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# The Stratigraphic Nomenclature of the Irish Offshore Basins



Published by the Department of the  
Environment, Climate and Communications  
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*Front cover.* Sheet-like basin floor sandstone beds in the Pennsylvanian Ross Sandstone Formation, Loop Head, Co. Clare. The dark, heterogeneous unit in the centre of the picture is a laterally-extensive slump deposit. (Photo: Pat Shannon)

Published in Ireland by the  
Department of the Environment, Climate and Communications  
29-31 Adelaide Road  
Dublin, D02 X285

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## The Stratigraphic Nomenclature of the Irish Offshore Basins

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Bibliographic reference

The Stratigraphic Nomenclature of the Irish Offshore Basins

Department of the Environment, Climate and Communications, PAD Special Publication 2/21.

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## FOREWORD

I am delighted to introduce this PAD Special Publication, entitled “The Stratigraphic Nomenclature of the Irish Offshore Basins”, that is a companion document to the published Standard Stratigraphic Nomenclature of Offshore Ireland: An Integrated Lithostratigraphic, Biostratigraphic and Sequence Stratigraphic Framework. Project Atlas. (Merlin Energy Resources Consortium, 2020), Petroleum Affairs Division, Department of Communications, Climate Action & Environment, Special Publication 1/21. This project was commenced several years ago and the integrated study and deliverables are a result of many knowledgeable individuals who each gave their time in a collaborative effort to produce a milestone user-friendly Atlas.

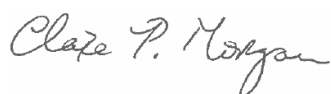
I would like to acknowledge their expertise and in particular the Stratigraphic Committee, spearheaded by Professor Pat Shannon, University College Dublin, School of Earth Sciences, who was greatly engaged with Departmental officials in the production of the stratigraphic names.

This new publication provides an interesting background and insight into the naming system for the newly defined stratigraphic nomenclature offshore Ireland. The selection of stratigraphic names underwent rigorous consideration and a systematic process. The result is a well-defined, comprehensive, unambiguous nomenclature that is evidence based. Additional stratigraphic names due to the recognition of new stratigraphic units, for example resulting from knowledge gained from future data acquisition or research, can be readily added to the established nomenclature, slotting easily into the naming logic. This Special Publication also provides guidelines for the naming of any such new stratigraphic units.

I am pleased to note that the Atlas is already being actively used by industry and academia in applications and research studies in our offshore basins. The Atlas and nomenclature have importance for understanding the geological development of the Irish offshore and its potential use in many spheres of offshore research and development, including offshore wind, carbon capture, geothermal studies etc.

I hope that the reader will enjoy this publication and gain an appreciation of the vivid account and attentive detail given to establishing the nomenclature. Some readers might even learn new Irish words as *Gaeilge* and become familiar with native Irish fish, birds, jewellery, plants and seashells!

I will end this Forward by stating that this new formal stratigraphic nomenclature is endorsed by the Department of the Environment, Climate and Communications and is recommended for use by all workers in the Irish offshore.



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# 1. INTRODUCTION

Over 50 years of research and exploration in the Irish offshore have provided a vast archive of geological and geophysical information from which the geological evolution of the region has been pieced together. A total of 161 exploration and appraisal wells, a significant number of development wells and a small number of important shallower boreholes have been drilled, while a very large volume of 2D and 3D seismic data has been acquired across the Irish offshore. In addition, a number of important regional wide-angle seismic reflection and refraction profiles have helped constrain the deep crustal structure and controls on the main basins. The history of exploration has been summarised in various publications, including Naylor & Shannon (2011) and Shannon (2018).

Ireland is surrounded by Mesozoic and Cenozoic sedimentary basins with a variety of sizes and orientations, lying in water depths ranging from less than 100 m to more than 3000 m (**Figure 1**). The broad tectono-stratigraphic evolution of the Irish offshore basins is now relatively well constrained as a result of the existing data, exploration and research (Naylor & Shannon, 2011). The location, orientation and development of the basins were controlled by crustal structure, inherited structural fabrics and regional tectonism. Pre-Caledonian, Caledonian and Variscan basement fabrics provided the structural template for the basins, with reactivation of inherited lineaments facilitating basin development from the initial break-up of the Pangaeon supercontinent to the formation of the North Atlantic Ocean. Variscan mountain collapse led to the initiation of a set of small, isolated intermontane Permian basins overlying deformed Upper Palaeozoic strata in the south of Ireland, while further north the Upper Carboniferous succession was relatively unaffected by Variscan deformation. A set of Early Triassic rift basins, with sandy continental deposits, developed in the Celtic Sea, Porcupine, Slyne, Erris and Rockall regions (Štolfová & Shannon, 2009). This was followed by Late Triassic and Early Jurassic thermal subsidence leading to marine marl and claystone-dominated deposition. The major period of rift basin formation was in the Late Jurassic, with continental to deep marine sandy to muddy deposits, followed by Early Cretaceous marine conditions in the basins west of Ireland, linked to major plate reorganization (Doré *et al.*, 1999) and to the onset of crustal hyperextension (Whiting *et al.*, 2021). In contrast, continental conditions prevailed in the Celtic Sea basins during Early Cretaceous times, linked to the development of rifting and seafloor spreading in the Bay of Biscay (Robinson *et al.*, 1981; Shannon, 1991). Upper Cretaceous chalk deposition was ubiquitous throughout the Irish offshore basins, followed by regressive sandy deltaic Early Cenozoic deposition in the basins west of Ireland. Mid-Late Cenozoic rapid subsidence resulted in deep water mudstone- and siltstone-dominated deposition with widespread





The thickest succession in the Irish offshore is in the Porcupine Basin, where in excess of 10 km of Devonian-Carboniferous to Cenozoic strata are preserved (Shannon & Naylor, 1998). The basins of the Rockall region contain up to 7 km of Carboniferous to Cenozoic strata (Shannon *et al.*, 1999; Mackenzie *et al.*, 2002), with 3-4 km of predominantly Carboniferous-Jurassic sediments with some Cretaceous and thin Cenozoic strata in the Slyne and Erris basins (Chapman *et al.*, 1999; Dancer *et al.*, 1999). A detailed review of the Upper Palaeozoic-Mesozoic stratigraphy of the basins west of Ireland is presented in Stoker *et al.* (2017), with the Cenozoic stratigraphy described in McDonnell & Shannon (2001) and Stoker *et al.* (2005). Overall, the large Irish basins have similarities with other basins in the Atlantic region, including the conjugate margin basins offshore eastern Canada (Sinclair *et al.*, 1994; Williams *et al.*, 1999).

A formal structural nomenclature for the Irish offshore was published in 1999 and 2002 in two Petroleum Affairs Division Special Publications (Naylor *et al.*, 1999, 2002). The systematic nomenclature followed a similar approach to that adopted in the UK and Norwegian North Sea regions (Rhys, 1974; Rønnevik *et al.*, 1975; Deegan & Schull, 1977; Blystad *et al.*, 1995). In the Irish structural nomenclature, the names of Irish saints were used for new basins and also in re-naming some previously recognised basins. The names chosen for use in the structural nomenclature related to established figures in Irish history, albeit embellished by folklore. In the case of structural highs and prominent igneous features, names of mystical islands and associated waves/breakers or mythological characters, long established and well founded in Irish folklore, were used. This gave a unique Irish dimension to the structural nomenclature. A similar approach of having an Irish flavour to the names was adopted for the stratigraphic nomenclature presented in this publication, with details presented in the following chapters.

Despite more than 50 years of drilling and seismic data, and a large volume of resultant publications in the scientific literature, to date there has been no formal, comprehensive and unified stratigraphic nomenclature for the Irish offshore. Stratigraphic names used in reports and in the published literature have been informal, random and ad hoc, with individual companies and researchers giving different names to the same stratigraphic units, and with little detail concerning formal identification or robust regional correlation of units. This has resulted in duplication, confusion and a lack of coherency and consistency. The aim of the new formal stratigraphy, coming approximately 20 years after the structural nomenclature, is to provide a unified system with clearly defined stratigraphic units conforming to the established principles of stratigraphic nomenclature. The resultant stratigraphic framework is based on a detailed and integrated biostratigraphic and lithostratigraphic re-evaluation and synthesis of all of the offshore wells, together with key seismic profiles. The work was carried

out by the Merlin Energy Consortium and funded by Irish Shelf Petroleum Studies Group of Ireland's Petroleum Infrastructure Programme (PIP), and the details are found in the resultant comprehensive Stratigraphic Atlas (Merlin Energy Resources Consortium, 2020).

The Stratigraphic Atlas provides comprehensive details of each of the units, with the relevant information on each of the units at group, formation and member level. In addition, a number of informal units were also described but were not formally named as they tend to be limited to single well penetrations. The nomenclature system and the names used in the new Atlas were selected by the authors of the present Special Publication. Little background information was presented in the Atlas on the names or the themes used therein. Therefore, as a complementary publication to the Atlas, this Special Publication provides the background and the details to the nomenclature system and explains the thematic strategy adopted, together with the themes and the stories behind the new names. Each of the following chapters gives the details and the background to the choice of the new names, and provides a very brief summary of the key stratigraphic units, with the full details provided in the Atlas. The present Special Publication also provides guidelines for the naming of new or future units.

The new nomenclature framework will be an important reference for any geological work in the Irish offshore, including any such work associated with the renewable energy sector.

## 2. THE NEW NOMENCLATURE FRAMEWORK

The objective of the new, formal stratigraphic nomenclature for the Irish offshore basins is to provide a robust, workable and future-proofed stratigraphic framework that can be used by academic, industry and government researchers. It is designed to avoid potential confusion with existing stratigraphic nomenclature, both formal and informal, for the onshore Irish geology and elsewhere in neighbouring offshore regions, and to integrate with the structural nomenclature for offshore Ireland (Naylor *et al.*, 1999, 2002).

In erecting a new and unified stratigraphic framework for the entire Irish offshore, a balance was struck between the necessity to define clearly, in accordance with accepted international principles of stratigraphic nomenclature, new thematic unit names while at the same time maintaining, where appropriate and possible, key stratigraphic names that are well established in the published literature. Therefore, within the new nomenclature framework, existing names were maintained where it could be demonstrated that stratigraphic units in the Irish offshore basins correlated clearly with existing named successions in nearby jurisdictions or with the Irish onshore. Group and formation names that are well established in the published literature were kept unless there was a convincing argument not to do so. For example, Lower Jurassic stratigraphic units in several of the Irish offshore basins, both west and south of Ireland, correlate closely with units defined in the west of Scotland, south of England and Yorkshire. These names were kept in order to reflect the continuity of these units. Likewise, much of the well-established Triassic stratigraphy in the UK East Irish Sea region can be correlated with a high degree of certainty into the Irish sector of the Irish Sea basins and the UK relevant nomenclature was maintained in the Irish offshore for these units.

Because the stratigraphy in the Irish offshore often varies considerably between basins due to the variations in the tectono-sedimentary development, different names were required for age-equivalent strata in different basins. The new stratigraphic nomenclature therefore incorporates more than 300 names. Almost 200 new names were required at group, formation and member levels. New names were constrained by existing onshore and other usage in order to avoid duplication and confusion. So as to ensure avoidance of any duplication the proposed names were cross-checked against the Geological Survey Ireland's (GSI) comprehensive online rock unit lexicon of the names within the 1:1000000 bedrock map for in the Irish onshore region ([www.gsi.ie](http://www.gsi.ie)), and the British Geological Survey (BGS) lexicon (British Geological Survey, 2020). The spellings of new names for land features were taken from the Ordnance Survey Ireland (OSi) website ([www.osi.ie](http://www.osi.ie)).

Throughout the stratigraphic framework, the new names have a unique Irish connection. For a variety of reasons, the names of famous people, Irish towns/villages and difficult-to-pronounce names were avoided. There are, however, a few exceptions that fall into the latter category. It was considered that some iconic Irish features could not be omitted from the names used and, as they are difficult to pronounce for readers unfamiliar with Ireland and Irish culture, the phonetic pronunciation is also given. In the structural nomenclature for the Irish offshore (Naylor *et al.*, 1999, 2002), the names of Irish saints, well established in history and folklore, were used for the sedimentary basins, while the structural highs and major igneous features (e.g. Donn, Túr igneous centres) were typically ascribed names of mythical and generally underworld figures, often of a somewhat malevolent character.

In a link to the structural nomenclature, the extrusive igneous units within the stratigraphy framework continue the theme of Irish dark underworld folklore due to their deep underworld origins and unpredictability of their existence. This theme was woven throughout the framework, irrespective of the epoch. Igneous rocks are encountered at multiple levels of the rock record offshore Ireland from the Eocene to Triassic strata in the Rockall, Erris, Slyne, Porcupine basins and Goban Spur area. No igneous members were named in the Fastnet, Celtic Sea, Irish Sea and Kish Bank basins. The igneous units were most often included as members within a formation, though one is included as a formation in the Erris and Slyne basins. Only the extrusive igneous rocks have been named in this scheme, including lava flows, pillow lavas, and tuffs, and intrusive rocks were not named.

A thematic nomenclature was considered desirable in order to provide an optimum degree of logical coherency to the stratigraphic framework, and to make it easier for researchers to understand and make sense of the naming system through the stratigraphic succession. In view of the large number of names required it was impossible to find a single embracing theme that covered the entire stratigraphy from the Recent to the Upper Palaeozoic. Therefore, the new names encompass a range of themes, each recognising an element of Irish nature, history, heritage, folklore or location. There are links within and between many of the themes and the names, and also between the geological elements and the names, e.g. member names are often linked to the formation name, while there is sometimes a hierarchical link in the size or scale of the group, formation or member to that of the name. These linkages are intended to act as an *aide memoire* to make the nomenclature more logical and understandable to the reader, as well as highlighting aspects of unique cultural and other elements of Ireland.

Themes were stratigraphically-focussed, with a specific theme for each Period or major part thereof (e.g. separate themes for Upper, Middle and Lower Jurassic) from the Recent back to the Devonian. The themes are summarised in **Figure 2**, and details of each theme,

together with the linking characteristics between and within themes, are presented in the relevant chapters.

<b>Irish Offshore Stratigraphic Nomenclature Themes</b>	
<b>Pleistocene-Pliocene</b>	UK nomenclature from Hebrides, Celtic Sea and Irish Sea
<b>Pliocene-Miocene</b>	UK nomenclature where proven, otherwise Irish artefacts/jewellery
<b>Paleogene</b>	Irish bays, coves and inlets
<b>Upper Cretaceous</b>	Fish (Irish/Gaelic names)
<b>Lower Cretaceous</b>	Fish (fresh water for Celtic Sea; salt water for west of Ireland basins)
<b>Upper Jurassic</b>	Irish coastal features (peninsulas, headlands and points)
<b>Middle Jurassic</b>	Native Irish birds
<b>Lower Jurassic</b>	Hebrides and south of England nomenclature where proven, otherwise Irish lakes
<b>Triassic</b>	Historical and archaeological features and musical instruments for west of Ireland and Celtic Sea basins; UK nomenclature for Irish Sea basins
<b>Permian</b>	UK nomenclature
<b>Carboniferous</b>	UK or onshore Irish nomenclature where proven, otherwise native Irish flora and fauna: flora for Upper Carboniferous and marine fauna for Lower Carboniferous
<b>Devonian</b>	Colours (Irish/Gaelic names)
<b>Igneous strata</b>	Irish underworld folklore

Figure 2. Irish offshore stratigraphic nomenclature themes.

## STRATIGRAPHIC NOMENCLATURE DESCRIPTION

Each of the following chapters consists of an introduction to the theme and the naming strategy, together with some information on the theme, the name of the group or formation, or of the nomenclature link between constituent members and the formation. Some limited information is provided on new member names but these are not generally described in detail. A brief summary of the key features of the groups and formations is provided. The key features described for each stratigraphic unit are Name, Age, Type Well, Distribution, Lithology and Depositional Environment. The detailed geological information is based upon the details given in the Stratigraphic Atlas (Merlin Energy Consortium, 2020), to which the reader is referred for greater detail.

Within each chapter, the group and formation names are described, together with details of the derivation of the names and, in some instances, a background or historical story of relevance. The constituent members are also generally named. The type well, and the depth of the type section (normally in metres below Kelly Bushing (KB) for wells, and metres below seabed for ocean drilling programme references), are given for each formation with a new name. Where existing formation names from the UK onshore or offshore are used, key reference sections in the Irish offshore are listed instead of the type section/type well. In addition, appropriate references to type and key sections in the UK are given to enable the

reader to source additional detail. The lateral distribution of the group or formation is confined to the Irish offshore in this publication and is generally limited to the proven occurrence of the stratigraphic unit in Irish wells or boreholes. While seismic extrapolation indicates that some units are likely to have a wider extent than proven in boreholes, a conservative approach is taken in the summary here regarding the current proven extent of units in order to minimise speculation, especially beyond the limits of individual basins into adjacent undrilled or sparsely drilled basins.

The descriptions within each chapter are presented in stratigraphic order, starting with the youngest strata and proceeding down the stratigraphic column from the Recent to the pre-Devonian. In a few instances such as the Upper Cretaceous, formations extend across most of the basins in the Irish offshore and the stratigraphic detail is relatively easy to present. However, in most instances there are significant differences between basins. In these cases, the stratigraphy of the basins lying off the west coast are described first, followed by those off the south coast, and then the basins lying off the east coast. **Enclosure 1** is a regional chronostratigraphic summary chart of the groups, formations and members.

### 3. PLEISTOCENE – PLIOCENE

#### NOMENCLATURE THEME

The names of the Pleistocene and Pliocene stratigraphy offshore Ireland were extended in this study from the UK sector (Stoker *et al.*, 2011). The upper Pleistocene includes the Brython Glacigenic Group and the Eilean Siar Glacigenic Group. The groups offshore Ireland are divided based on proximity to the ice sheet, and the ice-related processes which resulted in the deposition. Below the glacially influenced deposits, the lower Pleistocene to upper Pliocene non-glacial groups from the UK were also extended into Ireland, including the Demetae Group and Hebrides Margin Group.

#### STRATIGRAPHIC UNITS

The uppermost stratigraphy contained in the framework consists of glacially influenced deposits, remnant of the Pleistocene Ice Age. The Irish landmass was covered with a continental-scale glacier which extended beyond the land into the Celtic Sea and the Atlantic Ocean. Beneath this ice shelf, subglacial and proglacial deposits developed, termed the Brython Glacigenic Group. Beyond the limit of the ice sheet and into the open water, dominantly marine claystones were deposited, with some evidence of ice-contact processes. These distal sediments are contained within the Eilean Siar Glacigenic Group. Between the two groups are mixed facies, reflecting the waning and waxing of the ice sheet and resulting in a zone of interfingering of mixed facies. The base of the glacigenic sequence is bounded by a regional unconformity in the Pleistocene (mid-Ionian), marking the transition to the underlying non-glacial sediment. Below this unconformity, non-glacial sediments are divided into the Demetae Group and the Hebrides Margin Group. The Demetae Group contains terrestrial to shallow marine deposits while the Hebrides Margin Group represents shelf-margin to deep water deposits. This non-glacial sequence is bounded below by the regional Pliocene mid-Zanclean unconformity. The sequences are described from youngest to oldest, from west to east, with the Atlantic basins described first, followed by southern then eastern basins. Groups are described first, followed by the units therein. No subdivisions of the groups were made in the current study, and new subdivisions could be developed in the future by the geological community.

