession characteristic of this formation in these basins. Below this horizon, the formation is characterised by high amplitude, parallel seismic facies, reflecting the interbedded limestone-claystone succession within the formation. The formation displays notably higher seismic amplitudes than the overlying Currane Formation (see **Figure D.6.4**, **Figure D.6. 6**).

Regional correlation. The Leane Formation is a lateral equivalent to the Blue Lias and Gill formations in the northern North Celtic Sea, and South Celtic Sea basins. In the Porcupine, Slyne and Erris basins the formation is equivalent to the lower and middle parts of the Meelagh Formation. The Leane Formation equates to the lower and middle sections of the Blue Lias Formation in England and South Wales (see Cox *et al*., 1999), and to the lower and middle parts of the Breakish and Blue Lias formations in northwest Scotland (see Cox *et al.,* 1999; Morton, 2004; Simms *et al.*, 2004).

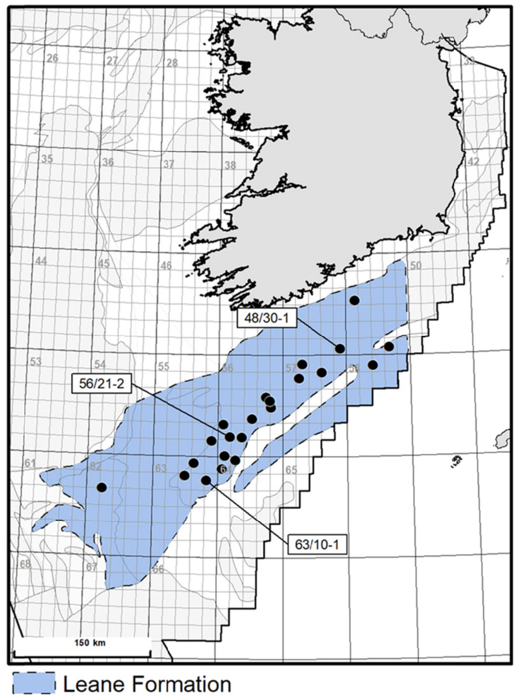
Source rock characterisation. The Leane Formation is dominated by organic-lean samples but also contains a good range of samples with increased TOC contents (**Figure D.6. 48**). Apart from one very organic-rich sample, samples from the Fastnet Basin show low hydrocarbon yields and a Type IV to Type III kerogen composition, resulting in poor hydrocarbon generation potential. The high mean TOC value for the Fastnet Basin is skewed by the presence of this one coal sample, which is also true for well 49/11-1 in the North Celtic Sea Basin that shows a very high mean TOC value on the TOC bubble map in **Figure D.6. 48**. HI values are higher in wells from the North and South Celtic Sea basins and the kerogen can be characterised as Type II/III, with gas to mixed oil and gas generation potential.

In well 49/29-1 in the South Celtic Sea Basin the Leane Formation is part of source rock interval Low J1 that was identified in project IS16/01 (BeicipFranlab, 2017).

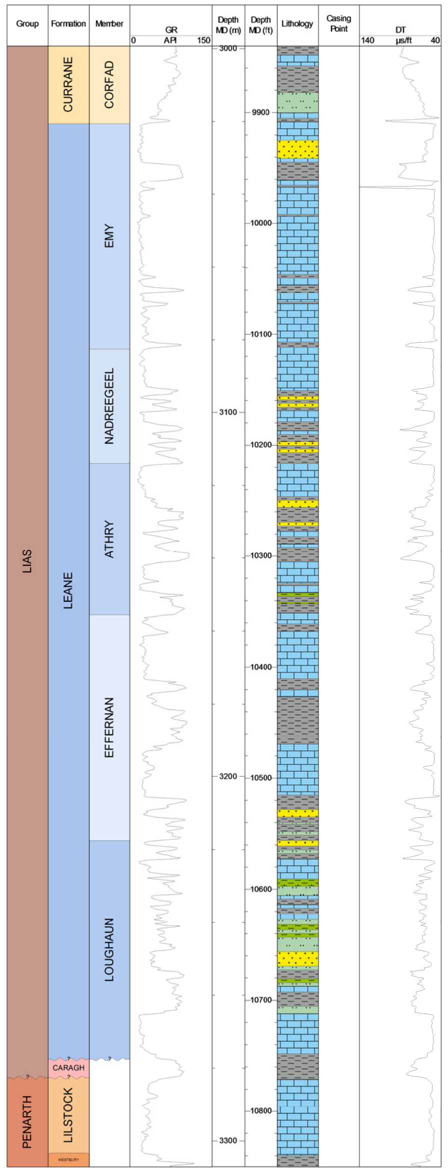
Comparison with Eastern Canada. The Leane Formation is age equivalent to the Argo Formation (dominantly halites) of the Jeanne d'Arc Basin, offshore east coast Canada.



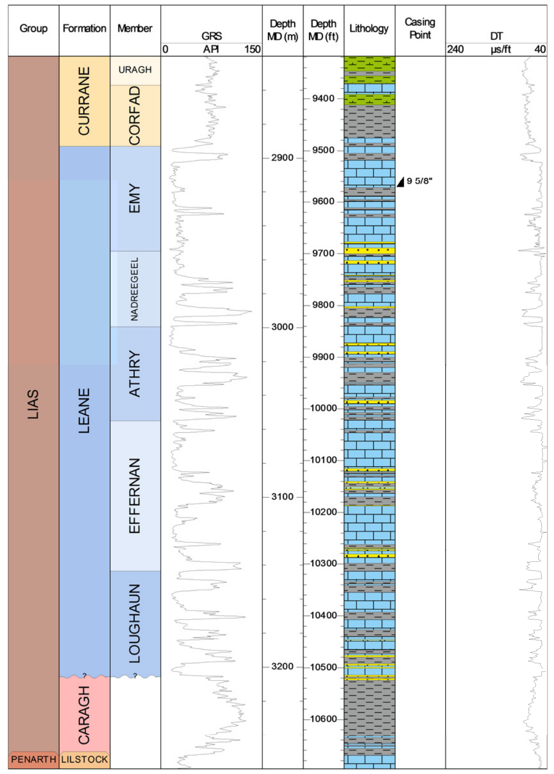
48/30-1
Reference well; Leane Formation



Leane Formation



63/10-1
Reference well; Leane Formation, Athry, Effernan, Emy, Loughaun, Nadreegeel Members



56/21-2
Type well; Leane Formation, Athry, Effernan, Emy, Loughaun, Nadreegeel Members

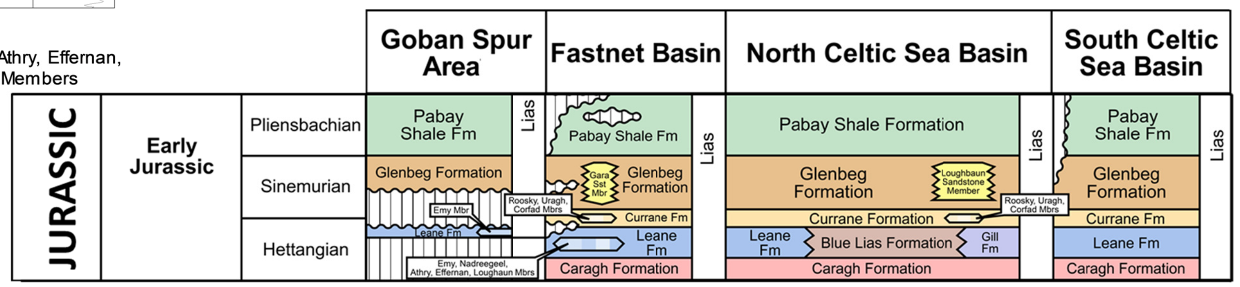


Figure D.6. 45. ***Leane Formation type and reference wells, location and distribution.***

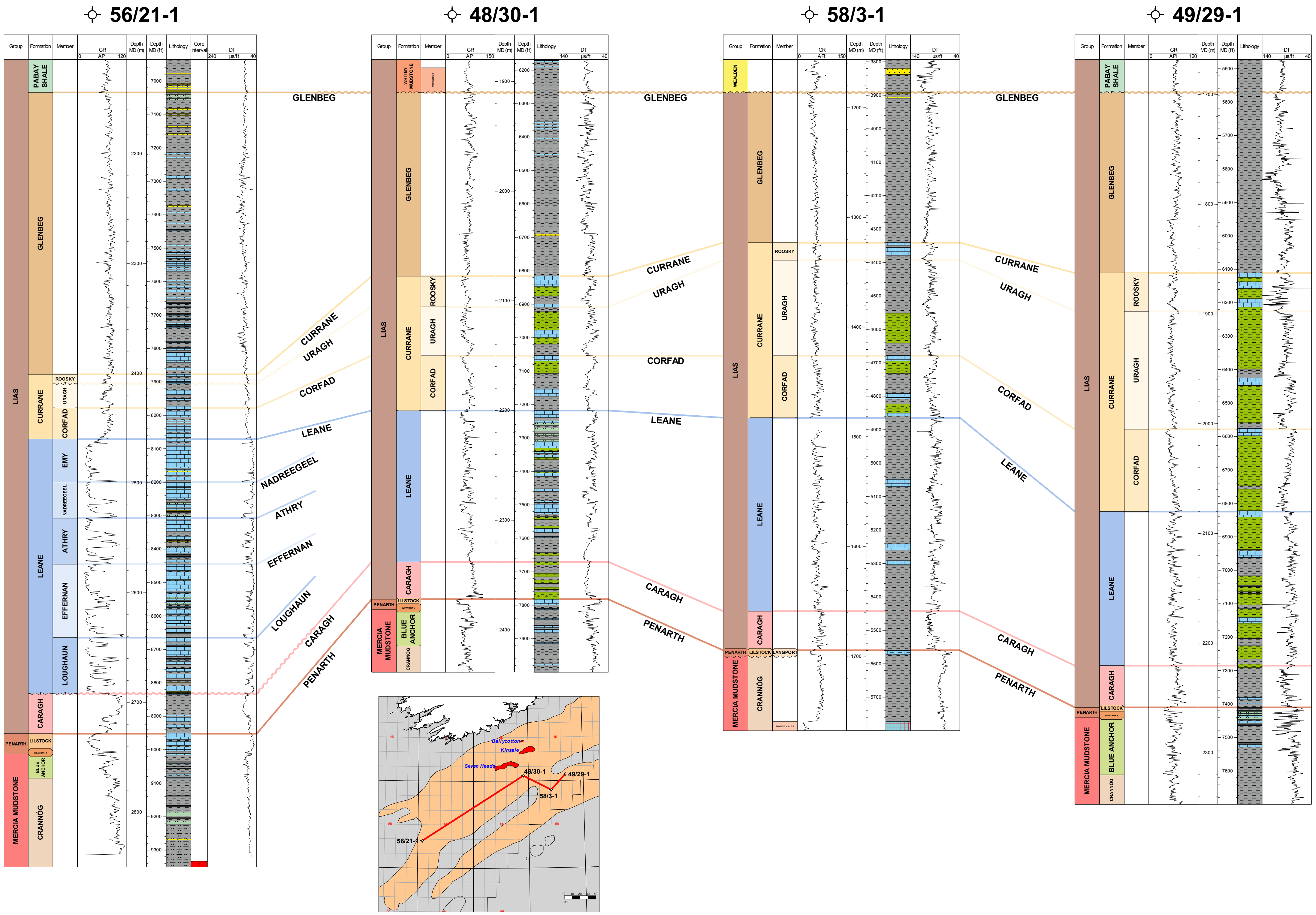


Figure D.6. 46. *Well correlation of Leane, Currane and Glenbeg formations from Fastnet Basin, North Celtic Sea Basin to South Celtic Sea Basin showing lateral relationships and member subdivisions.*

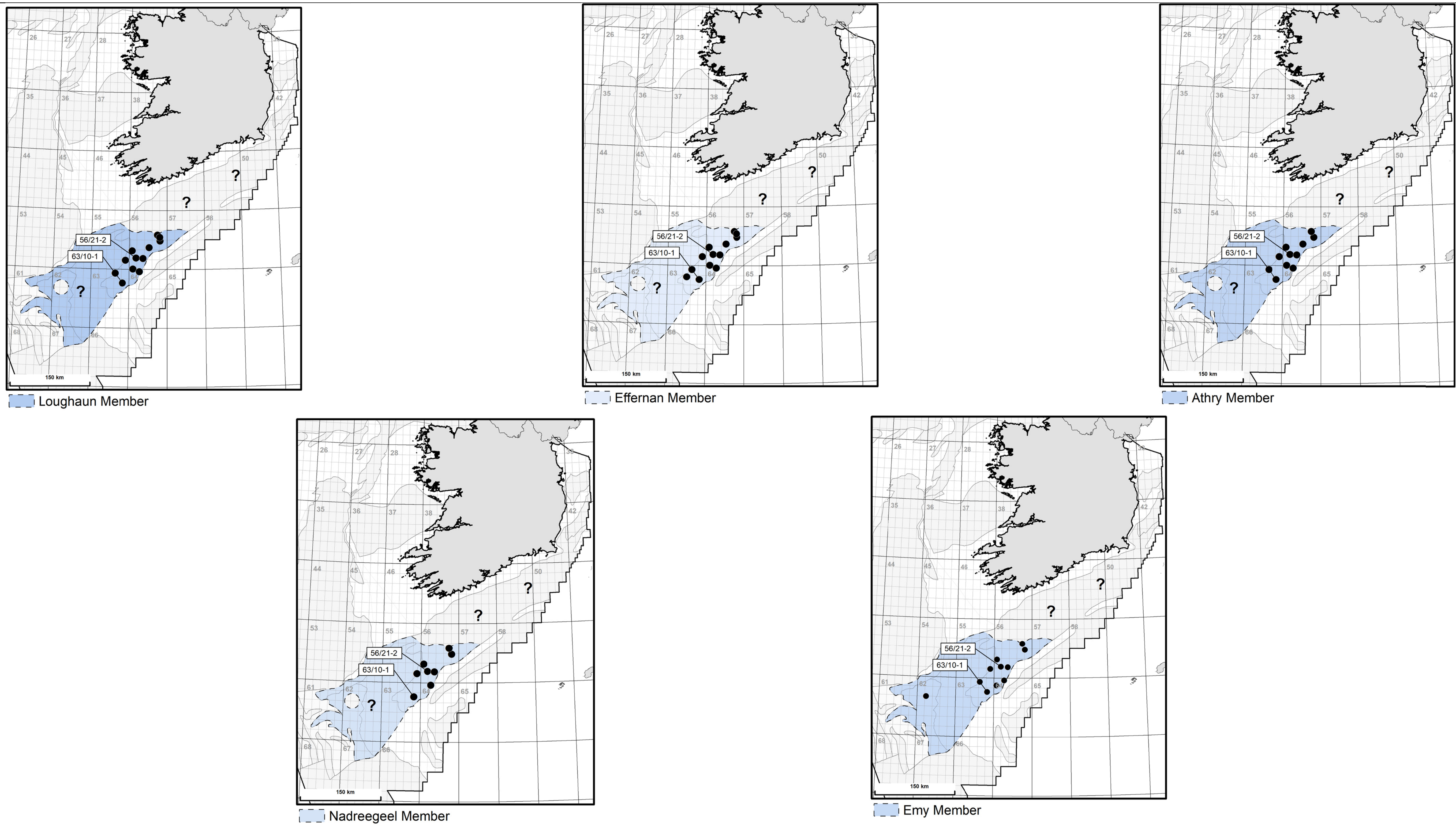
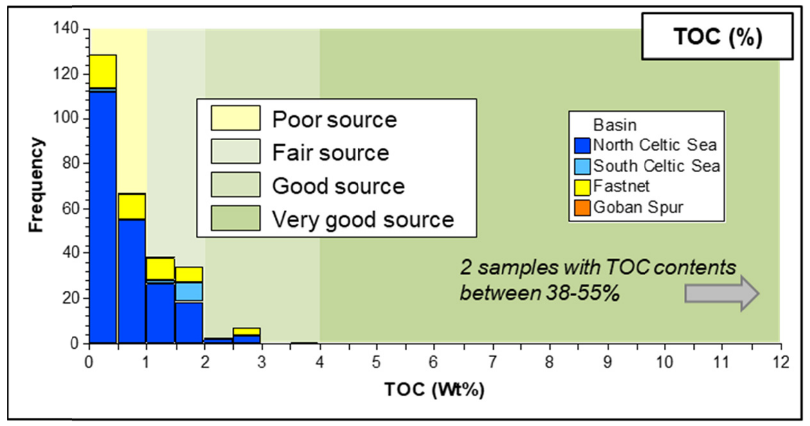
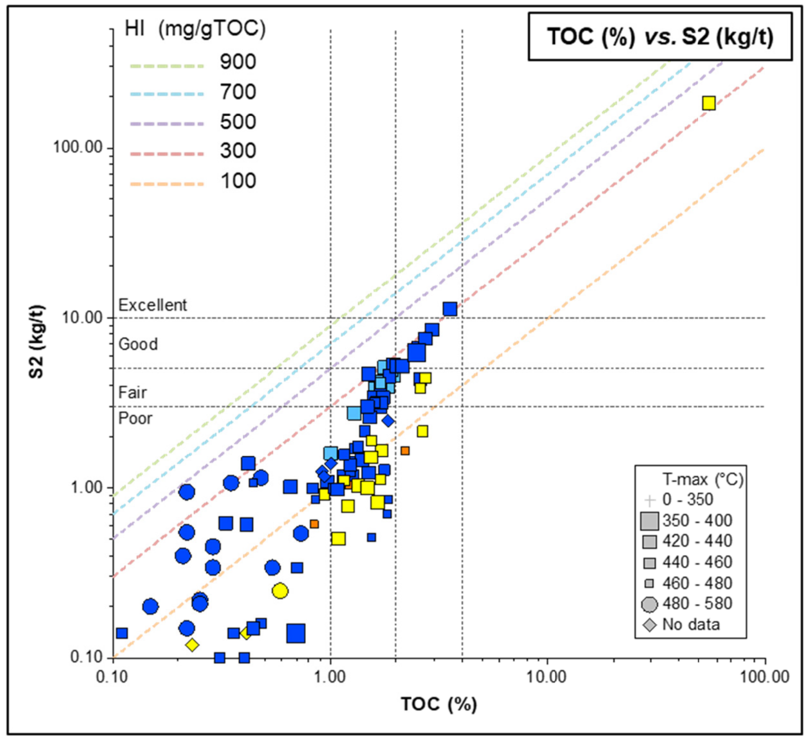


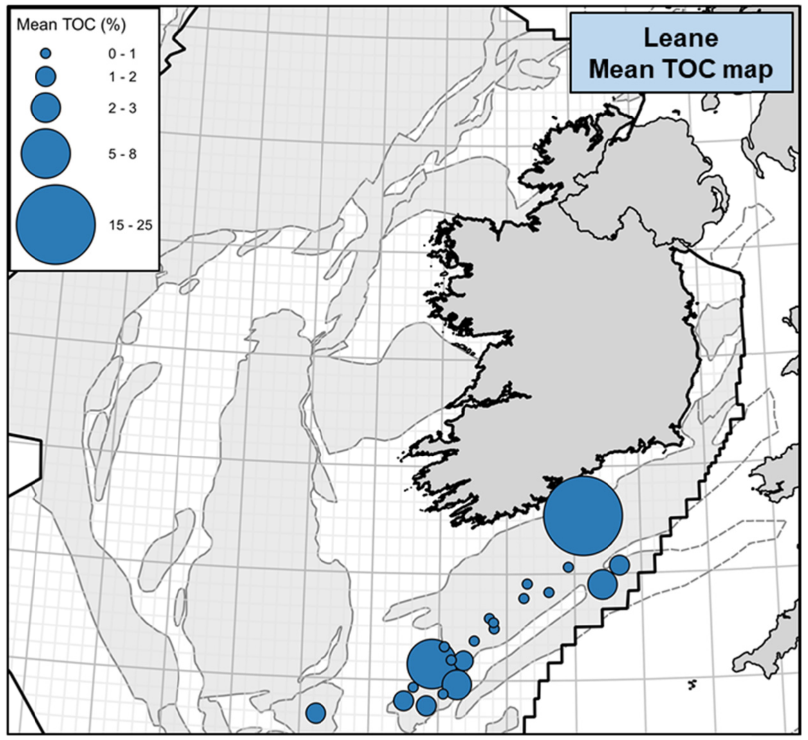
Figure D.6. 47. ***Distributions of Athry, Effernan, Emy, Loughaun and Nadreegeel members, of the Leane Formation.***

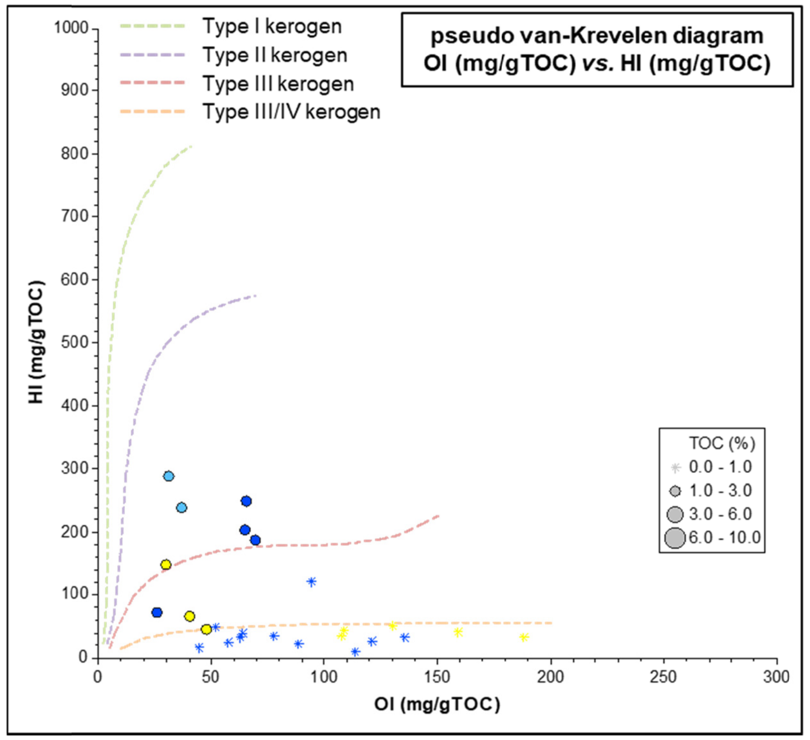
Leane Formation

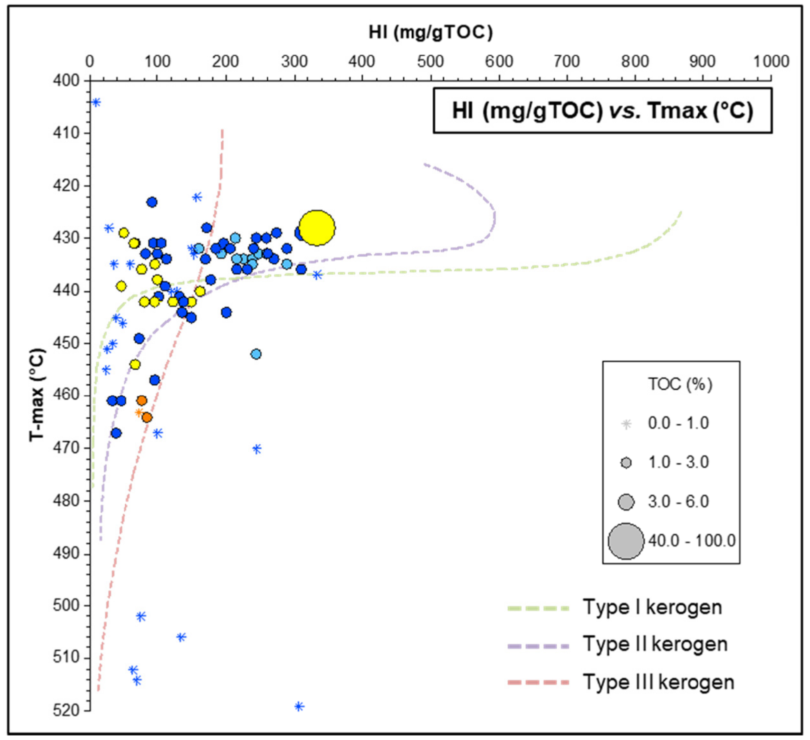
Basin	TOC (%) No. Wells	No. Samples	Min	Max	Avrg.	HI (mg/gTOC) No. Wells	No. Samples	Min	Max	Avrg.
North Celtic Sea	10	219	0.01	38.00	0.87	9	100	1	1300	200
South Celtic Sea	1	13	0.27	1.94	1.45	1	11	159	289	229
Fastnet	9	49	0.17	55.20	2.11	6	20	32	334	90
Goban Spur	1	3	0.84	2.19	1.42	1	3	73	84	78











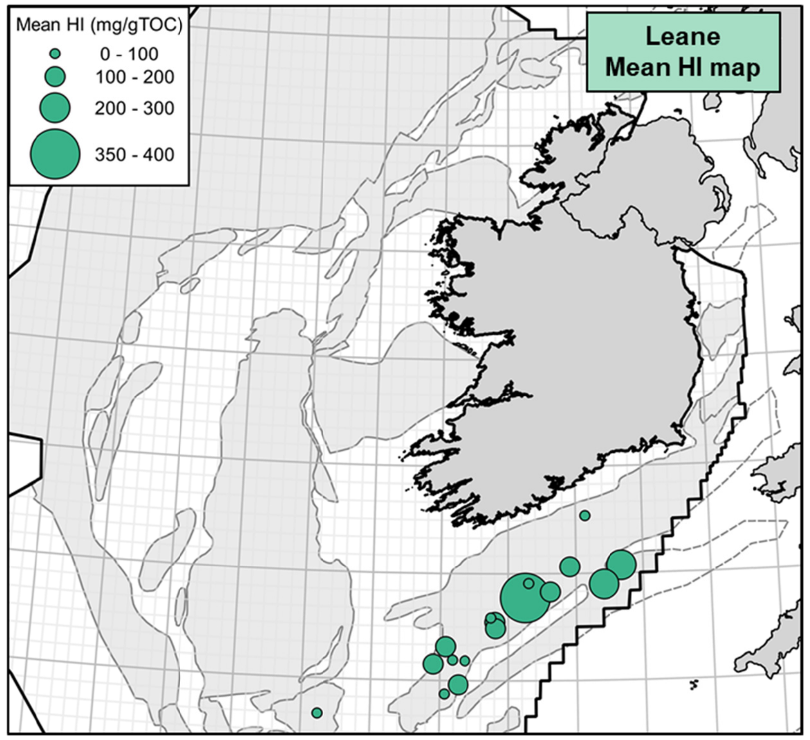


Figure D.6. 48. ***Leane Formation source rock characteristics, offshore Ireland.***

Athry Member (New)

The Athry Member is defined here as an interbedded succession of claystones and limestones with subordinate sandstones, of mid Hettangian age, which occurs within the Fastnet Basin, offshore south of Ireland. The top third of this unit comprises a prominent limestone. These sediments lie between Nadreegeel and Effernan members of the Leane Formation.

Sediments now referred to this member in the Fastnet Basin were previously referred to as Liassic Limestone Unit (J-4) by Murphy & Ainsworth (1991). The type well for this unit (56/21-2) proposed by these authors is also used here as the type well for the Athry Member. This unit was originally part of the Liassic Limestone (described by Robinson *et al.,* 1981; Ainsworth, 1989; Ainsworth *et al*., 1989; Rutherford & Ainsworth, 1989).

Name. After Athry Lough, Connemara, County Galway.

Type section. 56/21-2: 2999.5-3055m below KB. See Figure D.6. 45.

Reference sections. 63/10-1: 3114-3155m below KB. See Figure D.6. 45.

Lithology. The member comprises an interbedded succession of claystones and limestones, with the top third of this unit comprising a prominent limestone development. Subordinate sandstones beds or stringers are also developed. The limestones are off white to cream, light to medium grey, light brown, mudstone, locally wackestone, micritic to cryptocrystalline, locally silty/sandy, grains clear, subrounded, well indurated, and locally grade to argillaceous limestones or dolomitic limestones. The claystones are light to medium grey, greenish grey, non to calcareous, and grade locally to marls. The thin sandstone units are white to light grey, very fine to fine grained, well sorted, subangular to subrounded, friable to moderately well indurated, and often very calcareous.

Wireline log character. The member is characterised by highly serrated, wireline log motifs, reflecting the interbedded nature of the lithologies. The high gamma ray values and low sonic velocities indicate the mudrocks, while the low gamma ray values and high sonic velocities reflect the carbonates. At the top of the Athry Member a boxcar log profile is recognised reflecting a thickened limestone unit.

Upper boundary. The upper boundary is placed at the downward lithological change from the lower claystones of the Nadreegeel Member to the upper limestones of the Athry Member. On wireline log criteria, this is taken as a sharp decrease in gamma ray values, in association with a sharp increase in sonic velocity.

Lower boundary. The lower boundary is denoted by a downsection lithological change from a basal claystone to the upper limestones of the Effernan Member. This is reflected on wireline log criteria as a sharp decrease in gamma ray values, with a coincident sharp increase in sonic velocity.

Thickness. The member varies in thickness from 14m (63/4-1) to 63.5m (56/18-1), although the upper boundary is an unconformity in the latter well.

Biostratigraphic characterization. Dated by ostracods and dinocysts. Calcareous ostracod recovery is poor to very good. Occurring within Ostracod Zone IOJ2 (*pars*) and Palynological Subzone DM2A1 (*pars*).

Age. Early Jurassic, mid Hettangian.

Depositional environment. Non-marine (freshwater to brackish water) to marine, inner shelf. The Athry Member was deposited in an alternating non-marine (freshwater to brackish water) to a locally low energy, very shallow marine shelf environment. The presence of large numbers of freshwater/brackish water ostracods is characteristic of the member. Localised marine incursions are indicated by the presence of marine microfaunas and dinocysts.

Distribution. The member is recognisable within the Leane Formation in the Fastnet Basin. Its presence further north in the North Celtic Sea Basin is uncertain; while not recognised within the Leane Formation in well penetrations in this basin, it is possible that the member could be recognised in as yet undrilled parts of this basin.

Regional correlation. The Athry Member appears to be laterally equivalent to the uppermost Mullagh and lower part of the Emo members, Meelagh Formation, within the Slyne Basin. The member is correlateable to the middle part of the Blue Lias and Gill formations offshore east of Ireland (northern North Celtic Sea and South Celtic Sea basins) and onshore England (Cox *et al.,* 1999). In northwest Scotland the lower parts of the Breakish and Blue Lias formations are equivalents to the Athry Member (Morton, 2004; Simms *et al.*, 2004).

Comparison with Eastern Canada. The Athry Member is age equivalent to the Argo Formation (dominantly halites) of the Jeanne d'Arc Basin, offshore east coast Canada.

Effernan Member (New)

The Effernan Member is defined here for a limestone dominated succession, in association with two prominent claystone beds, of early Hettangian age, which occurs in the Fastnet Basin, offshore south of Ireland. These sediments lie between Athry and Loughaun members.

Sediments now referred to this member in the Fastnet Basin were previously referred to as Liassic Limestone Unit (J-3) by Murphy & Ainsworth (1991). The type well for this unit (56/21-2) proposed by these authors is used here as the type well. This unit was originally part of the Liassic Limestone (described by Robinson *et al.,* 1981; Ainsworth, 1989; Ainsworth *et al*., 1989; Rutherford & Ainsworth, 1989).