## EILEAN SIAR GLACIGENIC GROUP

The name is derived from the Scottish Gaelic for Western Isles (Stoker *et al.*, 2011). The Eilean Siar Glacigenic Group originally was described for the glacial deposits along the Hebrides Shelf and the inner Hebridean region. This distal, glacially influenced group is now documented in the Merlin Energy Consortium (2020) Atlas, to extend southward along the Atlantic margin into the basins offshore Ireland. This group interdigitates with the shallow water glacigenic deposits of the Brython Group.

*Age:* Holocene to Pleistocene, mid-Ionian.

*Reference section in Ireland:* IODP Leg 307 Site U1316A (965 – 1003 m below sea bed), on the eastern margin of the Porcupine Basin.

*Distribution:* Rockall, Donegal, Slyne, Erris, Macdara, Bróna, Porcupine, Goban Spur basins, and eastwards towards the Celtic Sea basins where the group merges with the Brython Glacigenic Group.

*Lithology:* The sequence contains claystone, nannofossil ooze, rare sandstone interbeds, and occasional dropstones.

*Depositional Environment:* Deposited in ice-marginal to distal marine settings, indicating some ice contact related processes.

## BRYTHON GLACIGENIC GROUP

The name *Brython* is Welsh for the Britons, the indigenous Celtic people of Britain who lived between the Iron Age and the Middle Ages (Stoker *et al.*, 2011). This stratigraphic group is widely present in the Irish Sea basins and along the southern basins offshore Ireland, reflecting the extensive subglacial deposits derived from the last glacial maximum. To the west, offshore Ireland, the deposits are found along the shallow shelf (approximately <200m present day water depth) adjacent to the landmass. The group eventually grades into the more distal marine deposits of the Eilean Siar Glacigenic Group.

*Age:* Mid Pleistocene, mid-Ionian to Holocene.

*Reference section in Ireland:* Well 42/12-1 (182.9 – 221.5 m below KB) in the Central Irish Sea Basin.

*Distribution:* Kish Bank, Central Irish Sea, North Celtic Sea, South Celtic Sea, and Fastnet basins, and along the western margin of the Irish landmass.

*Lithology:* Variable lithology due to large geographic extent, includes diamicton till, sandstone, interbedded claystone and dropstones.

*Depositional Environment:* Deposited in subglacial to proglacial environments.



## HEBRIDES MARGIN GROUP

The Hebrides Margin Group was extended from the Hebrides Shelf and eastern flanks of the UK Rockall Basin, to the Atlantic basins offshore Ireland. This non-glacial group lies beneath the glacially influenced Eilean Siar Glacigenic Group. Note that the base of this group is older than the proximal equivalent of the Demetae Group.

*Age:* Middle Pleistocene, mid Ionian, to upper Pliocene, Piacenzian.

*Reference section in Ireland:* IODP Leg 307 Site U1316A (1003.3 – 1015.5 m below sea bed), Porcupine Basin; IODP Leg 307 Site 1317A (1003.3 – 1015.5 m below sea bed), Porcupine Basin.

*Distribution:* Rockall, Porcupine, Goban Spur Basin, and eastwards towards the Celtic Sea basins where it merges with the proximal deposits of the Demetae Group.

*Lithology:* Variable lithology with sandstone, siltstone, claystone, pebbles. One instance of volcanic ash was encountered to date in the Rockall Basin.

*Depositional Environment:* Environments range from the shelf margin to deep water.

## DEMETAE GROUP

The *Demetae* were a native tribe of Celtic people from the Iron Age and Roman period who inhabited southwest Wales (Stoker *et al.*, 2011). The Demetae Group was originally described in the eastern basins between Ireland and the UK in the Irish Sea region. The Demetae Group is revised to also extend throughout the southern Celtic Sea basins and along the western margin of the Irish landmass, where it merges with the distal equivalent of the Hebrides Margin Group.

*Age:* Middle Pleistocene, mid Ionian, to basal Early Pleistocene, Gelasian.

*Reference section in Ireland:* 42/8-1A (164.6 – 309.1 m below KB).

*Distribution:* Kish Bank, Central Irish Sea, North Celtic Sea, South Celtic Sea, and Fastnet basins, and along the western nearshore region of the present day Irish landmass.

*Lithology:* Sandstone interbedded with claystone and lignite.

*Depositional Environment:* Fluvial and shallow marine.

## 4. PLIOCENE – MIOCENE

### NOMENCLATURE THEME

Names used in the mid-Pliocene (Zanclean) to the base Miocene (Aquitaine) framework are a combination of new and existing formation and member names. Existing group (Troana) and formation names (Ròn, Fulmair) from the UK follow the theme of native animals and birds. New names followed the theme of Irish jewellery and artefacts including the Dord, Amulet, Triskele and Claddagh formations. Many items chosen for this theme were researched at the National Museum of Ireland in Dublin.

### STRATIGRAPHIC UNITS

The Pliocene to Miocene interval is primarily a marine sequence of claystones, mudstones and sandstones in the western basins. Carbonate facies are also found, for example in the Fastnet Basin, and in deep water carbonate oozes of the Atlantic basins. The Troana Group name has been adopted for all Irish basins where this age stratigraphy is present. New formations and members were applied to the Donegal, Slyne, Porcupine, Goban Spur, and Fastnet basins, while existing UK formation names have been applied in Rockall Basin and Goban Spur area. The stratigraphy of this age interval was not encountered in the Erris Basin, and is absent from the Celtic Sea basins and the eastern Irish basins.

### TROANA GROUP

The Troana Group and its formations were originally described by Stoker *et al.* (2007) for deep water calcareous contourites and shallow marine sandstones of the UK Rockall Basin and Hebrides margin. The name *traona* is the Scottish Gaelic translation for corncrake, an endangered small brown bird with a distinctive ‘*kerrx-kerrx*’ call. The group has been extended into the Irish Rockall, Donegal, Slyne, Macdara, Bróna, Porcupine and Fastnet basins, and the Goban Spur area. The base of the Troana Group is unconformable and occurs at the Oligocene and Miocene boundary.

**Ròn Formation.** *Ròn* is the Scottish Gaelic and Irish translation for seal, the marine mammals common in Atlantic waters. The Ròn Formation is the distal lithological equivalent to the Dord Formation.

*Age:* Zanclean - Langhian.

*Reference section in Ireland:* DSDP Leg 80 Site 548A (1476 – 1582.8 m below sea bed) and DSDP Leg 80 Site 550 (4577.4 – 4747.9 m below sea bed), Goban Spur area.

*Distribution:* Rockall Basin, Goban Spur area, Porcupine Abyssal Plain and on the continental slope at the Outer Boundary High and Merlin Basin.

*Lithology:* Nannofossil chalk and ooze, with local limestone and bioclastic sandstones.

*Depositional Environment:* Deep water marine.

**Dord Formation.** A dord is a type of long musical horn, created during the Bronze Age in Ireland. This formation contains three members also with musical origins including the Clogán Sandstone (Irish translation of a 'bell', pronounced "*claw-gawn*"), Carnyx Sandstone (wind instrument from Iron Age) and the Crotal Sandstone members (a rattle from the Bronze Age). The Dord Formation is the proximal equivalent to the Ròn Formation.

*Age:* Messinian - Langhian.

*Type Section:* Well 56/21-2 (447 – 595 m below KB) in the Fastnet Basin.

*Distribution:* Donegal, Slyne, Macdara, Bróna, Porcupine, Fastnet basins and Goban Spur area.

*Lithology:* Marine derived claystone and interbedded sandstone, with infrequent lignite and marl. *Depositional Environment:* Inner to outer shelf to bathyal slope setting.

**Fulmair Formation.** The Scottish and Irish translation of fulmar, a gull-like bird. The Fulmair Formation is the distal equivalent to the Amulet Formation.

*Age:* Burdigalian - Aquitanian.

*Reference section in Ireland:* DSDP Leg 80 Site 550 (4717.9 – 4736.0 m below sea bed), Goban Spur area; DSDP Leg 94 Site 610 (3082.0 – 3155.2 m below sea bed), Rockall Basin.

*Distribution:* Rockall Basin and Goban Spur area.

*Lithology:* Nannofossil chalk and ooze, chalky mudstone, wackestone, siltstone.

*Depositional Environment:* Deep water marine.

**Amulet Formation.** Amulets, used in the Late Bronze Age in Ireland, were special objects that would bring good luck and protection. The Amulet Formation is the intermediary facies between the deep marine Fulmair Formation and the carbonate and claystone sequences of the Fastnet Basin.

*Age:* Burdigalian - Aquitanian.

*Type Section:* Well 35/29-1 (1222 – 1539 m below KB) in the Porcupine Basin.

*Distribution:* Bróna, Porcupine basins and Goban Spur area.

*Lithology:* Glauconitic to calcareous silty claystone with interbedded limestone, siltstone and sandstone.

*Depositional Environment:* Bathyal to slope deposits.

**Triskele Formation.** The triskele is an ancient symbol of the triple spiral with a variety of meanings for early Pagans. There is evidence of use starting in the Neolithic Stone Age, as seen on the entrance of the 5200 year old Newgrange passage tomb, Co. Meath.

*Age:* Burdigalian - Aquitanian.

*Type Section:* Well 55/30-1 (575 – 620 m below KB) in the Fastnet Basin.

*Distribution:* Fastnet Basin.

*Lithology:* Limestone, interbeds of claystone that can be glauconitic, fossiliferous and pyritic.

*Depositional Environment:* Marine, outer shelf.

**Claddagh Formation.** The claddagh ring is an Irish symbol for love, loyalty and friendship, depicted by a heart, crown and a pair of hands. The direction that the heart points on the finger indicates one's relationship status. The Claddagh Formation is the lateral equivalent to the Triskele and Dunmanus Formations.

*Age:* Burdigalian - Aquitanian.

*Type Section:* Well 56/21-1 (439 – 567 m below KB) in the Fastnet Basin.

*Distribution:* Fastnet Basin.

*Lithology:* Variable from claystone, sandstone, limestone and marls.

*Depositional Environment:* Marine, outer shelf.

**Dunmanus Formation.** The name is taken from Dunmanus Bay in west Co. Cork which separates the Mizen Peninsula from Sheep's Head Peninsula. The upper part of this formation occurs in the Early Miocene and extends into the Oligocene.

*Age:* Aquitaine - Rupelian.

*Type Section:* Well 56/21-2 (660 - 974 m below KB) in the Fastnet Basin.

*Distribution:* Fastnet Basin and North Celtic Sea Basin.

*Lithology:* Limestone.

*Depositional Environment:* Marine, outer shelf to upper slope.

## 5. PALEOGENE (Oligocene, Eocene and Paleocene)

### NOMENCLATURE THEME

The nomenclature for the Oligocene, Eocene and Paleocene was derived from Ireland's bays, coves and inlets. New names were assigned at group, formation and member levels. The bays that are found on the southern coast lend their names to the units in Fastnet and North Celtic Sea basins, to maintain a geographical linkage. Names of bays on the west coast were given to units in the western offshore basins. An *aide memoire* is that the unit names within the Goban Spur area all start with the letter 'C', Clew, Cashen and Cashla, relating to the dominant lithology of chalk and calcareous ooze. The Lunula Group of the Celtic Sea basins borrowed the 'artefacts/jewellery' theme from the younger Miocene, as well as one member in the Porcupine Basin. Igneous occurrences are found in early Cenozoic and follow the theme of dark Irish mythology. The three existing groups and two formations from the UK sector that were correlated into Irish basins follow the theme of Hebridean culture and birds.

### STRATIGRAPHIC UNITS

The existing Toirsgian, Stronsay and Rockall-Hebrides Volcanic groups have been extended into Irish Atlantic Basins. Two new groups have been named with the Tralee Group for the Porcupine, Goban Spur and Fastnet, and the Lunula Group for the Celtic Sea basins. The lithology of the interval is mainly deep water deposits, with marginal marine to fluvial deposits occurring in the Celtic Sea and Irish Sea basins, reflecting periods of exhumation. The Oligocene and upper Eocene are eroded from the Erris and Slyne basins, as well as parts of the North Celtic Sea Basin. Similarly, the Paleocene is eroded from all basins to the south of Ireland. In the Erris, Slyne and Porcupine basins, the Eocene to Paleocene strata sits unconformably on the Lower Paleocene to Late Cretaceous Chalk Group.

### TOIRSGIAN GROUP

The name is the Gaelic translation of a peat-cutting spade used in the blanket bogs of the Hebrides. The group was defined in Stoker *et al.* (2007) to represent deep marine sediments. The group has been extended into Ireland for the Rockall and Porcupine basins and the Goban Spur area. Additionally, the group has been applied to the Fastnet Basin which contains middle to outer shelf marine deposits. The formations used within the group

include the existing Fachach Formation, for the Irish Rockall Basin, and six new formation names for the remaining basins.

**Fachach Formation.** *Fachach* is the Scottish Gaelic translation for puffin. The small seabirds are sometimes nicknamed 'sea parrots' because of their brightly coloured beaks. They are found in Ireland, Scotland and other regions of Northern Europe. This deep water formation of the Rockall Basin is the equivalent to the deposits of the Kinnagoe Formation of the Porcupine Basin.

*Age:* Chattian - Rupelian.

*Reference section in Ireland:* Well 5/22-1 (2533 – 2742 m below KB) in the Rockall Basin.

*Distribution:* Rockall Basin.

*Lithology:* Calcareous to silty claystones, siltstones and interbedded sandstones.

*Depositional Environment:* Deep marine, upper to middle bathyal setting.

**Kinnagoe Formation.** Kinnagoe Bay is found along the Inishowen Peninsula, Co. Donegal. In 1588, the Spanish Armada ship, '*La Trinidad Valencera*', struck a reef in the bay and sunk. The captain paid local Irishmen for the use of their boats to rescue the stricken sailors. The Spaniards were forcibly marched to Dublin where they eventually surrendered to the English Deputy. Over 150 sailors fled to Scotland while 100 were held in Dublin castle. While being transported on a different ship, they managed to commodore the vessel and sail home to Spain. This formation contains the Quern Sandstone Member.

*Age:* Chattian - Rupelian.

*Type Section:* Well 35/30-1 (1401 – 2293.5 m below KB) in the Porcupine Basin.

*Distribution:* Porcupine Basin and Goban Spur area.

*Lithology:* Claystone, sandstone, siltstone, limestone and marl.

*Depositional Environment:* Distal marine from outer shelf and bathyal setting.

### **Information Box No. 1: Spanish Armada**

The Spanish Armada was a fleet of armed ships that tried unsuccessfully to invade England in 1588. Animosity between Spain and England existed over access to the valuable resources in the Americas, as well as religious differences. In the early 1580's, King Philip II of Spain began to plan an invasion of England. The resulting fleet of Spanish ships was heavily armed, but also large and slow, and manned by inexperienced crewmen. In contrast, the English fleet comprised smaller, faster and easier to manoeuvre ships, manned by skilled sailors. Over 130 ships left Lisbon (which was under the control of Spain at the time) in 1588, and were met by the British Navy in the English Channel, where long-range gun duels ensued. In the early hours of the morning, the English sent eight fire ships (vessels filled with gunpowder and set alight) towards the Armada, dispersing the Spanish fleet. Later that morning, the English attacked the Spanish near the port of Gravelines, France. Around 120 ships fought until the English had sunk two Spanish ships and gravely damaged the others. The Spanish Armada fled northwards into the North Sea, to retreat westward around Ireland. However, the fleet was ill-prepared for the harsh North Atlantic conditions, and 24 ships and over 6000 men were lost along the west coast of Ireland.

**Tranarossan Formation.** Named after the tranquil bay in Co. Donegal on the Rosguill Peninsula.

*Age:* Priabonian.

*Type Section:* 35/29-1 (2232 – 2290 m below KB) in the Porcupine Basin.

*Distribution:* Porcupine Basin and Goban Spur area.

*Lithology:* Deep marine marls and calcareous claystones.

*Depositional Environment:* Deep marine, outer shelf and bathyal setting.

**Carraveg Formation.** Carraveg Bay is located in Co. Galway. The formation is coeval to the Kinnagoe and Tranarossan formations.

*Age:* Chattian - Priabonian.

*Type Section:* DSDP Leg 80 Site 549A (2573.0 - 2693.7 m below sea bed) in the Goban Spur area.

*Distribution:* Found in the DSDP well only. Defined for the Goban Spur area, including the Pendragon Basin, Merlin High and the Outer Boundary High.

*Lithology:* Pelagic to silty, biogenic chalk and carbonate ooze.

*Depositional Environment:* Deep marine, bathyal depths with warm surface water temperatures for high carbonate production.

**Dunmanus Formation.** The name is taken from Dunmanus Bay in west Co. Cork which separates Mizen Head from Sheep's Head peninsulas to the north. The upper part of this formation occurs in the Early Miocene and extends into the Oligocene.

*Age:* Aquitaine - Rupelian.

*Type Section:* Well 56/21-2 (660 – 974 m below KB) in the Fastnet Basin.

*Distribution:* Fastnet Basin and North Celtic Sea Basin.

*Lithology:* Limestone.

*Depositional Environment:* Outer to upper slope marine setting.

**Barley Formation.** Named after Barley Cove on the Mizen Peninsula in Co. Cork. Along with several bays in the southwest of Ireland, preserved onshore deposits in Barley Cove were produced by a tsunami, triggered from an earthquake offshore Portugal in 1755.

*Age:* Chattian - Rupelian.

*Type Section:* Well 56/18-1 (519.5 – 797 m below KB).

*Distribution:* Fastnet Basin.

*Lithology:* Sandstones with interbedded claystone, limestone and marl.

*Depositional Environment:* Outer shelf depositional setting.

**Clonea Formation.** Named after Clonea Bay, near Ballinacourty Point Lighthouse in Co. Waterford.

*Age:* Priabonian.

*Type Section:* Well 56/18-1 (797 – 893 m below KB).

*Distribution:* Fastnet Basin.

*Lithology:* Limestone, changing laterally into claystone and sandstones towards the north eastern Fastnet Basin.

*Depositional Environment:* Marine, mid to outer shelf environment.



## LUNULA GROUP

This group borrows its theme from the Irish artefacts previously mentioned in the Paleogene. The name was derived from the golden crescent-shaped necklace from the Early Bronze Age. This group was deposited between periods of uplift and as a result, contains continental to marginal marine deposits, and is unconformity-bounded above and below. This group was not subdivided into any formations.

*Age:* Chattian - Lutetian.

*Type Section:* Well 49/9-1 (250 – 438.5 m below KB).

*Distribution:* Celtic Sea and Irish Sea basins.

*Lithology:* Sandstone with interbeds of siltstones, claystones and coal.

*Depositional Environment:* Fluvial to marginal marine environments.

## STRONSAY GROUP

The name originates from Stronsay Island in Orkney, Scotland. The group was established in the Faroe-Shetland and North Sea basins, and later in the UK Rockall (Stoker *et al.*, 2007). The group has been extended into the Irish Rockall, Erris and Slyne basins. In Ireland, this group represents deep marine deposits and an igneous formation.

**Ventry Formation.** Named after Ventry Bay on the Dingle Peninsula in Co. Kerry. This formation contains the Pulleen Sandstone Member, located in the Macdara Basin shallow borehole (16/28-Sb01).

*Age:* Bartonian - Lutetian.

*Type Section:* Well 5/22-1 (2742 – 3095 m below KB).

*Distribution:* Rockall and Macdara basins.

*Lithology:* Claystones, siltstones and sandstones, often tuffaceous and calcareous.

*Depositional Environment:* Deep marine, upper to middle bathyal water depths.

**Druid Formation.** This extrusive igneous unit was named after the druids, the educated upper tier of ancient Celtic societies, who were believed to have magical abilities. As an age equivalent to the Stronsay Group, this igneous unit was given formation status, rather than member status, because it was unconformably bound, has an extensive development and does not occur within an age equivalent stratigraphic formation.

*Age:* Lutetian; refer to Atlas for detailed radiometric dating results.

*Type Section:* Well 18/20-1 (427 – 546.5 m below KB) in the Slyne Basin.

*Distribution:* Slyne and Erris basins.

*Lithology:* Altered basaltic lavas, tuffs, and obsidian.

*Depositional Environment:* Subaerial lava flow at 19/13-Sb02, possible interbedded marine evidence in 11/20-Sb01.

## **TRALEE GROUP**

This Paleocene to Eocene group is named after Tralee Bay in Co. Kerry. The bay is known for its large number of shipwrecks and the lighthouse situated on Little Samphire Island. The Tralee Group is present in the Porcupine, South Bróna, and Fastnet basins, and Goban Spur area. Within the southwestern and western basins, the deposits include deep marine with influxes of shallow marine sediment, while in the Fastnet basin, depositional conditions comprised a shallow marine shelf. Formations in the Goban Spur area have a dominant lithology of chalk and calcareous ooze and therefore begin their names with 'C' (Clew, Cashen and Cashla formations).

**Trawbreaga Formation.** Named after Trawbreaga Bay on the Inishowen Peninsula in Co. Donegal. This formation contains the Upper and Lower Fintragh Sandstone members.

*Age:* Bartonian - Lutetian.

*Type Section:* Well 35/8-2 (1022 – 1639 m below KB).

*Distribution:* Porcupine Basin and Goban Spur area.

*Lithology:* The formation is dominantly claystone, with sandstone members.

*Depositional Environment:* The formation was deposited in a deep marine setting, with influxes of shallow marine deposition.

**Gweedore Formation.** Named for the Anglicized version of *Goath Dobhair* (translation of "the aqueous estuary"), a bay located in Co. Donegal. This formation contains a number of members named after western Irish bays, including the Blacksod, Oranmore, Brandon, Kilkieran, Drumcliff and Newport Sandstone members and the lowermost deep water Ballyheige Member. A basaltic lava member called the Péist Member (pronounced "pay-sht") is named after an Irish word for monster. These serpent-like beasts were thought to have created the riverways through Ireland, while being chased away by mythical heroes and Christian saints.

*Age:* Ypresian - Thanetian.

*Type Section:* Well 35/13-1 (1816 – 2803 m below KB) in the Porcupine Basin.

*Distribution:* Porcupine Basin and Goban Spur area.

*Lithology:* The unit includes marine claystones, siltstones, sandstones, coals and lavas.

*Depositional Environment:* The unit was deposited in marine, outer shelf to upper bathyal conditions, moving upwards into inner shelf to marginal marine delta front to delta plain settings.

**Gweebarra Formation.** The name is taken from Gweebarra Bay located in Co. Donegal. The bay contains the abandoned island of Inishkeel which is known for St Conall's 6<sup>th</sup> century monastery. The two members of this formation are the Broadhaven Chalk Member, and the underlying Bertraghboy Sandstone Member.

*Age:* Thanetian - Selandian.

*Type Section:* Well 35/18-1 (2322 – 3720 m below KB).

*Distribution:* Porcupine Basin and the Goban Spur area.

*Lithology:* Marly to calcareous claystones with evidence of remobilised chalks and sandstone.

*Depositional Environment:* Outer shelf to bathyal marine setting, with evidence of gravity flow deposits including slumped chalk and clastic fans.

**Clew Formation.** Named after Clew Bay in Co. Mayo. The bay was the stronghold of Grace O'Malley, known in Irish folklore as *Granuaile*, the famous Pirate Queen who controlled the region in the 1500s.

*Age:* Bartonian - Lutetian.

*Type Section:* DSDP Leg 80 Site 548A (1629.6 – 1674.7 m below sea bed).

*Distribution:* South Bróna Basin, Goban Spur area, Merlin High, Pendragon Basin and Porcupine Abyssal Plain area.

*Lithology:* Chalk, occasional chert.

*Depositional Environment:* Marine, upper bathyal to abyssal water depths.

**Cashen Formation.** Named for Cashen Bay, the estuary of the River Feale in Co. Kerry.

*Age:* Ypresian - Thanetian.

*Type Section:* DSDP Leg 80 Site 549 borehole (2803.1 – 2877.5 m below sea bed).

*Distribution:* Goban Spur area, from the South Bróna Basin, Merlin High, Outer Boundary High, and Porcupine Abyssal Plain.

*Lithology:* Pelagic, marly and argillaceous chalks.

*Depositional Environment:* Abyssal marine environment.

**Cashla Formation.** Cashla Bay is located on the north side of Galway Bay, Co. Galway. The Martello Rosaveel (*Ros a' Mhíl*) Tower was constructed in Cashla Bay in the early 1800s to guard against the anticipated French invasion by Napoleon's army (**Information Box No. 3**).

*Age:* Thanetian - Selandian.

*Type Section:* DSDP Leg 80 Site 549 borehole (2877.5 - 2907.1 m below sea bed).

*Distribution:* Interpreted to extend in the Goban Spur area and Porcupine Abyssal Plain, with time equivalence to the Coulagh Formation in the Rockall Basin.

*Lithology:* Biogenic carbonate ooze, chalks occurring with ash and chert intervals.

*Depositional Environment:* Deep marine, pelagic setting.

**Rosscarbery Formation.** Named after the bay in Co. Cork. The area is known for the 4000-year-old Neolithic portal tomb, Calahaencladdig (in Irish, *Caillichín Cladaigh*, translated to, "the little witch of the sea-shore").

*Age:* Lutetian.

*Type Section:* Well 56/21-2 (1059 – 1130 m below KB).

*Distribution:* Fastnet Basin.

*Lithology:* Glauconitic, bioclastic, and nummulitic limestone.

*Depositional Environment:* Deposition occurred in shallow marine shelf conditions after a period of erosion and exhumation in the Paleocene and Early Eocene.

## **ROCKALL-HEBRIDES VOLCANIC GROUP**

Originally named by Stoker *et al.* (2007) after the Hebrides Islands, and Rockall Island, a lonely outcrop of granite on the Rockall High in the Atlantic. The unit is typified by basaltic lava deposits, tuffaceous mudstones and deepwater claystones. The group is present in western Irish basins including the Rockall, Erris, Slyne and Macdara, extending from the Paleocene (Selandian) to the Eocene (Ypresian). It is overlaid unconformably by the Stronsay Group.

**Killeany Formation.** Named after the bay on the island of Inishmore of the Aran Islands of Co. Galway. Inishmore is the home to the prehistoric fort, *Dún Aonghasa*, which is over 3000 years old.

*Age:* Ypresian.

*Type Section:* Well 12/2-1 (2584 – 3035 m below KB).

*Distribution:* Rockall, Erris, and Macdara basins.

*Lithology:* Non calcareous to calcareous claystone and siltstone, can be tuffaceous near base, with infrequent limestone beds.

*Depositional Environment:* Middle to upper bathyal marine. environment.

**Coulagh Formation.** This bay is located on the northern side of the Beara Peninsula, Co. Cork. Overlooking the bay, is the Ballycrovane Ogham Stone, the tallest known in the world, standing 5.3m high. The Coulagh Formation contains the Sheephaven Chalk, Mweenish and Rusheen members.

*Age:* Thanetian - Selandian.

*Type Section:* Well 5/22-1 (3246 – 3912 m below KB).

*Distribution:* Rockall and Erris basins.

*Lithology:* Claystones and siltstones, with members containing silty claystones with volcanoclastic sandstones, and remobilised chalk.

*Depositional Environment:* Marine deep water to slope setting and gravity deposits, with proximity to a volcanic centre.

## 6. UPPER CRETACEOUS

### NOMENCLATURE THEME

The new stratigraphic names used for the Upper Cretaceous stratigraphic units are based on the names of saltwater fish species recorded in Irish waters. The theme continues into the Danian (earliest Paleocene) to reflect the continuation of the open marine setting that prevailed from the Late Cretaceous. The description of the Danian stratigraphy is therefore provided in this chapter, rather than in the Paleogene chapter.

Fish and fishing have played an important role in Irish society since pre-historical times. Many legends and stories are associated with fish and fishing and some of these are outlined in this and especially in the next chapter (Lower Cretaceous). The strong links between Ireland and Newfoundland extend beyond the geological connections and are linked closely with Irish fisherman crossing the Atlantic to fish in the Grand Banks, and eventually settling in the Newfoundland region. The Gaelic (Irish) name for Newfoundland is *Talamh an Éisc* (Land of the Fish).

Fish species names have been used in the Upper Cretaceous of the UK Continental Shelf (North Sea and West of Shetlands) and in order to avoid any confusion or presumed exact stratigraphic correlation, the new formation names used in Irish waters are the Gaelic/Irish version of the fish species. However, the descending stratigraphic order of the fish-based formations in the UK (Cod, Mackerel, Flounder, Herring) are maintained in the Upper Cretaceous successions in the Irish offshore but with the names being in Gaelic rather than English.

### STRATIGRAPHIC UNITS

Overall, the Upper Cretaceous succession is similar across the Irish offshore, with little variation between the basins, reflective of the uniform marine chalk depositional environment across much of Northwest Europe at the time. In the Rockall Basin, the stratigraphic nomenclature established for the UK and Norwegian sectors of the North Sea and the adjacent UK sector of the basin is adopted at group (Shetland) and formation (Sullom, Jorsalfare, Kyrre and Macbeth) levels. Elsewhere the Upper Cretaceous, chalk-dominated stratigraphy is included in the Chalk Group that consists of six new formations. The Plenus Marl Member, a name and distinctive stratigraphic unit well established in the literature, is identified in the Porcupine, Fastnet, North and South Celtic Sea basins, while four new sedimentary members (Urchin Limestone Member, Squid Sandstone Member, Pomfret Sandstone Member and Blenny Member) are identified in the basal Upper Cretaceous

Cadóg Formation. In contrast to the names used for formations, none of the species used in the names of members are commercially fished in Irish waters. A basaltic lava-dominant unit (Changeling Member) has also been identified in the uppermost (Mangach) formation. See **Enclosure 1** for details.

## **SHETLAND GROUP**

The name comes from the Shetland Islands, off the northern Scottish coast, the most northerly part of Scotland and southeast of the Faroe Islands. The Shetland Group was originally defined by Deegan & Schull (1977).

**Sullom Formation.** This was defined by Knox *et al.* (1997) in the Faroe Basin, west of Shetland, following earlier work by Deegan & Schull (1977). It correlates with the Mangach Formation in the Chalk Group of the Slyne, Erris, Porcupine and Goban Spur basins.

*Age:* Danian.

*Reference sections in Ireland:* Well 5/22-1 (3912 – 3989 m below KB), Well 12/2-1 (3566 – 3611 m below KB), Well 12/2-2 (3732 – 2788.7 below KB) in the Rockall Basin.

*Distribution:* Within the Irish offshore the formation has only been encountered in the northeastern part of the Rockall Basin.

*Lithology:* Non-calcareous and calcareous claystones and interbedded limestones with localised sandstones.

*Depositional Environment:* Marine, outer shelf to upper bathyal environment.

**Jorsalfare Formation.** This was formally defined for the UK and Norwegian North Sea sectors by Johnson & Lott (1993), based on earlier work of Isaksen & Tonstad (1989) who first defined the formation in the Norwegian sector, Abbots (1991) and Deegan & Schull (1977).

*Age:* Late Maastrichtian – Late Campanian.

*Reference sections in Ireland:* Well 12/2-1 (3611 – 3726 m below KB), Well 12/2-2 (3788.7 – 3917 m below KB) in the Rockall Basin.

*Distribution:* Within the Irish offshore the formation has only been encountered in the northeastern part of the Rockall Basin.

*Lithology:* Calcareous claystones with locally interbedded limestones and rare stringers of sandstone.

*Depositional Environment:* Open marine outer shelf to upper bathyal environment.

**Kyrre Formation.** This was formally defined for the UK and Norwegian North Sea sectors by Johnson & Lott (1993), based on earlier work of Isaksen & Tonstad (1989) who first defined the formation in the Norwegian sector, Abbots (1991) and Deegan & Schull (1977).

*Age:* Middle Campanian - Late Turonian.

*Reference sections in Ireland:* Well 12/2-1 (3726 – 3887 m below KB), Well 12/2-2 (3917 – 4049 m below KB) in the Rockall Basin.

*Distribution:* Within the Irish offshore the formation has only been encountered in the northeastern part of the Rockall Basin.

*Lithology:* Non-calcareous and calcareous claystones with beds of limestones.

*Depositional Environment:* Low energy upper to middle bathyal environment.

**Macbeth Formation.** This was formally defined from the UK Viking Graben and East Shetland Basin by Johnson & Lott (1993), following earlier work of Abbots (1991) and Deegan & Schull (1977).

*Age:* Middle-Early Turonian.

*Reference sections in Ireland:* Well 12/2-1 (3887 – 3917.5 m below KB), Well 12/2-1z (3886 – 3917 m below KB) in the Rockall Basin.

*Distribution:* Within the Irish offshore the formation has been encountered only in the northeastern part of the Rockall Basin.

*Lithology:* Claystones with thin interbedded limestones.

*Depositional Environment:* Low energy open marine upper to middle bathyal environment.

## **CHALK GROUP**

The Chalk Group was originally defined by Rhys (1974) for the Upper Cretaceous chalky limestone succession in the UK Southern North Sea. The group was extended into the Central and Northern North Sea by Deegan & Schull (1977), with more recent revisions of the UK and Norwegian offshore lithostratigraphy provided by Gradstein & Waters (2016), and onshore formal definition of the group by Hopson (2005). Within the Irish offshore six constituent formations, all new names, are defined and have widespread distribution, reflecting the regional nature of deep water generally terrigenous-free depositional conditions that prevailed through much of NW Europe during Late Cretaceous times.



**Mangach Formation.** This is the Gaelic name (pronounced “*mang-gok*”) for pollock, a saltwater fish found in Irish waters. The largest concentrations are in the west and southwest. Juvenile pollock are found around harbours and rocky shores and migrate to deeper waters in their second winter. The formation contains the Changeling Member comprising four basaltic lava flows. In Irish folklore a changeling is a fairy child that has been left in place of a human child stolen by the fairies. Belief in changelings endured in parts of Ireland until as late as 1895, when Bridget Cleary was killed by her husband who believed her to be a changeling. The Mangach Formation correlates with the Sullom Formation in the Rockall Basin.

*Age:* Danian.

*Type section:* Well 35/8-1 (2411 – 2470 m below KB) in the Porcupine Basin.

*Distribution:* The Mangach Formation has been identified in the basins to the west and southwest of Ireland (Erris, Slyne, Porcupine and Goban Spur basins).

*Lithology:* Pelagic chalks and limestones with occasional calciturbidites. Basaltic lava flow deposits (Changeling Member) occur in the Porcupine Basin.

*Depositional Environment:* Low energy, open marine, outer shelf to abyssal, with occasional calciturbidite incursions.

**Trosc Formation.** This is the Gaelic name (pronounced “*trusk*”) for cod, a long-lived species once common in Irish waters but now has become less prevalent. Many Irish fishermen, especially from the southeast of Ireland, travelled seasonally across the Atlantic in the 18<sup>th</sup> and 19<sup>th</sup> centuries to fish the once bountiful supply of cod that inhabited the waters off Newfoundland. Some eventually settled in Newfoundland and Irish names and accents are still frequently found there.

*Age:* Late-Early Maastrichtian.

*Type section:* Well 35/8-1 (2470 – 2640 m below KB) in the Porcupine Basin.

*Distribution:* The Trosc Formation has been identified in the Slyne, Erris, Bróna, Porcupine, Goban Spur and South Celtic Sea basins. Undated chalks in the Fastnet and North Celtic Sea basins may correspond to the Trosc Formation.

*Lithology:* Pelagic chalks and limestones with rare claystones.

*Depositional Environment:* Low energy, open marine, outer shelf to upper bathyal, with occasional calciturbidite incursions.

**Ronnach Formation.** This is the Gaelic name (pronounced “*run-uck*”) for mackerel. The name was also chosen here because the formation is broadly equivalent to the Mackerel Formation of the Chalk Group in the UK Central North Sea Basin.

*Age:* Late-Early Campanian.

*Type section:* Well 35/8-2 (2638 – 2812 m below KB) in the Porcupine Basin.

*Distribution:* The Ronnach Formation has been identified in the Slyne, Erris, Porcupine, Goban Spur, Fastnet, North and South Celtic Sea basins.

*Lithology:* Low energy chalks and limestones with rare claystones and siltstones.

*Depositional Environment:* Low energy upper bathyal, open marine environment.

**Leith Formation.** This is the Gaelic name (pronounced “*leh*”) for flounder (sometimes known as ‘fluke’), a group of saltwater flatfish found in Irish waters. The name reflects the broad age equivalence to the Flounder Formation in the North Sea Basin.

*Age:* Late Santonian – Early Coniacian.

*Type section:* Well 48/19-2 (465 – 737 m below KB) in the North Celtic Sea Basin.

*Distribution:* The Leith Formation has been identified in the Slyne, Erris, Porcupine, Goban Spur, Fastnet, North and South Celtic Sea basins.

*Lithology:* Pelagic chalks and limestones with localised calcareous siltstones and calcareous sandstones

*Depositional Environment:* Low energy, open marine outer shelf to upper bathyal.

**Scadán Formation.** This is the Gaelic name (pronounced “*skod-awn*”) for herring. There is a long tradition of herring fishing in Irish waters going back to at least medieval times. The base of the formation contains the Plenus Marl Member, equivalent to the Plenus Marls (Jefferies, 1963; Deegan & Schull, 1977; Hopson, 2005), well established in the published literature, and present in the Porcupine, Goban, Fastnet, North and South Celtic Sea basins. An informal unit, the “83/20-Sb01 Sandstone”, is known from a single borehole location in the North Bróna Basin.

*Age:* Late Turonian – latest Cenomanian.

*Type section:* Well 56/12-1 (968 – 1131 m below KB) in the western North Celtic Sea Basin.

*Distribution:* The Scadán Formation has been identified in the Erris, Bróna, Porcupine, Goban, Fastnet, North and South Celtic Sea basins.

*Lithology:* Pelagic chalk and limestones, locally argillaceous and glauconitic.

*Depositional Environment:* Low energy marine, outer shelf to middle bathyal.

**Cadóg Formation.** This is the Gaelic name (pronounced “*cod-oh-g*”) for haddock, a saltwater fish occurring in Irish waters. The formation contains four members (Urchin Limestone Member, Squid Sandstone Member, Pomfret Sandstone Member and Blenny Member).

*Age:* Late-Early Cenomanian.

*Type section:* Well 48/24-3 (712 – 792 m below KB) in the North Celtic Sea Basin.

*Distribution:* With the exception of the Irish Sea basins and the Rockall and its flanking western ‘perched’ basins, the Cadóg Formation has been identified in all Irish offshore basins.