Name. After Lough Effernan, Cahiracon, County Clare.

Type section. 56/21-2: 3055-3143.5m below KB. See Figure D.6. 45.

Reference sections. 63/10-1: 3155-3217.5m below KB. See Figure D.6. 45.

Lithology. This member is defined here for a limestone dominated succession, in association with two prominent claystone beds. Thin beds/stringers of sandstone are also recognised.

The limestones are off white to cream, light to dark grey, light brown, mudstone, locally wackestone, micritic to cryptocrystalline, in part oolitic (for instance 56/21-2, 56/18-1), locally silty/sandy, grains clear, subrounded, well indurated, and locally grading to argillaceous limestones. The claystones are light to medium grey, greenish grey, light brown, non to calcareous, and grade locally to marls. The thin sandstone units are white to light grey, locally greyish orange pink to pale red, very fine to fine grained, well sorted, subangular to subrounded, friable to moderately well indurated, often very calcareous, and grade locally to siltstones.

Wireline log character. The upper and lower limestone units within this member exhibit low gamma ray values and high sonic velocities, with boxcar wireline log profiles, while the dominantly mudrock units developed midway and at the base of this member possess serrated high gamma ray values and low sonic velocities.

Upper boundary. The top of this unit is placed at a downsection lithological change from the basal claystone of the Athry Member to the upper limestones of the Effernan Member. On wireline log criteria, this is expressed as a sharp decrease in gamma ray values and an associated sharp increase in sonic velocity.

Lower boundary. The base of this unit is taken on a downward lithological change from a basal claystone to the upper limestones of the Loughaun Member. This is reflected on wireline log criteria as a sharp decrease in gamma ray values, with a coincident sharp increase in sonic velocity.

Thickness. The member ranges from 35.5m (63/4-1) to 102m (56/18-1) in thickness.

Biostratigraphic characterization. Dated by ostracods and dinocysts. Calcareous ostracod recovery is poor to very good. Occurring within Ostracod Zone IOJ2 (*pars*) and Palynological Subzone DM2A1 (*pars*).

Age. Early Jurassic, early Hettangian.

Depositional environment. Non-marine (freshwater/brackish) to marine, inner shelf. This member was laid down in an alternating non-marine (freshwater to brackish) to a low to high energy, marine inner shelf environment. The presence of large numbers of freshwater or brackish water ostracods is noted within this interval. Localised marine conditions are indicated by the presence of oolitic limestones.

Distribution. The member is recognisable within the Leane Formation in the Fastnet Basin. Its presence further north in the North Celtic Sea Basin is uncertain; while not recognised within the Leane Formation in well penetrations in this basin, it is possible that the member could be recognised in as yet undrilled parts of this basin.

Regional correlation. The Effernan Member is laterally equivalent to the uppermost part of the Moanmore and Mullagh members, of the Meelagh Formation, in the Slyne Basin. The member is also correlateable to the lower part of the Blue Lias and Gill formations offshore east of Ireland (northern North Celtic Sea and South Celtic Sea basins) and onshore England, plus the lower part of the Breakish and Blue Lias formations of northwest Scotland (see Cox *et al.,* 1999; Morton, 2004; Simms *et al.*, 2004).

Comparison with Eastern Canada. The Effernan Member is age equivalent to the Argo Formation (dominantly halites) of the Jeanne d'Arc Basin, offshore east coast Canada.

Emy Member (New)

The Emy Member is defined here as a limestone dominated unit, in association with a interbedded claystones and subordinate sandstone beds, of late Hettangian age. This unit is the upper member of the Leane Formation, and is present within the Fastnet Basin, offshore south of Ireland. This unit occurs between an overlying Inagh Formation, Corfad Member and an underlying Leane Formation, Nadreegeel Member.

Rocks now referred to this member in the Fastnet Basin were previously referred to as Liassic Limestone Unit (J-6) by Murphy & Ainsworth (1991). The type well for this unit proposed by these authors was 56/21-2 is used here as the type well. This unit was originally part of the Liassic Limestone (Robinson *et al.,* 1981; Ainsworth, 1989; Ainsworth *et al*., 1989; Rutherford & Ainsworth, 1989).

Name. After Emy Lough, County Monaghan.

Type section. 56/21-2: 2893-2955m below KB. See Figure D.6. 45.

Reference sections. 63/10-1: 3020.5-3082.5m below KB. See Figure D.6. 45.

Lithology. The member is dominated by limestones, in association with interbedded claystones and subordinate sandstones. The limestones are off white, light to medium grey, light brown, mudstone, locally wackestone to packstone, micritic to cryptocrystalline, locally silty or sandy, grains clear, rarely oolitic (for example 63/4-1), subrounded, and well indurated. The claystones are medium dark to dark grey, greenish grey, olive grey, rarely reddish brown, and non to calcareous, which grade locally to marls. Sandstones are white to light grey, very fine to fine grained, well sorted, subangular to subrounded, friable to moderately well indurated, and often calcareous.

Core from the 62/7-1 well (core 3) penetrated an upper interbedded/laminated sandstone and claystone interval, underlain by a claystone interval. The main claystones are locally laminated, and are dark grey/brown, slightly silty and fissile. Towards the top of the core the claystone possess abundant slickensides, while at the base of the core, abundant shell fragments are present, including the brachiopod *Lingula*.

Wireline log character. The member possesses a blocky log profile, with low gamma ray values and high sonic velocities, reflecting the dominantly limestone lithologies. The few thin high gamma spikes indicate interbedded thin claystones. A distinct claystone unit exhibiting high gamma ray values and slow sonic velocities is developed toward the top of the member.

Upper boundary. The top of this unit is placed at a downsection lithological change from the marls and calcareous claystones of the Currane Formation, Corfad Member, to the limestones of the Leanne Formation, Emy Member. On wireline log criteria, this is denoted by a sharp decrease in gamma ray values and a corresponding sharp increase in sonic velocity.

Lower boundary. The base of the unit is defined at a downward lithological change from a basal claystone to the upper limestones of the Nadreegeel Member. This is reflected on wireline log criteria by a sharp decrease in gamma ray values, with an associated sharp increase in sonic velocity.

Thickness. The member ranges from 20.5m (56/14-1) to a maximum thickness of 66m (64/1-1), but in the latter case the lower boundary was not penetrated.

Biostratigraphic characterization. Dated by ostracods and dinocysts. Calcareous ostracod recovery is poor to very good. Occurring within Ostracod Zone IOJ2 (*pars*) and Palynological Subzone DM2A1 (*pars*).

Age. Early Jurassic, late Hettangian.

Depositional environment. Non-marine (freshwater to brackish water) to marine, inner shelf. The Emy Member was deposited in a fluctuating non-marine (freshwater/brackish water) to marine, low to locally high energy, inner shelf environment. The presence of the brachiopod *Lingula*, recorded in core from the 62/7-1 well, suggests a shallow marine, coastal depositional environment in this well.

Distribution. The member is recognisable within the Leane Formation in the Fastnet Basin. Its presence further north in the North Celtic Sea Basin is uncertain; while not recognised within the Leane Formation in well penetrations in this basin, it is possible that the member could be recognised in as yet undrilled parts of this basin.

The member is also identified in the 62/7-1 well in the Goban Spur Basin and its distribution is therefore extended through the Celtic Platform from the Fastnet Basin. Whether it extends north eastwards into the southern part of the Porcupine Basin is unknown.

Regional correlation. The Emy Member appears to be laterally equivalent to the Meelagh Formation, Easky Member, in the Slyne Basin. Offshore east of Ireland (northern North Celtic Sea and South Celtic Sea basins) this unit is laterally equivalent to the upper parts of the Blue Lias and Gill formations. In northwest Scotland and onshore England this unit correlates with the upper parts of the Breakish and Blue Lias formations (see Cox *et al.,* 1999; Morton, 2004; Simms *et al.*, 2004).

Comparison with Eastern Canada. The Emy Member is age equivalent to the Argo Formation (dominantly halites) of the Jeanne d'Arc Basin, offshore east coast Canada.

Loughaun Member (New)

The Loughaun Member is defined here as an interbedded succession of claystones, limestones and thin sandstones, of early Hettangian age, which is present within the Fastnet Basin, offshore south of Ireland. These sediments lie between Effernan Member and the Caragh Formation.

Sediments now referred to this member in the Fastnet Basin were previously referred to as Liassic Limestone Unit (J-2) by Murphy & Ainsworth (1991). The type well for this unit (56/21-2) proposed by these authors is used here as the type well. This unit was originally part of the Liassic Limestone (Robinson *et al.,* 1981; Ainsworth, 1989; Ainsworth *et al*., 1989; Rutherford & Ainsworth, 1989).

Name. After Loughaun Lough, County Mayo.

Type section. 56/21-2: 3143.5-3205.5m below KB. See Figure D.6. 45.

Reference sections. 63/10-1: 3217.5-3277.5m below KB. See Figure D.6. 45.

Lithology. This member comprises an interbedded succession of claystones and limestones. Subordinate sandstones beds and stringers are also developed. The limestones are off white to cream, light to medium grey, light brown, mudstone, locally wackestone to packstone, micritic to cryptocrystalline, locally oolitic (for example 56/18-1, 63/4-1), locally silty or sandy, grains clear, subrounded, and well indurated. The claystones are medium dark to dark grey, greenish grey, and non- to calcareous, which grade locally to marls. Sandstones are white to light grey, very fine to fine grained, well sorted, subangular to subrounded, friable to moderately well indurated, often calcareous and locally grade to silty/sandy marls.

Wireline log character. The member exhibits a highly serrated log motif, reflecting the dominantly interbedded nature of the limestone and mudrock lithologies. The high gamma ray and low sonic velocities indicate the mudrocks, while the low gamma ray values and high sonic velocities reflect the carbonates and thin sandstones.

Upper boundary. The upper boundary is placed at a downsection lithological change from the basal claystone of the Effernan Member to the upper limestones of the Loughaun Member. On wireline log criteria, this is reflected as a sharp decrease in gamma ray values and a coincident sharp increase in sonic velocity.

Lower boundary. The lower boundary is denoted by a downward lithological change from limestones to the claystones of the Caragh Formation. This is indicated on wireline log criteria by an increase in gamma ray values and a corresponding decrease in sonic velocity.

Thickness. The member varies in thickness from 65.5m (56/22-1) to a maximum thickness of 143.5m (64/2-1), but the lower boundary is a possible unconformity in the latter well.

Biostratigraphic characterization. Dated by ostracods and dinocysts. Calcareous ostracod recovery is poor to very good. Occurring within Ostracod Zone IOJ2 (*pars*) and Palynological Subzone DM2A1 (*pars*).

Age. Early Jurassic, early Hettangian.

Depositional environment. Non-marine (freshwater to brackish water) to locally marine, inner shelf. The Loughaun Member was mainly deposited in a non-marine (freshwater to brackish) environment, denoted by the presence of large numbers of non-marine ostracods and miospores. Localised shallow water, marine incursions are envisaged by the presence of oolitic limestones.

Distribution. The member is recognisable within the Leane Formation in the Fastnet Basin. Its presence further north in the North Celtic Sea Basin is uncertain; while not recognised within the Leane Formation in well penetrations in this basin, it is possible that the member could be recognised in as yet undrilled parts of this area.

Regional correlation. The member is a lateral equivalent to the Meelagh Formation, Moanmore Member, of the Slyne Basin, the lower parts of the Blue Lias and Gill formations offshore east of Ireland (northern North Celtic Sea and South Celtic Sea basins) and onshore England, and the lower parts of the Breakish and Blue Lias formations of northwest Scotland (Cox *et al.,* 1999; Morton, 2004; Simms *et al.*, 2004).

Comparison with Eastern Canada. The Loughaun Member is age equivalent to the Argo Formation (dominantly halites) of the Jeanne d'Arc Basin, offshore east coast Canada.

Nadreegeel Member (New)

The Nadreegeel Member is defined here as an interbedded succession of limestones and claystones, of late Hettangian age, that is present in the Fastnet Basin, offshore south of Ireland. A prominent limestone unit is developed in the upper half of the member. This unit is present between the Emy and Athry members.

Sediments now referred to this member in the Fastnet Basin were previously referred to as Liassic Limestone Unit (J-5) by Murphy & Ainsworth (1991). The type well for this unit (56/21-2) proposed by these authors is used here as the type well. This unit was originally part of the Liassic Limestone (Robinson *et al.,* 1981; Ainsworth, 1989; Ainsworth *et al*., 1989 and Rutherford & Ainsworth, 1989).

Name. After Nadreegeel Lough, County Cavan.

Type section. 56/21-2: 2955-2999.5m below KB. See Figure D.6. 45.

Reference sections. 63/10-1: 3082.5-3114m below KB. See Figure D.6. 45.

Lithology. The upper half of this member is dominated by limestones, while the lower half comprises an interbedded succession of limestones, claystones and thin sandstones. The limestones are off white to cream, light to medium grey, light brown, mudstone, micritic to cryptocrystalline, locally oolitic (for example 55/30-1, 56/21-1) and well indurated. Locally these limestones are replaced by thin dolomite units. The claystones are medium to dark grey, non- to calcareous, and grade locally to marls. The thin sandstone units are white to light grey, very fine to fine grained, well sorted, subangular to subrounded, friable to moderately well indurated, and often very calcareous.

Wireline log character. The member possess highly serrated, wireline log motifs, reflecting the interbedded nature of the lithologies. The high gamma ray and low sonic velocities indicate the mudrocks, while the low gamma ray values and high sonic velocities reflect the carbonates and thin sandstones. At the top of the Nadreegeel Member a boxcar log profile is recognised reflecting a thickened limestone unit.

Upper boundary. The upper boundary is taken at a downsection lithological change from the basal claystone of the Emy Member, to the upper limestones of the Nadreegeel Member. This is reflected on wireline log criteria by a sharp decrease in gamma ray values, in association with a sharp increase in sonic velocity.

Lower boundary. The base of the unit is denoted by a downward lithological change from the lower claystones to the upper limestones of the Athry Member. This change is expressed on wireline log criteria by an abrupt decrease in gamma ray values, with a corresponding abrupt increase in sonic velocity.

Thickness. The member ranges from 28m (56/20-1) to a maximum thickness of 44.5m (56/21-2).

Biostratigraphic characterization. Dated by ostracods and dinocysts. Calcareous ostracod recovery is poor to very good. Occurring within Ostracod Zone IOJ2 (*pars*) and Palynological Subzone DM2A1 (*pars*).

Age. Early Jurassic, late Hettangian.

Depositional environment. Continental (freshwater to brackish water) to marine, inner shelf. This member was deposited in a fluctuating non-marine (freshwater/brackish) to marine, low energy, very shallow shelf environments. The freshwater or brackish conditions are denoted by the occurrence of rare non-marine ostracods, while the marine sediments are recognised by the localised occurrences of marine ostracod faunas.

Distribution. The member is recognisable within the Leane Formation in the Fastnet Basin. Its presence further north in the North Celtic Sea Basin is uncertain; while not recognised within the Leane Formation in well penetrations in this basin, it is possible that the member could be recognised in as yet undrilled parts of this basin.

Regional correlation. The Nadreegeel Member appears to be laterally equivalent to the upper part of the Emo and lower part of the Easky members, of the Meelagh Formation, in the Slyne Basin. Offshore east of Ireland (northern North Celtic Sea and South Celtic Sea basins) this member is laterally equivalent to the upper parts of the Blue Lias and Gill formations (Cox *et al.,* 1999). In northwest Scotland and onshore England this unit correlates with the lower parts of the Breakish and Blue Lias formations (Cox *et al.,* 1999; Morton, 2004; Simms *et al.*, 2004).

Comparison with Eastern Canada. The Nadreegeel Member is age equivalent to the Argo Formation (dominantly halites) of the Jeanne d'Arc Basin, offshore east coast Canada.

MEELAGH FORMATION (NEW)

The Meelagh Formation is defined here for the lower part of the Lias Group offshore west of Ireland. It comprises a cyclic continental (freshwater) to very shallow water sedimentary succession of early Late Sinemurian-Hettangian age. This unit lies between an overlying Inagh Formation and an underlying Conn Formation.

The Meelagh Formation is similar to the Leane Formation which is present in the Goban Spur, Fastnet and southern part of the North Celtic Sea basins to the south and east of Ireland. Both formations possess non-marine to very shallow marine sedimentary facies, with the sediments often comprising interbedded well indurated limestones and mudrocks. The Meelagh Formation can be differentiated from the Leane Formation by the presence of the anhydrite beds/laminae, localised reddened sediments, plus the occurrence of distinct sandstone beds. It is thought that Meelagh Formation is a more non-marine sedimentary succession compared to the Leane Formation. Although both formations have been subdivided into a number of members, each of their constituent units, could not be extended across the basins from the west of Ireland to the south and east of Ireland.

Sediments within this formation were previously referred to as the Broadford Beds (Trueblood & Morton, 1991; Trueblood, 1992; Dancer *et al*. 2005) and Broadford Beds Formation Equivalent (Scotchman & Thomas, 1995; Dancer *et al*. 1999) in the Slyne Basin. Since the work of Trueblood & Morton (1991) the stratigraphy of the Hebridean successions has been revised (for example Morton *in* Simms *et al*., 2004; Hesselbo *et al*., 1999; Hesselbo & Coe, 2008). One amendment arising from this is that the term Broadford Beds is now discontinued in favour of new name, Breakish Formation, in western Scotland. The Meelagh Formation differs from the section in onshore Skye, around Broadford (now referred to the Breakish Formation) in being non- to marginal marine, rather than fully marine in the Breakish Formation.

Eight new members are recognised, in descending stratigraphic order; Hollywood Member, Glennaun Member, Arroo Member, Lackagh Member, Easky Member, Emo Member, Mullagh Member and Moanmore Member (spelling

'MEELAGH' from first the letter of each member in ascending stratigraphic order). A well correlation of four type and reference wells for the formation and its constituent members is shown in **Figure D.6.52**. This figure shows the lateral variation between the members and the nature of the boundaries between them. The dominantly interbedded sandstone/carbonate/claystone beds of this succession can be subdivided into eight members based on their lithological, wireline and microfossil content. Definitions of the various members have been based on a number of lithological markers, including the occurrence of the more thickly developed limestones (for example in the Moanmore, Arroo and Hollywood members) or the more highly interbedded claystone and limestones sections (Mullagh, Lackagh and Glennaun members). At the same time, it is recognised that the more continental successions occur in the lower two-thirds of the formation, while the continental/shallow marine sediments are present in only the top third of the succession. At present, the members of the formation are only recognised in the Slyne Basin, though the undivided formation is recognised in the northern Porcupine Basin (for example 26/22-1A) and Erris Basin (12/13-1A), albeit in truncated, incomplete successions in these wells.

Name. After Lough Meelagh, County Roscommon.

Type section. 18/20-1: 3376.5-3861.5m below KB. See **Figure D.6. 49**.

Reference sections. 12/13-1A: 2039.5-2097m below KB. 18/25-1: 2805.5-3281m below KB. 19/11-1A: 3761-4186.5m below KB. 26/22-1A: 2200.5-2266m below KB. 27/4-1: 1145-1639m below KB. See **Figure D.6.50** and **Figure D.6.52**.

Lithology. The member mainly comprises an interbedded succession of mudrocks, limestones, sandstones. The sandstones are, however, less commonly developed within the formation. Interbedded anhydrites are also recognised within the members.

The limestones are off white, light to dark grey, light brown, olive grey, mudstone to packstone, micritic to cryptocrystalline, locally peloidal or sandy, and well indurated, which locally grade into dolomitic limestones or marls. The claystones are medium to dark grey, light greenish grey to greenish grey, light bluish grey, greyish orange, greyish brown, reddish brown to dusky red, in part red mottling, locally waxy, locally dolomitic, and non- to calcareous, and grading into siltstones. The sandstones are off white to medium grey, light brownish grey, very fine to medium grained, well sorted, subangular to subrounded, locally dolomitic, and non- to slightly calcareous, which locally grade to siltstones. Brownish grey, olive grey, cryptocrystalline, well indurated, dolomite stringers are rarely recorded. Beds and laminae of white to light grey, firm, anhydrite, are also observed.

Wireline log character. The wireline characteristics of the formation are highly variable within the Irish offshore wells due to the heterogeneous nature of the constituent lithologies. Where the anhydrites, sandstones and carbonates are developed, the wireline logs exhibit blocky profiles, with low gamma ray values and corresponding high sonic velocities. The claystones and siltstones possess slightly serrated high gamma ray values and low sonic velocities.

Upper boundary. The top of the formation is indicated by a downsection lithological change from the claystones of the Inagh Formation, Inniscarra Member, to the limestones of the Meelagh Formation, Hollywood Member. On wireline log criteria, this is indicated by an abrupt decrease in gamma ray values, coincident with a sharp increase in sonic velocity.

Lower boundary. The base of the unit is indicated by a downward lithological change from either sandstones or limestones to the mudrocks of the Conn Formation. This change is expressed on wireline log criteria by a sharp increase in gamma ray values, in association with a decrease in sonic velocity.

Subdivision. Eight new members are proposed, in descending stratigraphic order; Hollywood Member, Glennaun Member, Arroo Member, Lackagh Member, Easky Member, Emo Member, Mullagh Member and Moanmore Member.

Thickness. The formation varies in thickness from 153.5m (19/8-1) to a maximum of 509.5m (18/20-7).

Biostratigraphic characterization. Dated by non-marine ostracods and dinocysts. Microfossil resolution throughout this formation is generally poor due to the problems of drilling this rock unit. The drilling of this formation proved extremely difficult in the Slyne Basin wells (as in the Corrib Field), because of the development of well indurated limestone lithologies. In many cases ROPs were between 1 and 2m/hr which often led to very poor cuttings (milled ditch cuttings and rock flour). This had led to the poor microfaunal recovery. Where the formation could be drilled more easily (as in well 27/4-1) ostracod recovery is good to very good. The formation is characterised by Ostracod Zone IJO2 and Palynological Subzones DM2C1 to DM2A1 (*pars*).

Age. Early Jurassic, early Late Sinemurian-Hettangian.

Depositional environment. Non-marine (freshwater to brackish water) to marine, shoreface. The Meelagh Formation was mainly deposited within non-marine to marginal marine environments. It is only within the top unit (Hollywood Member) that marine ostracod faunas and dinocysts have been recovered. The occurrence of freshwater and brackish water ostracods (*Darwinula* spp., *Limnocythere* spp.), common to abundant miospores (including *Classopollis* pollen), localised reddened mudrocks and beds of anhydrite, in many of the members is suggestive of non-marine to marginal marine deposition. The *Classopollis* pollen occurs in semi-arid and arid conditions, with the plant occurring in lowland areas bordering lagoons (Vakhrameev, 1970; Sladen & Batten, 1984). The interbedded nature of the sediments (limestones, sandstones, mudrocks, anhydrite) would indicate rapidly fluctuating marginal environments.

Distribution. The formation is proven to be present in wells from the Erris, Slyne and northern Porcupine Basin. Its extent is taken to the mapped boundaries of the former two basins. It is likely to be present in the central and southern, as yet undrilled parts of the Porcupine Basin, as it is proven in the northern parts of this basin by well control.

At the northern (12/13-1A) and southern (26/22 and 26/21 blocks) limits of proven deposition of the formation, however, no member subdivisions have been made, and it is unknown at the present time whether the members that are recognisable in the Slyne Basin can be identified outside of this basin.

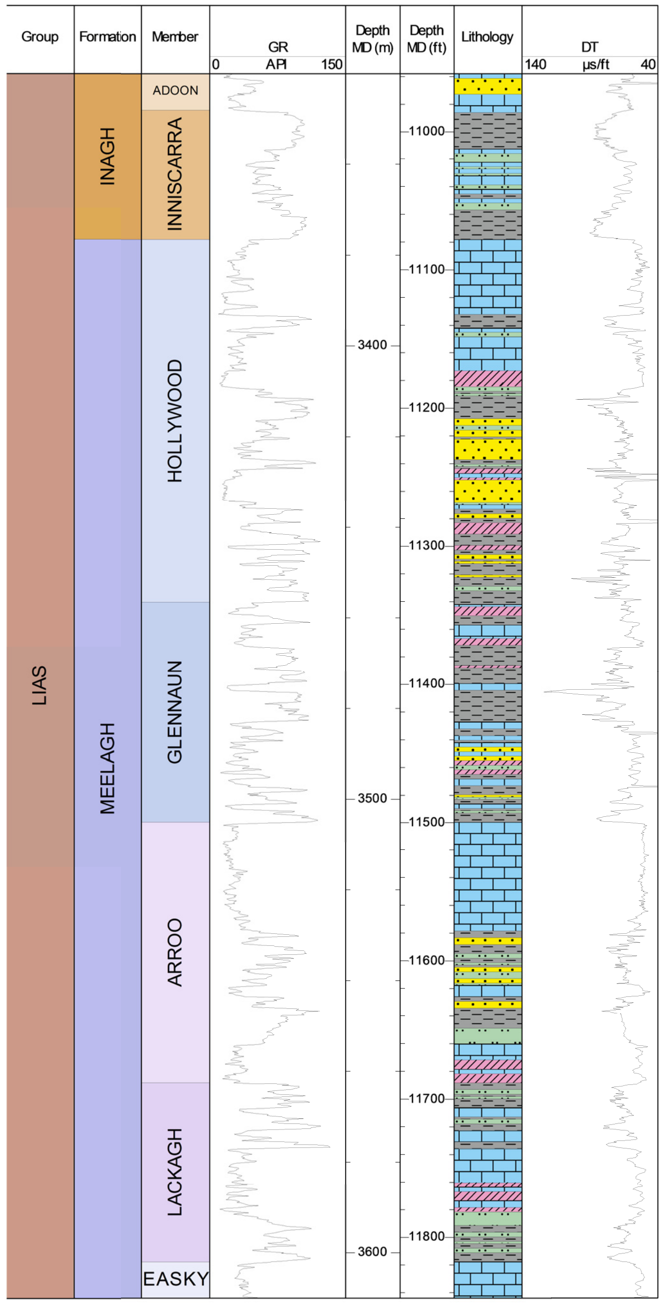
It is possible that the formation is present in the undrilled Conall and Rónán basins, on the north western flanks of the Rockall Basin, based on seismic interpretations.

Seismic expression. The Upper Sinemurian (Top Meelagh) seismic horizon is recognised in the Erris, Slyne and Porcupine basins and approximates to the top of the Meelagh Formation. In the Slyne Basin, the horizon is recognisable, for example, in the 27/4-27/5 area (see **Figure D.4.5**) and Corrib Field area, blocks 18/20-18/25 (see **Figure D.5.3**). In these areas, the seismic package below this horizon is marked by the development of high amplitude, banded seismic facies that reflects the interbedded mudrocks, limestones and sandstones of the Meelagh Formation. The seismic horizon has been interpreted in undrilled areas such as the flanks of the Porcupine Basin and the Conall and Rónán basins, on which basis extent of the formation is considered to possibly exist in these areas.

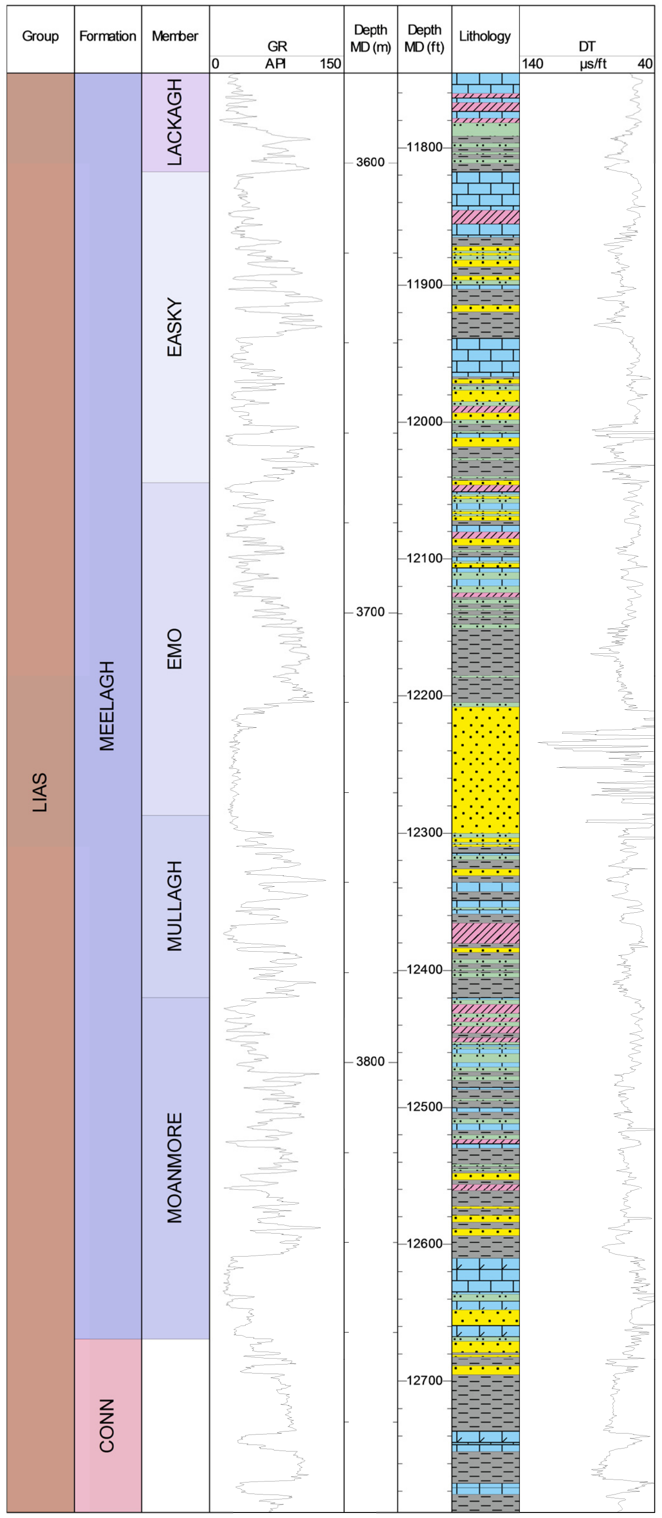
Regional correlation. The Meelagh Formation is a lateral equivalent to the Glenbeg, Currane, Leane, Blue Lias and Gill formations in basins to the south and east of Ireland (Goban Spur, Fastnet, North Celtic Sea, South Celtic Sea and Central Irish Sea basins). In the onshore and offshore basins of England, the formation equates to Blue Lias Formation and Charmouth Mudstone Formation (Shales-with-Beef and Black Ven Marl members), and in northwest Scotland to the Breakish, Blue Lias Ardnish formations, plus the lower half of the Pabay Shale Formation (see Cox *et al.,* 1999; Morton, 2004; Simms *et al*., 2004).

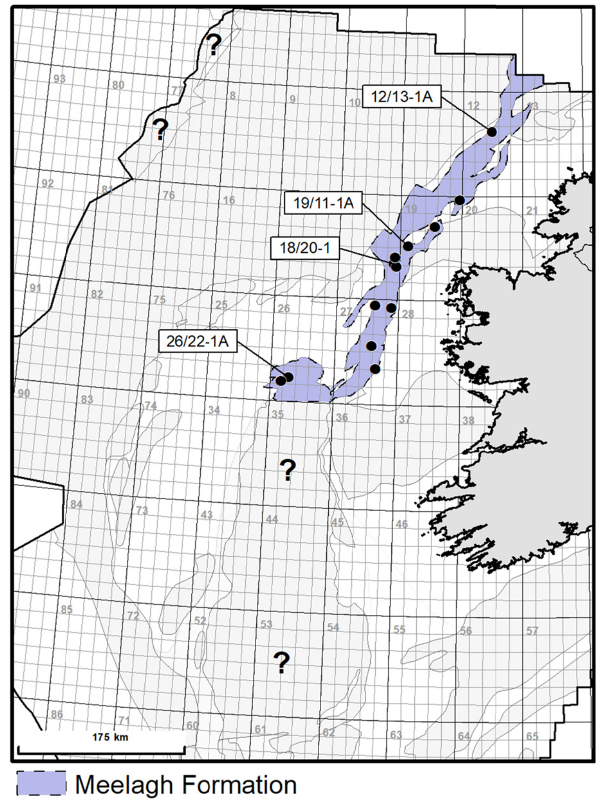
Source rock characterisation. The Meelagh Formation includes a few samples with elevated TOC contents greater than 1%, mainly in the Slyne Basin (**Appendix E**). It shows a mixed Type II/III kerogen composition, but hydrocarbon yields are low, and the source rock potential is limited.

Comparison with Eastern Canada. The Meelagh Formation is age equivalent to the Iroquois Formation (dominantly limestones and dolomites) and the Argo Formation (dominantly halites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.



18/20-1
Type well; Meelagh Formation, Arroo, Easky, Emo, Glennaun, Hollywood, Lackagh, Mullagh, Moanmore Members





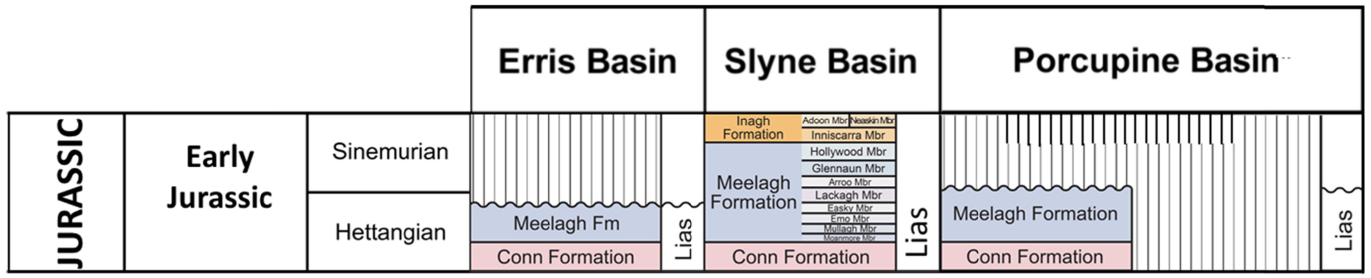


Figure D.6. 49. ***Meelagh Formation and constituent members 18/20-1 type well, with location and distribution map.***

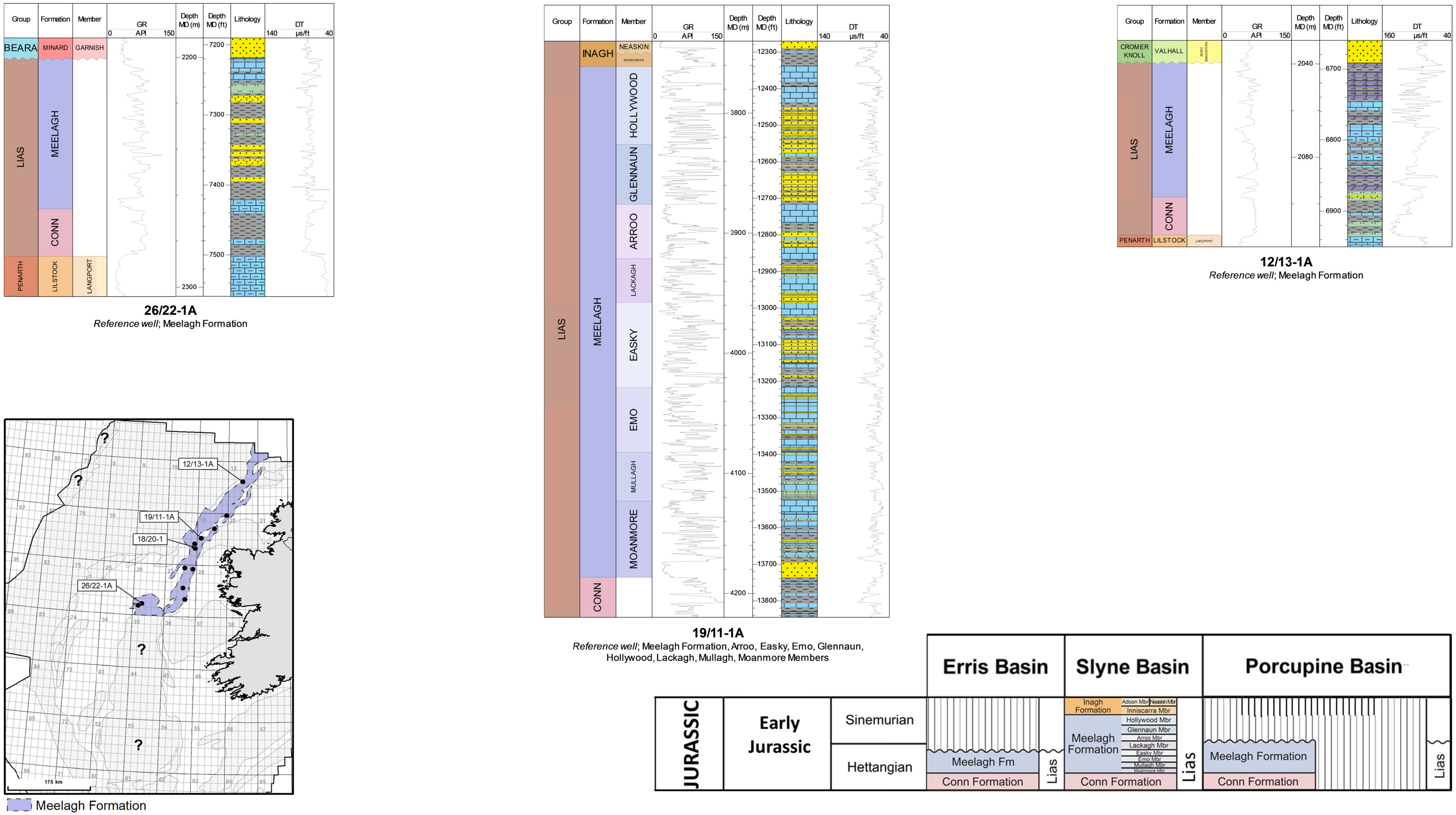


Figure D.6. 50. ***Meelagh Formation and constituent members reference wells with location and distribution map.***

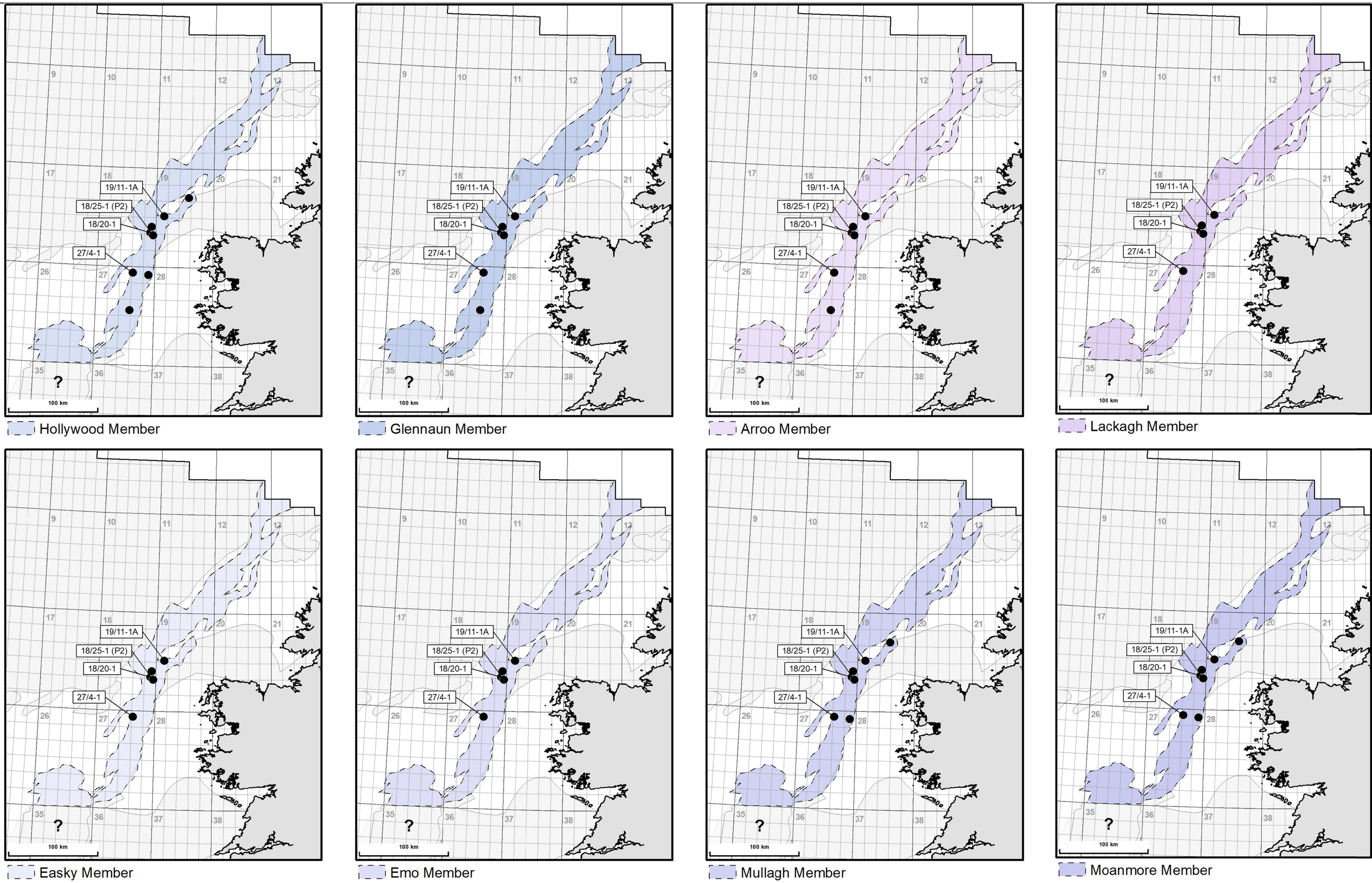


Figure D.6. 51. ***Meelagh Formation constituent members distribution maps.***

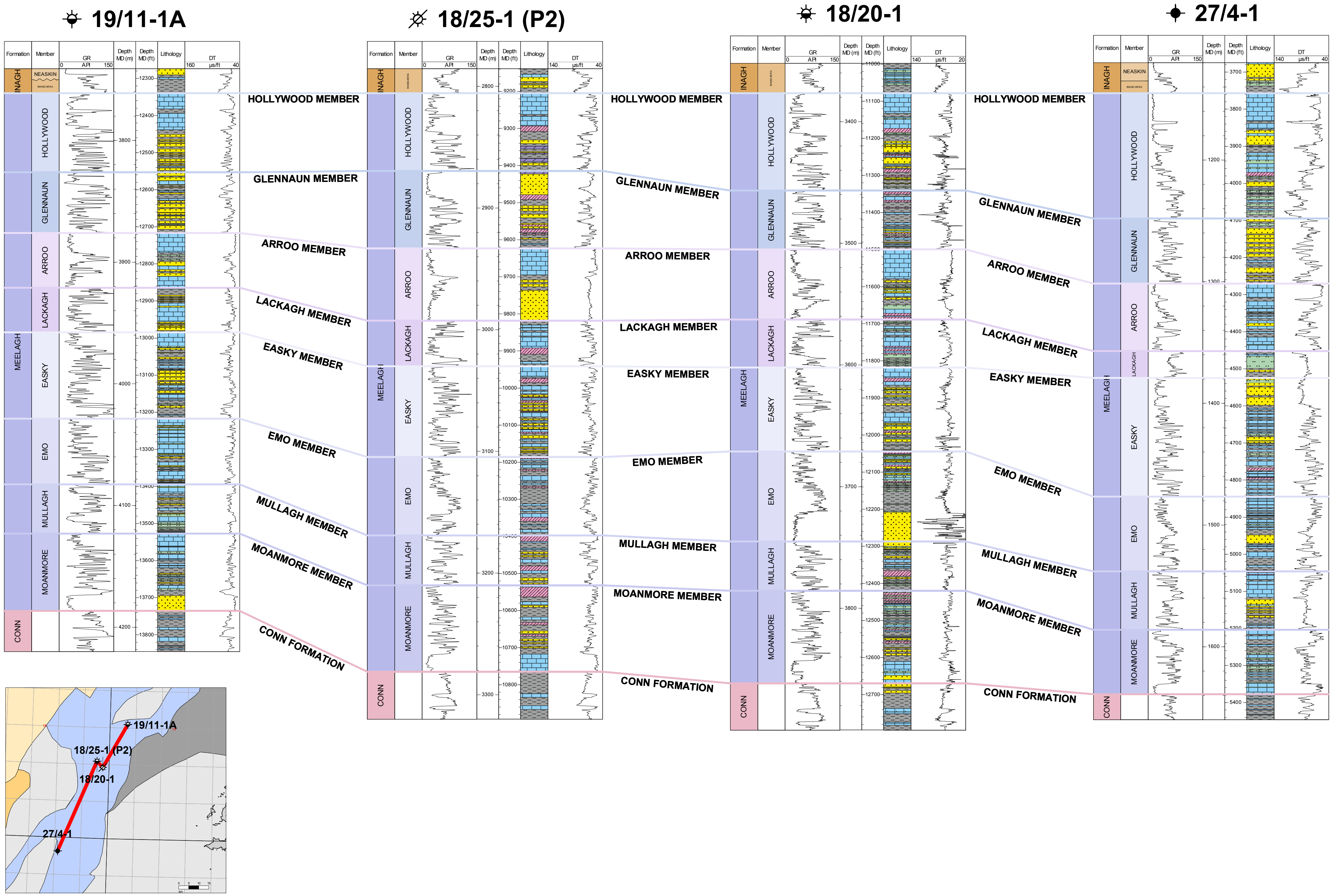


Figure D.6. 52. *Correlation of Meelagh Formation and constituent members type and reference wells.*

Arroo Member (New)

The Arroo Member is defined here as a dominantly interbedded succession of claystones and limestones, of Early Sinemurian age, which is present within the Slyne Basin, offshore west of Ireland. These rocks lie between the Glennaun and Lackagh members within the upper part of the Meelagh Formation.

Name. After Arroo Lough, County Leitrim.

Type section. 18/20-1: 3505-3562.5m below KB. See **Figure D.6. 49**.

Reference sections. 18/25-1: 2933-2992.5m below KB. 19/11-1A: 3876-3921m below KB. 27/4-1: 1301.5-1357m below KB. See **Figure D.6.50** and **Figure D.6.52**.

Lithology. The member mainly comprises an interbedded sequence of claystones and limestones. The claystone beds are mainly present between two thickened limestone units. The carbonates comprise off white, light to medium dark grey, light brown, mudstone, locally packstone, micritic to cryptocrystalline, locally peloidal, well indurated, limestones. The claystones are medium dark to dark grey, greenish grey, greyish brown, locally silty, locally dolomitic, and non- to calcareous. Sandstones are only locally present (for example 18/25-1), comprising white to medium light grey, very fine to medium grained, well sorted, subangular to subrounded, locally dolomitic, non-calcareous units, which locally grade to siltstones. Laminae of white, firm, anhydrite, are also observed.

Wireline log character. The upper and lower limestone units within this member exhibit low gamma ray values and high sonic velocities, with boxcar log profiles, while the interbedded claystone and limestones developed midway through this member possess highly serrated wireline logs profiles.

Upper boundary. The top of this unit is taken on a downsection lithological change from the lower claystones of the Glennaun Member, to the upper limestones of the Arroo Member. This is indicated on wireline log criteria by a sharp decrease in gamma ray values, in association with a sharp increase in sonic velocity.

Lower boundary. The base of this member is placed at the downsection change from the lower limestones to the upper claystones of the Lackagh Member. On wireline log criteria, this is reflected by an abrupt increase in gamma ray values, with a coincident decrease in sonic velocity.

Thickness. The member varies in thickness from 45m (19/11-1A) to 59.5m (18/25-1 (P2)).

Biostratigraphic characterization. Dating is by non-marine ostracods and miospores. Microfaunal faunal recovery is very sporadic. Occurring within Ostracod Zone IJO2 (*pars*) and Palynological Subzone DM2A2 (pars).

Age. Early Jurassic, Early Sinemurian.

Depositional environment. Non-marine to ?marginal marine, freshwater to ?brackish waters. This member was deposited in non-marine to possibly marginal marine environments. The presence of freshwater ostracods (for example 27/4-1), miospores and localised beds of anhydrite, in association with an absence of marine faunal indicators, would suggest a continental environment.

Distribution. The distribution of the component members of the Meelagh Formation is considered to be similar to that of the parent formation (see above for discussion). At the northern (12/13-1A) and southern (26/22 and 26/21 blocks) limits of proven deposition of the formation, however, no member subdivisions have been made, and it is unknown at the present time whether the members that are recognisable in the Slyne Basin can be identified outside of this basin.

Regional correlation. The member appears to be an equivalent to the upper part of the Currane Formation (Roosky Member) and the lower part of the Glenbeg Formation in the basins to the south and east of Ireland (Fastnet, North Celtic Sea, South Celtic Sea and Central Irish Sea basins). In the English onshore and offshore basins this member is laterally equivalent to the uppermost part of the Blue Lias Formation and the lower part of the Shales-with-Beef Member, Charmouth Mudstone Formation (Cox *et al.,* 1999). In northwest Scotland the member is laterally equivalent to the uppermost Breakish and Blue Lias formations, and part of the Ardnish Formation (see Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The Arroo Member is age equivalent to the lower sedimentary succession of the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Easky Member (New)

The Easky Member is defined here as a dominantly interbedded succession of mudrocks and limestones, of latest Hettangian age, which is present within the Slyne Basin, offshore west of Ireland. The unit occurs between the Lackagh and Emo members within the mid part of the Meelagh Formation.

Name. After Easky Lough, County Sligo.

Type section. 18/20-1: 3602-3671m below KB. See **Figure D.6. 49**.

Reference sections. 18/25-1: 3030-3104.5m below KB. 19/11-1A: 3957.5-4028.5m below KB. 27/4-1: 1379-1476.5m below KB. See **Figure D.6.50** and **Figure D.6.52.**

Lithology. The member mainly comprises an interbedded sequence of mudrocks and limestones. Rarer sandstone units (for example 27/4-1) and anhydrite laminae/beds are also present. The claystones are medium to dark grey, greenish grey, locally dolomitic, non- to calcareous, and grading into siltstones. The limestones are light to medium dark grey, light brown, olive grey, mudstone, cryptocrystalline, well indurated, which locally grade into dolomitic limestones. The locally developed sandstones are off white to medium grey, light brownish grey, very fine to fine grained, well sorted, subangular to subrounded, and non- to slightly calcareous. Beds of white to light grey, firm, anhydrite, are also present.

Wireline log character. The member possess highly serrated, wireline log motifs, reflecting the interbedded nature of the lithologies. The high gamma ray and low sonic velocities indicate the mudrocks, while the low gamma ray values and high sonic velocities reflect anhydrites, carbonates and sandstones. At the top of the Easky Member a boxcar log profile is recognised reflecting a thickened limestone unit.

Upper boundary. The top of the unit is taken at a downward lithological change from the lower claystones of the Lackagh Member to the upper limestones of the Easky Member. This is reflected on wireline log criteria by a sharp decrease in gamma ray values, in association with a sharp increase in sonic velocity.

Lower boundary. The base of this unit is taken at a downward lithological change from the lower claystones to the upper limestones of the Emo Member. This change is expressed on wireline log criteria by the sharp decrease in gamma ray values, with a corresponding increase in sonic velocity.

Thickness. The member varies in thickness from 69m (18/20-1) to 97.5m (27/4-1).

Biostratigraphic characterization. Dating is by non-marine ostracods and miospores. Microfaunal faunal recovery is very sporadic. Occurring within Ostracod Zone IJO2 (*pars*) and Palynological Subzone DM2A1 (*pars*).

Age. Early Jurassic, latest Hettangian.

Depositional environment. Non-marine to ?marginal marine (freshwater to ?brackish water). This member was deposited in non-marine to possibly marginal marine environments. The occurrence of freshwater ostracods (for example in 27/4-1), miospores and localised beds of anhydrite, in association with an absence of marine faunal indicators, would suggest a continental environment.

Distribution. The distribution of the component members of the Meelagh Formation is considered to be similar to that of the parent formation (see above for discussion). At the northern (12/13-1A) and southern (26/22 and 26/21 blocks) limits of proven deposition of the formation, however, no member subdivisions have been made, and it is unknown at the present time whether the members that are recognisable in the Slyne Basin can be identified outside of this basin.

Regional correlation. This member is the equivalent to the upper part of the Nadreegeel and the Emy members of the Leane Formation in the Fastnet Basin. It is an age equivalent to the upper sections of the undivided Leanne, Blue Lias and Gill formations to the south and east of Ireland (Goban Spur, North Celtic Sea, South Celtic Sea and Central Irish Sea basins). In the UK's onshore and offshore basins, the Easky Member equates to the upper sedimentary successions of the Blue Lias and Breakish formations (see Cox *et al.,* 1999; Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The Easky Member is envisaged to be age equivalent to the top sediments of the Argo Formation (dominantly halites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Emo Member (New)

The Emo Member is defined here as a dominantly interbedded succession of mudrocks and limestones, of mid. Hettangian age, which is present within the Slyne Basin, offshore west of Ireland. The Emo Member occurs between the Easky and Mullagh members within the lower half of the Meelagh Formation.

Name. After Emo Lake, County Laois.

Type section. 18/20-1: 3671-3745m below KB. See **Figure D.6. 49**.

Reference sections. 18/25-1: 3104.5-3169m below KB. 19/11-1A: 4028.5-4082.5m below KB. 27/4-1: 1476.5-1538m below KB. See **Figure D.6.50** and **Figure D.6.52.**

Lithology. The member mainly comprises an interbedded sequence of mudrocks and limestones. Rarer sandstone units (for example 18/20-1, 18/20-5) and anhydrite laminae/beds are also present. The claystones are medium to dark grey, reddish brown to dusky red, locally dolomitic, non- to calcareous, and grading into siltstones. The limestones are light to medium dark grey, olive grey, mudstone, cryptocrystalline, well indurated, which locally grade into marls. Locally developed sandstones are off white, very fine to fine grained, well sorted, subangular to subrounded, and non- to slightly calcareous. Beds of white to very light grey, firm, anhydrite, are also present.

Wireline log character. This unit possess highly serrated, wireline log motifs, reflecting the interbedded nature of the mudrocks, anhydrites, carbonates and sandstones. In general, the upper half of the member possess a serrated wireline log profile, with lower gamma ray values and higher sonic velocities reflecting the more carbonate dominated sections. The lower half of the member is generally more mudrock dominated, reflecting in a more highly serrated log motif, often with increased gamma ray values and decreased, serrated sonic velocities.

Upper boundary. The top of this member is placed at a downsection lithological change from the lower claystones of the Easky Member to the upper limestones of the Emo Member. This change is indicated on wireline log criteria by a sharp decrease in gamma ray values, in association with an increase in sonic velocity.

Lower boundary. The base of this member is indicated at a downward lithological change from the lower mudstones or sandstones, to the upper limestones of the Mullagh Member. This change is expressed on wireline log criteria by a sharp decrease in gamma ray values, with a corresponding increase in sonic velocity.

Thickness. The member ranges from 54m (19/11-1A) to a maximum thickness of 74m (18/20-1).

Biostratigraphic characterization. Dating is solely by non-marine ostracods and miospores. Occurring within Ostracod Zone IJO2 (*pars*), Palynological Subzone DM2A1 (*pars*).

Age. Early Jurassic, mid Hettangian.

Depositional environment. Non-marine to ?marginal marine (freshwater to ?brackish marine). This member was deposited in non-marine to possibly marginal marine environments. The occurrence of miospores, localised beds of anhydrite, and common reddened mudrocks, in association with an absence of marine faunal indicators, would suggest a continental environment.

Distribution. The distribution of the component members of the Meelagh Formation is considered to be similar to that of the parent formation (see above for discussion). At the northern (12/13-1A) and southern (26/22 and 26/21 blocks) limits of proven deposition of the formation, however, no member subdivisions have been made, and it is unknown at the present time whether the members that are recognisable in the Slyne Basin can be identified outside of this basin.

Regional correlation. The member is equivalent in age to the Athry and the lower part of the Nadreegeel members of the Leane Formation in the Fastnet Basin. It is an age equivalent to the middle sections of the undivided Leanne, Blue Lias and Gill formations to the south and east of Ireland (North Celtic Sea, South Celtic Sea and Central Irish Sea basins). The Emo Member is a laterally equivalent to the middle successions of the Blue Lias and Breakish formations in the UK onshore and offshore basins (see Cox *et al.,* 1999; Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The Emo Member is age equivalent to the upper sediments of the Argo Formation (dominantly halites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Glennaun Member (New)

The Glennaun Member is defined here as a dominantly interbedded succession of mudrocks and sandstones, of Early Sinemurian age, which is present within the Slyne Basin, offshore west of Ireland. This unit occurs between the Hollywood and Arroo members within the upper part of the Meelagh Formation.

Name. After Glennaun Lough, County Galway.

Type section. 18/20-1: 3456.5-3505m below KB. See **Figure D.6. 49**.

Reference sections. 18/25-1: 2869.5-2933m below KB. 19/11-1A: 3826-3876m below KB. 27/4-1: 1248-1301.5m below KB. See **Figure D.6.50** and **Figure D.6.52.**

Lithology. The member comprises an interbedded sequence of mudrocks and sandstones. Locally developed peloidal limestones and anhydrite are also present. The mudrocks are light to medium dark grey, light greenish grey, with locally orangey red mottling, locally waxy, locally dolomitic, and non- to calcareous. The sandstones are white to light grey, light brownish grey, very fine to medium grained, well sorted, subangular to subrounded, and non- to slightly calcareous. The rarer limestone beds are off white to dark grey, mudstone to packstone, micritic to cryptocrystalline, locally peloidal, well indurated, and locally grade into marls. Beds of white to buff, firm, anhydrite, are also present.

Wireline log character. This unit displays highly serrated, wireline log motifs, reflecting the interbedded nature of the mudrocks, anhydrites, carbonates and sandstones.

Upper boundary. The top of the unit is indicated by a downsection lithological change from the lower claystones of the Hollywood Member, to the upper limestones or sandstones of the Glennaun Member. This is denoted on wireline log criteria by a sharp decrease in gamma ray values, coincident with a sharp increase in sonic velocity.

Lower boundary. The base of this unit is indicated by a downsection lithological change from claystones to the upper limestones of the Arroo Member. This change is expressed on wireline log criteria by an abrupt decrease in gamma ray values, with a corresponding abrupt increase in sonic velocity.

Thickness. The member varies in thickness from 48.5m (18/20-1) to 63.5m (18/25-1 (P2)).

Biostratigraphic characterization. Dating is by non-marine ostracods and miospores. Microfaunal faunal recovery is highly sporadic. Occurring within Ostracod Zone IJO2 (*pars*) and Palynological Subzone DM2A2 (*pars*).

Age. Early Jurassic, Early Sinemurian.

Depositional environment. Non-marine to ?marginal marine (freshwater to ?brackish marine). This member was deposited in non-marine to possibly marginal marine environments. The presence of freshwater ostracods (for example 18/25-1), miospores and localised beds of anhydrite, in association with an absence of marine faunal indicators, would suggest a continental environment.

Distribution. The distribution of the component members of the Meelagh Formation is considered to be similar to that of the parent formation (see above for discussion). At the northern (12/13-1A) and southern (26/22 and 26/21 blocks) limits of proven deposition of the formation, however, no member subdivisions have been made, and it is unknown at the present time whether the members that are recognisable in the Slyne Basin can be identified outside of this basin.

Regional correlation. The Glennaun Member is laterally equivalent to the lower sediments of the Glenbeg Formation in the Fastnet, North Celtic Sea and South Celtic Sea basins. In the UK's onshore and offshore basins, the member appears to equate to the Charmouth Mudstone Formation, Shales-with-Beef Member, and the upper part of the Ardnish Formation and the lower part of the Pabay Shale Formation, Hallaig Member (Cox *et al.,* 1999; Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The Glennaun Member is age equivalent to the lower sedimentary succession of the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Hollywood Member (New)

The Hollywood Member is defined here as a heterolithic succession of mudrocks, dolomites, limestones and sandstones, of early Late Sinemurian age, which occurs in the Slyne Basin, offshore west of Ireland. The Hollywood Member is the upper unit of the Meelagh Formation and lies between an overlying Inagh Formation, Inniscarra Member and an underlying Glennaun Member.

The upper part of the member is often developed as a limestone unit. In the Slyne Basin wells such as 27/4-1, this limestone was termed the "Bandon Unit" by Serica Energy.

Name. After Hollywood Lake, County Monaghan.

Type section. 18/20-1: 3376.5-3456.5m below KB. See **Figure D.6. 49**.

Reference sections. 18/25-1: 2805.5-2869.5m below KB. 19/11-1A: 3761-3826m below KB. 27/4-1: 1145-1248m below KB. See **Figure D.6.50** and **Figure D.6.52**.

Lithology. The member comprises an interbedded sequence of claystones, siltstones, dolomites, limestones and sandstones. The claystones and siltstones are light to medium dark grey, light greenish grey, reddish brown to reddish purple, locally waxy, locally dolomitic, and non- to calcareous. The sandstones are white to light grey, very fine to medium grained, well sorted, subangular to subrounded, and non- to calcareous. The limestone beds are off white, light to medium dark grey, olive grey, locally mottled, mudstone to packstone, micritic to cryptocrystalline, locally sandy, locally peloidal, well indurated, and locally grade into calcareous sandstones. Brownish grey, olive grey, cryptocrystalline, well indurated, dolomite stringers are rare. Beds and laminae of anhydrite, white to very pale orange, and firm, are also present.

Wireline log character. This unit displays a highly serrated wireline log profile, reflecting the interbedded nature of the sandstone, mudrock and limestone lithologies. At the top of the Hollywood Member the thickened limestone unit possesses low gamma ray values and high sonic velocities, exhibiting a distinct boxcar wireline log motif.

Upper boundary. The top of the member is indicated by a downsection lithological change from the claystones of the Inagh Formation, Inniscarra Member, to the upper limestones of the Meelagh Formation, Hollywood Member. This is expressed on wireline log criteria as an abrupt downward decrease in gamma ray values, associated with a sharp increase in sonic velocity.

Lower boundary. The base of this member is indicated by a downsection lithological change from the lower claystones to the upper limestones or sandstones of the Glennaun Member. On wireline log criteria, this is indicated by a sharp decrease in gamma ray values and a corresponding sharp increase in sonic velocity.

Thickness. The member varies in thickness from 53.5m (27/13-1A) to 103m (27/4-1).

Biostratigraphic characterization. Dating is by non-marine ostracods and miospores. Microfaunal faunal recovery is very sporadic. Occurring within Ostracod Zone IJO2 (*pars*) and Palynological Subzones DM2A2 (pars) to DM2B.