*Lithology:* Clean to argillaceous pelagic chalks and limestones with glauconitic claystones, siltstones, sandstones and shallow marine limestones.

*Depositional Environment:* Low energy marine, inner to outer shelf.

## 7. LOWER CRETACEOUS

### NOMENCLATURE THEME

The new names for the Lower Cretaceous units continue the theme of fish names used in the Upper Cretaceous. However, in contrast to the Upper Cretaceous, significant variations in the stratigraphy occur across the Irish offshore, reflecting the differing tectonostratigraphic development of the basins west of Ireland from those to the south of Ireland. Early Cretaceous development in the Celtic Sea region, south of Ireland, took place in a broadly non-marine environment before marine transgression in the Apto-Albian heralded the ultimate onset of chalk deposition that dominated the Late Cretaceous sedimentation in all the basins. Reflecting the general continental depositional environment, the new names in the Celtic Sea basins are based on freshwater fish. In contrast, the new names adopted in the basins of the Atlantic, where Early Cretaceous deposition was marine in nature, are of saltwater fish. To reflect further these differences between the basins, the new names used in the Celtic Sea are the English rather than the Gaelic names, while the theme of Gaelic names for the saltwater fish continue in the marine setting of the Atlantic basins.

### STRATIGRAPHIC UNITS

At group level, the Lower Cretaceous successions in the basins south of Ireland show a broad similarity to the well documented stratigraphy of the south of England while the west of Ireland successions resemble those of the UK North Sea/west of Shetland. Therefore, the relevant UK group names have been maintained, with Selborne, Wealden and Purbeck groups in the Fastnet and North Celtic Sea basins, and the Cromer Knoll Group in the basins west of Ireland. Within the Cromer Knoll Group, five new formation names are established (Spurdog, Bradán, Salán, Ballach, Gurnard), together with three existing names (Rødby, Carrack, Valhall), while most of the formations contain a number of newly defined members. In the Selborne Group, the well-established Gault Formation from the UK onshore has five new members defined. The Wealden Group contains four new formations (Carp, Eel, Rainbow Claystone and Tench), some of which also contain new members. As with the other chapters, descriptions are only provided at group and formation level, although some aspects of naming of important members are mentioned. The stratigraphic and geographical location of all units, including the members, are shown in **Enclosure 1**.

The following descriptions continue the format of going from top to bottom in the stratigraphy, and from west to east with the west of Ireland basins successions described

first (Cromer Knoll Group), followed by the basins south of Ireland (Selborne, Wealden and Purbeck groups).

## **CROMER KNOLL GROUP**

The Cromer Knoll Group was defined by Rhys (1974) in the Southern North Sea, later extended by Deegan & Schull (1977) into the Central and Northern North Sea, and by Ritchie *et al.* (1996) into the West of Shetland area.

**Rødby Formation.** Originally defined for the North Sea by Larsen (1966), with later additions and modifications by Deegan & Schull (1977), Isaksen & Tonstad (1989), Lott & Knox (1994) and others. It contains the Oakshee Member of submarine pillow lavas and hyaloclastites at DSDP Leg 80 sites and a submarine pillow basalt unit recorded in the DSDP Leg 80 sites 550B and 551 in the Porcupine Abyssal Plain. In Irish folklore, an Oakshee is a tree fairy who protects trees and is capable of inflicting severe retribution, e.g. poverty or illness, on anyone who harms a fairy tree. The Rødby Formation correlates with the Spurdog Formation in the Slyne Basin, with the upper parts of the Bradán and Salán formations in the Porcupine and Goban Spur basins respectively, and with the Gault Formation in the Fastnet, North and South Celtic Sea basins.

*Age:* Late – Middle Albian.

*Reference sections in Ireland:* Well 12/13-1A (1214 – 1337 m below KB) in the Erris Basin, Well 44/23-1 (4664.5 – 4694.5 m below KB) in the Porcupine Basin.

*Distribution:* Present in the Erris and Porcupine basins and in the Porcupine Abyssal Plain region.

*Lithology:* Calcareous claystones, marls and argillaceous limestones.

*Depositional Environment:* Open marine, low energy outer shelf environment.

**Spurdog Formation.** Named after a spiny dogfish shark found in temperate waters including those of western Ireland. A small member of the shark family, it is easily recognisable by a pair of 'spikes' located along its back, directly in front of the dorsal fins. Spurdogs have a tendency to hunt in dog-like packs. Its Gaelic name, *Fíogach Gobach*, is regarded as being too challenging to pronounce. The formation contains one member (Megrin Sandstone Member).

*Age:* Late – Middle Albian.

*Type section:* Well 18/20-7 (722.5 – 846.5 m below KB) in the Slyne Basin.

*Distribution:* Present in the Slyne Basin, it is tentatively interpreted to be present in the Macdara Basin.

*Lithology:* Glauconitic calcareous and claystones, with a glauconitic sandy unit (Megrim Sandstone Member) present towards the base of the formation.

*Depositional Environment:* Shallow marine, well oxygenated inner to mid shelf.

**Bradán Formation.** This is the Gaelic name (pronounced “*bra-dawn*”) for salmon. The legend of the ‘salmon of knowledge’ is famous in Irish mythology (**Information Box No. 2**). The Bradán Formation contains six newly named members, one of which (Sheerie) is igneous in nature. In Irish folklore sheerie are the souls of unbaptized children and combine elements of fairy and human nature. They tend to be very angry towards humans and emit a mewling sort of sound. One informal dolomite unit, the “35/15-1 Dolomite”, is present in the lower half of the formation in a single well in the central part of the Porcupine Basin. The first letters of the other five members (**B**oladh, **R**oc, **A**rrowtooth, **D**aba and **A**Ngler) spell the formation name (Bradán). All are named after fish found in Irish waters.

*Age:* Late Albian – Late Aptian.

*Type Section:* Well 35/8-2 (2920.5 – 3649.5 m below KB) in the Porcupine Basin.

*Distribution:* It has been identified in the northern and central parts of the Porcupine Basin. It is age-equivalent to the Rødby and Carrack formations in the Erris Basin and southern parts of the Porcupine Basin and the Spurdog Formation in the Slyne Basin.

*Lithology:* A mudstone-dominated succession with interbedded sandstones, limestones and dolomites. Five distinctive sandstone, claystone or calcareous claystone members, and one igneous (tuffaceous) member, occur within the formation.

*Depositional Environment:* Its depositional history spans a broad range of depositional environments from deltaic and marginal marine to inner and locally outer shelf settings, with occasional localised sediment gravity flows.

## Information Box No. 2: The Salmon of Knowledge

This Irish legend tells of a dark pool in the shade of overhanging hazel trees on the river Boyne, in Co. Meath, containing a salmon that had eaten the nuts of the magical trees and had acquired all the knowledge of the world. Prophecy said that whoever ate the salmon would gain the knowledge for themselves.

A druid name Finnegas lived by the river for 30 years attempting to catch the fish. A young boy named Fionn mac Cumhail, who would become the great leader of the Fianna tribe of Ireland, was sent to be educated by Finnegas and to clean and cook for the druid.

One day, Finnegas caught the magical fish, gave it to Fionn to cook but instructed him not to eat a single piece of it. When Fionn was turning the fish on the fire he burnt his fingers and put them into his mouth to relieve the pain. As a result, he had tasted the fish and gained all the knowledge of the world.

The legend doesn't say what became of the disappointed Finnegas.

**Carrack Formation.** This was defined by Johnson & Lott (1993) in the UK North Sea Basin.

*Age:* Early Albian – Late Aptian.

*Reference sections in Ireland:* Well 12/13-1A (1337 – 1399 m below KB) in the Erris Basin; Well 44/23-1 (4694.5 – 4720 m below KB) in the Porcupine Basin.

*Distribution:* In the Irish offshore the formation is proven in the Erris and Porcupine basins.

*Lithology:* Non-calcareous to calcareous claystones, with rare stringers of sandstones.

*Depositional Environment:* Low energy, generally restricted, outer shelf environment.

**Salán Formation.** This is the Gaelic name (pronounced “sal-lawn”) for sprat, a small saltwater fish that is native to Irish waters and is preyed on by larger fish such as mackerel. It correlates with the combined Rødby and Carrack formations in the Porcupine and Erris basins and the Spurdog Formation in the Slyne Basin.

*Age:* Late Albian – ?Late Aptian.

*Type section:* Well 62/7-1 (2190 – 2499 m below KB) in the Goban Spur Basin.

*Distribution:* The formation is proven only in the Goban Spur Basin. The title letter of the formation name corresponds to the ‘S’ in Goban Spur Basin to reflect its uniqueness to this basin.

*Lithology:* Limestone dominated with thin beds of calcareous claystones, marl and sandstones.

*Depositional environment:* Low energy, marine, inner to outer shelf.

**Ballach Formation.** This is the Gaelic name (pronounced “*bal-lock*”) for wrasse, a saltwater fish found in Irish waters.

*Age:* Early Aptian – Late Barremian.

*Type section:* Well 62/7-1 (2499 – 2686.5 m below KB) in the Goban Spur Basin.

*Distribution:* The formation is proven to date only in the Goban Spur Basin. The first letter of the formation name corresponds with the ‘**B**’ in Goban Spur Basin to reflect the uniqueness to this basin.

*Lithology:* Predominantly limestones, argillaceous in places, with a thickly bedded sandstone unit in the middle of the formation.

*Depositional environment:* Low energy, oxygenated marine, inner shelf.

**Valhall Formation.** This was defined by Deegan & Schull (1977) in the Central and Northern North Sea; extended into the Southern North Sea by Lott & Knox (1994) and into the West of Shetland region by Ritchie *et al.* (1996) and Stoker (2016). In the Irish offshore the formation contains four sandstone members (Sól Sandstone, Siorc Sandstone and Scatálá Sandstone, Tope Sandstone), and four limestone members (Troscín Limestone, Leathóg Limestone, Doingean Limestone and Langa Limestone). All are named (Gaelic names) after fish found in Irish waters. One informal unit, the “Upper 34/19-1 Conglomerate”, is present on the northwest margin of the Porcupine Basin.

*Age:* Early Aptian – Early Barremian.

*Reference sections in Ireland:* Well 12/13-A (1399 – 2039.5 m below KB) in the Erris Basin; Well 35/19-1 (4181.5 – 5042 m below KB), Well 44/23-1 (4720 – 5000 m below KB) in the Porcupine Basin.

*Distribution:* The formation is proven in the Rockall, Erris, Porcupine and Goban Spur basins.

*Lithology:* Predominantly marls and calcareous claystones with localised limestones, sandstones and occasionally conglomerates.

*Depositional Environment:* A wide range of environments is represented including alluvial, high energy shallow water through to outer shelf open marine conditions.



**Gurnard Formation.** This is the name of a bottom feeding saltwater fish found in Irish waters. A prehistoric-looking fish, normally red in colour, has the unusual ability to grunt and growl using muscles associated with its swim bladder. It is thought that this is used to keep schools of fish together. The title letter (**G**) of the formation name reflects the main area of its distribution in the Goban Spur Basin. Together, the first letter of each of the three new names in the Cromer Knoll formations (**G**urnard, **B**allach, **S**alán), represent, in ascending stratigraphic order, the first letter of the main basin name (Goban Spur Basin), while also being coincidentally the initials of the famous Irish playwright George Bernard Shaw, a Nobel laureate and an Oscar winner, who was known widely as 'GBS'.

*Age:* Late – ?Early Hauterivian.

*Type section:* Well 62/7-1 (2686.5 – 2884 m below KB) in the Goban Spur Basin.

*Distribution:* The formation is only known from the Goban Spur Basin and part of the nearby Pendragon Basin.

*Lithology:* Interbedded limestones and sandstones, with the limestones dominating the upper half of the formation and the sandstones predominant in the lower half.

*Depositional environment:* Low energy, well oxygenated marine, inner shelf.

## **SELBORNE GROUP**

This is named after the type locality of Selborne in Hampshire. First defined as the Selbornian Stage by Jukes-Browne & Hill (1900), it was formally modified to the Selborne Group by Hopson *et al.* (2008). It is the transitional interval between the Chalk and the Wealden groups containing shallow marine glauconitic sandstones. Offshore Ireland, the Selborne Group comprises the Gault Formation.

**Gault Formation.** This is well established in the south of England stratigraphy, containing glauconitic sandstones, calcareous and sandy claystones and siltstones. First described by Hailstone (1816), it was formalised by Rawson (1992). Within the formation in the Irish offshore, five new members are defined (see **Enclosure 1**), all named after freshwater fish. The Shad Sandstone Member is found in the Fastnet Basin. The names of the other four new members, in the North Celtic Sea Basin (with the uppermost member also found in the South Celtic Sea Basin), start with the first four letters of the alphabet (Agone Sandstone, Bream Sandstone, Char Sandstone and Dace Limestone). The Bream Sandstone and Agone Sandstone members in North Celtic Sea Basin correspond respectively to the 'B' and 'A' sandstone reservoirs, frequently referred to in the published literature, at the Kinsale Head gas field.

*Age:* Late Albian.

*Reference sections in Ireland:* Well 49/16-A5 (807 – 945 m below KB), Well 49/26-1A (990.5-1077 m below KB), Well 56/18-1 (1120.5 – 1152 m below KB) in the North Celtic Sea Basin; Well 56/26-2 (1116 – 1132.5 m below KB) in the Fastnet Basin.

*Distribution:* Widespread within the Fastnet, North and South Celtic Sea basins.

*Lithology:* Glauconitic sandstones, glauconitic calcareous claystones, sandy claystones and siltstones and limestones.

*Depositional Environment:* Well oxygenated, shallow, inner to mid shelf setting.

## **WEALDEN GROUP**

Wealden Group strata, characterised by arenaceous-dominant strata and common continental redbeds in the south of England, were first described by Drew (1861). They are well established in the published literature (Allen, 1981), with the type sections in the Weald, and were formally described by Hopson *et al.* (2008). Wealden Group strata are present in the North and South Celtic Sea and the Fastnet basins. The succession is undivided within the South Celtic Sea Basin. However, in the North Celtic Sea and Fastnet basins, the large number of wells drilled have allowed subdivision into formations and members with some significant differences from the UK type sections occurring, while differences also occur westwards through the North Celtic Sea Basin and into the Fastnet Basin. Four new formations and two new members are defined.

**Eel Formation.** Named after the snake-like, catadromous fish species (it spawns and is born at sea, then migrates into inland waters to eat and grow) present in Irish rivers and lakes. One new member (Rudd Sandstone) is defined within the formation.

*Age:* Late Aptian.

*Type Section:* Well 48/24-5A (856.5 – 1124 m below KB) in the North Celtic Sea Basin.

*Distribution:* This is present in the western part of the North Celtic Sea Basin and throughout the adjacent Fastnet Basin.

*Lithology:* An interbedded succession of claystones, sandstones and coals with localised limestones and dolomitic beds.

*Depositional Environment:* A set of environments ranging from continental through to nearshore marine setting, including fluvial, bay head deltas, tidal flats and estuarine settings.

**Tench Formation.** Named after the coarse freshwater fish occurring in rivers, canals and limestone lakes throughout Ireland. One new member (Roach Member) is defined within the formation. Two additional informal units, the “56/12-1 Limestone” and the “63/10-1 Urgonian Sediments” have been identified in the formation.

*Age:* Early Aptian – Late Barremian.

*Type Section:* Well 56/18-1 (1191 – 1317 m below KB) in the westernmost North Celtic Sea Basin.

*Distribution:* This formation is identified in the western part of the North Celtic Sea Basin and throughout the Fastnet Basin. Its distribution is similar to that of the overlying Eel Formation.

*Lithology:* Predominantly calcareous claystones, including one distinctive claystone unit (Rudd Member), and with occasional interbedded limestone and sandstone units.

*Depositional Environment:* Well oxygenated, marginal marine to inner shelf, representative of a transgressive succession.

**Carp Formation.** Named after the coarse freshwater fish found in Irish rivers and lakes.

*Age:* Intra-Late Barremian – Late Valanginian.

*Type Section:* Well 56/21-2 (1490 – 1986 m below KB) in the Fastnet Basin.

*Distribution:* The formation is currently restricted to the southern part of the Fastnet Basin. However, it may extend further northwards into an area where the Wealden Group is currently undivided.

*Lithology:* The formation is composed of an interbedded succession of red claystones containing sphaerosiderite nodules, and siltstones, sandstones and occasional carbonates, together with carbonaceous fragments.

*Depositional Environment:* Continental, alluvial, fluvial and lacustrine. The sandstones are interpreted as point bars, stacked channel and braided stream complexes, while the claystones are interpreted as floodplain, lacustrine and overbank deposits.

**Rainbow Claystone Formation.** Named after the rainbow trout, a freshwater fish found in many lakes, especially in limestone terranes, throughout Ireland. A favourite with anglers, the success of the rainbow trout fishing in Irish lakes is due to the stocking policies of the past number of years.

*Age:* Intra-Barremian – Early Hauterivian.

*Type Section:* Well 56/12-1 (1549 – 2025 m below KB) in the southwestern North Celtic Sea Basin.

*Distribution:* The formation occurs in the southwestern part of the North Celtic Sea and the northern part of the Fastnet Basin. In the latter basin it is age equivalent to much of the Carp Formation and was previously referred to as the Wealden Clay.

*Lithology:* The formation is dominated by claystones, with minor sandstones, dolomites and coals. Sphaerosiderite nodules are common throughout the formation.

*Depositional Environment:* A broadly continental, freshwater, low energy setting of lakes, floodplains and lagoons. Some brackish to brief shallow marine incursions developed towards the top of the formation.

## **PURBECK GROUP**

The successions within the Purbeck Group, with type sections in Dorset and the Isle of Purbeck in southern England, are well established in the published literature, and the group was formalised by Hopson *et al.* (2008). It lies beneath the Wealden Group strata and marks the transition from the predominantly clastic continental facies of the Lower Cretaceous Wealden downwards into the calcareous and argillaceous brackish and marginal marine facies, and into the Upper Jurassic marine-dominant facies of the Upper Jurassic. Within the Irish offshore three calcareous and argillaceous formations are defined, with one distinctive sandstone member (Stickleback Sandstone Member) in the oldest (Pollan) formation. The names of the three formations in the Purbeck Group start with the letter 'P' to reflect their similarities and, as pike, perch and pollan are commonly found in lakes, they have been chosen as names to reflect the lacustrine depositional environment for these formations. Purbeck Group strata occur in the North Celtic Sea Basin and probably locally and partially in some places in the Fastnet and South Celtic Sea basins.

**Pike Formation.** Named after the coarse freshwater fish common in rivers, canals and lowland lakes throughout Ireland. Long lived, pike often grow to large sizes.

*Age:* Early Valanginian – Late Berriasian.

*Type Section:* Well 48/19-1A (1499 – 1650.5 m below KB) in the North Celtic Sea Basin.

*Distribution:* The formation occurs in the North Celtic Sea Basin, possibly extending into the extreme northeastern part of the Fastnet Basin.

*Lithology:* Claystones, locally organic-rich, with interbedded siltstones, sandstones, thin carbonates and occasional conglomerates.

*Depositional Environment:* Continental, predominantly fresh water low energy lacustrine environment, with occasional higher energy fluvial or alluvial influxes into the lacustrine environment.

**Perch Formation.** Named after the coarse freshwater fish found in lakes and rivers in Ireland.

*Age:* Berriasian.