Age. Early Jurassic, early Late Sinemurian.

Depositional environment. Non-marine to marginal marine (freshwater to ?brackish waters) to marine, inner shoreface. This Hollywood Member was deposited in an fluctuating non-marine to inner shelf environment. The presence of freshwater and brackish water ostracods (for example 27/4-1), miospores and localised beds of anhydrite, is suggestive of a continental environment, while the occurrence of marine ostracods and dinocysts would indicate a shallow marine, inner shelf, environment.

Distribution. The distribution of the component members of the Meelagh Formation is considered to be similar to that of the parent formation (see above for discussion). At the northern (12/13-1A) and southern (26/22 and 26/21 blocks) limits of proven deposition of the formation, however, no member subdivisions have been made, and it is unknown at the present time whether the members that are recognisable in the Slyne Basin can be identified outside of this basin.

Regional correlation. The member is equivalent to the middle sediments of the Glenbeg Formation within the Fastnet, North Celtic Sea and South Celtic Sea basins. The Hollywood Member appears to equate to the uppermost part of the Shales-with-Beef Member and the lower part of the Black Ven Marl Member, Charmouth Mudstone Formation, in the onshore and offshore basins of England (Cox *et al.,* 1999). In northwest Scotland this member appears to be laterally equivalent to the lower part of the Pabay Shale Formation (parts of the Hallaig Sandstone and Torosay Sandstone members) (Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The Hollywood Member is age equivalent to the upper part of the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Lackagh Member (New)

The Lackagh Member is defined here as a dominantly interbedded succession of mudrocks and limestones, of earliest Sinemurian-latest Hettangian age, which is present within the Slyne Basin, offshore west of Ireland. This member occurs between the Arroo and Easky members within the mid part of the Meelagh Formation.

Name. After Lackagh Lough, County Leitrim.

Type section. 18/20-1: 3562.5-3602m below KB. See **Figure D.6. 49**.

Reference sections. 18/25-1: 2992.5-3030m below KB. 19/11-1A: 3921-3957.5m below KB. 27/4-1: 1357-1379m below KB. See **Figure D.6.50** and **Figure D.6.52.**

Lithology. The member mainly comprises an interbedded sequence of mudrocks and limestones. Rare sandstones and anhydrite are also present. The claystones are medium dark grey, brown, light greenish grey, locally silty, with local anhydrite streaks, non- to calcareous, and grading into siltstones. The limestones are light to medium dark grey, light brown, mudstone to packstone, micritic to cryptocrystalline, locally peloidal, well indurated, and locally grade into dolomitic limestones. The minor sandstones are off white to medium grey, very fine to fine grained, well sorted, subangular to subrounded, and non- to slightly calcareous. Beds of white to buff, firm, anhydrite, are also recognised.

Wireline log character. This member exhibits a distinct wireline log profile, with a bow shaped highly serrated log motif. Carbonates and thin anhydrites are present in the centre, while mainly mudstones occur at the top and bottom of the member.

Upper boundary. The top of the unit is taken at the downward lithological change from the lower limestones of the Arroo Member to the upper mudstones of the Lackagh Member. This is indicated on wireline log criteria, by a sharp increase in gamma ray values, coinciding with a sharp decrease in sonic velocity.

Lower boundary. The base of the member is placed at the downward lithological change from the lower mudstones to the upper carbonates of the Esky Member. This is reflected on wireline log criteria by an abrupt decrease in gamma ray values, with a coincident sharp increase in sonic velocity.

Thickness. The member ranges from 22m (27/4-1) to a maximum of 47.5m (18/20-7).

Biostratigraphic characterization. Dating is solely by non-marine ostracods and miospores. Occurring within Ostracod Zone IJO2 (*pars*) and Palynological Subzone DM2B.

Age. Early Jurassic, earliest Sinemurian-latest Hettangian.

Depositional environment. Non-marine to ?marginal marine (freshwater to ?brackish waters). This member was deposited in non-marine to possibly marginal marine environments. The presence of miospores and localised beds of anhydrite, in association with an absence of marine faunal indicators, would suggest a continental environment.

Distribution. The distribution of the component members of the Meelagh Formation is considered to be similar to that of the parent formation (see above for discussion). At the northern (12/13-1A) and southern (26/22 and 26/21 blocks) limits of proven deposition of the formation, however, no member subdivisions have been made, and it is unknown at the present time whether the members that are recognisable in the Slyne Basin can be identified outside of this basin.

Regional correlation. This member appears to be the age equivalent to Corfad and Uragh members of the Currane Formation in the Fastnet, North Celtic Sea, South Celtic Sea and Central Irish Sea basins, and the upper sedimentary successions of the Blue Lias and Breakish formations of the UK's onshore and offshore basins (see Cox *et al.,* 1999; Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The Lackagh Member is age equivalent to the lower part of the Iroquois Formation (dominantly limestones and dolomites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Moanmore Member (New)

The Moanmore Member is defined here as a dominantly interbedded succession of mudrocks and limestones, of early Hettangian age, which is present within the Slyne Basin, offshore west of Ireland. The unit is the basal unit of the Meelagh Formation and lies between the Meelagh Formation, Mullagh Member and the Conn Formation.

Name. After Moanmore Lough, County Clare.

Type section. 18/20-1: 3785.5-3861.5m below KB. See **Figure D.6. 49**.

Reference sections. 18/25-1: 3210-3281m below KB. 19/11-1A: 4123-4186.5m below KB. 27/4-1: 1586-1639m below KB. See **Figure D.6.50** and **Figure D.6.52.**

Lithology. The member mainly comprises an interbedded sequence of claystones and limestones. The claystone beds are sandwiched between two thickened limestone units. The carbonates comprise off white, light to medium dark grey, greyish brown, mudstone, cryptocrystalline, well indurated, limestones, which often grade to dolomitic limestones. The claystones are light to medium grey, locally light greenish grey, pale red, greyish red to reddish brown, locally silty, locally dolomitic, and non- to calcareous. Sandstones are rare, and comprise white to medium light grey, very fine to fine grained, well sorted, subangular to subrounded, locally dolomitic, non-calcareous units. Beds of white to light grey, firm, anhydrite, are also present.

Wireline log character. The thickened upper and lower units within this member exhibit low gamma ray values and high sonic velocities, with boxcar wireline log motifs, reflecting the interbedded limestone, sandstone and anhydrite beds, while the interbedded claystone and limestones developed midway through this member possess highly serrated wireline logs profiles.

Upper boundary. The top of the unit is indicated by a downsection lithological change from the lower claystones of the Mullagh Member, to the upper limestones or anhydrites of the Moanmore Member. This is denoted on wireline log criteria by a sharp decrease in gamma ray values, in association with coincident increase in sonic velocity.

Lower boundary. The base of the unit is indicated by a downsection lithological change from limestones or sandstones, to the claystones of the Conn Formation. This change is expressed on wireline log criteria as an abrupt increase in gamma ray values and a coincident decrease in sonic velocity.

Thickness. The member varies in thickness from 44m (27/5-1) to a maximum of 76m (18/20-1).

Biostratigraphic characterization. Dating is solely by miospores. Occurring within Palynological Subzone DM2A1 (*pars*).

Age. Early Jurassic, early Hettangian.

Depositional environment. Non-marine to ?marginal marine (freshwater to ?brackish waters). The Moanmore Member was deposited in non-marine to possibly marginal marine environments. The presence of miospores, beds of anhydrite, and locally reddened sediments, in association with an absence of marine faunal indicators, would suggest a continental environment.

Distribution. The distribution of the component members of the Meelagh Formation is considered to be similar to that of the parent formation (see above for discussion). At the northern (12/13-1A) and southern (26/22 and 26/21 blocks) limits of proven deposition of the formation, however, no member subdivisions have been made, and it is unknown at the present time whether the members that are recognisable in the Slyne Basin can be identified outside of this basin.

Regional correlation. The member is a lateral equivalent to the Loughbaun Member of the Leane Formation in the Fastnet Basin. It is an age equivalent to the lower intervals of the undivided Leanne, Blue Lias and Gill formations to the south and east of Ireland (North Celtic Sea, South Celtic Sea and Central Irish Sea basins). In the UK's onshore and offshore basins, the Moanmore Member equates to the lower sedimentary successions of the Blue Lias and Breakish formations (Cox *et al.,* 1999; Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The Moanmore Member is age equivalent to the lower part of the Argo Formation (dominantly halites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Mullagh Member (New)

The Mullagh Member is defined here as a dominantly interbedded succession of mudrocks, limestones and anhydrites, of mid Hettangian age, which is present within the Slyne Basin, offshore west of Ireland. This member occurs between the Emo and Moanmore members within the lower half of the Meelagh Formation.

Name. After Mullagh Lough, County Cavan.

Type section. 18/20-1: 3745-3785.5m below KB. See **Figure D.6. 49**.

Reference sections. 18/25-1: 3169-3210m below KB. 19/11-1A: 4082.5-4123m below KB. 27/4-1: 1538-1586m below KB. See **Figure D.6.50** and **Figure D.6.52.**

Lithology. The member is dominated by an interbedded succession of mudrocks, limestones and anhydrites. Minor sandstone beds are also present. The claystones are medium to dark grey, locally light greenish grey, light bluish grey, greyish orange, locally dolomitic, non- to calcareous, and grading into siltstones. The limestones are light to medium light grey, mudstone to locally packstone, rarely silty or sandy, micritic to cryptocrystalline, well indurated, and locally grade into dolomitic limestones. Minor sandstones are light brownish grey, very fine to fine grained, well sorted, subangular to subrounded, and non- to slightly calcareous. Beds and laminae of white to buff, firm, anhydrite, are also present.

Wireline log character. This member displays a highly serrated wireline log profile, reflecting the interbedded nature of the sandstone, claystone, carbonate and anhydritic lithologies. Two distinct dominantly mudrock units (high gamma ray values and low sonic velocities), plus two distinct limestone units (low gamma ray values and high sonic velocities), are recognised within this member.

Upper boundary. The top of this unit is placed at a downward lithological change from the lower mudrocks or sandstones of the Emo Member, to the upper limestones of the Mullagh Member. On wireline log criteria, this change is denoted by a sharp decrease in gamma ray values, with a corresponding increase in sonic velocity.

Lower boundary. The base of the member is indicated by a downsection lithological change from claystones to the upper limestones or anhydrites of the Mullagh Member. This is reflected on wireline log criteria by a sharp decrease in gamma ray values, in association with an increase in sonic velocity.

Thickness. The member varies in thickness from 40.5m (18/20-1) to 48.5m (18/20-7).

Biostratigraphic characterization. Dating is solely by miospores. Occurring within Palynological Subzone DM2A1 (*pars*).

Age. Early Jurassic, mid. Hettangian.

Depositional environment. Non-marine to ?marginal marine (freshwater to ?brackish water). This member was deposited in non-marine to possibly marginal marine environments. The occurrence of miospores, plus localised beds of anhydrite, in association with an absence of marine faunal indicators, would suggest a continental environment.

Distribution. The distribution of the component members of the Meelagh Formation is considered to be similar to that of the parent formation (see above for discussion). At the northern (12/13-1A) and southern (26/22 and 26/21 blocks) limits of proven deposition of the formation, however, no member subdivisions have been made, and it is unknown at the present time whether the members that are recognisable in the Slyne Basin can be identified outside of this basin.

Regional correlation. The Mullagh Member is laterally equivalent to the Effernan Member of the Leane Formation in the

Fastnet Basin. It is an age equivalent to the lower intervals of the undivided Leanne, Blue Lias and Gill formations to the south and east of Ireland (North Celtic Sea, South Celtic Sea and Central Irish Sea basins). In the UK's onshore and offshore basins, this member is a lateral equivalent to the lower parts of the Blue Lias and Breakish formations (Cox *et al.,* 1999; Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The Mullagh Member is age equivalent to the lower part of the Argo Formation (dominantly halites) of the Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

PABAY SHALE FORMATION

The Pabay Shale was first described, as the Pabba Shales, by Woodward (1897), from the Isle of Skye, western Scotland. The unit was later redefined, as the Pabay Shale Formation, by Hesselbo *et al*. (1998), and its stratigraphical range extended from the Early Sinemurian (basal Semicostatum Zone) to Late Pliensbachian (intra Margaritatus Zone). The formation is well developed in the Upper Glen-1 well, drilled in the northern part of the Isle of Skye (see **Figure D.6.16** here, and also figure 23 in Hesselbo *et al*., 1998). As redefined by the latter authors, the formation included several sandstone members, including the Suisnish Sandstone Member. Morton (1999) separated out the lower part of the Pabay Shale Formation as described by Hesselbo *et al*. (1998) as the new Ardnish Formation (which was also described by Morton, in Simms *et al*., 2004), however, Hesselbo & Coe (2008) grouped this back with the Pabay Shale Formation.

According to the BGS Lexicon the type section is the Isle of Pabay, Inner Hebrides, Scotland (Morton & Hudson, 1995), although the Isle of Skye section at Boreraig had been previously proposed as the type section by Morton (in Simms *et al*., 2004).

The Pabay Shale Formation name is applied to western offshore Ireland basins following the proposals of previous authors (such as Trueblood & Morton, 1991, as "Pabba Shale") to extend western Scotland, Hebridean lithostratigraphic nomenclature into western offshore Ireland area, for example the Slyne and Erris basins. This recommendation has been followed by subsequent workers in the area, for example, Scotchman & Thomas (1995) and Chapman *et al*. (1999).

In the current study, this usage has been extended to the whole of offshore Ireland, to include basins to the south and eastern offshore Ireland, namely the Goban Spur, Fastnet, South Celtic Sea and North Celtic Sea basins. This approach was preferred to the alternative of extending the Charmouth Mudstone Formation name from southern England (following standard BGS nomenclature, Cox *et al*., 1999) into eastern offshore Ireland.

It is also considered likely as a result of the present study that the formation extends also into the Porcupine Basin, and maybe also the Conall and Rónán basins, though the formation has not yet been penetrated in any wells in these basins.

As defined in offshore Ireland, the formation ranges from latest Sinemurian (Raricostatum Zone equivalent) to latest Pliensbachian in age. The extension of the upper range limit in Ireland to the top of the Pliensbachian is primarily due to the lack of the Scalpay Sandstone Formation in offshore Ireland, a sandstone formation which overlies the Pabay Shale Formation, in the uppermost Pliensbachian, in northwest Scotland.

Argillaceous dominated marine sediments in Ireland that correlate with the mid part of the Pabay Shale Formation in Scotland (i.e. early Late Sinemurian), are assigned in offshore Ireland to new formations, i.e. the Inagh Formation in the western Irish basins and the Glenbeg Formation (upper part) in eastern offshore Ireland basins. In addition, the lowermost part of the Pabay Shale Formation in western Scotland, of earliest Sinemurian to early Late Sinemurian age, is developed in a different facies in western offshore Ireland basins, which is separated as the marginal marine Meelagh Formation (formerly known in this area as the "Broadford Beds", see above for discussion).

The Pabay Shale Formation is subdivided into four members in the Slyne Basin. These comprise, in descending stratigraphic order; Allua Member, Barnahallia Member, Ardra Member and Poulnamuck Member (spelling 'PABA' from first the letter of each member in ascending stratigraphic order). Distributions of these members are shown in **Figure D.6.54**. This formation has not been subdivided into members in those wells located to the east and south of Ireland (Goban Spur, Fastnet, South Celtic Sea and North Celtic Sea basins), although sequence subdivisions can be recognised in all areas. Should the presence of the formation be proven in the Porcupine Basin and Erris Basin, it is probable that the member subdivisions that are defined in the Slyne Basin will be recognised in these other basins also.

Reference sections in offshore Ireland. 18/20-1: 2868.5-3301m below KB. 19/11-1A: 3508-3723.5m below KB. 27/13-1A: 2176-2519m below KB. 56/21-1: 1938.5-2144m below KB. See **Figure D.6. 53**.

Lithology. This formation is dominantly a mudrock (claystone/siltstone) succession. Stringers and beds of limestone occur throughout the formation. Sandstone stringers and thin beds are rare within this unit.

The claystones are medium light to greyish black, slightly micromicaceous, rare carbonaceous specks, locally highly pyritic, non- to variably calcareous, and grade into argillaceous siltstones or calcareous claystones. The siltstones are medium dark grey, and non- to calcareous, and grade into argillaceous calcareous siltstones. The stringers and beds of limestone comprise off white to light grey, light brown, mudstone, microcrystalline, locally argillaceous, well indurated, carbonates. The sandstones are off white, light brownish grey, light to medium grey, very fine to fine grained, well sorted, subangular to subrounded, and non- to calcareous.

The more calcareous, medium grey coloured, sediments are recognised in the upper intervals of Pabay Shale Formation in the Fastnet and North Celtic Sea Basins. Similarly, the more arenaceous sediments (laminae and thin beds of off white to light grey, very fine to fine grained, well sorted, subrounded, sandstones and sandy claystones) are recognised in the Fastnet Basin (for example 56/21-1, 64/1-1) and in the northern part of the North Celtic Sea Basin (for example 41/30-1, 42/21-1, 50/2-1, 50/3-1).

In the North Celtic Sea Basin, a prominent basal claystone unit is recognised (for example 49/9-1, 50/2-1, 50/3-3). At present this unit has not be formalised in this present study.

Wireline log character. The formation displays lower gamma values and higher sonic velocities than the overlying formation. The wireline log motifs are generally finely serrated, due to the predominance of mudrocks. Localised limestone beds and stringers are denoted by gamma ray and sonic velocity spikes. Overall the wireline logs traces exhibit subparallel or bow shaped motifs. In the Slyne Basin, to the west of Ireland, four members can be recognised on their wireline log motifs. In the south and east of Ireland the Pabay Shale Formation has not be subdivided. Of note, however, is the prominent bulge at the base of the formation in the more northerly wells within the North Celtic Sea Basin, characterised by higher gamma ray values and slower sonic velocities.

Upper boundary. In the south and east of Ireland's offshore wells, the top of this formation is taken at a downsection lithological change from the dark grey to greyish black, non- to slightly calcareous mudrocks of the Whitby Mudstone Formation, Whitewood Member, to the medium to dark grey, variably calcareous, claystones of the Pabay Shale Formation. This is expressed on wireline log criteria by a decrease in gamma ray values and a corresponding increase in sonic velocity.

Offshore west of Ireland, the upper boundary is denoted by a downward lithological change from the dark grey to greyish black non-calcareous, claystones of the Whitby Mudstone Formation, Ree Member, to the silty claystones/siltstones of the Pabay Shale Formation, Allua Member. This is denoted on wireline log criteria by a decrease in gamma ray values and a corresponding increase in sonic velocity.

Lower boundary. In the Celtic Sea Basin, the boundary is placed at downsection change from claystones to the more non-calcareous, claystones and siltstones of the Glenbeg Formation. This change is reflected on wireline log criteria by a decrease in gamma ray values and a corresponding increase in sonic velocity. In the Fastnet Basin, this change is reflected on wireline log criteria by an increase in gamma ray values and a coincident decrease in sonic velocity where the boundary is a mudrock/mudrock contact, or by a marked decrease in gamma ray values, coinciding with an increase in sonic velocity, where the boundary is a mudrock/sandstone contact.

Offshore west of Ireland the base of this formation is taken at a downsection lithological change from claystones to either limestones or sandstones of the Inagh Formation, Neaskin or Adoon members. This change is reflected on wireline log criteria by a decrease in gamma ray values, with a corresponding increase in sonic velocity.

Note that the base of the Pabay Shale Formation is placed at a slightly lower stratigraphical level in west of Ireland basins than in the Fastnet and North Celtic Sea basins.

Subdivision. This formation is subdivided into four new members offshore west of Ireland (Slyne Basin). In descending stratigraphic order, they comprise; Allua Member, Barnahallia Member, Ardra Member, and Poulnamuck Member. In the south and east offshore Ireland (Goban Spur, North Celtic Sea, South Celtic Sea and Fastnet basins), this formation has not been subdivided into members in the current study.

Thickness. The formation varies in thickness from 46m (27/4-1) to 730.5m (49/9-1). These variations are due to the frequent presence of unconformities either above or within the formation.

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. In the basins to the south and east of Ireland (Goban Spur, Fastnet, North Celtic Sea and South Celtic Sea basins), calcareous microfossil recovery is good within the Late Pliensbachian interval. However, in the Early Pliensbachian interval calcareous microfossil recovery is sporadic, with the best recovery noted in the more northerly North Celtic Sea Basin wells. In the Slyne Basin, to the west of Ireland, calcareous microfaunal recovery is generally good throughout the sedimentary succession.

West of Ireland (Slyne Basin): Occurring within Ostracod Zones IJO9 (*pars*) to IJO5 (*pars*), Foraminiferal Zones IJF6 to IJF2 (*pars*) and Palynological Subzones DM3A (*pars*) to DM2C3 (*pars*).

South and east of Ireland (Goban Spur, Fastnet, North Celtic Sea and South Celtic Sea basins): Occurring within Ostracod Zones IOJ8 to IOJ5, Foraminiferal Zones IFJ8 to IFJ7 and Palynological Subzones DM3A *(pars)* to DM2D.

Age. Early Jurassic, Late Pliensbachian-latest Sinemurian. The base of the formation is of latest Sinemurian age in the Slyne Basin area, however, in the Fastnet and Celtic Sea basins the base of the formation is of earliest Pliensbachian age.

Depositional environment. Marine, inner to outer shelf. In the basins to the west of Ireland the Pabay Shale Formation was deposited in a generally low energy, below wave base, inner to outer shelf environment. Both the micro- and macrofaunas are moderately diverse and moderately to very abundant, indicating oxygenated bottom waters. Localised intervals of poor microfossil recovery or barren zones are indicative of dysaerobic/anoxic bottom water conditions.

The Pabay Shale Formation in the basins to the south and east of Ireland can be broadly subdivided into two sections. The Early Pliensbachian sediments in the Goban Spur, Fastnet, South Celtic Sea, and the south and middle parts of the North Celtic basins yield sparser faunas suggesting very low energy levels, leading to major periods of marine restriction (anoxic and dysaerobic bottom waters) and were deposited in an outer shelf setting (Murphy & Ainsworth, 1991). In the Late Pliensbachian, conditions ameliorated, denoted by rich and diverse micro- and macrofaunas, in association with an increase in calcareous deposition, probably in an inner to mid shelf environment. In the northern part of the North Celtic Sea Basin, most of the Pabay Shale Formation was deposited in a shallow marine, well oxygenated, environment, denoted by the often profuse marine microfaunas. The presence of localised sands (for instance in 42/21-1) suggests erosion of high relief sources (?Irish Mainland) to the northwest of the well location.

Distribution. The formation is proven to be present in the Slyne Basin west of Ireland, but is not confirmed in the Erris Basin, where it is absent from the 12/13-1A well (due to the presence of an unconformity). However, the formation is considered to most likely to be present in deeper parts of the Erris Basin based on seismic evidence. The formation occurs extensively in the North Celtic Sea, South Celtic Sea and Fastnet basins, and is also present in the Goban Spur Basin. Due to its widespread distribution, it is considered likely that the formation is present in the as yet undrilled parts of the Porcupine Basin, Conall and Rónán basins.

Seismic expression. The Top Pliensbachian (Top Pabay) seismic horizon is identified widely across offshore Ireland, in the Slyne, Fastnet, South Celtic Sea and North Celtic Sea basins. This horizon ties precisely to the top of the Pabay Shale Formation and the hard (= peak) event that marks the horizon reflects the significant sonic velocity shift at the top of the formation. An unconformity may be developed at this level, as is suggested within the north eastern part of the North Celtic Sea Basin (see Figure D.6.8), including the tie to the 41/30-1 well where upper part of the formation is cut out at this level.

Regional correlation. This unit is developed throughout offshore Ireland. It is likely also to be present in the UK South Celtic Sea, Bristol Channel and St. George's Channel basins. Lateral equivalents of this unit occur in southern Britain (the upper part of the Charmouth Mudstone Formation (Belemnite Marl and Green Ammonite Mudstone members), Dyrham Formation and the lower part of the Beacon Limestone Formation (lower section of the Marlstone Rock Member) (see Cox *et al.,* 1999). The Pabay Shale Formation offshore Ireland is laterally equivalent to the Pabay Shale Formation and Scalpay Sandstone Formation in the Hebrides Basin, northwest Scotland (see Simms *et al*., 2004).

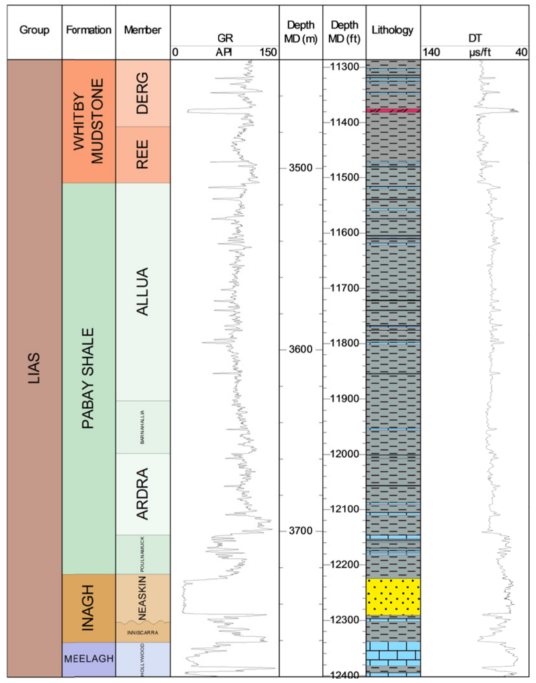
Source rock characterisation. The Pabay Shale Formation shows varying characteristics in its source potential across the different basins offshore Ireland (Figure D.6. 55). It is characterised by very good to excellent source potential in the Slyne Basin, with high TOC contents and hydrocarbon yields (S2), and a Type II to Type II/III kerogen composition. In contrast, in the North Celtic Sea, the Fastnet, and Goban Spur basins TOC contents and hydrocarbon yields are lower. In these areas the Pabay Shale Formation shows a mainly Type III kerogen composition, making it a largely gas-prone source rock. Some samples from well 49/9-1 in the North Celtic Sea Basin show a Type II/III kerogen composition, indicating increased oil source rock potential, however.

TOC and HI data are shown in **Figure D.6. 56** for two wells (27/13-1A from the Slyne Basin and 49/9-1 from the North Celtic Sea Basin) that display good source rock data sets, alongside other well data including well logs, sequences, lithology and stratigraphic (lithostratigraphic and chronostratigraphic) subdivisions. The development of source rocks over this interval in the 27/13-1A well has been illustrated previously (Scotchman & Thomas, 1995). It can be seen from these displays that the richest source interval within the Pabay Shale Formation is in the lower part, which incorporates the Ardra and lower Barnahallia members in the 27/13-1A well, which corresponds to the J13 sequence; this interval is of Early to early Late Pliensbachian in age. In the 49/9-1 well, the equivalent rich interval appears to be of expanded thickness, but again corresponds to the lower part of the formation and the J13 sequence.

In the 27/13-1A well, the source rock is well expressed by the crossover in the sonic and resistivity logs, as was also illustrated by Scotchman & Thomas (1995) over the same interval.

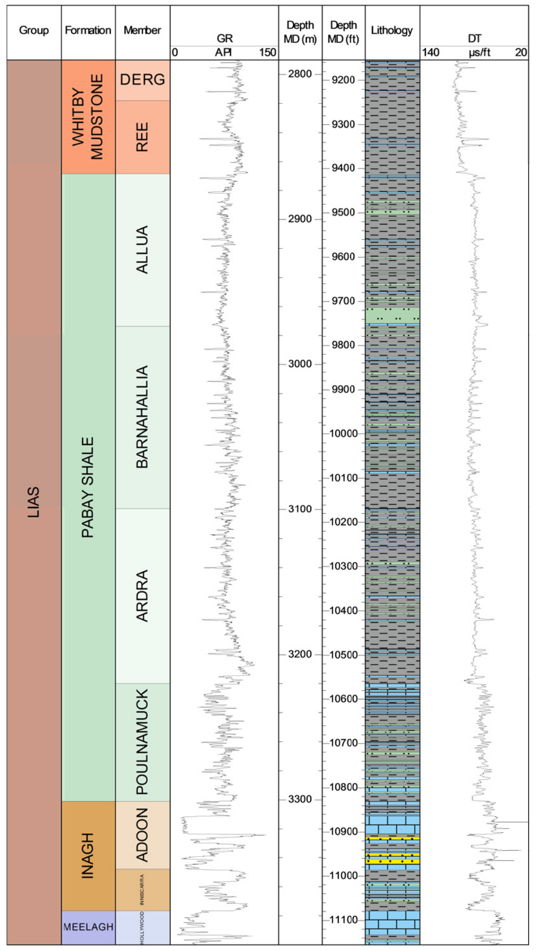
The lower Pabay Shale Formation source rock interval recognised in this study appears to generally equate to the Low J2a source interval that was identified in project IS16/01 (BeicipFranlab, 2017). In the latter study, however, these exactly correlative lower Pabay Shale Formation, sequence J13 intervals in these two wells were regarded as different source rock ages, that is the Low J1 (Sinemurian) source rock in the 27/13-1A well and the Low J2a (Pliensbachian) source rock in the 49/9-1 well (see **Figure D.6. 56** for comparison with the current project interpretations).

Comparison with Eastern Canada. The Pabay Shale Formation is age equivalent to the lower part of the Downing Formation (claystones) and possibly to the uppermost part of the Iroquois Formation (dominantly limestones and dolomites) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.