*Type Section:* Well 48/19-1A (1650 – 1702 m below KB) in the North Celtic Sea Basin.

*Distribution:* Present in the North Celtic Sea Basin, with its southwesterly limit at the boundary between the North Celtic Sea and the Fastnet basins.

*Lithology:* Claystones becoming increasingly calcareous downwards in the formation with the development of limestone beds.

*Depositional Environment:* Continental, freshwater to occasionally brackish lacustrine deposition environment.

**Pollan Formation.** Named after the coarse freshwater whitefish, known from five lakes in Ireland. Interestingly, while pollan are found in some Arctic regions they are not found in any other European country outside the island of Ireland. The formation contains one distinctive member (Stickleback Sandstone Member).

*Age:* Early Berriasian – Late Tithonian.

*Type Section:* Well 48/19-1A (1964.5 – 2048.5 m below KB) in the North Celtic Sea Basin.

*Distribution:* The formation is limited to the North Celtic Sea Basin and to an adjacent part of the South Celtic Sea Basin.

*Lithology:* Interbedded claystones, often calcareous, and limestones with occasional localised siltstones and sandstones. One notable unit (Stickleback Sandstone Member) is defined at member status.

*Depositional Environment:* Continental, mainly low energy lacustrine environment, with localised shallow marine incursions in the northern part of the North Celtic Sea Basin. The Stickleback Sandstone Member reflects a higher energy alluvial or fluvial clastic input close to the northwestern margin of the basin.

## 8. UPPER JURASSIC

### NOMENCLATURE THEME

The theme for new stratigraphic names for the Upper Jurassic stratigraphic units is Irish coastal features and a hierarchy scheme has been adopted, whereby groups are named after peninsulas, formations are named after headlands and members are named after points. Additionally, new names for geological units in offshore western basins (Porcupine, Slyne, Rockall, Macdara and Bróna basins) are taken from western coastal features, and new names in southern basins (Goban Spur, Fastnet, North and South Celtic Sea basins) are taken from southern coastal features. As coastal features are often used in the naming of onshore geological units, care has been taken to ensure that the new names adopted for this new offshore nomenclature system have not already been used in the Geological Survey of Ireland's Bedrock Lexicon ([www.gsi.ie](http://www.gsi.ie)).

### STRATIGRAPHIC UNITS

The following descriptions continue the format of going from top to bottom in the stratigraphy, and from west to east with the western (Atlantic margin) basins successions described first, followed by the southern Goban Spur, Fastnet and Celtic Sea basins. In the case of the Atlantic margin basins two new groups are defined, namely the Muckross Group (Slyne and Rockall basins) and the Beara Group (Porcupine, Macdara and Bróna basins and the Late – ?Middle Jurassic section in the Slyne Basin).

### MUCKROSS GROUP

Named after the Muckross Peninsula in Co. Donegal. This group comprises the Tithonian to Late Oxfordian section found in the Rockall and Slyne basins. Two new formations are defined within the group.

**Dawros Formation.** Named after Dawros Head in Co. Donegal, on which the ruins of a signal tower (**Information Box No. 3**) can be found. The remains of a post-medieval settlement with a well preserved corn drying kiln are also to be found on Dawros Head. The Dawros Formation contains one new informal unit, the "12/2-2 Upper Sandstone".

*Age:* Tithonian – intra Early Kimmeridgian.

*Type Section:* Well 19/11-1A (1016 – 1294 m below KB) in the Slyne Basin.

*Distribution:* The formation is found in the Slyne Basin and in the northeastern part of the Rockall Basin.

*Lithology:* The formation is dominated by claystones and siltstones with stringers and thin beds of limestone and dolomite.

*Depositional Environment:* In the Rockall Basin the argillaceous sediments are interpreted to have been deposited in a quiet marine, outer shelf, environment, with anoxic bottom waters, while the sandstone unit (“12/2-2 Upper Sandstone”) is interpreted to be a turbidite deposit. In the Slyne Basin two depositional environments are recognised, namely a middle to outer shelf or possibly upper bathyal marine environment, as represented by claystones with a high gamma ray response, and a shallower (inner shelf) marine environment, as represented by claystones with a low gamma ray response.

**Sybil Formation.** Named after Sybil Head, Co. Kerry. This headland on the Dingle Peninsula was a prominent location for the filming of the Star Wars, where the iconic 6<sup>th</sup> century Skellig Michael beehive huts were recreated for the big screen to represent the lost world of *Ahch-To*, where the Jedi Order was founded.

*Age:* Intra Early Kimmeridgian – intra Late Oxfordian.

*Type Section:* Well 19/11-1A (1294 – 2127.5 m below KB) in the Slyne Basin.

*Distribution:* The formation is found in the Slyne Basin.

*Lithology:* The formation is dominantly claystone/silty claystone, in association with thin limestone and dolomite stringers with rare sandstone beds.

*Depositional Environment:* Marine, inner to outer shelf, to possibly upper bathyal.

### Information Box No. 3: Signal Towers

Signal towers were constructed along the coast of Ireland during the early part of the 19th century in response to repeated attempts by French forces to invade Ireland during the late 18th century. A chain of 81 towers were built at strategic locations along the northwest, west, south and southeast coastlines from Malin Head to Dublin. Construction and staffing of the majority of the towers took place between 1804 and 1806. The towers were generally built to the same design, which was square in plan (4.5m square internally), two storeys high (9m in height), flat roof with parapet and a main entrance at first floor level on the seaward side, which was accessed by ladder. Machicolations were built over the doorway and at the landward corners of the tower and fireplaces and chimneys were built into the splayed rear wall (O'Sullivan & Downey, 2012).

The purpose of the towers was to provide defensible accommodation for the naval signalling crew and military guard, which usually comprised eight to twelve men. Signal towers were an important component of the coastal defence system in conjunction with Martello towers and batteries. Their role was to signal information on offshore shipping to adjacent signal towers, to naval vessel ships offshore and to pass information to the inland guard by messenger. This information was communicated by means of hoisting and lowering a large rectangular flag, a smaller blue pendant and four black balls, which were made of hoops covered in canvas, in various configurations on a system centred on a tall mast that was positioned on the seaward side of the signal tower.

The working life of the signal towers did not last long. Following Napoleon's defeat at Waterloo in 1815 the threat of invasion diminished and most of the signal towers were abandoned and subsequently fell into disrepair. Some were used as signal stations during World War I and during World War II coastal watching posts were erected close to the signal towers (O'Sullivan & Downey, 2012). The ruins of many of the signal towers can still be found dotted around the coast on numerous headlands.

### BEARA GROUP

Named after the Beara Peninsula in Co. Cork, which was named after Princess Beara who was married to Owen Mór, once the King of Ireland. Legend has it that in honour of his wife Princess Beara, who hailed from Spain, Owen Mór named the peninsula after her. The peninsula has a large number of sites of mythological, historical and archaeological interest, including the Cailleach Beara (Hag of Beara), Allihes disused copper mines and the world's tallest Ogham stone. The peninsula straddles counties Cork and Kerry, which are connected



by spectacularly scenic roads, the Cahah Pass and the Healy Pass, the latter of which was constructed in 1847 as a famine relief project.

The Beara Group is defined for the Late Jurassic section found in the Porcupine, North Bróna, South Bróna and Macdara basins. The lower part of the group (Minard Formation), also extends into the Slyne Basin. Three new formations are defined within the group.

**Dursey Formation.** Named after Dursey Head in Co. Cork. This headland is on Dursey Island and is the most south-westerly point of Ireland. Dursey Island is connected to the mainland by Ireland's only cable car at the time of this publication.

The Dursey Formation contains three new members: the Leck Sandstone Member, the Streedagh Sandstone Member and the Selkie Member, which is an extrusive basalt. A 'Selkie' is a Celtic mythological creature, similar to a mermaid, that lives in the sea as a seal but in order to take on a human form and live on land they must shed their skin and tail. Legend has it that if a man finds a female's Selkie's skin, the Selkie is forced to marry him.

*Age:* Tithonian – latest Kimmeridgian.

*Type Section:* Well 26/28-5 (1992 – 2485.5 m below KB) in the Porcupine Basin.

*Distribution:* The formation is found in the Porcupine Basin and in the North Bróna Basin.

*Lithology:* Dominantly claystones and organic-rich claystones, in association with thin limestone, dolomite, and sandstone beds. The Leck Sandstone Member comprises interbedded conglomerates, sandstone, siltstone and claystones. The Streedagh Sandstone Member is dominantly sandstones with interbedded mudrocks. While both members are coeval with each other, they are considered to have different sediment provenances and depositional settings. Two thick conglomerate units are also recognised within this formation, namely the "26/28-4Az Conglomerate" and the "Lower 34/19-1 Conglomerate".

*Depositional Environment:* Marginal marine (?lacustrine) to marine, inner shelf. The depositional environment for the Leck Member is interpreted to be a deep marine gravity flow setting. The depositional environmental for the Streedagh Sandstone Member is uncertain but previous operators have suggested a non-marine sandstone-rich fluvial environment, to an inner shelf marine environment or a submarine fan setting.

**Bolus Formation.** Named after Bolus Head on the Iveragh Peninsula, Co. Kerry. A War Memorial to the 11 airmen of the US Navy's Patrol Squadron VB110, who were lost on 27<sup>th</sup> February 1944 when on a patrol, can be found on Bolus Head. Their aircraft, US Navy Liberator "63939", was reported missing and it is believed to have crashed into sea after striking the Great Skellig Rock. None of the airmen's remains were ever recovered. This headland has the ruins of an early 19<sup>th</sup> century signal tower (**Information Box No. 3**).

The Bolus Formation contains four newly named members; the Doorin Member, the Rinroe Member, the Rinvyle Sandstone Member and the Emlagh Sandstone Member.

*Age:* Late Kimmeridgian – intra Late Oxfordian.

*Type Section:* Well 26/28-5 (2485.5 – 2755.5 m below KB) in the Porcupine Basin.

*Distribution:* The formation is found in the Porcupine Basin and in the North Bróna Basin.

*Lithology:* Dominantly mudrocks with interbedded dolomite and limestone beds. The Rinvyle Sandstone and Emlagh Sandstone members comprise interbedded sandstone, siltstone and claystones.

*Depositional Environment:* Marine, inner to outer shelf, possibly to upper bathyal. The Rinvyle Sandstone and Emlagh Sandstone members are interpreted as deep water gravity flows into possibly a submarine fan or slope apron setting.

**Minard Formation.** Named after Minard Head, Co. Kerry. This headland, located on the Dingle Peninsula, has the ruins of Minard Castle, which was a stronghold of the Knight of Kerry. The castle was attacked in 1650 by the forces of Oliver Cromwell who tried to destroy it by detonating charges at each of its corners. The castle stayed standing; however, all the occupants were killed and the castle was rendered uninhabitable due to the sustained structural damage. The damage to the corners of the castle can be seen today. The castle was also one of the film locations used in the film 'Ryan's Daughter'.

The Minard Formation contains four newly named members: the Renard Member, the Dooneragh Member, the Tonakeera Member and the Garnish Member, all of which are only identified in the Porcupine Basin.

*Age:* Intra Late – ?Middle Oxfordian.

*Type Section:* Well 26/28-1 (2241 – 2735 m below KB) in the Porcupine Basin.

*Distribution:* The formation is found in the Porcupine and Slyne basins.

*Lithology:* Interbedded mudrocks and sandstones. Dolomite and limestone beds are also present, with localised occurrences of breccias or conglomerates.

*Depositional Environment:* Continental to marginal marine through to inner shelf in the Porcupine Basin, while in the Slyne Basin the depositional environment is more non-marine.

## HOOK GROUP

Named after the Hook Peninsula in Co. Wexford. This is a prominent peninsula on the eastern side of the estuary of the 'Three Sisters' (rivers Suir, Nore and Barrow). It is also home to the Hook Lighthouse, which was built in the 13<sup>th</sup> Century by William Marshal, Earl of Pembroke, and is the world's oldest operational lighthouse. On the eastern side of the estuary in Co. Waterford is the townland of Crooke. Oliver Cromwell, during his siege of Waterford in the mid 17<sup>th</sup> century, is reputed to have said that the town would fall "by Hook or Crooke"; which is believed to be the origin of the phrase. Cromwell failed to capture Waterford city and left Ireland shortly after the failure of the siege, never to return.

The Hook Group is defined for the Upper Jurassic section found in the Fastnet, North and South Celtic Sea basins. It is also tentatively interpreted in the Goban Spur Basin. Four newly named formations are defined in this group.

**Knockadoon Formation.** Named after Knockadoon Head in Co. Cork. This headland has the ruins of an early 19<sup>th</sup> century signal tower (**Information Box No. 3**). The headland is also a nature reserve and in December 2003, a Hume's Warbler was sighted, which was the first record of this species of bird in Ireland.

*Age:* Tithonian.

*Type Section:* Well 48/19-1A (2448.5 – 2818.5 m below KB) in the North Celtic Sea Basin.

*Distribution:* The formation is found in the North Celtic Sea Basin.

*Lithology:* Dominantly claystone dominated with localised sandstone and conglomerate occurrences.

*Depositional Environment:* Mainly continental through to brackish marine.

**Baginbun Formation.** Named after Baginbun Head, Co. Wexford. This headland provides shelter to the adjacent Baginbun Beach, which is a popular spot with locals and tourists. However, this is a significant site in Irish history as it was from here that the Norman conquest of Ireland began, when a Norman vanguard of 100 men led by Raymond le Gros landed near Baginbun in 1170. Having fixed Baginbun Head with ditches and ramparts, some of which are still visible today, they set up a temporary fortification and robbed cattle to feed themselves. When an army of a few thousand local Celts approached, Le Gros and his men, knowing that they were outnumbered, began whipping and frightening the cattle into a frenzy. Just as the Celts were at the gates the Normans released the distraught cattle, who stampeded and trampled the attacking army. The Normans followed and won the battle. Norman reinforcements arrived shortly afterwards and Waterford subsequently fell to the invading forces. The name Baginbun is derived from that fateful invasion; the two boats that Le Gros used to land were named “Le Bag” and “Le Bun”.

The Baginbun Formation contains one newly named member, the Cowdy Limestone Member.

*Age:* Late-Early Kimmeridgian.

*Type Section:* Well 49/14-3 (2164 – 2802.5 m below KB) in the North Celtic Sea Basin.

*Distribution:* The formation is found in the Fastnet, North and South Celtic Sea basins.

*Lithology:* A calcareous sedimentary succession of interbedded limestones, dolomites, marls, sandstones, claystones and localised conglomerates. The lithology of the Cowdy Limestone Member is dominantly oolitic limestone with thin interbedded claystones.

*Depositional Environment:* Continental to marine, inner shelf.

**Galley Formation.** Named after Galley Head in Co. Cork. The headland is home to the Galley Head Lighthouse, which was constructed in 1875. At the time of its construction it was the most powerful lighthouse in the world and its light could be seen in clear weather at a distance of 30 km.

*Age:* Intra Early Kimmeridgian – latest Oxfordian.

*Type Section:* Well 49/9-2 (1335 – 1550 m below KB) in the North Celtic Sea Basin.

*Distribution:* The formation is found in the Fastnet and the North Celtic Sea Basin. A penetration of the formation is tentatively interpreted in the 62/7-1 well (Goban Spur Basin).

*Lithology:* A poorly calcareous sedimentary succession of interbedded sandstones, limestones (not oolitic) and mudrocks.

*Depositional Environment:* Continental, freshwater to brackish, with minor marginal marine/nearshore marine incursions.

The Galley Formation contains one newly named member, the Púca Member, which is a series of extrusive basalt flows, that occurs in the Goban Spur Basin.

Púca is the Irish Gaelic word for ghost or spirit. Legend has it that they can change their shape and take on the form of various animals. They can also take the form of humans but will have animal features. While having a tendency to cause mischief and terrify humans, the Púca is considered to be benevolent and can protect or warn humans from impending harm. Folklore has it that Brian Boru, the High King of Ireland from 941 to 1014 AD, is the only person to have ridden a Púca, which he did by using a special bridle incorporating three hairs of the Púca's tail.

**Dunbrattin Formation.** Named after Dunbrattin Head in Co. Waterford. One of a series of promontory forts along the Waterford coastline, the site at Dunbrattin covers an area of approximately six hectares.

The Dunbrattin Formation contains two newly named members, the Dunworly Sandstone Member and the Frower Member.

*Age:* Late - ?Early Oxfordian.

*Type Section:* 49/9-2 (1550 – 1790 m below KB) in the North Celtic Sea Basin.

*Distribution:* The formation is only found in the North Celtic Sea Basin.

*Lithology:* Interbedded succession of claystones, which are often red in colour, siltstones, sandstones and conglomerates. The Dunworly Sandstone Member is dominantly sandstones and conglomerates and the Frower Member consists of claystones and siltstones.

*Depositional Environment:* Continental.

## 9. MIDDLE JURASSIC

### NOMENCLATURE THEME

The names for all stratigraphic units in the Middle Jurassic (broadly Aalenian through Callovian) in the Irish offshore basins are new. The names have an ornithological theme, using the names of birds recorded in Ireland. All are, or were, native to Ireland. Some species are common, others have dwindling numbers and a few are increasing in numbers. A few, having been hunted to extinction in previous centuries, were reintroduced in recent years and are beginning to recolonise parts of the country. All the bird species in the new Irish Middle Jurassic nomenclature are terrestrial or land birds.

The nomenclature adopted for the Middle Jurassic is based on a hierarchy of species. Groups were named after large raptors, while formations bear the names of smaller raptors. The names of members are based on other birds, with member names in the Celtic Sea (Curlew, Chiffchaff, Chough) beginning with the letter 'C'.

### STRATIGRAPHIC UNITS

Relatively complete Middle Jurassic successions are proven in the Slyne and North Celtic basins, with partial sections proven in the Fastnet Basin. They may have a wider geographic distribution, with possible (but undrilled) Middle Jurassic in the 'perched' basins (e.g. Conall/Rónán) on the western flanks of the Rockall Basin and in the Rockall Basin itself. Strata previously assumed to be of Middle Jurassic age in the Porcupine Basin have now been redated as Late Jurassic in age (Merlin Energy Resources Consortium, 2020). However, Middle Jurassic may also be present elsewhere in the basin.

Two new and broadly co-eval groups have been defined, with the Kite Group in the west of Ireland (Slyne Basin) and the Eagle Group in the Goban Spur and Celtic Sea basins. The Kite Group consists of two new formations and six new members, while the Eagle Group has three new formations and three new members. As with the other chapters, the succession is described from the top down, and from west to east. Full details of the stratigraphy are provided in the Merlin Stratigraphic Atlas, while the succession is summarised in

**Enclosure 1.**

## KITE GROUP

The Kite Group, present in basins west of Ireland, takes its name from the Red Kite, a large raptor, extinct in Ireland since the middle of the 19<sup>th</sup> century and recently reintroduced successfully. It is an elegant, graceful bird, larger than a buzzard, and is now spreading beyond the reintroduction sites in counties Wicklow and Down. In 2012 they bred successfully for the first time in almost 200 years.

**Kestrel Formation.** Named after a small falcon common throughout Ireland. It is the only Irish bird of prey that hovers, making it distinguishable from other raptors. It is the second most common bird of prey in Ireland after the Sparrowhawk. The formation contains one member (Kingfisher Limestone Member).

*Age:* Late-Early Bajocian.

*Type Section:* Well 18/20-1 (1991.5 – 2167.5 m below KB) in the Slyne Basin.

*Distribution:* The formation is proven in the Slyne Basin. However, it may also be present within undrilled parts of the Porcupine Basin.

*Lithology:* The formation comprises grey mudrocks, with one unit (Kingfisher Limestone Member) of interbedded limestones and claystones at the base of the formation.

*Depositional Environment:* Marine, well oxygenated, low energy inner shelf.

**Harrier Formation.** Named after the Hen Harrier, a medium sized raptor, that winters in coastal and lowland areas and breeds in heather moorland and young forestry where it nests on the ground. The formation contains five members (in descending stratigraphic order): Wren, Skylark, Sparrow, Robin and Dunnock, with names based on common small birds.

*Age:* Earliest Bajocian – latest Early Aalenian.

*Type Section:* Well 18/20-1 (2167.5 – 2556 m below KB) in the Slyne Basin.

*Distribution:* The formation has only been proven in the Slyne Basin. However, it may be present within undrilled parts of the Porcupine Basin.

*Lithology:* The formation is dominated by claystones, with thin limestone stringers, with a basal interbedded calcareous claystone – limestone unit.

*Depositional Environment:* Well oxygenated, low energy marine, inner shelf.

## EAGLE GROUP

The Eagle Group, present in the Goban Spur and Celtic Sea basins, was named after Eagles, Ireland's largest birds of prey. The Golden Eagle and the larger White-tailed Eagle were both driven to extinction in Ireland in the 18<sup>th</sup> and early 20<sup>th</sup> centuries respectively but have recently been reintroduced and have begun to breed successfully again.

**Peregrine Formation.** Named after the falcon that breeds on coastal and inland cliffs, including quarries and occasionally high buildings such as church steeples. Its numbers diminished in the 1950s and 1960s due to the effects of pesticide poisoning but with the banning of the responsible pesticides numbers are rising again. The fastest animal on the planet, it can dive at speeds in excess of 300 km/hour. The formation contains one member (Curlew Member).

*Age:* Late-latest Middle Bathonian.

*Type Section:* Well 50/6-1 (1800.5 – 1935.5 m below KB) in the North Celtic Sea Basin.

*Distribution:* The formation has been recorded in wells in the North Celtic Sea Basin.

*Lithology:* The formation is dominated by limestones (wackestones to grainstones, locally oolitic and bioclastic), with sandstones and subsidiary calcareous claystones. Locally, a distinctive claystone unit (Curlew Member) is present at the top of the formation.

*Depositional Environment:* Mostly marine, high energy shallow inner shelf, with the upper (Curlew Member) part deposited in a continental to very shallow marine environment, marking a shallowing at the top of the Bathonian.

**Merlin Formation.** Named after the Merlin a small species of falcon similar in shape to the Peregrine. Although elusive, it is widely distributed during the winter, and breeds rarely in Ireland. It nests on the ground in moorland, mountain and upland blanket bog. The formation contains one member (Chiffchaff Limestone Member).

*Age:* Latest - Middle Bathonian.

*Type Section:* 49/9-1 (909 – 1241.5 m below KB) in the North Celtic Sea Basin.

*Distribution:* The formation has been recorded in wells in the North Celtic Sea Basin.

*Lithology:* Calcareous and non-calcareous claystones. A thin limestone unit (Chiffchaff Limestone Member) is identified in the central part of the formation, with a localised informal sandstone unit, the "42/21-1 Upper Sandstone", recorded in the lower part of the formation in the type well.

*Depositional Environment:* Low energy, well oxygenated marine, inner to middle shelf, with its commencement marking a transgressive event.



**Sparrowhawk Formation.** Named after the Sparrowhawk, a small, fast, low-flying raptor with great agility and ability to fly through small gaps and branches in trees in pursuit of its prey. It is widespread and is probably the most common bird of prey in Ireland. The formation contains one distinctive member (Chough Sandstone Member) in the northern half of the North Celtic Sea Basin, with two informal units, the “50/3-1 Limestone” and the “62/7-1 Sandstone” present at the base of the formation in the North Celtic Sea and Goban Spur basins respectively.

*Age:* Late Bajocian – Middle Aalenian.

*Type Section:* 49/9-1 (1241.5 – 1335.5 m below KB) in the North Celtic Sea Basin.

*Distribution:* The formation has been recorded in the North Celtic Sea, Fastnet and Goban Spur basins.

*Lithology:* Predominantly claystones and siltstones. Sandstones and subsidiary limestones characterise the Chough Sandstone Member present in the northern half of the North Celtic Sea Basin.

*Depositional Environment:* Predominantly marine, low energy inner to outer shelf with periods of marine restriction. The sandstones of the Chough Sandstone Formation represent a high energy shallow shelf environment.

## **UNASSIGNED GROUP**

A single sandstone unit of intra-Callovian to Late Bathonian age occurs in the 12/2-2 well in the Rockall Basin. The informal “12/2-2 Lower Sandstone”, with marine inner shelf affinities, is unconformably bound, top and bottom, and is age equivalent to the Peregrine Formation in the North Celtic Sea Basin.

## 10. LOWER JURASSIC

### NOMENCLATURE THEME

The new stratigraphic names for the Lower Jurassic successions are based on the names of Irish lakes. In view of the very significant amount of detail available on the succession, a large number of new formation and member names were needed. These were chosen mostly from the entries on the Ordnance Survey Ireland (OSi) database of Irish lakes ([www.osi.ie](http://www.osi.ie)). Some are well known lakes while others are less familiar. Unlike the coastal features theme of the Upper Jurassic, where there was a geographical link between the feature and the basin in which the new stratigraphic unit is developed, it was not possible to include a linking geographical component between the lake name and the stratigraphic unit. There were too many new formation and member names and too few lakes in the required geographical location. In consequence, the new stratigraphic nomenclature for the Lower Jurassic provides a journey through virtually every county in the country and to lakes both big and very small, mostly natural and a few man-made.

### STRATIGRAPHIC UNITS

Lower Jurassic strata, generally shallow marine in nature, have been recorded in virtually all the Irish offshore basins. They reflect deposition during a regional marine transgression across a low lying topography. Comparable Lower Jurassic successions are recorded and well documented in adjacent and nearby basins in other jurisdictions, including the UK onshore and offshore, the Netherlands, the north of Germany, and in the Newfoundland-Grand Banks basins. The Lower Jurassic succession is encompassed with a single group, the Lias Group, covering all the Irish offshore basins.

A number of well-established stratigraphic names from the UK onshore and offshore are maintained in the Irish offshore, based on their similarity and correlation with successions in the UK. Ten new formations are defined, together with 22 new members, in the Lower Jurassic. In most instances the new member names have a linkage with the formation name. This normally takes the form of the first letter of the member names spelling or indicating the name of the formation (**Figure 3**).

As with the other chapters, stratigraphic descriptions for the new units are provided only for the formations, although some aspects of naming of important members are mentioned. However, the stratigraphic and geographical location of all units, including the members, are shown in **Enclosure 1**.

The following descriptions continue the format of going from top to bottom in the stratigraphy. Where possible, the descriptions are given from west to east with the successions west of Ireland (Slyne, Erris and Porcupine basins) described first, followed by the Goban Spur - Celtic Sea basins to the southwest, south and east (minor occurrences in the Irish Sea) of Ireland.

## LIAS GROUP

The name, well established in the literature from the type section in Dorset in the south of England and from other onshore successions in the UK, comes from the middle English word for a hard limestone. It is regionally extensive and contains several organic-rich formations with good to excellent source potential. It was formalised as a group by Cox *et al.* (1999). It has a Hettangian to early Aalenian age span, conformably overlies the Penarth Group and is conformably overlain by the Kite (Irish Atlantic basins) or the Eagle (Celtic Sea basins) group succession.

A number of well-established formation names are maintained in the Irish offshore. These include the Dun Caan Shale, Whitby Mudstone, Pabay Shale and Blue Lias formations. The Whitby Mudstone and Pabay Shale formations are present in both the west of Ireland and the south of Ireland basins although different constituent members are present in the two regions.

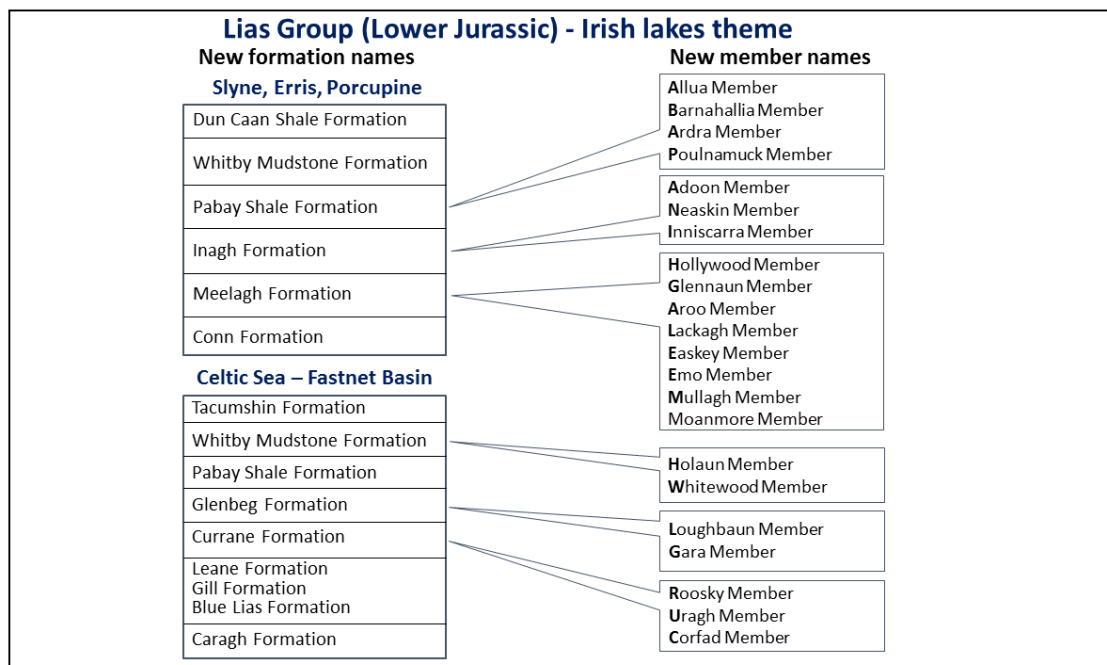


Figure 3. Thematic relationship between new formation and member names in the Lias Group (Lower Jurassic) of offshore Ireland.

## West of Ireland Basins

The complete Lias Group succession is present in the Slyne Basin, with the two oldest (Hettangian) formations encountered in the Erris Basin and the North Porcupine Basin. The six formations and constituent members, from youngest to oldest, are as follows:

**Dun Caan Shale Formation.** Named after a flat-topped hill on the Isle of Raasay, western Scotland. The type section is at Bearreraig Bay on the Isle of Skye, western Scotland. The stratigraphy in the Hebrides region is well documented in the literature (Morton, 1965). Present in the Slyne Basin, it is a lateral equivalent of the Tacumshin Formation and the upper part of the Whitby Mudstone Formation of the Fastnet and North Celtic Sea basins.

*Age:* Early Aalenian – Late Toarcian.

*Reference sections in Ireland:* Well 18/20-1 (2556 – 2651 m below KB), Well 27/4-1 (887.5 – 935 m below KB) in the Slyne Basin.

*Distribution:* The formation is present in the Slyne Basin.

*Lithology:* Dominated by claystones with localised thin limestone beds and stringers.

*Depositional Environment:* Well oxygenated marine inner shelf.

**Whitby Mudstone Formation.** Named from the type section in the coastal exposure at Whitby in Yorkshire, England (Cox *et al.*, 1999). In the Slyne Basin the formation is subdivided into an upper Derg Member and a lower Ree Member. The members were named after two large lakes on the River Shannon. Two different members are present in the south of Ireland basins (see below)

*Reference section (west of Ireland):* Well 18/20-1 (2651 – 2868.5 m below KB) in the Slyne Basin.

*Age:* Early Late - Early Toarcian.

*Distribution:* The formation is present in wells in the Slyne Basin and also in the Goban Spur, North and South Celtic Sea and Fastnet basins (see below).

*Lithology:* Claystones and silty claystones. Organic laminated bituminous claystones, with significant source potential, are present in both members.

*Depositional Environment:* Marine, inner to middle shelf, generally low energy and deposited below wave base. Bottom waters were often restricted (dysaerobic to anoxic).

**Pabay Shale Formation.** First described (Woodward, 1897) from the Isle of Skye, western Scotland with the type section on the Isle of Pabay, Inner Hebrides, Scotland (Morton & Hudson, 1995). The formation in the Slyne Basin is subdivided into four members. From bottom to top within the formation these are the **P**oulnamuck, **A**rdra, **B**arnahallia and **A**llua members (**Figure 3**). The first letters of each of the member names spell 'PABA' to reflect the first four letters of the formation name.

*Reference sections (west of Ireland):* Well 18/20-1 (2868.5 – 3301 m below KB), Well 19/11-1A (3508 – 3723.5 m below KB), 27/13-1 (2176 – 2519 below KB) in the Slyne Basin.

*Age:* Pliensbachian.

*Distribution:* The formation is widely distributed throughout the Irish offshore basins, proven by drilling in the Slyne, Goban Spur, North and South Celtic Sea and Fastnet basins.

*Lithology:* Dominated by a mudrock (claystone/siltstone) succession. Occasional limestone stringers and rare sandstones occur within the formation. In the Slyne Basin it has very good to excellent source potential.

*Depositional Environment:* Marine, inner to outer shelf environment. Within parts of the Celtic Sea region periods of marine restriction (anoxic to dysaerobic conditions) developed, while elsewhere deposition occurred in a low to very low energy but oxygenated setting.

**Inagh Formation.** Named after Lough Inagh, a freshwater lake in the picturesque Inagh Valley in Connemara, Co. Galway. The formation is subdivided into three members: the oldest **I**nniscarra Member, the central **N**easkin Member and the youngest **A**doon Member. The first letter of each member's name form the first three letters of the formation name (**Figure 3**). The Inagh Formation is age equivalent to the upper part of the Glenbeg Formation in the Goban Spur – Celtic Sea – Fastnet Basin region.

*Type Section:* Well 18/20-1 (3301 – 3376.5 m below KB) in the Slyne Basin.

*Age:* Late Sinemurian.

*Distribution:* Proven by drilling in the Slyne Basin.

*Lithology:* An interbedded claystone, limestone and sandstone succession. The most arenaceous part of the succession is the Neaskin Member.

*Depositional Environment:* The Inniscarra Member represents the deposits of a low energy inner shelf system; the Neaskin Member, containing sandstones and claystones, is interpreted as the product of an estuarine to shallow marine environment; the Adoon Member represents an inner shelf setting.

**Meelagh Formation.** Named after Lough Meelagh in Co. Roscommon, in northwestern Ireland, that contains a range of freshwater, coarse fish, and also the endangered European eel. The formation was previously referred to in the literature as the Broadford Beds. In the Slyne Basin the formation is subdivided into eight members, distinguished on the basis of lithological markers including the thickness of the limestone beds or the interbedded nature of claystone and limestone sections. The members (from bottom to top) are: Moanmore, **M**ullagh, **E**mo, **E**askey, **L**ackagh, **A**roo, **G**lennaun and **H**ollywood. The first letters of the upper seven member names spell out the name of the formation. The lowest member was a late addition to the stratigraphy and it was decided, as one of the reasons for the 'Moanmore' name, to choose another name beginning with '**M**' in order to keep with the pattern of names (**Figure 3**). The member names are taken from small lakes in Ireland.

*Type Section:* Well 18/20-1 (3376.5 – 3861.5 m below KB) in the Slyne Basin.

*Age:* Early Late Sinemurian – Hettangian.

*Distribution:* The complete Meelagh Formation succession is present in the Slyne Basin, with the lower part of the formation encountered in the Erris and North Porcupine basins.

*Lithology:* The members, and the formation in general, mainly comprise an interbedded succession of mudrocks, limestones and occasional sandstones. Interbedded anhydrites also occur within the members.

*Depositional Environment:* Predominantly non-marine (freshwater to brackish) setting, interbedded with marginal marine and shoreface facies. The formation is predominantly continental in the lower part of the succession, with the more marginal marine influences only in the top third of the formation.

**Conn Formation.** Named after Lough Conn, Ireland's seventh largest lake, in Co. Mayo in the west of Ireland. Noted for its salmon and trout fishing, it is connected to the Atlantic Ocean by the River Moy. The formation forms the lowest unit in the Lias Group in the Atlantic margin basins. It is age-equivalent to the Caragh Formation in the Goban Spur – Celtic Sea – Fastnet basins area.

*Type Section:* Well 18/20-1 (3861.5 – 3907 m below KB) in the Slyne Basin.

*Age:* Earliest Hettangian.

*Distribution:* The formation is proven in the Erris, Slyne and North Porcupine basins, west of Ireland.

*Lithology:* The formation is claystone dominant. Two prominent limestone beds are often present in the middle part of the formation but no separate members are defined.

*Depositional Environment:* Low energy, well oxygenated inner shelf, marine environment.

## South and East of Ireland Basins

A complete or partial Lias Group succession is found in the Goban Spur, Fastnet, North and South Celtic Sea basins. Some of the lower parts of the group are also recorded in the Irish Sea basins (Central Irish Sea and Kish Bank basins) in the Irish sector. Two formations (Whitby Mudstone and Pabay Shale) are also present in the Hebrides and west of Ireland basins while others are age-equivalent to formations found west of Ireland. The nine formations, and seven constituent members, are as follows:

**Tacumshin Formation.** Named after Tacumshin (pronounced “*ta-come-shin*”) Lake in County Wexford. It is a haven for many bird species and is designated as a Special Protected Area under the EU Bird Directive, and also a Special Area of Conservation. It is age equivalent to the Dun Caan Shale Formation in the Slyne Basin.

*Type Section:* Well 64/1-1 (1297.5 – 1643 m below KB) in the Fastnet Basin.

*Age:* Early Aalenian – Late Toarcian.

*Distribution:* The formation is developed across the Goban Spur, Fastnet, North and South Celtic Sea basins.

*Lithology:* The formation is dominated by claystones, often calcareous and sometimes silty, with local thin glauconitic siltstones and occasional sandstones. Stringers of argillaceous limestones and limestones are also present.

*Depositional Environment:* Well oxygenated, marine, inner to possibly middle shelf, with possible minor marine restriction towards the base of the formation.

**Whitby Mudstone Formation.** Named from the type section in the coastal exposure at Whitby in Yorkshire, England (Cox *et al.*, 1999). In the Goban Spur and Celtic Sea basins the formation is subdivided into an upper **Holaun** Member and a lower **Whitewood** Member. These two members were named after Holaun Lough in County Clare and Whitewood Lake in County Meath. The first letters of the member names correspond to the first two letters of the formation name. Stories tell of a mysterious creature in Whitewood Lake, similar to, but smaller than, the Loch Ness monster. The formation contains two different members in the Slyne Basin (see above, Derg Member and Ree Member).

*Reference sections (south of Ireland):* Well 56/21-1 (1497.5 – 1938.5 m below KB) in the Fastnet Basin; Well 49/9-1 (1449 – 1761.5 m below KB) in the North Celtic Sea Basin.

*Age:* Early Late – Early Toarcian.