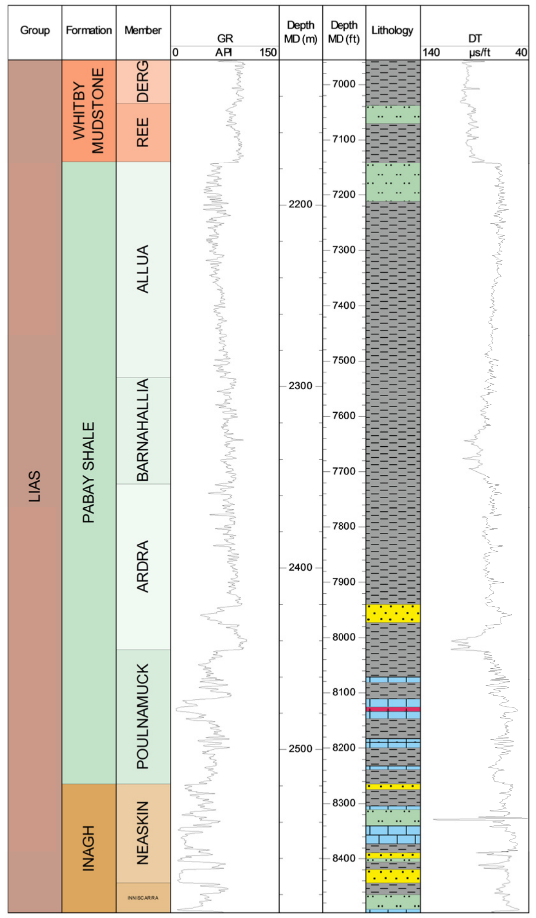
19/11-1A

Reference well; Pabay Shale Formation, Allua, Barnahallia, Ardra, Poulnamuck Members



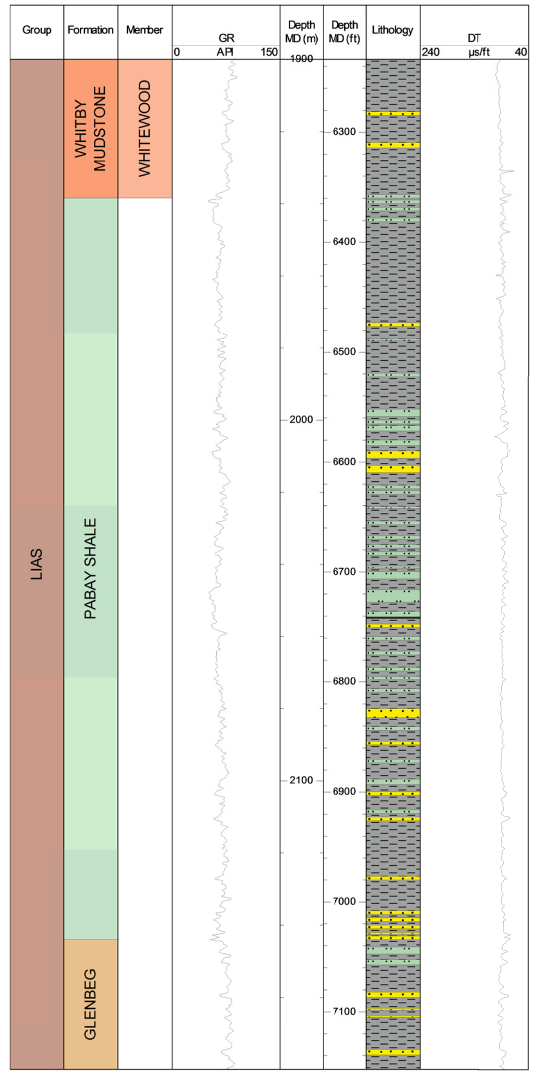
18/20-1

Reference well; Pabay Shale Formation, Allua, Barnahallia, Ardra, Poulnamuck Members



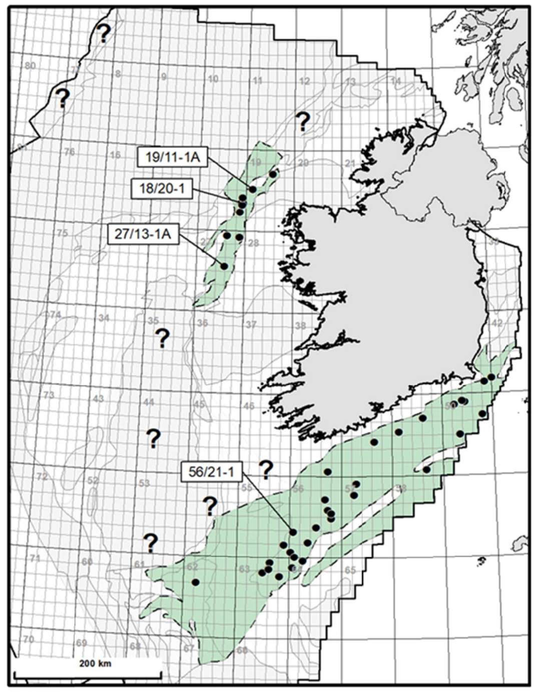
27/13-1A

Type well; Allua, Barnahallia, Ardra, Poulnamuck Members
Reference well; Pabay Shale Formation



56/21-1

Reference well; Pabay Shale Formation



Pabay Shale Formation

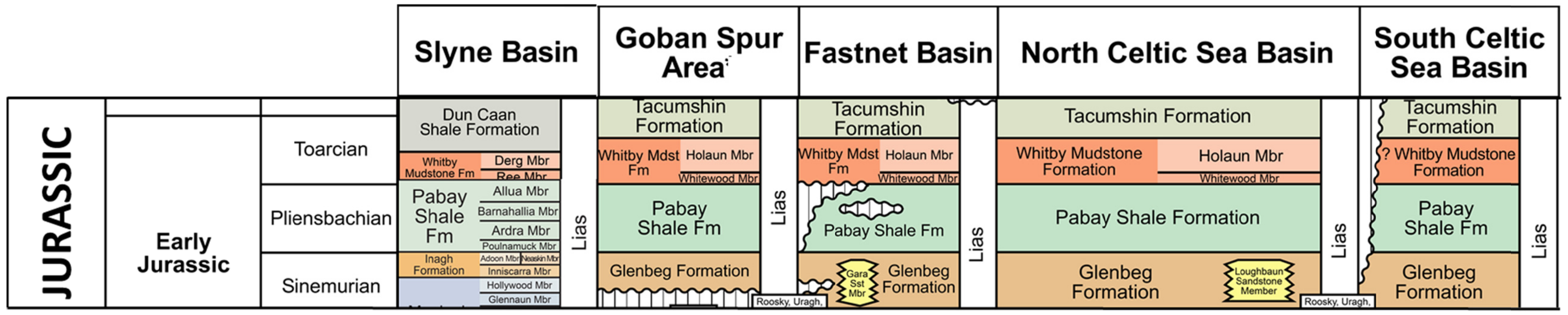


Figure D.6. 53. ***Pabay Shale Formation reference wells, and constituent member type and reference wells.***

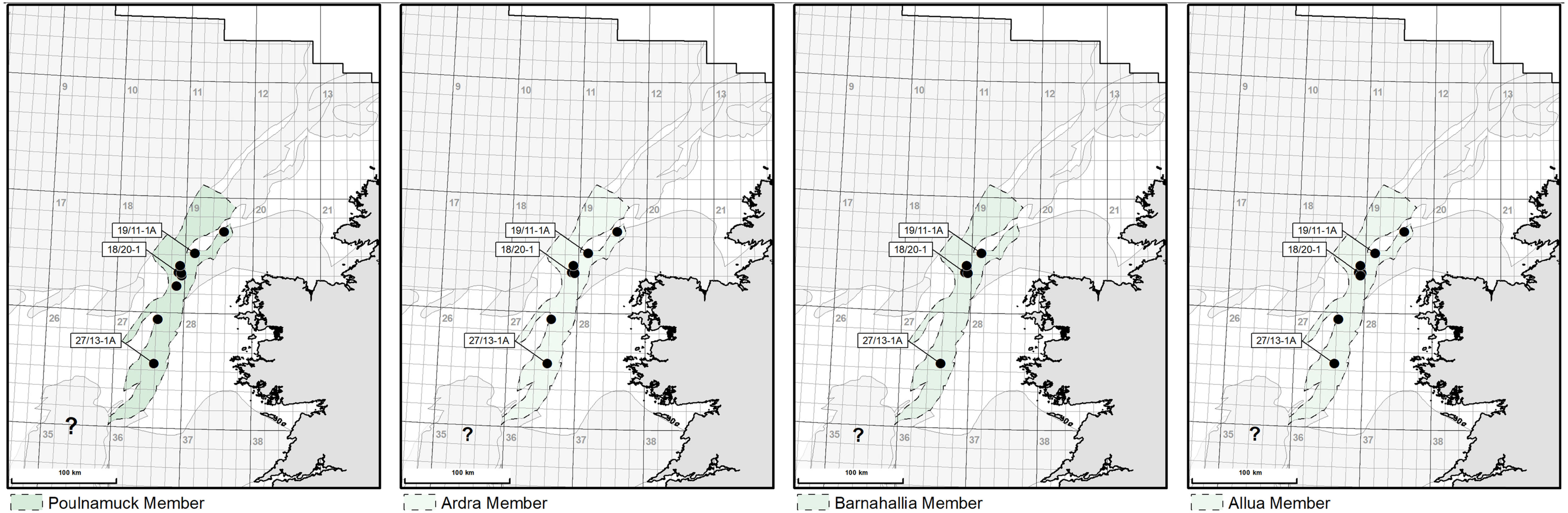
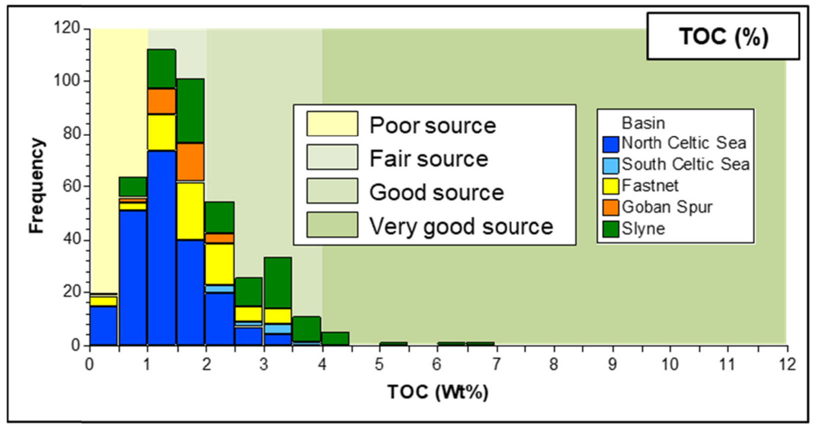
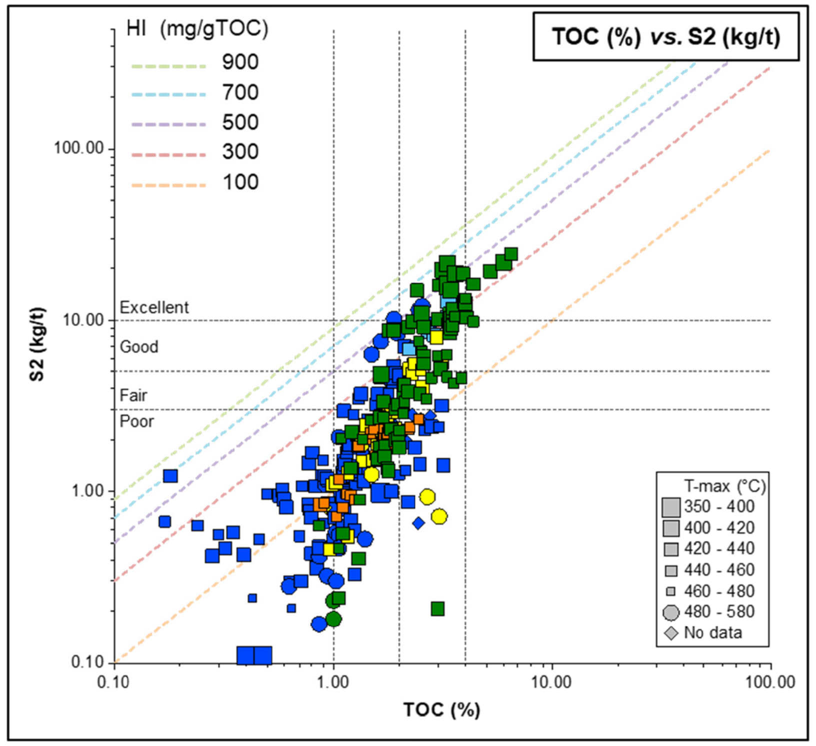


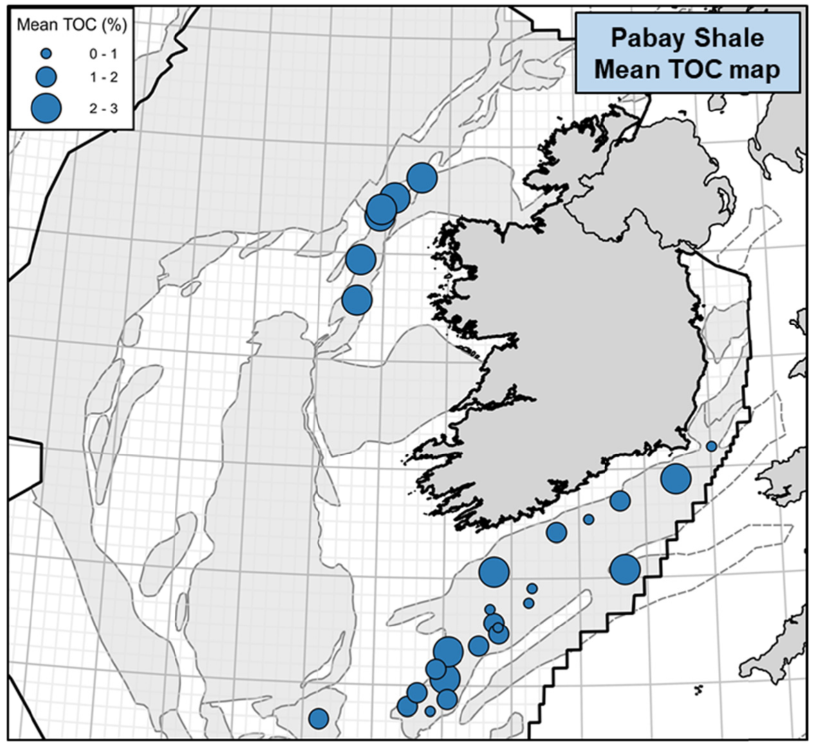
Figure D.6. 54. ***Pabay Shale Formation member location maps.***

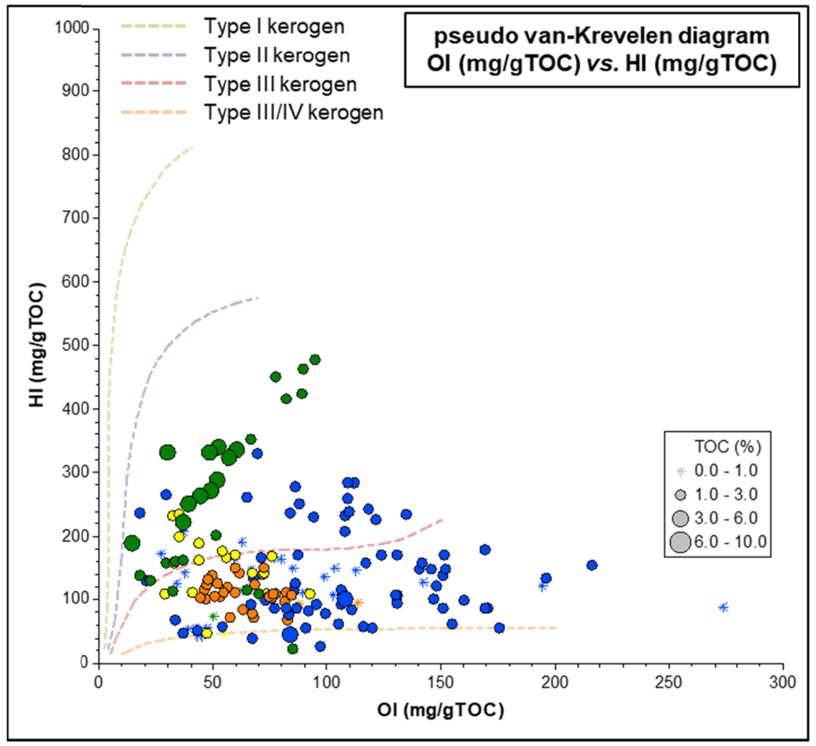
Pabay Shale Formation

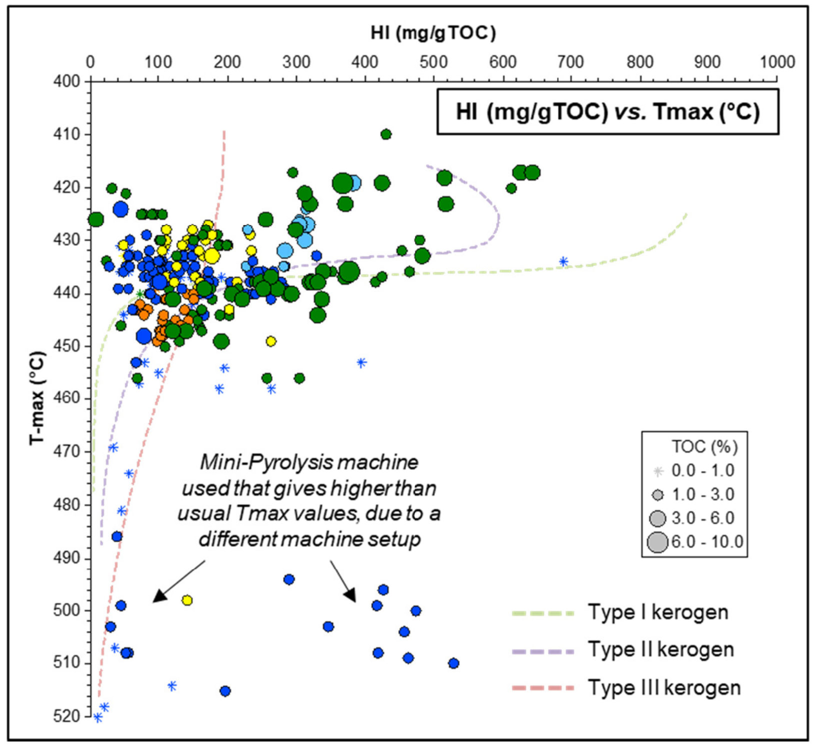
Basin	TOC (%) No. Wells	TOC (%) No. Samples	TOC (%) Min	TOC (%) Max	TOC (%) Avrg.	HI (mg/gTOC) No. Wells	HI (mg/gTOC) No. Samples	HI (mg/gTOC) Min	HI (mg/gTOC) Max	HI (mg/gTOC) Avrg.
North Celtic Sea	13	211	0.17	3.31	1.3	12	145	9	689	146
South Celtic Sea	1	10	2.23	3.53	2.9	1	10	227	383	295
Fastnet	7	71	0.17	3.40	1.9	6	38	23	263	144
Goban Spur	1	31	0.88	2.44	1.6	1	31	68	150	110
Slyne	7	110	0.38	6.50	2.4	7	86	7	642	240











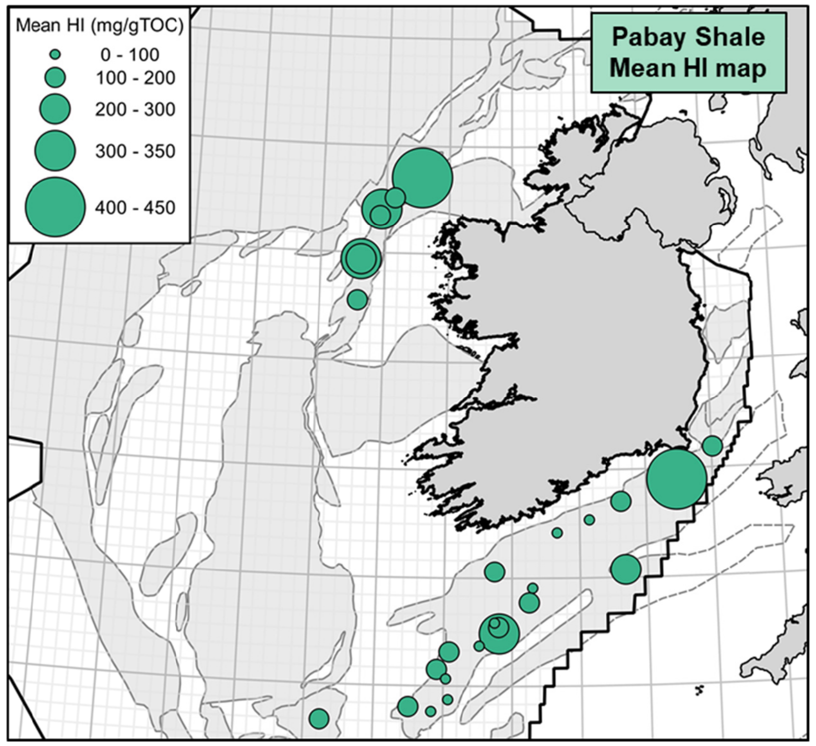


Figure D.6. 55. ***Pabay Shale Formation source rock characteristics, offshore Ireland.***

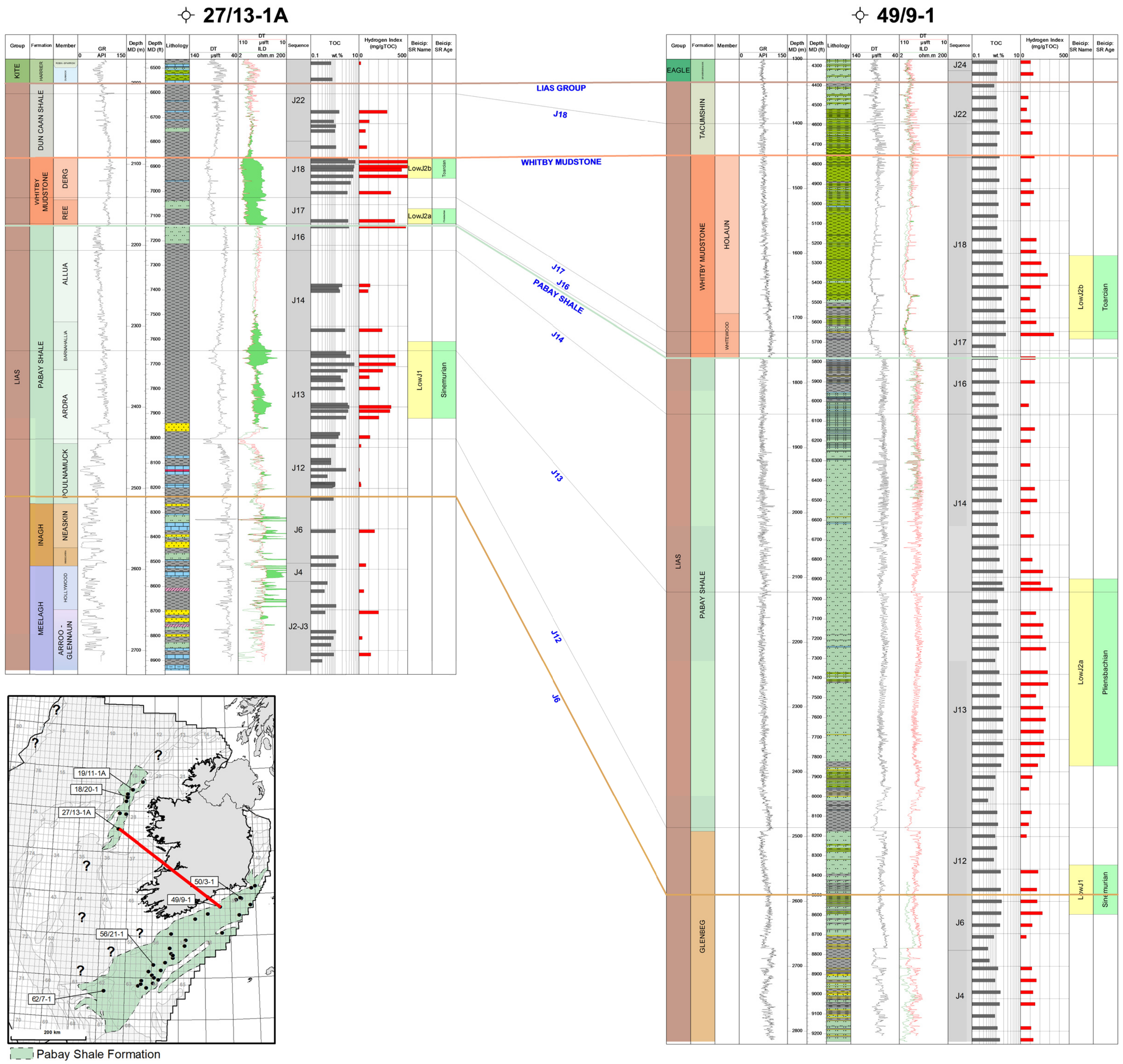


Figure D.6. 56. ***Pabay Shale Formation, Whitby Mudstone Formation and Glenbeg Formation source rock characteristics and sequence subdivisions, 27/13-1A, 49/9-1 wells, offshore Ireland. Includes comparison with source rock intervals identified by BeicipFranlab (2017).***

Allua Member (New)

The Allua Member has been previously termed the "Scalpa Sandstone" in offshore western Ireland (for example Trueblood & Morton, 1991; Trueblood, 1992; Scotchman & Thomas, 1995), particularly with reference to the 27/13-1A Slyne Basin well, however, there are no sandstones present in this interval and a new name is therefore ascribed to this unit. This member appears to correlate age wise with the Scalpay Sandstone Formation (the correct name for the former "Scalpa Sandstone") as developed in the Inner Hebrides, western Scotland. The latter sandstone appears to have passed laterally into claystone towards offshore Ireland and it is notable that in the Upper Glen-1 well, there is far less sandstone in the Scalpay Sandstone Formation interval than there is elsewhere on the Isle of Skye and Raasay (see **Figure D.6. 16**), proving that the lateral passage to claystone is taking place over a relative short distance within the Hebrides Basin.

The Allua Member is the upper, Late Pliensbachian, unit of the Pabay Shale Formation in the Slyne Basin. It lies between the overlying Whitby Formation, Ree Member and the underlying Barnahallia Member (of the Pabay Shale Formation).

Name. After Lough Allua, County Cork.

Type section. 27/13-1A: 2176-2295m below KB. See **Figure D.6. 53**.

Reference sections. 18/20-1: 2868.5-2973.5m below KB. 19/11-1A: 3508-3628m below KB. See **Figure D.6. 53**.

Lithology. This member largely comprises a silty claystone or siltstone unit. The silty claystones are medium to dark grey, micromicaceous, rare carbonaceous specks, common to abundantly pyritic, non- to slightly calcareous, subblocky to fissile, and grading to siltstones. The siltstones are medium to dark grey, dark olive grey, and locally argillaceous. Rare light grey, light brown, mudstone, microcrystalline, well indurated limestone stringers are also present.

Wireline log character. The member displays slightly lower gamma values and higher sonic velocities than the overlying and underlying members. Generally, the member possesses slightly serrated, bow shaped wireline log motifs. In the type well (27/13-1A) a slight coarsening up wireline log profile can be recognised, from claystone to silty claystones through to siltstones. The gamma ray and sonic velocity spikes indicate limestone stringers or beds.

Upper boundary. The top of this member is placed at a downsection lithological change from the dark grey to greyish black, non- to slightly calcareous, claystones of the Whitby Mudstone Formation, Ree Member, to the silty claystones or siltstones of the Pabay Shale Formation, Allua Member. On wireline log criteria, this change is denoted by a decrease in gamma ray values, with a corresponding increase in sonic velocity.

Lower boundary. The base of this member is taken on a downward lithological change from silty claystones to the claystones of the Barnahallia Member. This is expressed on wireline log criteria as an increase in gamma ray values, with a coincident decrease in sonic velocity.

Thickness. The member varies in thickness from 105m (18/20-1) to 125.5m (18/20-7).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is generally good. Occurring within Ostracod Zones IJO8 to IJO7, Foraminiferal Zones IJF6 to IJF5 (*pars*) and Palynological Subzone DM3A (*pars*).

Age. Early Jurassic, Late Pliensbachian.

Depositional environment. Marine, inner shelf. The Allua Member was deposited in a generally low energy, inner shelf environment. Both the micro- and macrofaunas are diverse and often abundant, indicating well oxygenated bottom waters.

Distribution. The member is proven to be present in the Slyne Basin west of Ireland, but is not confirmed in the Erris Basin, where it is absent from the 12/13-1A well (due to the presence of an unconformity). However, the Pabay Shale Formation (and its constituent members) is considered to most likely to be present in deeper parts of the Erris Basin. It is also considered likely that the formation, and its constituent members, is present in the as yet undrilled parts of the Porcupine, Conall and Rónán basins, based on the known presence of the Lias Group in the northern part of the Porcupine Basin, and on interpreted intra Lower Jurassic seismic horizons in the Conall and Rónán basins.

Regional correlation. This unit is age equivalent to the top sediments of Pabay Shale Formation of the Goban Spur, Fastnet and North Celtic Sea basins. The member is laterally equivalent to the Marlstone Rock Formation and the lowermost part of the Beacon Limestone Formation in the southern Britain, and the mid part of the Scalpay Sandstone Formation in northwest Scotland (see Cox *et al.,* 1999; Morton, 2004; Simms *et al.,* 2004).

Comparison with Eastern Canada. The Allua Member is age equivalent to the lower part of the Downing Formation (claystones) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Ardra Member (New)

The Ardra Member comprises a dominantly mudrock unit, of Early Pliensbachian age, which occurs between the Barnahallia and the Poulnamuck members, in the Slyne Basin.

Name. After Ardra Lough, County Cavan.

Type section. 27/13-1A: 2353.5-2445m below KB. See **Figure D.6. 53**.

Reference sections. 18/20-1: 3099.5-3220m below KB. 19/11-1A: 3657-3702m below KB. See **Figure D.6. 53**.

Lithology. This member is dominantly a silty claystone unit. The claystones are dark grey to olive black, slightly micromicaceous, rare carbonaceous specks, generally silty, non- to slightly calcareous, and subblocky to fissile. Stringers of off white to light grey, mudstone, microcrystalline, well indurated, limestone stringers are also present, more especially within the mid-section. An off white to light grey, very fine to fine grained, well sorted, subangular to subrounded, locally pyritic, locally argillaceous, calcareous sandstone bed is present in the 27/13-1A well.

Wireline log character. This unit exhibits a finely serrated, slightly bowed wireline log motif, reflecting the dominantly mudrock lithologies, with the thinly bedded carbonates developed mid-section. At the base of the member an increase in gamma ray values reflects the presence of a non-calcareous claystone. Overall this member has slightly low gamma ray values and slightly higher sonic velocities than the overlying member.

Upper boundary. The top of this member is taken at a downward lithological change from claystones of the Barnahallia Member to the silty claystones of the Ardra Member. This is expressed on wireline log criteria as a slight decrease in gamma ray values, with a coincident slight increase in sonic velocity.

Lower boundary. The base of this member is recognised by a downsection lithological change from non-calcareous claystones to the calcareous claystones of the Poulnamuck Member. On wireline log criteria, this is denoted by a decrease in gamma ray values, in association with an increase in sonic velocity.

Thickness. The member varies in thickness from 45m (19/11-1A) to a maximum of 120.5m (18/20-1). The thickest development of the member is seen in the centre of the Slyne Basin.

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is generally good. Occurring within Ostracod Subzones IJO5b to IJO5a, Foraminiferal Zone IJF3 (*pars*) and Palynological Subzone DM2D (*pars*).

Age. Early Jurassic, Early Pliensbachian.

Depositional environment. Marine, inner shelf. The Ardra Member was laid in a low energy, below wave base, inner to outer shelf environment. Both the micro- and macrofaunas are moderately diverse and locally very abundant, indicating well oxygenated bottom waters.

Distribution. The member is proven to be present in the Slyne Basin west of Ireland, but is not confirmed in the Erris Basin, where it is absent from the 12/13-1A well (due to the presence of an unconformity). However, the Pabay Shale Formation (and its constituent members) is considered to most likely to be present in deeper parts of the Erris Basin. It is also considered likely that the formation, and its constituent members, is present in the as yet undrilled parts of the Porcupine Basin, Conall and Rónán basins.

Regional correlation. The Ardra Member is an age equivalent to the lower sedimentary succession of the Pabay Shale Formation of the Goban Spur, Fastnet, North Celtic Sea and South Celtic Sea basins. In the southern Britain the member is laterally equivalent to the upper part of the Charmouth Mudstone Formation, upper part of the Belemnite Marl and the Green

Ammonite Mudstone members (Cox *et al.,* 1999; Simms *et al.,* 2004), while in northwest Scotland it is equivalent to the upper part of the Pabay Shale Formation.