*Distribution:* Developed in the Goban Spur, Fastnet, North and South Celtic Sea basins. It is also present in the Slyne Basin (see above).

*Lithology:* Claystones and silty claystones. Organic laminated bituminous claystones with significant source potential, are present in both members.

*Depositional Environment:* Marine, inner to middle shelf, generally low energy and deposited below wave base. Bottom waters were often restricted (dysaerobic to anoxic) in the lower part of the formation and more oxygenated in the upper part of the formation that reflects a more inner shelf setting.

**Pabay Shale Formation.** First described (Woodward, 1897) from the Isle of Skye, western Scotland with the type section on the Isle of Pabay, Inner Hebrides, Scotland (Morton & Hudson, 1995). The formation is undivided in the general Goban Spur – Celtic Sea – Fastnet region, unlike the Slyne Basin region where four members are defined (see above). However, one informal unit, the “42/21-1 Lower Sandstone” is present in the northern part of the North Celtic Sea Basin.

*Reference section (south of Ireland):* Well 56/21-1 (1938.5 – 2144 m below KB) in the Fastnet Basin.

*Age:* Pliensbachian.

*Distribution:* The formation is widely distributed throughout the Irish offshore basins, proven by drilling in the Slyne, Goban Spur, North and South Celtic Sea and Fastnet basins.

*Lithology:* Dominated by a mudrock (claystone/siltstone) succession. Occasional limestone stringers and rare sandstones occur within the formation.

*Depositional Environment:* Marine, inner to outer shelf environment. Within parts of the Celtic Sea region periods of marine restriction (anoxic to dysaerobic conditions) developed, while elsewhere deposition occurred in a low to very low energy but oxygenated setting. The informal “42/21-1 Lower Sandstone” unit reflects deposition in moderate energy inner shelf environment.

**Glenbeg Formation.** Named after Glenbeg Lough, a freshwater lake on the Beara Peninsula in County Cork in the southwest of Ireland. Two distinct sandy members (**G**ara Sandstone Member and **L**oughbaun Sandstone Member) are defined within the formation. The first letter of the members’ names forms the first two letters of the formation name.

*Type Section:* Well 63/4-1 (794.5 – 1067 m below KB) in the Fastnet Basin.

*Age:* Late – Early Sinemurian.

*Distribution:* The formation is developed across the Goban Spur, Fastnet, North and South Celtic Sea basins.

*Lithology:* Predominantly claystones but with important and substantial sandstone units.



*Depositional Environment:* Marine, inner to outer shelf. The main argillaceous succession was deposited in a low energy setting, with the Gara Sandstone Member developed in a delta fringe setting (delta front and slope), and the Loughbaun Sandstone Member developed as sandy shelf ridges.

**Currane Formation.** Named after Lough Currane in County Kerry. Three members are defined within the formation: **C**orfad, **U**ragh and **R**oosky members, recognised in the Fastnet and North Celtic Sea basins. These are named after lakes in counties Monaghan, Kerry and Donegal respectively. The first letter of the members' names form the first three letters of the formation name.

*Type Section:* Well 56/21-2 (2782.5 – 2893 m below KB) in the Fastnet Basin.

*Age:* Earliest Sinemurian – latest Hettangian.

*Distribution:* The formation has been identified in the Fastnet, North and South Celtic Sea and Central Irish Sea basins.

*Lithology:* A cyclic succession of marls, calcareous claystones and limestones, with the top of each cycle marked by an argillaceous limestone. It is more calcareous than the overlying Glenbeg Formation.

*Depositional Environment:* Marine, low energy inner shelf, with dysaerobic or anoxic conditions developed in the upper parts of the Uragh and Roosky members.

**Leane Formation.** Named after Lough Leane (pronounced “*lane*”), the largest of the three lakes of Killarney in County Kerry. Innisfallen, an island in the lake, had an early Middle Ages monastery that was a centre of scholarship. Its Gaelic name, *Loch Léin*, means “the lake of learning”. According to popular legend, it is where Brian Boru, the High King of Ireland who defeated the Viking army at the Battle of Clontarf in 1016, was educated. The formation has five members: **L**oughaun, **E**ffernan, **A**thry, **N**adreegeel and **E**my, named after lakes in counties Mayo, Clare, Galway, Cavan and Monaghan. The first letters of the member names spell the formation name. The Leane Formation is a lateral equivalent to the Blue Lias and Gill formations in the eastern part of the North Celtic Sea Basin and in the Central Irish Sea Basin.

*Type Section:* Well 56/21-2 (2893 – 3205.5 m below KB) in the Fastnet Basin.

*Age:* Hettangian.

*Distribution:* The formation is present in the Fastnet, western and central parts of the North and South Celtic Sea basins and in the Goban Spur Basin.

*Lithology:* An interbedded succession of limestones, claystones and sandstones with rare dolomites. The succession is more heterogeneous in the Fastnet Basin than in the Celtic Sea basins.

*Depositional Environment:* Within the Fastnet Basin the formation was deposited in an alternating freshwater/brackish to inner shelf marine environment, reflecting a transgressing/regressing shoreline during the onset of the Early Jurassic regional marine transgression. Further east, in the North and South Celtic Sea basins, the more argillaceous nature of the formation is interpreted to represent a more marine dominant environment with highly restricted bottom waters.

**Gill Formation.** Named after Lough Gill, a freshwater lake located mainly in County Sligo but extending into part of County Leitrim. It was the setting for the Nobel Laureate William Butler Yeats' famous poem 'The Lake Isle of Innisfree'. The Gill Formation is the lateral equivalent to the Blue Lias and Leane formations.

*Type Section:* The nearest apparently complete section to the UK/Ireland median line is UK well 103/2-1 (893 – 927 m below KB) in the St George's Channel Basin at the eastern end of the North Celtic Sea Basin. The reference section in the Irish offshore is well 50/10-1 (1868.5 – 1895 m below KB) in the easternmost part of the North Celtic Sea Basin.

*Age:* Hettangian.

*Distribution:* Only encountered in the Irish sector in one well in the easternmost part of the North Celtic Sea Basin, it is present in the UK sector of the St George's Channel Basin.

*Lithology:* Predominantly mudstones with subsidiary interbedded limestone beds and stringers.

*Depositional Environment:* Marine, low energy, inner to outer shelf.

**Blue Lias Formation.** The formation name is embedded in the literature and is recognised through much of the UK onshore and offshore, as well as much of NW Europe and the Newfoundland-Labrador basins off the east coast of Canada. The type section is at Saltford railway cutting in Somerset, with key UK onshore sections at Lyme Regis in Dorset and Watchet on the Somerset coast. It was formally defined by Cox *et al.* (1999). In the UK the formation has a late Rhaetian to Sinemurian age but is restricted to a Hettangian age where proven in the Irish offshore. It is equivalent to the Leane and Gill formations in the Goban Spur, Fastnet and other parts of the Celtic Sea basins.

*Reference sections in Ireland:* Well 50/3-3 (1037 – 1124 m below KB) in the eastern North Celtic Sea basin; Well 41/30-1 (1847.5 – 1909 m below KB) in the southernmost Central Irish Sea Basin.

*Age:* Hettangian.

*Distribution:* It has been proven by drilling in the extreme eastern part of the North Celtic Sea and in southernmost part of the Central Irish Sea basins.

*Lithology:* Alternations of limestones and mudrocks, the latter often laminated and organic rich. A rhythmic cyclicity is recognised in outcrops in Somerset and Dorset and may also be present in places in the Irish offshore.

*Depositional Environment:* Marine, inner to outer shelf. Bottom waters varied from well oxygenated to dysaerobic and anoxic, interpreted to reflect climatic cycling (Milankovitch cyclicity) (Weedon, 1986).

**Caragh Formation.** Named after Lough Caragh (pronounced “*kara*”) in the Glencar Valley in the Reeks district of County Kerry. Sometimes known as Glencar Lake, this freshwater lake lies within a large Special Area of Conservation. The Caragh Formation is a direct equivalent to the Conn Formation in the Atlantic margin basins (see above).

*Type Section:* Well 56/21-2 (3205.5 – 3252 m below KB) in the Fastnet Basin.

*Age:* Earliest Hettangian.

*Distribution:* It is present in the Fastnet, North and South Celtic Sea and Central Irish Sea basins.

*Lithology:* Predominantly claystones with some limestones and rare calcareous sandstone stringers.

*Depositional Environment:* Marine, inner shelf, deposited in low energy well oxygenated waters.

## 11. TRIASSIC

### NOMENCLATURE THEME

Names used in the Triassic framework are a combination of existing names and new names. Group names were derived from the existing UK terminology. New formations and members that are unique to Ireland follow the theme of archaeology. Formations in the western offshore basins were named after traditional boats, reflecting Ireland's use of different types of vessels for fishing, transportation and warfare. Boats were also chosen to compliment the fluvial, lacustrine and marine origins of the Triassic deposits. New formation names in the southern offshore basins reflect ancient structures built by early civilizations, and member units include Ireland's heritage of music and traditional instruments. Igneous units encountered within the Triassic sediments continue with the theme of dark Irish mythology.

### STRATIGRAPHIC UNITS

Many of the Triassic sequences across Ireland's offshore basins share common lithological and depositional characteristics with those found in the UK sector and the Central Irish Sea Basin. The Triassic sediments range from continental deposits in the oldest sections, to coastal and shallow marine deposits in the youngest sections. Similarities allow for the continuation of selected names from UK sector Triassic groups, formations and members into the Irish basins. The Penarth, Mercia Mudstone, Sherwood Sandstone Group names are used for the Late to Early Triassic sequence offshore Ireland. The UK formations and members of the Mercia Mudstone and Sherwood Sandstone groups are correlated within the Central Irish Sea and Kish Bank basins. As well, the Blue Anchor Formation of the Mercia Mudstone Group, and the formations and members of the Late Triassic Penarth Group are continued for parts of the Slyne, Erris, Porcupine, Fastnet and North and South Celtic Sea basins. New formation and member names were assigned to the Sherwood Sandstone and Mercia Mudstone groups in the southern and western regions (Rockall, Slyne, Erris, Porcupine, Fastnet, North and South Celtic Sea basins).

### PENARTH GROUP

The Penarth Group contains the Lilstock Formation and the underlying Westbury Formation (Warrington *et al.*, 1980). The marine to coastal deposits were extensive across the offshore Irish basins, extending across the Rockall, Erris, Slyne, Porcupine, Fastnet, North and South Celtic Sea and Central Irish Sea basins. The sequence in Ireland is considered a

continuation of the Penarth Group from southwest England, south Wales and Northern Ireland.

**Lilstock Formation.** The Lilstock Formation was previously described by Warrington *et al.* (1980) in South Wales.

*Age:* Late Triassic, Rhaetian.

*Reference section in Ireland:* Wells 18/25-1 (3323.5 – 3351.5 m below KB) in the Slyne Basin, and 50/12-3 (2965.5 – 2974.5 m below KB) in the North Celtic Sea Basin.

*Distribution:* Slyne, Erris, Porcupine, Fastnet, North and South Celtic Sea basins, and partially in the Central Irish Sea Basin.

*Lithology:* The unit comprises an upper carbonate unit (Langport Member) and underlying interbedded limestones and mudstones (Cotham Member).

*Depositional Environment:* Brackish to lagoonal deposits, followed by shallow carbonate-rich marine deposits.

**Westbury Formation.** The Westbury Formation was described in South Wales by Warrington *et al.* (1980) and later by Gallois (2009).

*Age:* Late Triassic, Rhaetian.

*Reference section in Ireland:* Wells 18/25-1 (3351.5 – 3356.5 m below KB) and 18/20-1 (3934 – 3938 m below KB) in Slyne Basin; 56/21-2 (3270 – 3272m below KB) in the Fastnet Basin.

*Distribution:* The Westbury Formation is found in the Slyne, Erris, Porcupine, Fastnet, North and South Celtic Sea basins.

*Lithology:* The formation is dominantly organic rich claystone with interbeds of limestone.

*Depositional Environment:* Deposits occurred during a transgression with low energy, widespread shallow marine conditions.

## **MERCIA MUDSTONE GROUP**

The Mercia Mudstone Group, ranging from Late Triassic early Rhaetian to Middle Triassic Anisian, was initially described by Warrington *et al.* (1980) for the continental to shallow marine deposits. In the Central Irish Sea and Kish Bank basins, formation names from the UK sector of this group were retained, including (from youngest to oldest) the Elswick Mudstone, Warton Halite, Dowbridge Mudstone, Preesall Halite, and Leyland Formations (Warrington, 1974; Evans & Wilson, 1975; Jackson & Johnson, 1996). The overlying

lacustrine Blue Anchor Formation in the lower Rhaetian to upper Norian was also correlated across the southern basins and noted in the Erris Basin. New formations and members were created for units in the Norian to Anisian stages in the Erris, Slyne, Porcupine, South Celtic Sea, North Celtic Sea and Fastnet basins.

**Blue Anchor Formation.** The Blue Anchor Formation was named after the Blue Anchor cliff in southwest England.

*Age:* Late Triassic, lower Rhaetian to upper Norian.

*Reference section in Ireland:* Well 56/22-1 (1840.5 – 1875.5 m below KB) in the Fastnet Basin.

*Distribution:* The formation is found in the northern Erris Basin, Fastnet, North and South Celtic Sea basins. The Blue Anchor Formation was likely eroded in the Slyne, Porcupine, Rockall, Central Irish Sea and Kish Bank.

*Lithology:* The formation is dominantly claystone with interbeds of thin dolomite, dolomitic limestone and anhydrite.

*Depositional Environment:* Deposition occurred during early stages of the Rhaetian marine transgression, as shallow interconnected lacustrine systems.

**Currach Formation.** The *currach* (pronounced “*curr-ruck*”) is a traditional boat made with a wicker frame, and covered with animal hide, sometimes in multiple layers. The Uilleann Halite Member (pronounced “*ill-un*”) is named for the uilleann pipes, an Irish instrument similar to bagpipes which uses the elbow to inflate (*uilleann* = elbow).

*Age:* Late Triassic, Norian to Middle Triassic, Anisian

*Type Section:* Well 12/13-1A (2190.5 – 2495.5 m below KB) in the Erris Basin.

*Distribution:* Slyne, Erris and northern Porcupine basins. The Uilleann Halite Member is found in the Slyne Basin.

*Lithology:* Dominantly red claystone with local coarser beds, often overlying halite, claystone and anhydrite beds.

*Depositional Environment:* Dominantly continental, with evidence of coastal floodplain to inland sabkhas and playa lakes.

**Crannóg Formation.** The Crannóg Formation (pronounced “*crah-noge*”) is named for the artificial island forts constructed in lakes or shallow water settings by Celtic people beginning in the Bronze Age. The Bodhrán Sandstone Member (pronounced “*bow-rawn*”) takes its name from the frame drum, native to Ireland. The Feadóg Halite Member (pronounced “*fad-ohg*”) is named after the *feadóg* (tin whistle), a traditional Irish musical instrument.

*Age:* Late Triassic, Norian to Carnian.

*Type Section:* Well 55/30-1 (2117 – 2415.5 m below KB) in the Fastnet Basin.

*Distribution:* The Crannóg Formation is found in the Fastnet, North and South Celtic Sea basins.

*Lithology:* The formation contains mainly reddish claystone to siltstone, with sandstone and halite within the members.

*Depositional Environment:* The sequence was deposited in a continental setting, with evidence of fluvial, aeolian, lacustrine and sabkhas deposits.

**Cairn Formation.** The name is derived from the pile of stones often found at landmarks or built on top of a summit. Preserved megalithic tombs in Ireland are in the form of court cairns (Creevykeel, Co. Sligo) and chambered cairns (Newgrange passage tomb, Co. Meath).

*Age:* Middle Triassic, Ladinian to Anisian.

*Type Section:* Well 55/30-1 (2415.5 – 2493 m below KB) in the Fastnet Basin.

*Distribution:* Fastnet, North Celtic Sea and South Celtic Sea basins, possibly extending into the Goban Spur area.

*Lithology:* The unit is dominantly claystone and siltstone of a reddish brown colour, ranging from calcareous to dolomitic and anhydritic. Rare sandstones and limestones can be present (e.g. Fastnet Basin).

*Depositional Environment:* Continental deposits ranging from lacustrine to inland and coastal sabkhas.

**Elswick Mudstone Formation.** The unit was first described in west Lancashire, northwestern UK.

*Age:* Late Triassic, Norian to Carnian.

*Reference section in Ireland:* Well 42/12-1 (416 – 502 m below KB).

*Distribution:* Found only in the well 42/12-1 in the Central Irish Sea Basin.

*Lithology:* Dominantly reddish, non-calcareous to calcareous silty claystones to claystones.

*Depositional Environment:* Continental loess deposits.

**Warton Halite Formation.** The formation was named for the village and airfield east of Lytham St Ann's in Lancashire, UK.

*Age:* Late Triassic, Carnian.

*Reference section in Ireland:* Well 42/12-1 (502 – 563 m below KB) in the Central Irish Sea Basin.

*Distribution:* Central Irish Sea Basin.

*Lithology:* Halite with interbedded reddish, calcareous to non-calcareous claystones.

*Depositional Environment:* The sequence was deposited in hypersaline conditions of an extensive single brine pan extending through the Central and East Irish Sea and other adjacent basins in the UK.

**Dowbridge Mudstone Formation.** This formation is named for the village of Dowbridge in west Lancashire.

*Age:* Middle Triassic, Ladinian to Anisian.

*Reference section in Ireland:* Well 42/12-1 (563 – 992 m below KB) in the Central Irish Sea Basin.

*Distribution:* Central Irish Sea and Kish Bank basins.

*Lithology:* The unit comprises red to grey, non-calcareous to calcareous claystones to silty claystones.

*Depositional Environment:* Deposited in an arid continental environment, likely as loess deposits near evaporated lacustrine or near coastal plain environments.

**Preesall Halite Formation.** The Preesall Halite Formation was named after the village of Preesall, Lancashire.

*Age:* Middle Triassic, Anisian.

*Reference sections in Ireland:* Wells 33/21-1 (338.5 – 529 m below KB) in the Kish Bank Basin and 42/12-1 (992 – 1039.5 m below KB) in the Central Irish Sea Basin.

*Distribution:* The unit extends into the Central Irish Sea and Kish Bank basins.

*Lithology:* Halite with interbedded red claystones, locally grading to siltstone.

*Depositional Environment:* Deposition occurred in hypersaline shallow water conditions, which extended over the East Irish Sea, Kish Bank, and Central Irish Sea basins.



**Leyland Formation.** The unit is named for the town of Leyland located in central Lancashire. Members include the Ansdell Mudstone, Blackpool Mudstone, Cleveleys Mudstone, Fylde Halite, Mythop Halite, Rossall Halite and Stanah members.

*Age:* Middle Jurassic, Anisian.

*Reference sections in Ireland:* Wells 33/17-2A (177 – 1053 m below KB) and 33/21-1 (529 – 1304.5 m below KB) in the Kish Bank Basin; 42/12-1 (1039.5 – 1425 m below KB) and 42/16-1 (1131.5 – 1150 m below KB) in the Central Irish Sea Basin.

*Distribution:* Central Irish Sea and Kish Bank basins.

*Lithology:* Deposits range from claystone to siltstone to thick halite.

*Depositional Environment:* Continental to shallow marine environments.