Comparison with Eastern Canada. The Ardra Member is age equivalent to the lower part of the Downing Formation (claystones) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Barnahallia Member (New)

The Barnahallia Member comprises a dominantly mudrock unit, of intra Late Pliensbachian age, which occurs between the Allua and Ardra members (of the Pabay Shale Formation), in the Slyne Basin.

Name. After Barnahallia Lough, County Galway.

Type section. 27/13-1A: 2295-2353.5m below KB. See **Figure D.6. 53**.

Reference sections. 18/20-1: 2973.5-3099.5m below KB. 19/11-1A: 3628-3657m below KB. See **Figure D.6. 53**.

Lithology. This member is dominantly a claystone unit. The claystones are dark grey to greyish black, slightly micromicaceous, with rare carbonaceous specks, silty, non- to slightly calcareous, and subblocky to fissile. Rare, off white to light grey, mudstone, microcrystalline, well indurated limestone stringers are also present.

Wireline log character. This unit exhibits a slightly serrated, slight funnel shaped wireline log motif. The low gamma ray and high sonic velocity spikes reflect the presence of limestone stringers or beds.

Upper boundary. The top of this unit is denoted by a downward lithological change from the silty claystones of the Allua Member to the claystones of the Barnahallia Member. This is expressed on wireline log criteria as a slight increase in gamma ray values, with a coincident slight decrease in sonic velocity.

Lower boundary. The base of this unit is taken at a downsection lithological change from claystones to the silty claystones of the Ardra Member. This is reflected on wireline log criteria as a slight decrease in gamma ray values, with a coincident slight increase in sonic velocity.

Thickness. The member varies in thickness from 29m (19/11-1A) to a maximum of 126m (18/20-1).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is poor to good. Occurring within Ostracod Zone IJO6, Foraminiferal Zones IJF5 (*pars*) to IJF4 and Palynological Subzone DM3A (*pars*).

Age. Early Jurassic, intra Late Pliensbachian.

Depositional environment. Marine, inner shelf. The Barnahallia Member was deposited in a generally low energy, below wave base, inner shelf environment. The micro- and macrofaunas are moderately diverse and abundant, indicating well oxygenated bottom waters within the top half of the member, whereas a marked decrease in microfossil recovery is noted in the lower sections suggesting a period of marine restriction (?dysaerobic bottom waters).

Distribution. The member is proven to be present in the Slyne Basin west of Ireland, but is not confirmed in the Erris Basin, where it is absent from the 12/13-1A well (due to the presence of an unconformity). However, the Pabay Shale Formation (and its constituent members) is considered to most likely to be present in deeper parts of the Erris Basin. It is also considered likely that the formation, and its constituent members, is present in the as yet undrilled parts of the Porcupine Basin, Conall and Rónán basins.

Regional correlation. This member is age equivalent to the upper sediments of Pabay Shale Formation of the Goban Spur, Fastnet and North Celtic Sea basins. In the southern Britain this unit is laterally equivalent to the Dyrham Formation, while in northwest Scotland it is equivalent to the upper part of the Pabay Shale Formation and lower part of the Scalpay Sandstone Formation (Cox *et al.,* 1999; Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The Barnahallia Member is age equivalent to the lower part of the Downing Formation (claystones) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Poulnamuck Member (New)

The Poulnamuck Member comprises the lowest unit of the Pabay Shale Formation in the Slyne Basin. It comprises an interbedded claystone and limestone unit, of earliest Pliensbachian age, which occurs between an overlying Ardra Member and the underlying Adoon/Neaskin members of the Inagh Formation.

The Poulnamuck Member corresponds to the "Early Pliensbachian Marker" unit recognised by Serica Energy (2009) as a correlative wireline log and lithostratigraphic unit in the 27/4 area, Slyne Basin.

Name. After Lough Poulnamuck, County Cork.

Type section. 27/13-1A: 2445-2519m below KB. See **Figure D.6. 53**.

Reference sections. 18/20-1: 3220-3301m below KB. 19/11-1A: 3702-3723.5m below KB. See **Figure D.6. 53**.

Lithology. This unit comprises interbedded claystones and limestones. The claystones are medium grey to dark grey, slightly micromicaceous, rare carbonaceous specks, locally silty, non- to very calcareous, and subblocky to fissile, and grading to argillaceous siltstone. The limestone beds are off white to medium grey, light brownish grey, mudstone, microcrystalline and well indurated

Wireline log character. The unit possesses a serrated wireline log motif, reflecting the interbedded limestones and claystone lithologies. The limestones exhibit low gamma ray values and high sonic velocities, while the mudrocks are characterised by high gamma ray values and slower sonic velocities. This member has lower gamma ray values and increased sonic velocities compared to the overlying Ardra Member.

Upper boundary. The top of this member is denoted by a downsection lithological change from the non-calcareous claystones of the Ardra Member, to the calcareous claystones of the Poulnamuck Member. On wireline log criteria, this is expressed by a decrease in gamma ray values, in association with an increase in sonic velocity.

Lower boundary. The base of this member is indicated by a downsection lithological change from the mudrocks of the Pabay Shale Formation, Poulnamuck Member, to either the limestones or the sandstones of the Inagh Formation, Neaskin or Adoon members respectively. This change is denoted on wireline log criteria by a decrease in gamma ray values, with a corresponding increase in sonic velocity.

Thickness. The member varies in thickness from 19m (19/8-1) to a maximum of 83.5m (27/4-1z).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is generally good. Occurring within Ostracod Zones IJO4 to IJO3 (*pars*), Foraminiferal Zones IJF3 (*pars*) to IJF2 (*pars*) and Palynological Subzones DM2D (*pars*) to DM2C3 (*pars*).

Age. Early Jurassic, earliest Pliensbachian-latest Sinemurian.

Depositional environment. Marine, inner shelf. The Poulnamuck Member was laid down in a generally low energy, below wave base, inner shelf environment. Both the micro- and macrofaunas are moderately diverse and moderately abundant, indicating oxygenated bottom waters.

Distribution. The member is proven to be present in the Slyne Basin west of Ireland, but is not confirmed in the Erris Basin, where it is absent from the 12/13-1A well (due to the presence of an unconformity). However, the Pabay Shale Formation (and its constituent members) is considered to most likely to be present in deeper parts of the Erris Basin. It is also considered likely that the formation, and its constituent members, is present in the as yet undrilled parts of the Porcupine Basin, Conall and Rónán basins.

Regional correlation. This member is laterally equivalent to the lowermost sediments of Pabay Shale Formation of the Goban Spur, Fastnet, North Celtic Sea and South Celtic Sea basins. The formation is age equivalent to the upper part of the Charmouth Mudstone Formation, lower part of the Belemnite Marl Member of southern England, while in northwest Scotland it is equivalent to the upper part of the Pabay Shale Formation (see Cox *et al.,* 1999; Simms *et al*., 2004).

Comparison with Eastern Canada. The Poulnamuck Member is age equivalent to the lower part of the Downing Formation (claystones) and possibly to the uppermost part of the Iroquois Formation (dominantly limestones and dolomites) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

"42/21-1 Lower Sandstone"

This sandstone unit of Late Pliensbachian age, is present midway through the Pabay Shale Formation within the 42/21-1 well, located in the northern part of the North Celtic Sea Basin.

Type section. 42/21-1: 1924-1989.5m below KB. See **Figure D.6. 57**.

Lithology. This unit is dominated by sandstone. The sandstones are light to medium grey, very fine to fine grained, well sorted, subangular to subrounded, locally argillaceous, rarely glauconitic or pyritic, non-calcareous, and locally grading to siltstones. Thin interbeds of medium to dark grey, micromicaceous, variably calcareous, claystones are also present.

Wireline log character. The formation displays slightly lower gamma values and higher sonic velocities than the overlying and underlying formations. The gamma ray and sonic log traces are finely serrated and subparallel to one another.

Upper boundary. The top of this unit is denoted by a downward lithological change from the silty claystones/siltstones of the Pabay Shale Formation, to the sandstones of the "42/21-1 Lower Sandstone". This is reflected on wireline log criteria by a slight decrease in gamma ray values, coincident with a slight decrease in sonic velocity.

Lower boundary. The base of this unit is taken at a downward lithological change from sandstones to the silty claystones/siltstones of the Pabay Shale Formation. This is expressed on wireline log criteria by an increase in gamma ray values, in association with a corresponding decrease in sonic velocity.

Thickness. This member attains a thickness of 65.5m in the 42/21-1 well.

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is moderately good. Occurring within Ostracod Zone IOJ8, Foraminiferal Zones IFJ8 (*pars*) and Palynological Subzone DM3A (*pars*).

Age. Early Jurassic, Late Pliensbachian.

Depositional environment. Marine, inner shelf. The 42/12-1 Lower Sandstone" was deposited in a moderate energy, well oxygenated, inner shelf environment. These localised sands are envisaged to be the products of erosion from the Irish Mainland to the northwest of this well location.

Distribution. This member is only currently known from the 42/21-1 well in the North Celtic Sea Basin.

Regional correlation. This arenaceous unit is age equivalent to the top sediments of Pabay Shale Formation of the Goban Spur, Fastnet and North Celtic Sea basins, plus the Allua Member of the Pabay Shale Formation, of the Slyne Basin. In the southern Britain this unit appears to be laterally equivalent to the Marlstone Rock Formation or to the lower part of the Beacon Limestone Formation, while in northwest Scotland it is equivalent to the upper parts of the Pabay Shale Formation or Scalpay Sandstone formations (Cox *et al.,* 1999; Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The "42/12-1 Lower Sandstone" is laterally equivalent to the lower part of the Downing Formation (claystones) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

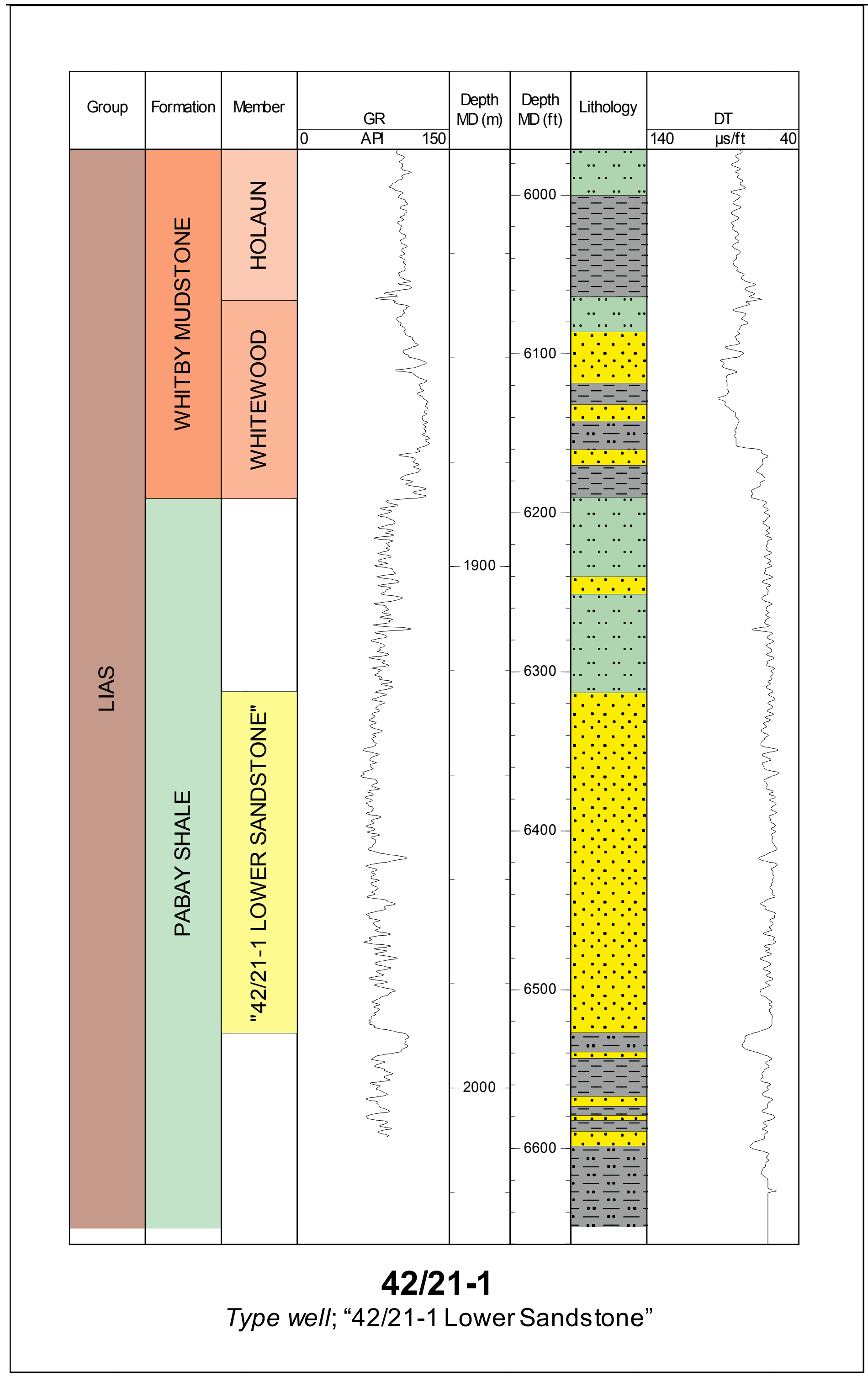


Figure D.6. 57. ***"42/21-1 Lower Sandstone" reference well.***

TACUMSHIN FORMATION (NEW)

The Tacumshin Formation is defined here for the calcareous claystone dominated part of the uppermost Lias Group, of Early Aalenian-Late Toarcian age, that is developed throughout the Goban Spur, Fastnet, North Celtic Sea and South Celtic Sea basins.

Rocks allocated to this formation in the Fastnet Basin were previously referred to as Lower-Middle Jurassic, Liassic Shale Unit (J-12) by Murphy & Ainsworth (1991). The type well for this unit proposed by these authors, 56/21-1, is not used as the type well for the formation offshore Ireland, however, because more complete, thicker sections, without unconformable boundaries, are now recognised.

The Tacumshin Formation occurs between the overlying Eagle Group, Sparrowhawk Formation and the underlying Whitby Mudstone Formation.

Name. After Tacumshin Lake, County Wexford.

Type section. 64/1-1: 1297.5-1643m below KB. See **Figure D.6. 58**.

Reference sections. 50/3-1: 1243.5-1516.5m below KB. 62/7-1: 3453-3918m below KB. See **Figure D.6. 58**.

Lithology. This formation is dominated by claystones, which are often very calcareous, more especially in their upper sections. The calcareous claystones are medium light to medium grey, light olive grey, micromicaceous, locally pyritic, and often soft to firm. The claystones and silty claystones are medium to dark grey, olive grey, micromicaceous, locally pyritic, locally sandy, variably calcareous, and blocky to subfissile. Locally thin beds or stringers of light to medium dark grey, trace glauconitic, locally sandy, siltstones are also present. The more silty and sandier units are recognised in three wells within the Fastnet Basin (56/21-1, 56/21-2 and 56/26-1) and also in two wells located in the northern part of the North Celtic Sea Basin (41/30-1 and 42/21-1). Stringers of argillaceous limestone and limestone, off white, light to medium grey, mudstone, locally wackestone, locally silty, micritic to cryptocrystalline, are present throughout the unit. Towards the base of the formation in some wells, for example, 62/7-1, an increase in the frequency of calcareous sediments (calcareous claystones/marls and argillaceous limestones) is observed.

Wireline log character. The formation displays characteristically slightly lower gamma values and slightly increased sonic velocities compared to the overlying and underlying formations. The wireline log curves are very finely serrated denoting the dominantly argillaceous nature of the sediments. The wireline log motifs exhibit both sublinear log responses, and locally slight bow shaped curves. At the base of the formation there is often a slightly bow shaped wireline log motif.

Upper boundary. The top of the formation is placed at a downsection lithological change from either the silty, poorly calcareous mudrocks of the Sparrowhawk Formation, or the sandstones of the Chough Sandstone Member, to the calcareous claystones of the Tacumshin Formation. On wireline log criteria, the boundary is taken at an increase in gamma ray values, in association with a decrease in sonic velocity, both of which are more pronounced where the Chough Sandstone Member is present at the base of the overlying Sparrowhawk Formation.

Lower boundary. The base of the formation is placed at a downsection lithological change from claystones to the poorly calcareous claystones of the Whitby Mudstone Formation. This is marked on wireline log criteria by a slight increase in gamma ray values and a corresponding slight decrease in sonic velocity.

Subdivision. No subdivision is recognised.

Thickness. The formation varies in thickness from 43m (50/12-3) to a maximum of 578m in the 56/26-1 well, but in this well the upper boundary is unconformable. The thickest sections of the formation are seen in the southern part of the North Celtic Sea Basin and the Fastnet Basin.

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is generally good to very good. Towards the base of the interval a decline in microfossil diversity and abundance is often noted. Occurring within Ostracod Subzones IOJ11c to IOJ11b, Foraminiferal Zone IFJ12 to IFJ11 (*pars*) and Palynological Subzones DM3D2 to DM3D1.

Age. Early Jurassic, Early Aalenian-Late Toarcian.

Depositional environment. Marine, inner to ?middle shelf. The Tacumshin Formation was deposited in a well oxygenated, marine, inner to possibly middle shelf environment, denoted by the often rich and diverse faunas recovered from the sediments (Murphy & Ainsworth, 1991). Towards the base of the formation a decline in microfossil recovery is often noted, possibly indicating some marine restriction.

Distribution. The formation is proven by well penetrations in the North Celtic Sea, South Celtic Sea, Fastnet and Goban Spur basins. Its depositional limit is extended to the present day outlines of these basins on the basis of seismic extrapolation. The formation appears on the basis of seismic evidence to be most also possibly present through the Celtic Platform area between the Fastnet and Goban Spur basins (see **Figure D.8.9**).

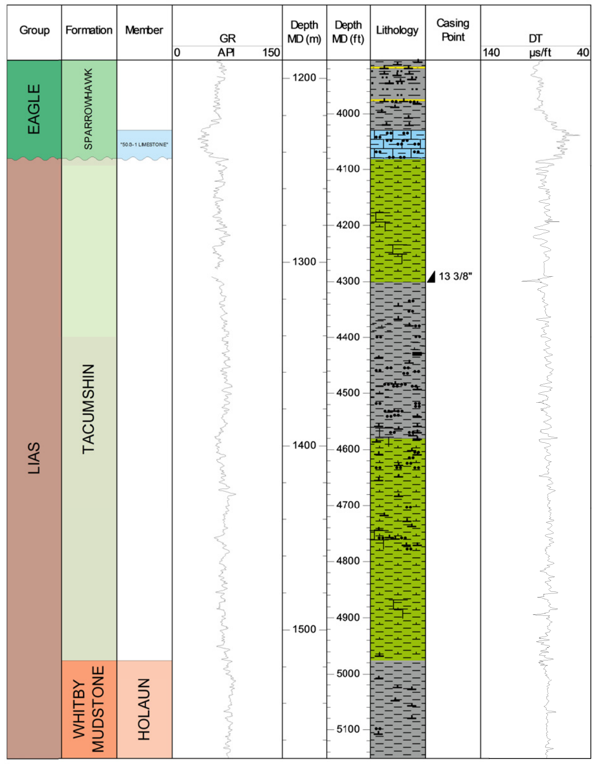
Seismic expression. The Aalenian (Top Lias) seismic horizon, that is recognised in the North Celtic Sea and South Celtic Sea basins ties to the top of the Tacumshin Formation (top of the Lias Group), as in the 49/9 area (see **Figure D.6. 5**).

Regional correlation. The formation is laterally equivalent to most of the Dun Caan Shale Formation within the Slyne Basin. The Tacumshin Formation is age equivalent to the Bridport Sand Formation in southern England and the upper part of the Whitby Mudstone Formation and overlying Blea Wyke Sandstone Formation in the Cleveland Basin, Yorkshire (see Cox *et al.,* 1999; Simms *et al*., 2004) and to the lower part of Bearreraig Formation, Dun Caan Shale Member, in northwest Scotland (see Morton, 2004; Simms *et al*., 2004).

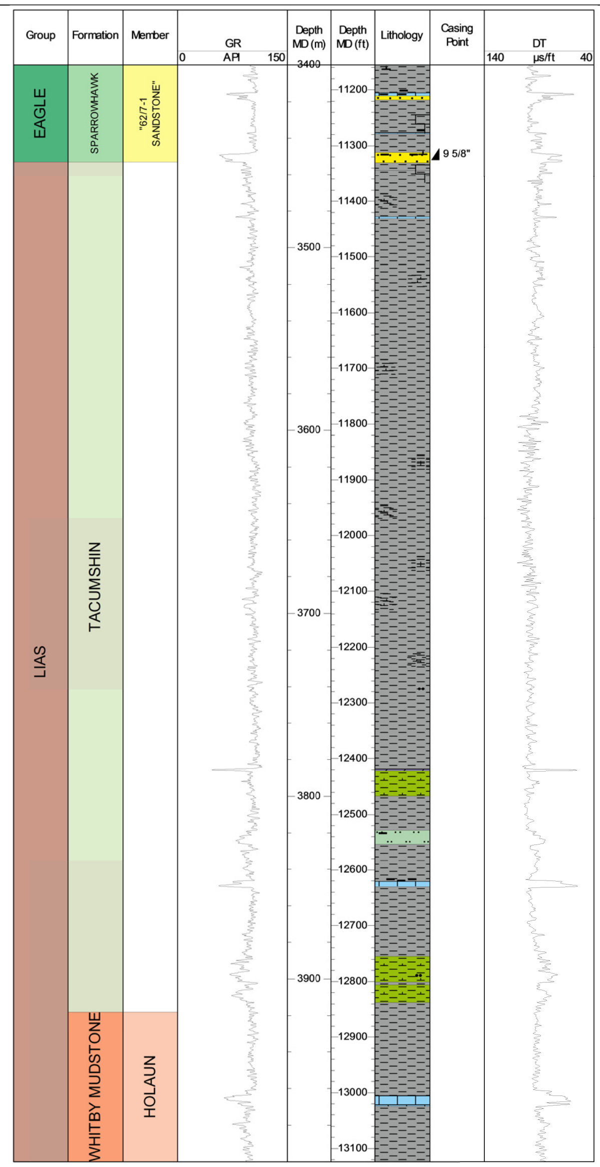
Source rock characterisation. The Tacumshin Formation contains some intervals with elevated TOC contents greater than 1% in the southern margin area offshore Ireland (**Figure D.6. 59**). In the Fastnet and Goban Spur basins samples show low hydrocarbon yields and only poor gas generative potential. Samples from the North Celtic Sea Basin show a mixed kerogen composition, varying from Type III to a more Type II kerogen. Although HI values are increased compared to the samples from the Fastnet and Goban Spur basins the formation only shows limited source potential.

In some wells in the Fastnet Basin the Tacumshin Formation is part of source rock interval Low J2b that was identified in project IS16/01 (BeicipFranlab, 2017).

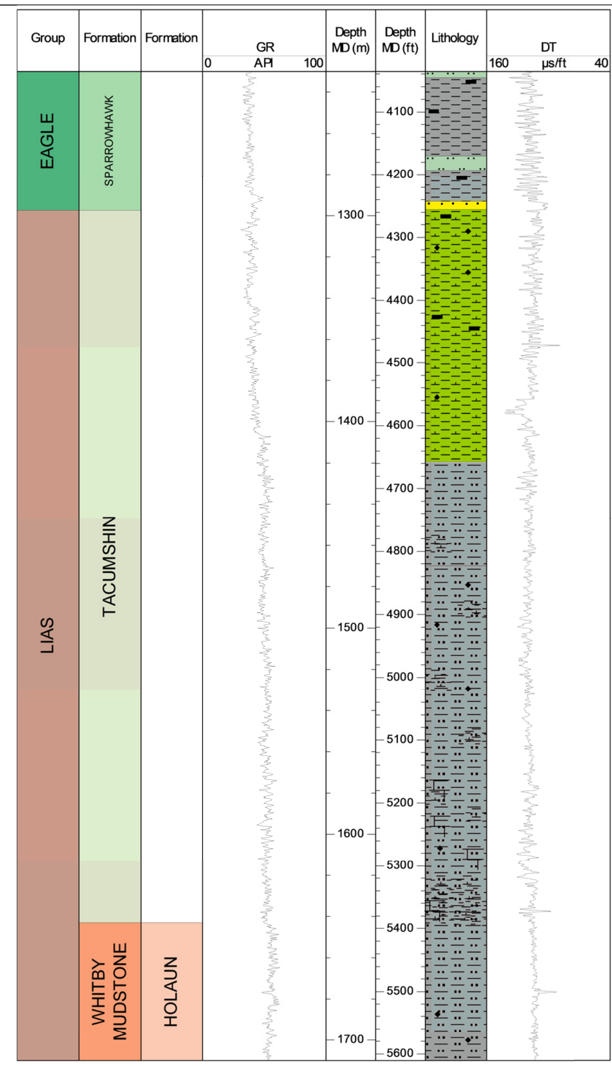
Comparison with Eastern Canada. The Tacumshin Formation is age equivalent to the lower part of the Downing Formation (claystones) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.



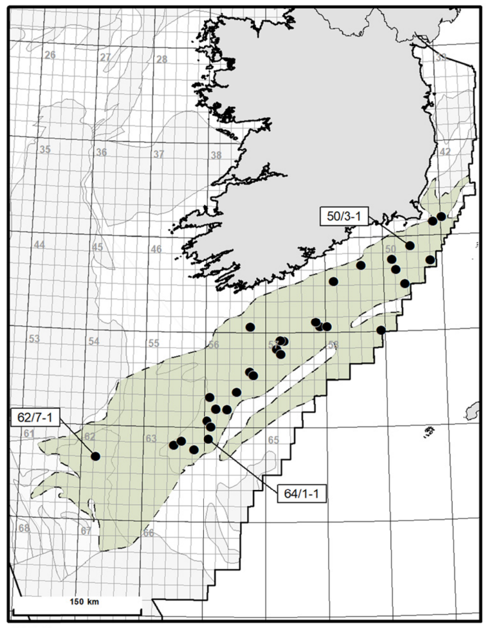
50/3-1
Reference well; Tacumshin Formation



62/7-1
Reference well; Tacumshin Formation



64/1-1
Type well; Tacumshin Formation



Tacumshin Formation

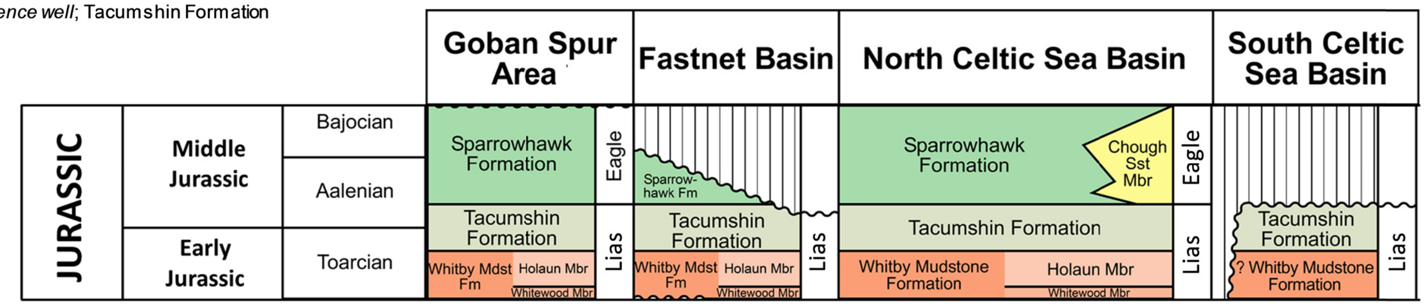
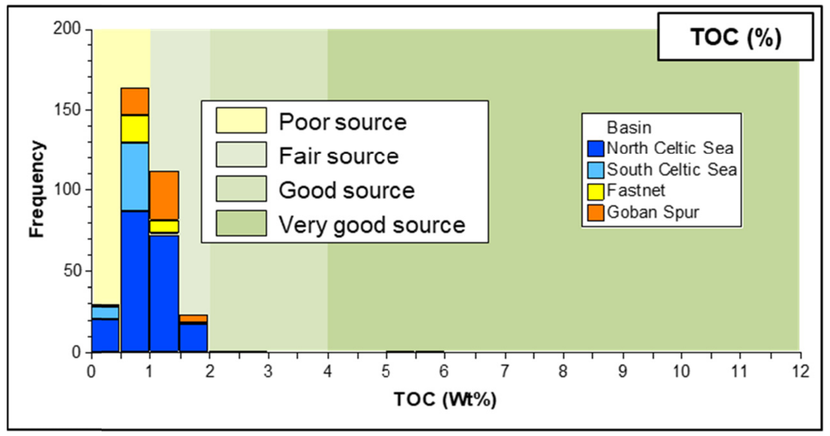
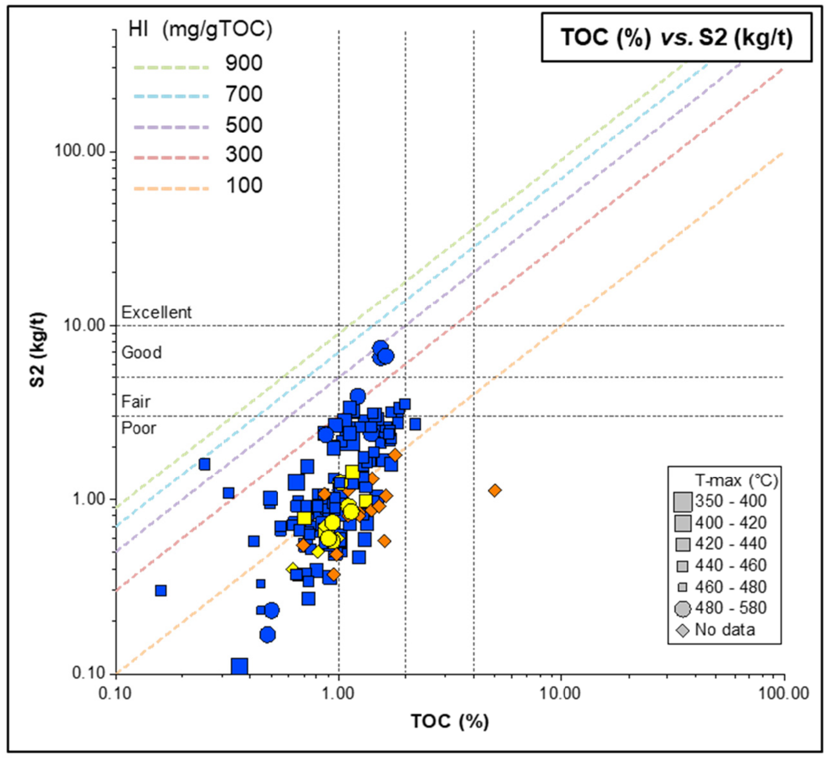


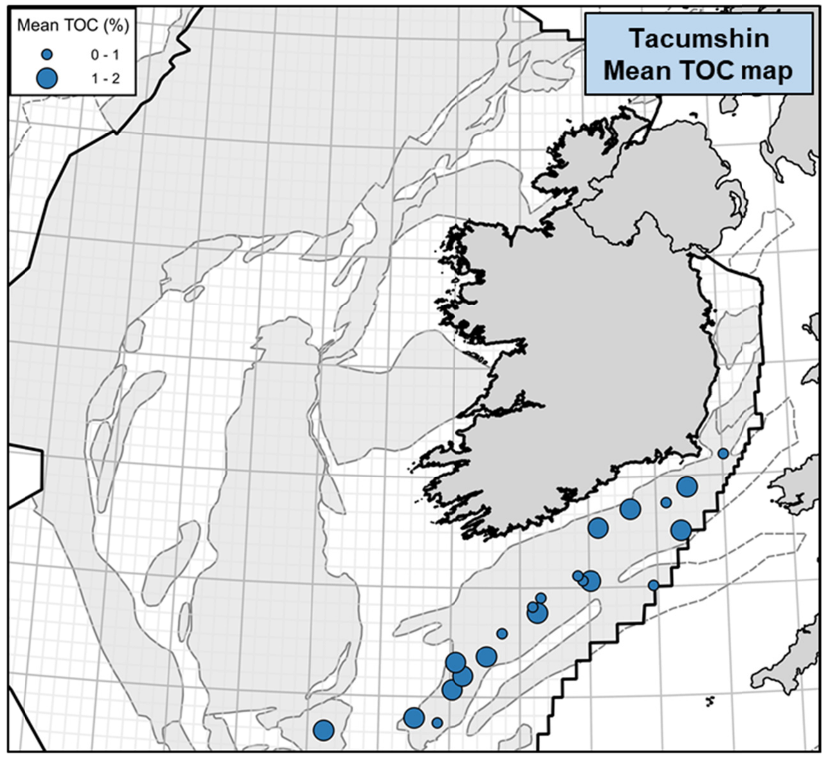
Figure D.6. 58. ***Tacumshin Formation type and reference wells, location and distribution map.***

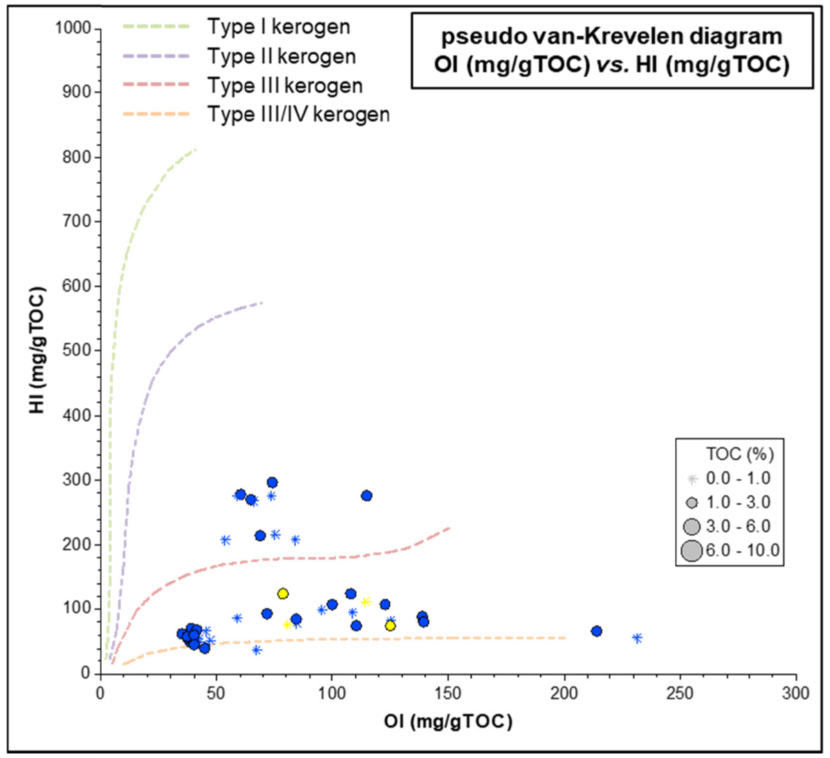
Tacumshin Formation

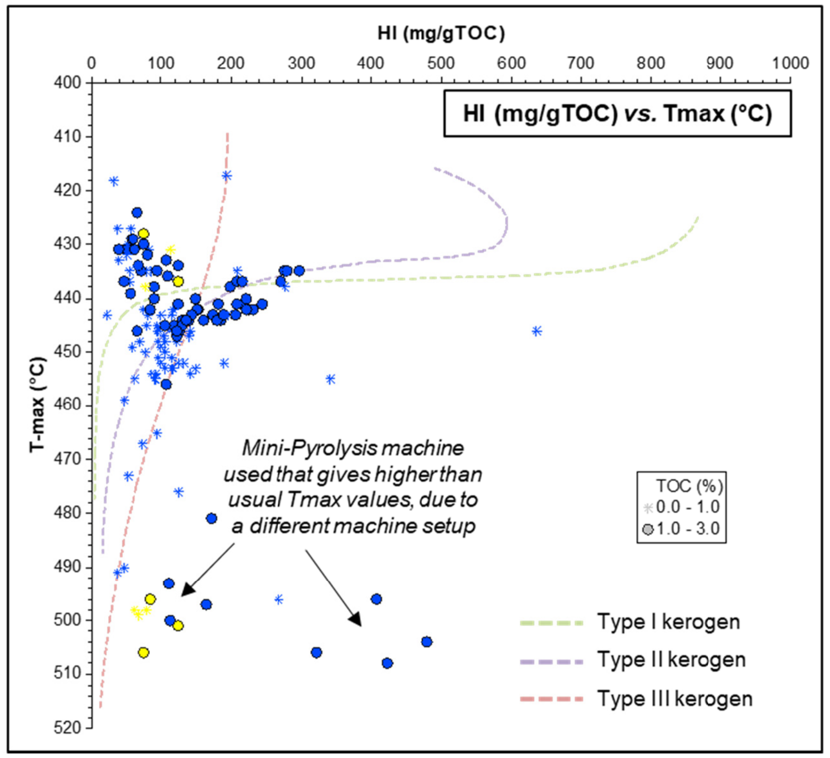
Basin	TOC (%) No. Wells	TOC (%) No. Samples	TOC (%) Min	TOC (%) Max	TOC (%) Avrg.	HI (mg/gTOC) No. Wells	HI (mg/gTOC) No. Samples	HI (mg/gTOC) Min	HI (mg/gTOC) Max	HI (mg/gTOC) Avrg.
North Celtic Sea	14	201	0.08	2.21	0.98	13	144	5	636	134
South Celtic Sea	1	51	0.1	1.07	0.66	-	-	-	-	-
Fastnet	5	31	0.2	5.7	1.19	4	18	61	124	80
Goban Spur	1	56	0.41	5.03	1.19	1	15	22	124	69











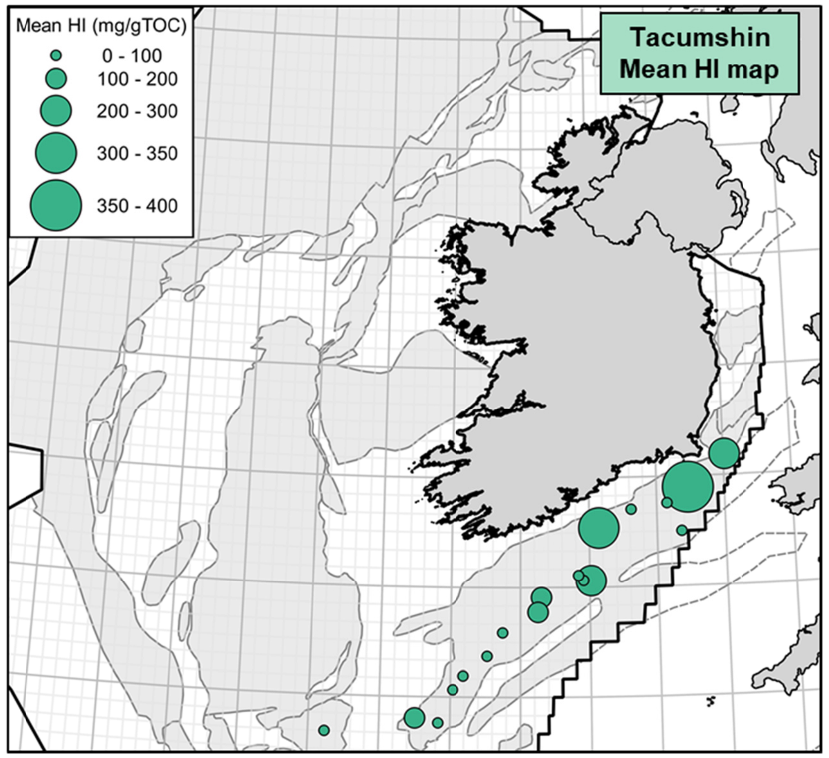


Figure D.6. 59. ***Tacumshin Formation source rock characteristics, offshore Ireland.***

WHITBY MUDSTONE FORMATION

The Whitby Mudstone Formation was defined by Cox *et al*. (1999) to largely replace the previously used term "Upper Lias". The formation is widespread in onshore Britain, from Yorkshire to the English Midlands to south western England. The type section is the coastal exposure at Whitby, in Yorkshire (Cox *et al*., 1999) and ranges from the base of the Toarcian to the Upper Toarcian. The formation is primarily developed as a dark grey claystone unit, which is laminated and bituminous in the lower part (Early Toarcian, Serpentinum Zone). The latter organic rich claystone has source rock potential (see below).

Ternan (2006) used the informal term Toarcian Shale Unit in the Slyne and Erris basins for sediments that correlate with the Whitby Mudstone Formation and also the Dun Caan Shale Formation.

In offshore Ireland, the Whitby Mudstone is applied to the early Late-Early Toarcian argillaceous dominated successions in all basins across the region.

The formation is subdivided into four members. In offshore Ireland, source rock facies are present in the Ree and Derg members of the Whitby Mudstone Formation in the Slyne Basin, and in the Whitewood and Holaun members in the North Celtic Sea, Fastnet and Goban Spur basins (see below for source rock descriptions). This rich source rock interval correlates with the Early Toarcian "T-OAE" ocean anoxic event organic rich interval that has been widely documented across wide areas of the northern hemisphere, including the North Sea (see discussion of J18 sequence, above).

The Fastnet and Celtic Sea Basin member names (Whitewood and Holaun members) first letters spell "WH" which reflects the Whitby Formation name.

Reference sections in offshore Ireland. 18/20-1: 2651-2868.5m below KB. 27/4-1: 935-1033.5m below KB. 49/9-1: 1449-1761.5m below KB. 56/21-1: 1497.5-1938.5m below KB. See **Figure D.6.60**.

Lithology. The claystones and silty claystones are medium to dark grey, greyish black to brownish black, often organic rich, locally highly pyritic, non- to slightly calcareous, subblocky to fissile, and grade locally to siltstones. The greyish black, organic rich, subfissile claystones are present throughout the Whitby Formation, Derg and Ree members, in the Slyne Basin wells. However, in the east and south of Ireland, these sediments are more prevalent in the lower member (Whitewood Member) of the Whitby Formation.

Stringers and thin beds of limestone, white, light grey to light brown, light to medium grey, mudstone, microcrystalline to cryptocrystalline, and generally well indurated, are also present. These sediments locally grade to dolomitic limestones. Minor, off white to light brown, very fine to fine grained, well sorted, subangular to subrounded, calcareous sandstones stringers are present in the Holaun Member in the 56/21-1 well.

Wireline log character. The formation displays characteristically higher gamma ray values and decreased sonic velocities than the overlying and underlying formations. The wireline log curves are finely serrated reflecting the overall mudstone lithology, while the low gamma ray and high sonic velocity spikes represent limestone beds or stringers. The upper units (Derg and Holaun members) possess wireline log motifs which exhibit subparallel gamma ray and sonic velocity curves to locally slightly bow shaped profiles. The lower units (Ree and Whitewood members) exhibits bow shaped, funnel and inverse funnel shaped wireline log motifs.

Upper boundary. In the south and east of Ireland's offshore wells, the top of this unit is placed at a downward lithological change from the medium to dark grey, claystones of the Tacumshin Formation to the dark grey, poorly calcareous, claystones of the Whitby Mudstone Formation, Holaun Member. This boundary is reflected on wireline logs by a slight increase in gamma ray values and a minor decrease in sonic velocity.

Offshore west of Ireland, the boundary is taken as a downsection lithological change from the medium to dark grey claystones of the Dun Caan Shale Formation, to the dark grey to greyish black, poorly calcareous, subfissile, Whitby Mudstone Formation, Derg Member. This change is expressed on wireline logs as a slight increase in the gamma ray values, with a corresponding decrease in sonic velocity. In addition to the reference wells illustrated in **Figure D.6.60**, the characteristic wireline log character of the formation, and the nature of the boundary with the overlying and underlying formations, is shown also in the wells 27/13-1A and 49/9-1 in **Figure D.6. 56**.

Lower boundary. In the south and east of Ireland's offshore wells, the base of this unit is taken at a downsection lithological change from the dark grey to greyish black, non-calcareous mudrocks to the medium to dark grey, variably calcareous, claystones of the Pabay Shale Formation. On wireline log criteria, the boundary is denoted by a decrease in gamma ray values and corresponding increase in sonic velocity.

Offshore west of Ireland, the boundary is denoted by a downsection lithological change from dark grey to greyish black non-calcareous, claystones to the silty claystones/siltstones of the Pabay Shale Formation, Allua Member. This is expressed on wireline log criteria by a decrease in gamma ray values and a corresponding increase in sonic velocity.

Subdivision. The formation is subdivided into differing members in the offshore west of Ireland, and in the offshore south and east of Ireland. Two members are recognised in the Slyne Basin, in descending stratigraphic order; the Derg Member and the Ree Member. In the Irish offshore basins to the east and south, two members are recognised, in descending stratigraphic order; the Holaun Member and the Whitewood Member.

Thickness. The formation varies in thickness from 25.5m (56/22-1) to 441m (56/21-1).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. In the basins to the south and east of Ireland (Goban Spur, Fastnet, North Celtic Sea and South Celtic Sea basins), calcareous microfossil recovery is good within the Late Toarcian interval, whereas within the Early Toarcian interval calcareous microfossil recovery is often very poor, with localised barren intervals. In the Slyne Basin, to the west of Ireland, calcareous microfaunal recovery is often very poor, with many sections barren of microfaunas. Localised pulses of agglutinating foraminifera and *Reinholdella* spp. are recognised.

West of Ireland (Slyne Basin): Occurring within Ostracod Subzone IJO9a, Foraminiferal Zones IJF8 to IJF7 and Palynological Subzones DM3B to DM3A (*pars*).

South and east of Ireland (Goban Spur, Fastnet, North Celtic Sea and South Celtic Sea basins): Occurring within Ostracod Subzone IOJ11a to Zone IOJ9 (*pars*), Foraminiferal Zones IFJ11 (*pars*) to IFJ9 and Palynological Subzones DM3C to DM3A (*pars*).

Ammonites have been recorded from this formation in a core from one well, 49/11-1 in the North Celtic Sea Basin. These were recorded from 8990ft-9020ft (2740.1m-2749.3m) from core 3 and are considered to be indicative of the "H. falciferum Zone" (equivalent to the Serpentinum Zone (Early Toarcian) in current ammonite zonal terminology), based on identifications of ammonites made by Dr. M. K. Howarth of the Natural History Museum, London (Paleoservices, 1973). This age is consistent with the stratigraphic position of the core, around 300ft (91m) above the base of the Whitby Mudstone Formation. It is unfortunate that in this well it is not possible to pick the boundary between the Whitewood and Holaun members or that between the J17 and J18 sequences, due to the presence of the 9 5/8" casing point at 9156ft (2971m) in this well which has affected the wireline log signature.

Age. Early Jurassic, early Late-Early Toarcian.

Depositional environment. Marine, inner to middle shelf. The Ree and Whitewood members were deposited in low energy, below wave base, inner to middle shelf marine environments. Bottom waters varied from oxygenated, through dysaerobic to anoxic within the Whitewood Member, while they were more restricted (dysaerobic to anoxic) in the Ree Member. Oxygenated bottom waters are indicated by the occurrence of both micro- and macrofaunas, while the occurrences of abundant/influxes of amorphous organic matter, phosphatic fish debris, *Tasmanites* spp., plus a general absence of bottom feeder faunas is indicative of anoxic bottom waters. The localised pulses of common/influxes of the foraminiferal genus *Reinholdella* spp. are envisaged to reflect less toxic bottom waters where this genus could thrive.

The Holaun Member was deposited in a marine, low energy, below wave base, inner shelf, environment. Bottom waters were generally well oxygenated, more especially in the upper half of the member. In the lower half of the Holaun Member both the micro- and macrofaunas are generally less diverse and abundant, possibly suggesting slightly harsher bottom waters conditions.

The Derg Member was deposited in a low energy, below wave base, inner shelf, marine environment. Bottom waters were often restricted (dysaerobic to anoxic), indicated by abundant/influxes of amorphous organic matter, *Pterospermella* spp., *Tasmanites* spp., and absence of bottom feeder faunas. The development of localised oxygenated bottom waters are indicated by the occurrences of foraminifera (common/influxes of *Reinholdella* spp. and rare to abundant, poorly preserved agglutinating foraminifera).

Distribution. The formation is proven in the North Celtic Sea, South Celtic Sea, Goban Spur, Slyne and Erris basins. It is considered likely that the formation extends also into the Porcupine Basin, though it has not yet been penetrated in any wells in this basin. The formation may, in addition, be present in the Conall and Rónán basins, on the western flank of the Rockall Basin. Maps showing the distribution of the Whitby Formation and its constituent members are shown in **Figure D.6.60** and **Figure D.6. 61**.

Seismic expression. A seismic marker termed the Toarcian (Whitby Mudstone) horizon has been identified in some parts of the North Celtic Sea Basin, for example, the 49/9 and 41/30-UK 103/1 areas (see **Figure D.6. 5** and **Figure D.6.8**).

Regional correlation. The Whitby Mudstone Formation is present throughout the Irish offshore. It is envisaged to be present within the offshore UK basins (Bristol Channel, St George's Channel and Celtic Sea basins). This formation is known to occur throughout much of the onshore UK (Seven Basin, East Midlands Shelf and the Cleveland Basin (see Cox *et al.,* 1999; Simms *et al*., 2004).

Lateral equivalents in southern England comprise the upper part of the Marlstone Rock Formation, most of the Beacon Limestone Formation, Eype Mouth Limestone Member, the lower sediments of the Bridport Sand Formation and the "Paper Shales" (see Ainsworth *et al.,* 1998; Cox *et al.,* 1999, Simms *et al*., 2004, Ainsworth & Riley, 2010). The Whitby Mudstone Formation correlates with the uppermost part of the Scalpay Sandstone Formation, and the Portree Shale and Raasay Ironstone formations in northwest Scotland (Morton, 2004; Simms *et al*., 2004).

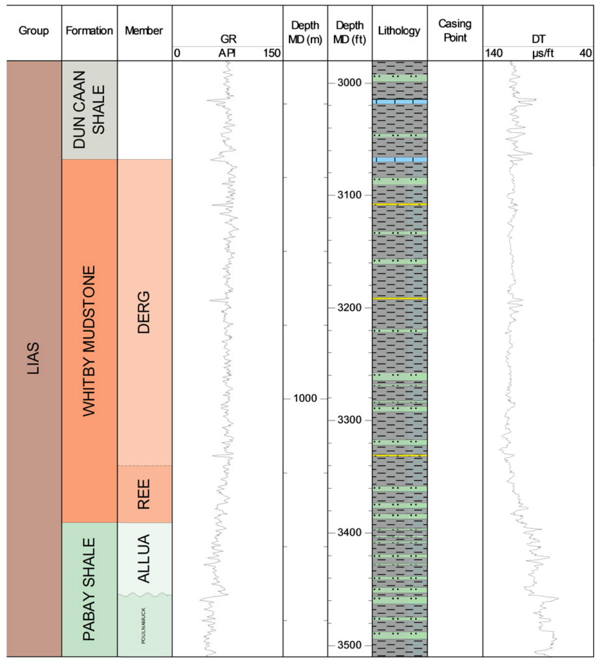
Source rock characterisation. The Whitby Mudstone Formation shows excellent source potential in the north west Irish margin and slightly lower source potential in the southern margin area (**Figure D.6.62**). In the Slyne Basin it can be characterised as an organic-rich interval with a marine Type II kerogen composition and excellent oil generation potential. In the North Celtic Sea Basin, it shows a mixed Type II/III kerogen composition, indicating input of terrestrial material. As a result, the source potential in the southern margin is mixed oil and gas prone. In the Fastnet and Goban Spur basins terrestrial material dominates the kerogen composition, making it a Type III source rock only showing gas generative potential. Although the data are not shown in **Figure D.6.62**, these differences are also seen in available visual kerogen data, with macerals of the vitrinite group dominating in the Fastnet Basin, whereas samples from the Slyne Basin are characterised by high proportions of amorphous liptinite.

TOC and HI data are shown in **Figure D.6. 56** for two wells (27/13-1A from the Slyne Basin and 49/9-1 from the North Celtic Sea Basin) that display good source rock data sets, alongside other well data including well logs, sequences, lithology and stratigraphic (lithostratigraphic and chronostratigraphic) subdivisions. The development of source rocks over this interval in the 27/13-1A well has been illustrated previously (Scotchman & Thomas, 1995). It can be seen from these displays that the richest source interval within the Whitby Mudstone Formation occurs through the formation in the 27/13-1A well (including both the Ree and Derg members), although the Derg Member appears to display the highest TOC and HI values. This correlates with the lower part of the Holaun Member in the 49/9-1 well and, again, with the lower part of the identified J18 sequence. This source rich level is in the lower part of the J18 sequence which correlates with the Toarcian Ocean Anoxic Event regionally, and the level at which organic rich sediments are known to occur over a wide region of the northern hemisphere.

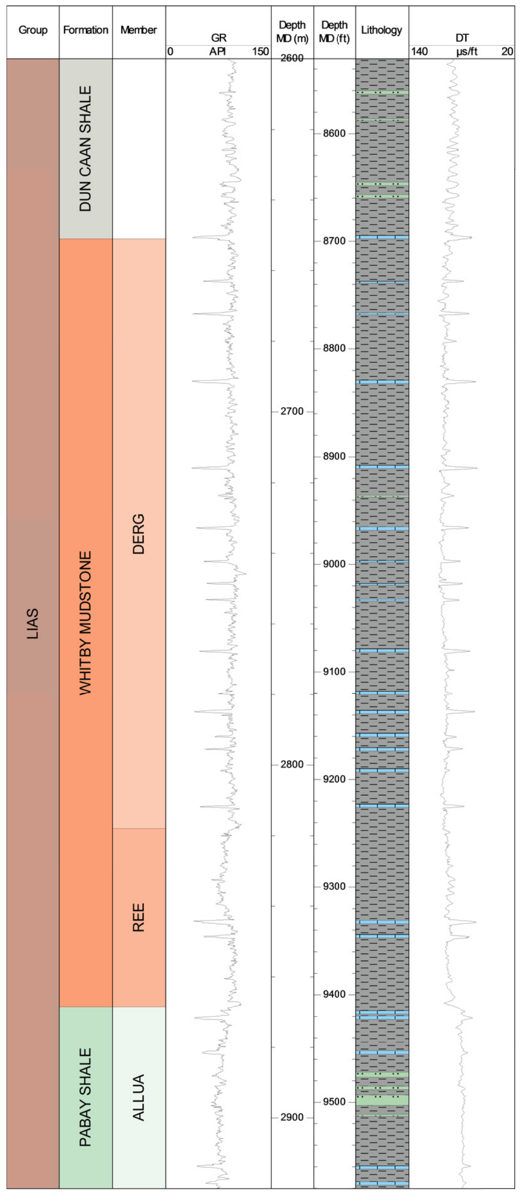
In the 27/13-1A well, the source rock is well expressed by the crossover in the sonic and resistivity logs, as was also illustrated by Scotchman & Thomas (1995) over the same interval.

The Whitby Mudstone Formation corresponds mainly to the source rock interval Low J2b (Toarcian) that was identified in project IS16/01 (BeicipFranlab, 2017), but is also part of interval Low J2a in some wells (see **Figure D.6. 56**).

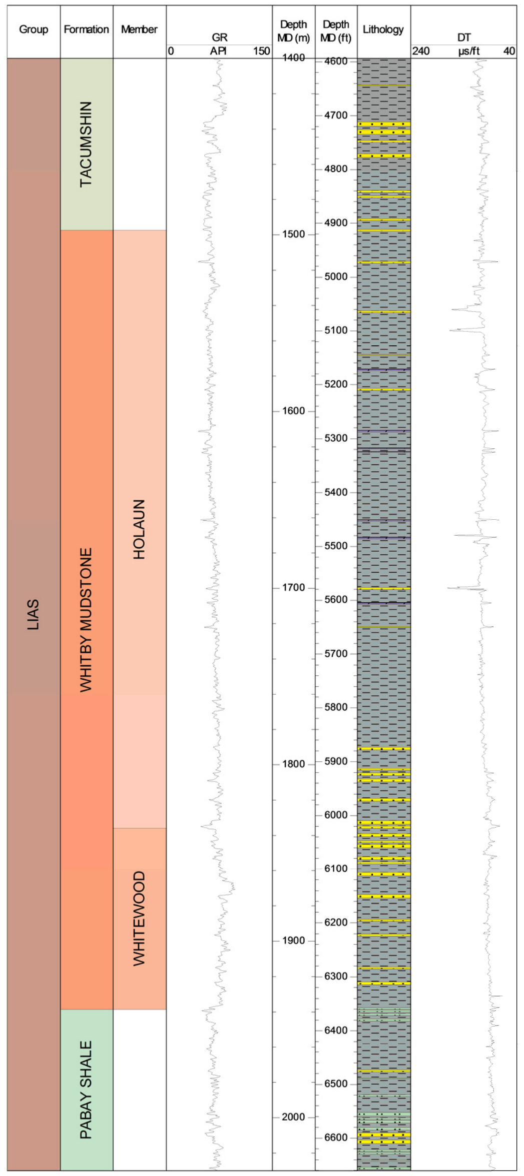
Comparison with Eastern Canada. The Whitby Mudstone Formation is age equivalent to the lower part of the Downing Formation (claystones) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.



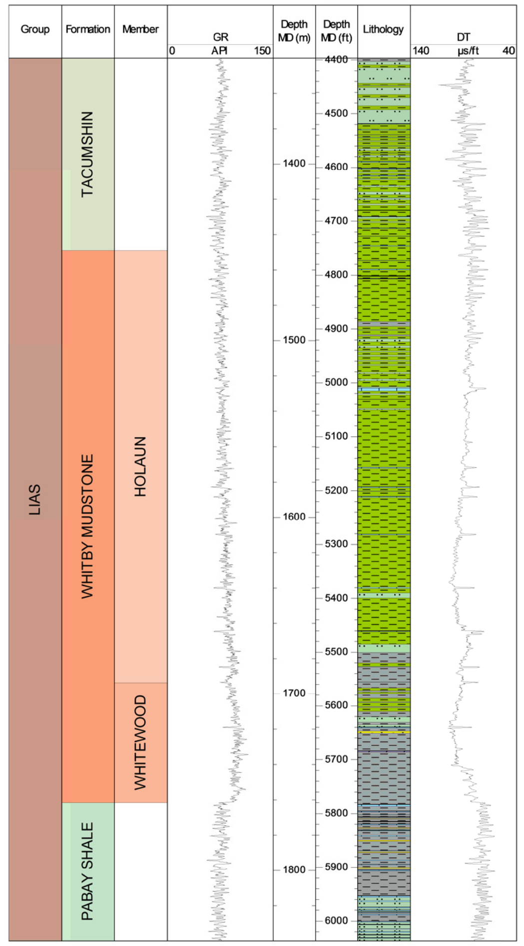
27/4-1
Reference well; Whitby Mudstone Formation, Derg and Ree Members



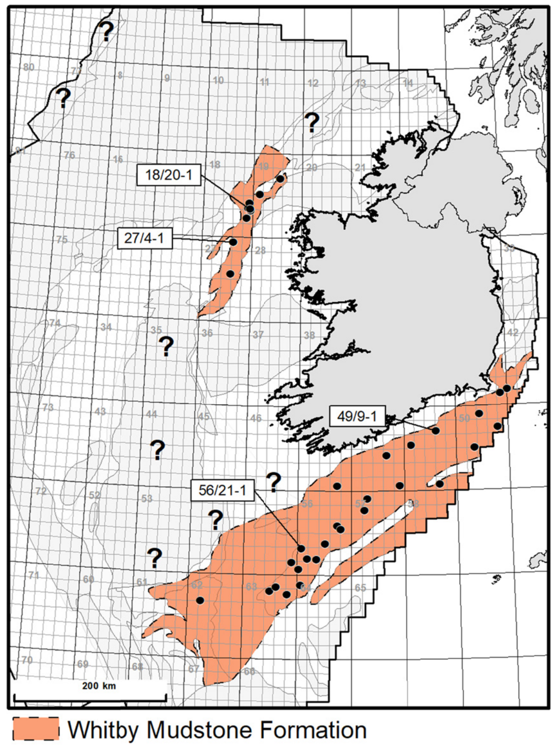
18/20-1
Type well; Derg and Ree Members
Reference well; Whitby Mudstone Formation



56/21-1
Type well; Holaun, Whitewood Members
Reference well; Whitby Mudstone Formation



49/9-1
Reference well; Whitby Mudstone Formation, Holaun, Whitewood Members



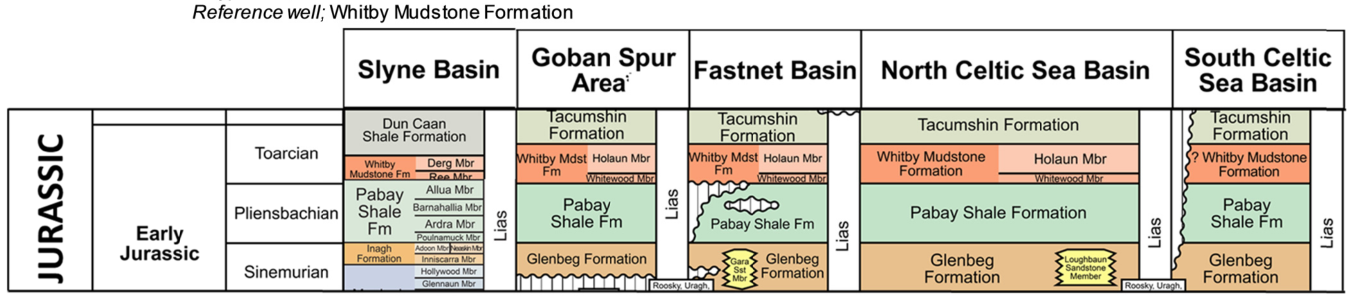


Figure D.6. 60. ***Whitby Mudstone Formation reference wells and constituent members type and reference wells.***

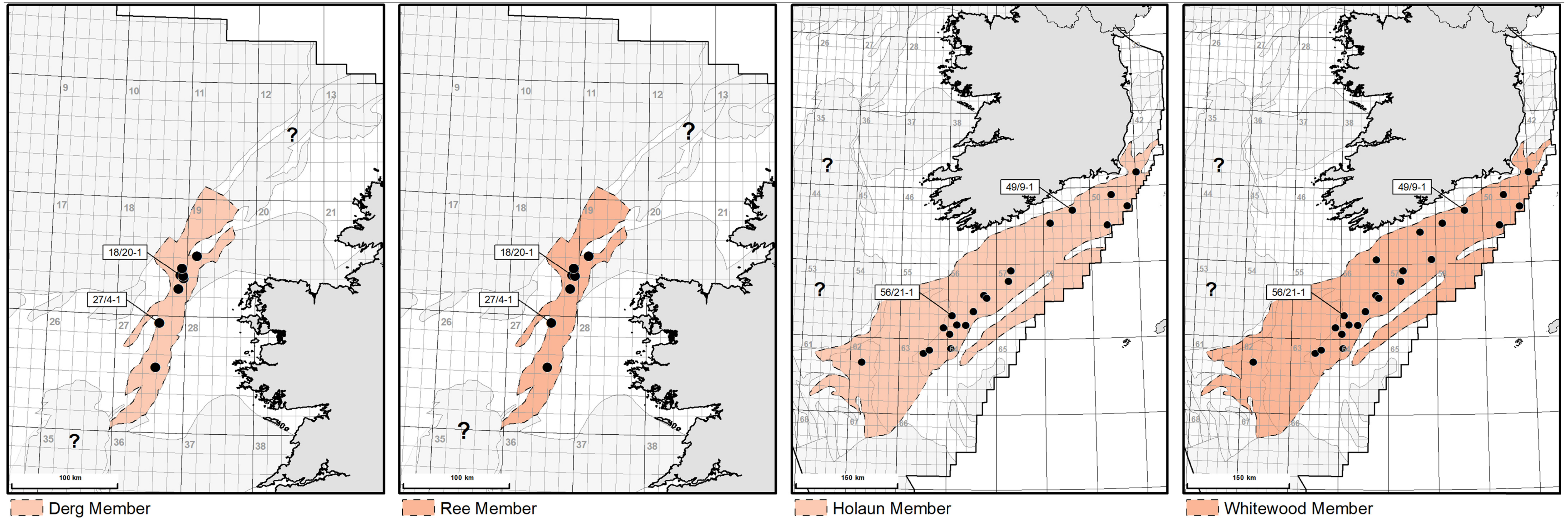
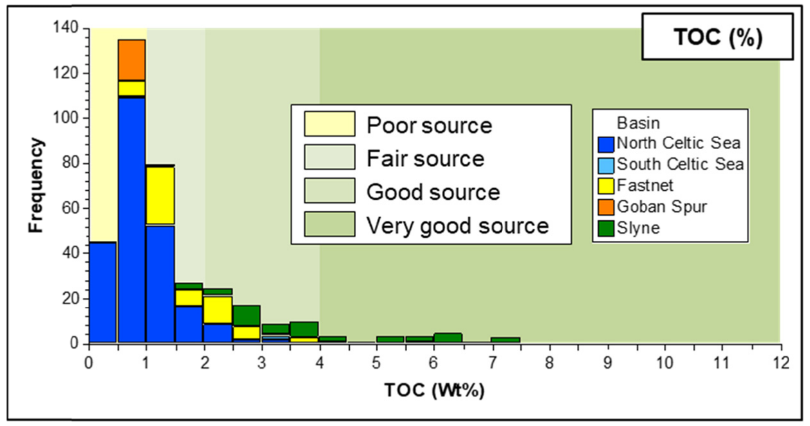


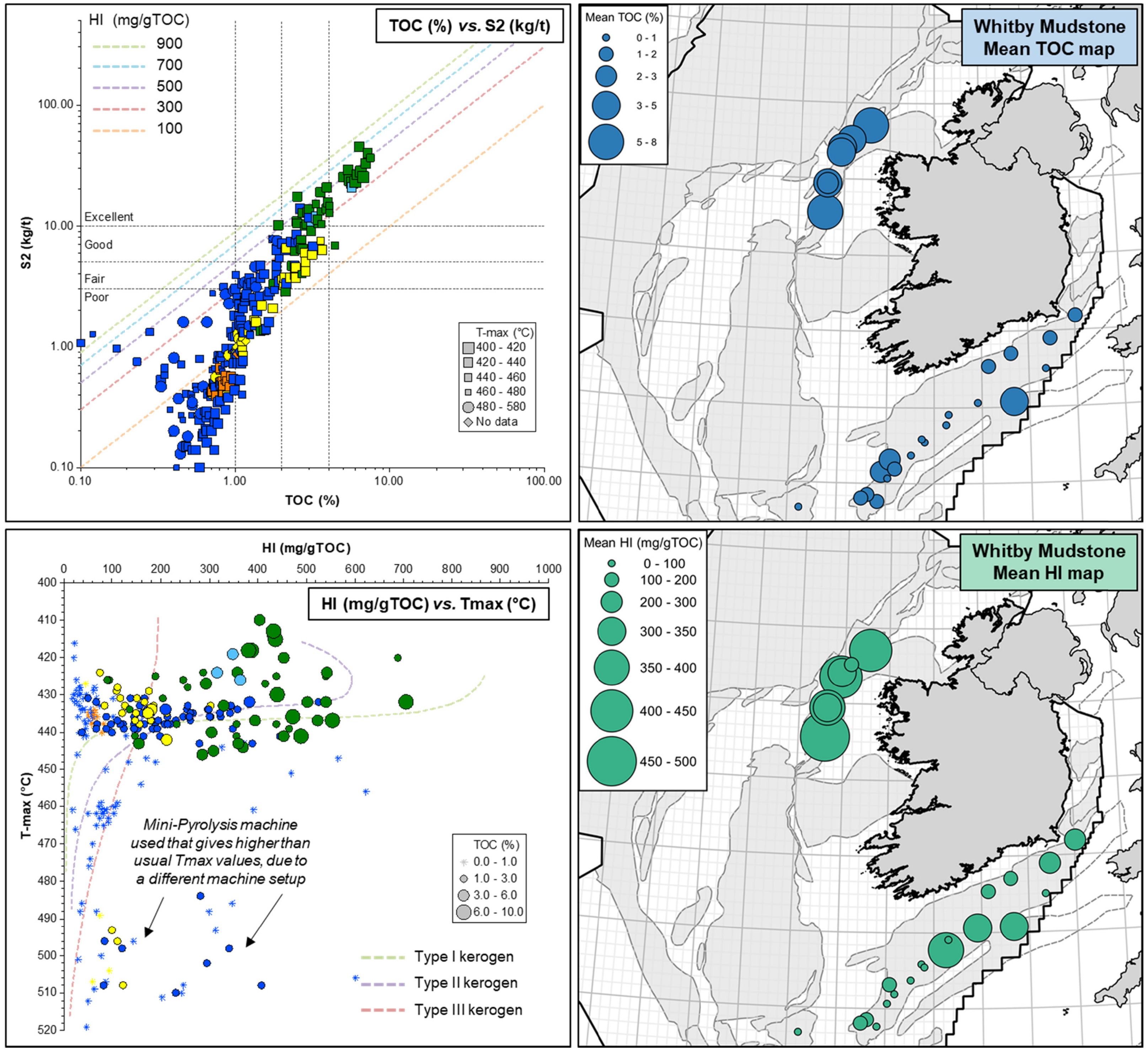
Figure D.6. 61. ***Whitby Mudstone Formation reference and member type and reference wells location and distribution maps.***

Whitby Mudstone Formation

(incl. ?WHITBY)

Basin	TOC (%) No. Wells	No. Samples	Min	Max	Avrg.	HI (mg/gTOC) No. Wells	No. Samples	Min	Max	Avrg.
North Celtic Sea	11	237	0.02	3.21	0.91	11	181	5	1150	179
South Celtic Sea	1	4	0.71	5.67	3.22	1	3	315	363	342
Fastnet	7	66	0.33	4.00	1.74	6	35	44	303	130
Goban Spur	1	20	0.70	1.04	0.84	1	18	50	83	63
Slyne	7	50	1.45	7.42	4.01	7	45	90	706	375





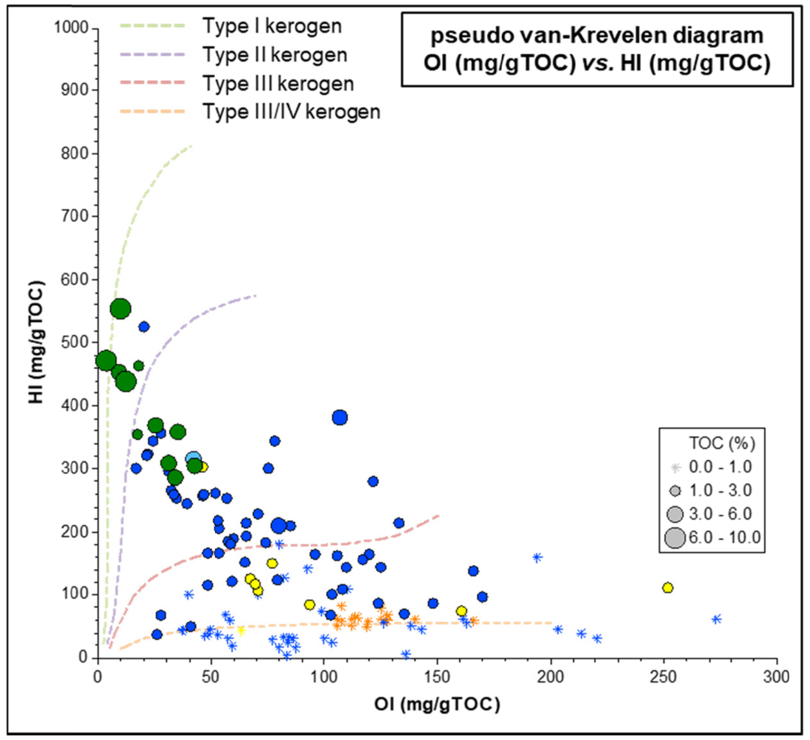


Figure D.6. 62. ***Whitby Mudstone Formation source rock characteristics, offshore Ireland.***

Derg Member (New)

The Derg Member is defined here for a dark grey to greyish black, organic-rich claystone/silty claystone dominated succession of the Whitby Mudstone Formation, of Early Toarcian age, that is developed in the Slyne Basin. It is probably present in both the Porcupine and Erris basins; however, no wells have penetrated this member in these two basins.

The Derg Member is the upper unit of the Whitby Formation in the west of Ireland and lies between an overlying Dun Caan Shale Formation and an underlying Whitby Mudstone Formation, Ree Member.

Name. After Lough Derg, with shores in counties Clare, Galway and Tipperary.

Type section. 18/20-1: 2651-2818m below KB. See **Figure D.6. 60**.

Reference section. 27/4-1: 935-1018m below KB. See **Figure D.6. 60**.

Lithology. The claystones and silty claystones are dark grey to greyish black, brownish black, generally organic-rich, locally highly pyritic, non- to poorly calcareous, and subfissile to fissile. Common stringers and thin beds of limestone, off white, light grey, light brown, mudstone, microcrystalline to cryptocrystalline, and well indurated, are present throughout the unit. A limestone is well developed within the member in the deviated 18/20-5 (P6) well.

Wireline log character. The claystones of this member possess slightly serrated, relatively high gamma ray and low sonic velocities. The low gamma spikes and high sonic velocities denote limestone stringers or beds. The wireline log motifs exhibit subparallel gamma ray and sonic velocity curves to locally slightly bow shaped profiles.

Upper boundary. The upper boundary is placed at a downward lithological change from the medium to dark grey claystones of the Dun Caan Shale Formation to the dark grey to greyish black, poorly calcareous, Whitby Mudstone Formation, Derg Member. This change is expressed on wireline log criteria as a slight increase in the gamma ray values, with a corresponding slight decrease in sonic velocity.

Lower boundary. The lower boundary is denoted by a downsection lithological change from the dark grey to greyish black, poorly calcareous claystones, to dark grey, slightly calcareous claystones of the Ree Member. On wireline log criteria, the boundary is taken at a decrease in gamma ray values, in association with a slight increase in sonic velocity.

Thickness. The member varies in thickness from 52m (27/13-1A) to a maximum of 167m (18/20-1).

Biostratigraphic characterization. Dated by dinocysts, foraminifera and ostracods. Calcareous microfaunal recovery is often very poor, with many sections barren of microfaunas. Localised pulses of agglutinating foraminifera and rare *Reinholdella* spp. are recognised. Occurring within Ostracod Subzone IJO9a (*pars*), Foraminiferal Zone IJF8 and Palynological Subzone DM3B.

Age. Early Jurassic, Early Toarcian.

Depositional environment. Marine, inner shelf. The Derg Member was laid down in a low energy, below wave base, inner shelf, marine environment. Bottom waters are often restricted (dysaerobic to anoxic), denoted by the occurrences of abundant/influxes of amorphous organic matter, *Pterospermella* spp., *Tasmanites* spp., and absence of bottom feeder faunas. Localised oxygenated bottom waters are recognised on the occurrences of foraminifera (common/influxes of *Reinholdella* spp. and rare to abundant poorly preserved agglutinating foraminifera).

Distribution. The member is proven to be present in the Slyne Basin and may also extend into the Erris Basin and the Porcupine Basin though is not yet proven by well penetrations in the latter two basins.

Regional correlation. The member is laterally equivalent to the lower and middle sections of the Holaun Member, Whitby Mudstone Formation within the Goban Spur, Fastnet, North Celtic Sea and South Celtic Sea basins. In southern Britain this unit is age equivalent to the lower and mid parts of the Eype Mouth Limestone Member, Charmouth Mudstone Formation and the lower and mid sections of the Whitby Mudstone Formation, while in northwest Scotland it is equivalent to the Portree Shale and Raasay Ironstone formations (see Cox *et al.,* 1999; Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The Derg Member is age equivalent to the lower part of the Downing Formation (claystones) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Holaun Member (New)

The Holaun Member is defined here for a medium to dark grey, claystone dominated succession of the Whitby Mudstone Formation, of early Late-Early Toarcian age, that is developed in the Goban, Fastnet, North Celtic Sea and South Celtic basins to the south and east of Ireland.

The Holaun Member is the thicker upper unit of the Whitby Formation, developed in the south and east of Ireland, and lies between an overlying Tacumshin Formation and an underlying Whitby Mudstone Formation, Whitewood Member.

Name. After Holaun Lough, County Clare.

Type section. 56/21-1: 1497.5-1836m below KB. See **Figure D.6. 60**.

Reference section. 49/9-1: 1449-1693.5m below KB. See **Figure D.6. 60.**

Lithology. The claystones are medium to dark grey, slightly micromicaceous, locally pyritic, locally silty, non- to calcareous, and subblocky to subfissile, grading locally to siltstone. The calcareous content of these sediments decreases in the lower halves of their respective sections. Localised stringers of limestone and dolomitic limestone, off white, light to medium grey, dark brownish grey, mudstone, micritic to cryptocrystalline, and generally well indurated, are also present. Rare, off white to light brown, very fine to fine grained, well sorted, subangular to subrounded, calcareous sandstones stringers are present in the 56/21-1 well.

Wireline log character. The claystones are denoted by finely serrated, relatively high gamma ray and low sonic velocities. The low gamma spikes and high sonic velocities denote limestone stringers or beds. The wireline logs exhibit subparallel gamma ray and sonic velocity curves through to a funnel shaped log motif. In the latter case this is denoting a slight upward increase in the calcareous nature of the claystones.

Upper boundary. The top of this unit is placed at a downward lithological change from the medium to dark grey, claystones of the Tacumshin Formation, to the dark grey, poorly calcareous, mudstones of the Whitby Mudstone Formation, Holaun Member. On wireline log criteria, this is expressed by slight increase in gamma ray values and corresponding decrease in sonic velocity.

Lower boundary. The base of this unit is placed on a downward lithological change from poorly calcareous mudstones to the dark grey to greyish black, often organic-rich, claystones of the Whitewood Member. This is expressed on wireline log criteria as an increase in gamma ray values, in association with a decrease in sonic velocity.

Thickness. The member varies in thickness from 20m (56/22-1) to a maximum of 348m (57/2-1).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is good within the Late Toarcian interval, whereas within the Early Toarcian interval recovery is often very poor, with localised barren intervals. Occurring within Ostracod Subzone IOJ11a to Zone IOJ10, Foraminiferal Zones IFJ11 (*pars*) to IFJ10 and Palynological Subzones DM3C to DM3B.

Age. Early Jurassic, early Late-Early Toarcian.

Depositional environment. Marine, inner shelf. The Holaun Member was deposited in a marine, low energy, below wave base, inner shelf, environment. Bottom waters are generally well oxygenated, more especially in the upper half of the member. In the lower half of the Holaun Member both the micro- and macrofaunas are generally less diverse and abundant, possibly suggesting slightly harsher bottom waters conditions.

Distribution. The member is proven to be present in the North Celtic Sea, Fastnet and Goban Spur basins and its extent is taken to the limits of these basins. The member is likely to extend through the Celtic Platform area between the Fastnet and Goban Spur basins. It is considered likely that the member is present in the South Celtic Sea Basin.

Regional correlation. In the Goban Spur, Fastnet, North Celtic Sea and South Celtic Sea basins this unit is laterally equivalent to the Derg Member, Whitby Mudstone Formation and the lower part of the Dun Caan Shale Formation. In the basins of southern Britain this member is laterally equivalent to the Eype Mouth Limestone Member, Charmouth Mudstone

Formation and the lower section of the Dun Caan Shale Formation (see Cox *et al.,* 1999; Simms *et al*., 2004). In northwest Scotland the Holaun Member is equivalent to the Portree Shale and Raasay Ironstone formations (Morton, 2004; Simms *et al.*, 2004).

Comparison with Eastern Canada. The Holaun Member is age equivalent to the lower part of the Downing Formation (claystones) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Ree Member (New)

The Ree Member is defined here for a dark grey to greyish black, organic-rich claystone dominated succession of the Whitby Mudstone Formation, of earliest Toarcian age, that is developed in the Slyne Basin. It is probably present in both the Porcupine and Erris basins; however, no wells have penetrated this member in these two basins.

The Ree Member is the lower unit of the Whitby Formation in the west of Ireland, and lies between an overlying Whitby Mudstone Formation, Derg Member and an underlying Pabay Shale Formation, Allua Member.

Name. After Lough Ree, a major lake on the River Shannon, with shores in counties Roscommon, Longford and Westmeath.

Type section. 18/20-1: 2818-2868.5m below KB. See **Figure D.6. 60**.

Reference section. 27/4-1: 1018-1033.5m below KB. See **Figure D.6. 60**.

Lithology. The claystones are dark grey to greyish black, brownish black, generally organic-rich, locally highly pyritic, locally silty, non- to slightly calcareous, and subfissile to fissile. Stringers of limestone, light grey to light brown, mudstone, microcrystalline to cryptocrystalline, and well indurated, are also present.

Wireline log character. The wireline log curves are finely serrated. The upper part of the member generally exhibits a bow shaped log motif, while the lower half is denoted by an inverse funnel shaped motif. In the latter case this is indicating an upward increase in the organic nature of the claystones.

Upper boundary. The top of the unit is placed on a downsection lithological change from the dark grey to greyish black, poorly calcareous claystones of the Derg Member, to the dark grey, slightly calcareous claystones of the Ree Member. This is expressed on wireline log criteria as a decrease in gamma ray values and a coincident increase in sonic velocity.

Lower boundary. The base of this unit is taken at a downward lithological change from non-calcareous claystones to the silty claystones/siltstones of the Pabay Shale Formation, Allua Member. On wireline log criteria, this change is indicated by a decrease in gamma ray values and a corresponding increase in sonic velocity.

Thickness. The member varies in thickness from 31m (19/11-1A) to a maximum of 50.5m (18/20-1).

Biostratigraphic characterization. Dated by foraminifera and dinocysts. Calcareous microfaunal recovery is often very poor, with many sections barren of microfaunas. Localised pulses of *Reinholdella* spp. are recognised. Occurring within Ostracod Subzone IJO9a *(pars)*, Foraminiferal Zones IFJ8 (*pars*) to IJF7 and Palynological Subzone DM3A (*pars*).

Age. Early Jurassic, earliest Toarcian.

Depositional environment. Marine, inner to middle shelf. The Ree Member was laid down in a low energy, below wave base, inner to middle shelf, marine environment. Bottom waters were often anoxic or dysaerobic, denoted by the presence of abundant/influxes of amorphous organic matter, phosphatic fish debris, *Tasmanites* spp., plus a general absence of bottom feeder faunas. Localised pulses of abundant specimens of the foraminiferal genus *Reinholdella* spp. (?opportunistic) are envisaged to reflect less toxic bottom waters where this genus could thrive.

Distribution. The member is proven to be present in the Slyne Basin and may also extend into the Erris Basin and the Porcupine Basin though is not yet proven by well penetrations in the latter two basins.

Regional correlation. The member is a direct lateral equivalent to Whitewood Member, Whitby Mudstone Formation, in the Goban Spur, Fastnet, North Celtic Sea and South Celtic Sea basins. The unit appears to be age equivalent to the "Paper Shales", the upper part of the Marlstone Rock Formation and the lower part of the Beacon Limestone Formation of southern England (Ainsworth *et al*., 1998; Cox *et al.,* 1999; Simms *et al*., 2004, Ainsworth & Riley, 2010), and also to the upper sediments of the Scalpay Sandstone Formation of northwest Scotland (Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The Ree Member is age equivalent to the lower part of the Downing Formation (claystones) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

Whitewood Member (New)

The Whitewood Member is defined here for a dark grey to greyish black, often organic-rich, claystone dominated succession of the Whitby Mudstone Formation, of earliest Toarcian age, that is developed in the Goban, Fastnet, North Celtic Sea and South Celtic basins to the south and east of Ireland.

The Whitewood Member is the thinner lower unit of the Whitby Formation, developed in the south and east of Ireland, and lies between an overlying Whitby Mudstone Formation, Holaun Member and an underlying Pabay Shale Formation.

Name. After Whitewood Lake, County Meath.

Type section. 56/21-1: 1836-1938.5m below KB See **Figure D.6. 60.**

Reference section. 49/9-1: 1693.5-1761.5m below KB. See **Figure D.6. 60**.

Lithology. The claystones are medium dark grey to greyish black, locally earthy, locally highly organic-rich, slightly micromicaceous, locally pyritic, non- to slightly calcareous, and subblocky to subfissile. Stringers of limestone, white, medium light to medium grey, mudstone, cryptocrystalline, and generally well indurated, are also present.

Wireline log character. The wireline log curves are slightly serrated. From the base of the member to approximately two-thirds up, gamma ray values increase, while sonic velocities decrease, denoting an increase in the organic nature of the claystones. Above this point gamma ray values decrease and sonic velocities increase, indicating an increase in the calcareous content of the claystones.

Upper boundary. The top of the unit is taken at a downsection lithological change from the poorly calcareous claystones of the Holaun Member to the dark grey to greyish black, often organic-rich, claystones of the Whitewood Member. This is indicated on wireline log criteria by an increase in gamma ray values, in association with a decrease in sonic velocity.

Lower boundary. The base of this member is denoted by a downward lithological change from the dark grey to greyish black, non-calcareous mudrocks to the medium to dark grey, variably calcareous, claystones of the Pabay Shale Formation. On wireline log criteria, the boundary is denoted by a decrease in gamma ray values and corresponding increase in sonic velocity.

Thickness. The member varies in thickness from 5.5m (56/22-1) to a maximum thickness of 102.5m (56/21-1).

Biostratigraphic characterization. Dated by ostracods, foraminifera and dinocysts. Calcareous microfossil recovery is very poor to good. Occurring within Ostracod Zone IOJ9 (*pars*), Foraminiferal Zone IFJ9 and Palynological Subzone DM3A (*pars*).

Age. Early Jurassic, earliest Toarcian.

Depositional environment. Marine, inner to middle shelf. The Whitewood Member was laid down in a low energy, below wave base, inner to middle shelf, marine environment. Bottom waters varied from oxygenated, through dysaerobic to anoxic. Oxygenated bottom waters are indicated by the occurrence of both micro- and macrofaunas, while the occurrences of abundant/influxes of amorphous organic matter, phosphatic fish debris, *Tasmanites* spp., plus a general absence of bottom feeder faunas is indicative of anoxic bottom waters. Localised pulses of abundant specimens of the foraminiferal genus *Reinholdella* spp. (?opportunistic) are envisaged to reflect less toxic bottom waters where this genus could thrive.

Distribution. The member is proven to be present in the North Celtic Sea, Fastnet and Goban Spur basins and its extent is taken to the limits of these basins. The member is likely to extend through the Celtic Platform area between the Fastnet and Goban Spur basins. It is considered likely that the member is present in the South Celtic Sea Basin.

Regional correlation. The unit is a direct lateral equivalent to Ree Member, Whitby Mudstone Formation, from the Slyne Basin. The unit appears to be age equivalent to the "Paper Shales", the upper part of the Marlstone Rock Formation and the lower part of the Beacon Limestone Formation of southern England (Ainsworth *et al*., 1998; Cox *et al.,* 1999; Simms *et al*, 2004, Ainsworth & Riley, 2010), and also to the upper sediments of the Scalpay Sandstone Formation of northwest Scotland (Morton, 2004; Simms *et al*., 2004).

Comparison with Eastern Canada. The Whitewood Member is age equivalent to the lower part of the Downing Formation (claystones) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.

UNASSIGNED GROUP

"12/2-2 Lower Sandstone"

This single sandstone unit of intra Callovian-Late Bathonian age occurs in the 12/2-2 well, located in the Rockall Basin. This sandstone unit is unconformably bounded and is present between the overlying Late Jurassic Muckross Group, Dawros Formation and the underlying Pennsylvanian Sorrel Group, "12/2-2 Claystone".

This unit is unusual on two counts, firstly in representing the only section that may be of Bathonian age (at least in part) in west of Ireland basins. Secondly, it represents the only section that may be of Callovian age, of marine origin, in the whole of offshore Ireland. Given these two observations it is possible that the dinocyst species that are indicative of Bathonian-Callovian ages actually are reworked into younger strata in this instance. As such this sandstone unit has been left in open nomenclature, with no group or formation assigned.

Type section. 12/2-2: 4353.5-4374m below KB. See **Figure D.6. 63**.

Lithology. This unit is dominated by sandstone. The sandstones are off white, light grey to light greenish grey, very fine to medium grained, moderately well sorted, subangular to subrounded, locally argillaceous, and calcareous.

Wireline log character. The unit displays a serrated, moderately high gamma ray and a slow sonic velocity wireline log motif.

Upper boundary. The top of this unit is marked by an unconformity and is indicated by a downsection lithological change from the silty claystones of the Muckross Group, Dawros Formation, to the sandstones of the "12/2-2 Sandstone". This is reflected on wireline log criteria by a decrease in gamma ray values, in association with a slight increase in sonic velocity.

Lower boundary. The base of the unit is marked by an unconformity. It is placed at a downward lithological change from sandstones to the claystones of the Carboniferous Sorrel Group, "12/2-2 Claystone". This is expressed on wireline logs by an decrease in gamma ray values, and a corresponding slight increase in sonic velocity.

Thickness. 20.5m thick in the 12/2-2 well.

Biostratigraphic characterization. This unit is dated by a moderately diverse dinocyst assemblage. These include *M. groenlandicum, K. kettonensis, D. filapicata* and *?D. willei*. Occurring within Palynological Zone DM5 (*pars*).

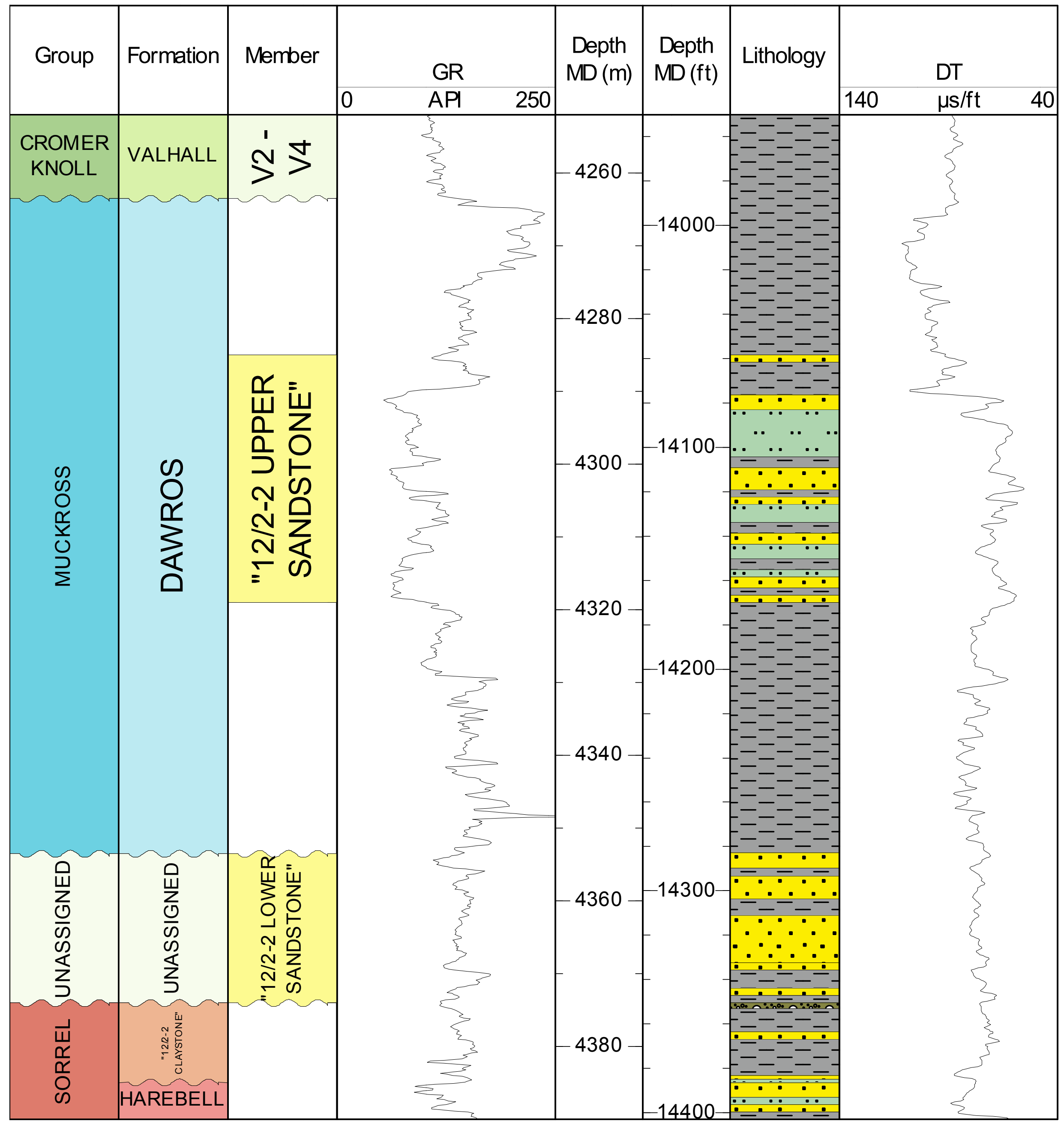
Age. Middle Jurassic, within the age range of intra Callovian-Late Bathonian.

Depositional environment. Marine, inner shelf.

Distribution. This unit has been identified only the 12/2-2 well in the Rockall Basin.

Regional correlation. This arenaceous unit is partly age equivalent to Bathonian aged Peregrine Formation in the North Celtic Sea Basin. The unit appears to be an age equivalent of the uppermost Great Estuarine Group (Kilmaluag and Skudiburgh formations) and the Staffin Bay Formation of northwest Scotland.

Comparison with Eastern Canada. This unit is laterally equivalent to the upper part of the Downing Formation (claystones) of the Carson, Horseshoe, Whale and Jeanne d'Arc basins, offshore east coast Canada.



12/2-2
Type well; "12/2-2 Lower Sandstone"

Figure D.6. 63. ***"12/2-2 Lower Sandstone", 12/2-2 well.***