## **SHERWOOD SANDSTONE GROUP**

The Sherwood Sandstone Group includes the Early to lower Middle Triassic strata and was initially described by Warrington *et al.* (1980). The continental deposits of the Sherwood Sandstone Group extend across all Irish basins. Western and southern basins received new names at formation and member level because of lack of stratigraphic continuity across basins and differing provenance. UK sector formation names from the East Irish Sea were incorporated into the Central Irish Sea and Kish Bank basins' nomenclature.

**Cot Sandstone Formation.** The name is taken from Irish cots, which are wooden flat bottom boats used mainly in estuaries, lakes and rivers in Ireland. The igneous Merrow Member is a series of lavas that flowed into the subaqueous deposits. To reflect the origins underwater, the name reflects the Irish Merrows, mer-people who lived in *Tír fo Thoinn* (the Land beneath the Waves).

*Age:* Middle Triassic, Anisian to Early Triassic, Induan.

*Type Section:* Well 12/2-1z (3943.5 – 4087 m below KB) in the Rockall Basin.

*Distribution:* Rockall Basin.

*Lithology:* The formation is composed of argillaceous to pebbly sandstones. The Merrow Member is amygdaloidal basaltic lava.

*Depositional Environment:* Continental fluvial, lacustrine, alluvial to sandflat environments.

**Corrib Sandstone Formation.** The Corrib Sandstone Formation was named after Ireland's second largest lake located in Co. Galway. Spectacular archaeological finds discovered in the murky depths include log boats and weapons, with some artefacts dated to be over 4500 years old from the Bronze Age. The formation is also the main producing sand in the Corrib gas field, located in the Slyne Basin.

*Age:* Middle Triassic, Anisian to Early Triassic, Induan.

*Type Section:* Well 27/5-1 (1030 – 1433 m below KB) in the Slyne Basin.

*Distribution:* Slyne and Erris basins.

*Lithology:* The unit is dominantly sandstone in the upper portion, and mainly siltstone and claystone rich in lower portion.

*Depositional Environment:* The unit was deposited in a continental braided river system with evidence of fluvial channels, floodplains and playa lacustrine deposits.

**Hooker Sandstone Formation.** The Galway Hooker is an iconic traditional sailing boat of southwest Connemara, Co. Galway. Its name originally referred to hook and line fishing, however due to lack of a reliable road network, the boats were also used to supply coastal communities and the Aran Islands with food supplies, turf (peat fuel), livestock and *poitín* (traditional illegal distilled alcohol).

*Age:* Middle Triassic, Anisian to Early Triassic, Induan.

*Type Section:* Well 26/21-1 (1860 – 2030.5 m below KB) in the North Porcupine Basin.

*Distribution:* Porcupine Basin.

*Lithology:* Sandstone with minor reddish brown siltstone and claystone.

*Depositional Environment:* Dominantly fluvial.

**Dolmen Sandstone Formation.** The name is derived from the Neolithic portal tombs, also called dolmens, which are found in Ireland consisting of two large upright stone pillars supporting an overlying capstone (e.g. Poul nabrone, Co. Clare).

*Age:* Middle Triassic, Anisian to Early Triassic, Induan.

*Type Section:* Well 55/30-1 (2493 – 2563 m below KB) in the Fastnet Basin.

*Distribution:* Fastnet, North and South Celtic Sea basins.

*Lithology:* Dominantly sandstone, with locally developed conglomerates and interbedded claystone, siltstone and limestone.

*Depositional Environment:* Continental setting, consisting of arid alluvial wadis to periodic fluvial deposits.

**Ormskirk Sandstone Formation.** The unit was named after the town in Lancashire.

*Age:* Middle Triassic, Anisian.

*Reference Sections in Ireland:* Wells 33/17-2A (1053 – 1211 m below KB) and 33/21-1 (1304.5 – 1546 m below KB) in the Kish Bank Basin; 42/8-1A (1138.5 – 1456.5 m below KB) in the Central Irish Sea Basin.

*Distribution:* Central Irish Sea and Kish Bank basins.

*Lithology:* Dominantly sandstone with locally developed siltstone and claystone.

*Depositional Environment:* Ranging from aeolian sand deposits on the margins of basins to fluvial deposits within the basins.

**St Bees Sandstone Formation.** Named after St Bees Head in Cumbria, the formation consists of two named members, the Calder Sandstone Member and Rottington Sandstone Member, plus an unnamed conglomerate found in 42/8-1A.

*Age:* Early Triassic, Olenekian to Induan.

*Reference Sections in Ireland:* Wells 33/17-1 (1097.5 – 1984 m below KB), 33/17-2A (1211 – 1311 m below KB) and 33/21-1 (1546 – 2338 m below KB) in the Kish Bank Basin.

*Distribution:* Central Irish Sea and Kish Bank basins.

*Lithology:* Sandstone with infrequent claystones and rare conglomerates.

*Depositional Environment:* Stacked continental fluvial deposits (Rottington Sandstone Member) and fluvial to aeolian deposits (Calder Sandstone Member).

## 12. PERMIAN

### NOMENCLATURE THEME

The stratigraphy of the Permian, previously described in the UK, was continued across to the Irish sector. The groups include the Zechstein, Cumbrian Coast and Appleby groups. No new groups or formations were added. If the Permian is subdivided in the future at formation level in the Slyne and Erris basins (presently only defined at group level), the reserved nomenclature theme is Irish landscapes (e.g. Heath, Moor).

### STRATIGRAPHIC UNITS

The Permian was encountered in the Erris, Slyne, Central Irish Sea and Kish Bank basins and consists of shallow, marginal marine and continental deposits. It is absent in the Porcupine, North Celtic Sea and Fastnet basins. The existing Zechstein Group was used to describe the Permian in the Erris and Slyne basins, without further subdividing the group into formations. The Cumbrian Coast Group and Appleby Group (Central Irish Sea and Kish Bank basins) contain one formation each, both derived from UK equivalents.

### ZECHSTEIN GROUP

The group was originally described by Rhys (1974, 1975) in the Southern North Sea Basin. No formations were used in the Irish sector due to lack of resolution.

*Age:* Upper Permian, Lopingian.

*Reference Sections in Ireland:* Wells 12/13-1A (2825 – 2843.5 m below KB) and 19/8-1 (2615.5 – 2634.5 m below KB) in the Erris Basin and 27/5-1 (1433 – 1640.5 m below KB) in the Slyne Basin.

*Distribution:* Erris and Slyne basins.

*Lithology:* Deposits include halite, anhydrite, limestone, dolomite, sandstone and claystone.

*Depositional Environment:* Marginal marine to inner shelf, and restricted coastal setting.

### CUMBRIAN COAST GROUP

The Cumbrian Coast Group was described by Barnes *et al.* (1994) in Cumbria, northwest England and extends from the Solway Basin, the Cheshire Basin, Isle of Man and the East Irish Sea (Brandon *et al.*, 1998). This group is recognised in Ireland from the Permian Lopingian to Guadalupian and contains the Manchester Marls Formation (Colter, 1978; Jackson & Johnson, 1996; Tonks *et al.*, 1931).

**Manchester Marls Formation.** This formation is extended from the UK in Irish basins. A carbonate unit is present as an informal member (“42/12-1 Carbonate”).

*Age:* Lopingian to Guadalupian.

*Reference Sections in Ireland:* Wells 33/17-1 (1894 – 1930 m below KB) in the Kish Bank Basin; 42/8-1Az (2437 – 2709.5 m below KB) and 42/12-1 (1647.5 – 1773 m below KB) in the Central Irish Sea Basin.

*Distribution:* Central Irish Basin and the Kish Bank Basin.

*Lithology:* Variable lithology including common dolomitic to non-calcareous claystones with interbedded argillaceous siltstones and sandstones.

*Depositional Environment:* The environments were difficult to resolve from the limited well data in Ireland; however, the Manchester Marls Formation described elsewhere includes shallow marine, near shore to continental deposits.

## **APPLEBY GROUP**

This lower Permian (Cisuralian) group was named for the town of Appleby in northwest England (Barnes *et al.*, 1994; Colter & Barr, 1978; Jackson & Johnson, 1996).

**Collyhurst Sandstone Formation.** The Collyhurst Sandstone Formation is extended into the Irish sector from the East Irish Sea Basin.

*Age:* Cisuralian.

*Reference Sections in Ireland:* Wells 33/17-1 (1930 – 2032.4 m below KB) in the Kish Bank Basin and 42/12-1 (1773 – 1990 m below KB) in the Central Irish Sea Basin.

*Distribution:* Central Irish Sea and Kish Bank Basin.

*Lithology:* The formation is mainly sandstone with some non-calcareous claystone and siltstones.

*Depositional Environment:* The unit was deposited in a continental setting with aeolian dune topography, and possibly playa lake environments.

## 13. CARBONIFEROUS

### NOMENCLATURE THEME

The majority of group and formation names in the Carboniferous are new to the framework. In the Pennsylvanian, new names were selected for the western offshore basins (Porcupine, Slyne, Erris, Rockall) and part of the Central Irish Sea Basin. Names reflect Ireland's native flora and fauna, and the continental depositional environment of the sequence. New group names include the Sorrel and Blackburn groups. UK group names of the Pennsylvanian including the Warwickshire Group and Pennine Coal Measures Group were continued into parts of the North Celtic Sea, Central Irish Sea and Kish Bank basins.

The Mississippian sequence is dominantly marine and was named using the theme of "*She sells seashells by the seashore*", the tongue-twister inspired by the famous palaeontologist Mary Anning from Lyme Regis in Dorset. The Gaelic translation of various shells was used for many of the names. New group names include the Muirín, Sliogán and Bairneach. The only pre-existing name incorporated from the onshore was the Cork Group (Kinsale Formation), which correlates to the offshore.

### STRATIGRAPHIC UNITS

The Carboniferous has been penetrated throughout the offshore basins. Similarities across the western basins warranted the use of the same groups across similar aged stratigraphy in the Pennsylvanian and the Mississippian.

The Pennsylvanian in the southern and eastern basins were assigned to the existing UK groups. However, three new Mississippian groups were required, reflecting the lithological differences and disconnected nature of the sequence at this level. Groups were subdivided into formations where possible in the upper Pennsylvanian and in the Mississippian. No members were assigned.

### SORREL GROUP

The name of the group was derived from the native perennial that can be found growing in Irish woodlands in the spring. The sorrel is also known as the wood shamrock and the wood sour. The Sorrel Group contains multi-coloured argillaceous to arenaceous strata and is present in the Rockall, Slyne, Erris, and Porcupine basins. Within the Sorrel Group, the formations include the Foxglove, Harebell, and Bird's-foot. An informal unit tentatively called

the “12/2-2 Claystone” is present at the top of the Sorrel Group in the Rockall Basin in a single well.

**Foxglove Formation.** The native foxglove is common in Irish woodlands, moors, and coastal areas. The flowering plant is poisonous and is also known by the name ‘fairy fingers’. It is believed that the flowers will cause bad luck if they are brought into one’s house.

*Age:* Pennsylvanian, early Autunian.

*Type Section:* Well 12/2-1z (4087 – 4328 m below KB) in the Rockall Basin.

*Distribution:* Rockall Basin.

*Lithology:* The formation is composed of light orange to reddish interbedded sandstones and claystones, with rare limestones and coal fragments.

*Depositional Environment:* The unit was deposited in continental to marginal coastal regions, within a dry arid environment.

**Harebell Formation.** The harebell is a native plant found in exposed limestone, grasslands and dunes. Other names include ‘blue thimble’ and ‘goblin’s thimble’.

*Age:* Pennsylvanian, early Autunian to Stephanian C.

*Type Section:* Well 12/2-1z (4328 – 4450 m below KB) in the Rockall Basin.

*Distribution:* The formation is found in the Rockall Basin and in one well in the Porcupine Basin (34/15-1).

*Lithology:* Interbedded sandstones and claystones with beds of oolitic, bioclastic and/or dolomitic limestone and rare coal laminae.

*Depositional Environment:* The unit was deposited in continental, to marginal marine to inner shelf conditions.

**Bird’s-Foot Formation.** This formation takes its name from the native bird’s-foot trefoil (Latin for ‘three-leaved plant’), a small yellow wildflower with black, claw-like seed pods resembling a bird’s foot, or the Devil’s claw. The flower was believed to ward off evil and was often woven into wreaths. The flower was also often picked by school children to keep in their pockets to protect them against their teacher’s wrath.

*Age:* Pennsylvanian, Stephanian C.

*Type section:* Well 26/21-1 (2030.5 – 2176 m below KB) in the Porcupine Basin.

*Distribution:* The formation is found in the Rockall, Slyne and the northern part of the Porcupine Basin.

*Lithology:* The succession consists of interbedded sandstones, siltstones, claystones and infrequent limestones beds.

*Depositional Environment:* Continental environment with marginal marine to near shore to deltaic influence.

## **BLACKTHORN GROUP**

The blackthorn is a knotty thorned shrub that is used to make a traditional walking stick, called a *shillelagh*, which also doubled up as a clubbed fighting instrument. The plant also produces fruit called sloes that can be steeped with gin and sugar to produce sloe gin, a traditional Irish tippie. The name Blackthorn was chosen for this group to reflect the colour of this black coaly interval, which is the source rock for the Corrib gas field in the Slyne Basin. The group is equivalent to the Pennine Coal Measures Group and lower Warwickshire Group in the southern and eastern basins. The group was not subdivided into formations.

*Age:* Stephanian Cantabrian to Westphalian Langsettian.

*Type Section:* Well 36/16-1A (1311.5 – 2528.38 m below KB).

*Distribution:* The Blackthorn Group is found in the Donegal, Slyne, Erris and Porcupine basins.

*Lithology:* The group is a succession of argillaceous to arenaceous sandstone, siltstone, and claystone with numerous coal intervals. Sandstones can be locally tuffaceous, with rare dolomite and limestone.

*Depositional Environment:* The continental to marginal marine sequence is dominantly derived from lower to upper deltaic flood plain grading upwards to upper deltaic and swampy coal-forming environments.

## **WARWICKSHIRE GROUP**

The Warwickshire Group was initially described by Powell *et al.* (2000), with the name taken from the Warwickshire Coalfield in the Pennine Basin, England. In Ireland, the group is composed of characteristic reddish argillaceous to arenaceous sediments with coal. The group is Pennsylvanian, Bolsovian to Stephanian C in age and is found in the Kish Bank and Central Irish Sea basins. One new formation, the Thistle Formation, found in the Central Irish Sea Basin, has been assigned to the uppermost portion of the group. The upper portion of the Warwickshire Group is absent from the Kish Bank Basin. The lower part of the group is undifferentiated.



**Thistle Formation.** Numerous species of thistle are found in Ireland with the most recognizable probably being the prickly purple Spear Thistle.

*Age:* Pennsylvanian Stephanian B to Stephanian C.

*Type Section:* Well 42/12-1 (1990 – 2647 m below KB).

*Distribution:* Central Irish Sea Basin.

*Lithology:* The unit consists of interbedded sandstones, claystones and rare dolomite, limestone and coals.

*Depositional Environment:* Environments include continental to marginal marine, from alluvial fan to fluvial deposits.

## **PENNINE COAL MEASURES GROUP**

The Pennine Coal Measures Group was extended into the Irish offshore from the established descriptions of the East Irish Sea Basin (Wakefield *et al.*, 2016). In North Celtic Sea, Central Irish Sea and Kish Bank basins, the group name was retained due to its similarity of coal-bearing strata. The group, however, was not further subdivided into formations. The group is equivalent to the lower portion of the coal-rich Blackthorn Group in the western margin basins. The lower stages (Duckmantian to Langsettian) of the group are equivalent to the onshore Coolbaun Coal Formation (e.g. Co. Kilkenny) and the Coal Measures of Northern Ireland.

*Age:* Pennsylvanian, Bolsovian to Langsettian.

*Reference section in Ireland:* Well 33/22-1 (631 – 866 m below KB) in the Kish Bank Basin.

*Distribution:* North Celtic Sea, Central Irish Sea and Kish Bank basins.

*Lithology:* The group is composed of sandstones, siltstones, claystones and coals.

*Depositional Environment:* The lower portion of the sequence was likely deposited in a marginal marine setting, with an increase of continental fluvial influence in the younger strata.

## **MUIRÍN GROUP**

The name of the group is taken from the Irish word for scallop and is pronounced “*mwir-eeen*”. The name is not to be confused with ‘*múirín*’ (accent on the *ú*), which can mean a brief shower or compost. The symbol of the scallop shell has multiple meanings; it can relate to the weary traveller, *The Birth of Venus* (Botticelli, 1452), and St James the Apostle. In nature, scallops can have over 200 eyes that line its mantle, sensing light and movement. They are the only free-swimming bivalve mollusc that can propel themselves forward by

opening and closing their shell. The group is found in the Porcupine and Erris basins. It is subdivided into the Ruacan Formation for the Mississippian Arnsbergian to Brigantian, and the Mussel Formation for the Ivorian to Brigantian. The base of the group is variable in age, with the oldest strata recorded in the Porcupine Basin.

**Ruacan Formation.** *Ruacan* is the Irish translation for cockle, which is an edible marine mollusc. This formation was named in tandem with the underlying Mussel Formation, as 'cockles and mussels' originate from a famous Irish ballad, *Molly Malone*. The song tells a story of a young fishmonger named *Molly Malone* who pushes her wheelbarrow through the streets broad and narrow, crying, "Cockles! And Mussels! Alive! Alive-O!". She tragically dies of a fever, and her statue can be found today on Suffolk Street in Dublin.

*Age:* Mississippian, Arnsbergian to Brigantian.

*Type Section:* Well 19/5-1 (1176.5 – 2051 m below KB) in the Erris Basin.

*Distribution:* Erris Basin and Porcupine Basin.

*Lithology:* The formation contains interbedded sandstone, siltstone and claystone, rare conglomerates, coals, and limestone.

*Depositional Environment:* Marine shelf environment in the lower strata, evolving to proximal marginal marine and continental environments.

**Mussel Formation.** This formation is named in tandem with the overlying Ruacan Formation, as 'cockles and mussels' are associated with the famous Irish ballad, *Molly Malone*. The base of the Mussel Formation differs, based on limited data availability. The base of the formation extends to the Mississippian Ivorian in the Porcupine Basin, whereas in the Erris Basin, the base of the formation is Arundian.

*Age:* Mississippian, Brigantian to Ivorian.

*Type Section:* Well 19/5-1 (2051 – 2584.4 m below KB) in the Erris Basin.

*Distribution:* Erris and Porcupine basins, identified in one well in each basin to date.

*Lithology:* The unit is composed of interbedded sandstone, siltstone and claystone.

*Depositional Environment:* Largely continental, with possible marginal marine influence.

## **SLIOGÁN GROUP**

Sliogán is taken from the Irish translation of shell and is pronounced “*schlu-gawn*”. The group is Mississippian Arnsbergian to Pendleian in age and is unique to the South Celtic Sea Basin. The group has not been subdivided into formations.

*Age:* Mississippian, lower Namurian, Arnsbergian? to Pendleian.

*Type Section:* Well 58/3-1 (2644 – 2857.4 m below KB) in the South Celtic Sea Basin.

*Distribution:* South Celtic Sea Basin.

*Lithology:* Dominantly grey claystones, siltstones with infrequent sandstone laminae.

*Depositional Environment:* Marine setting likely ranging from inner to outer shelf.

## **BAIRNEACH GROUP**

The group name means barnacle or limpet in the Irish language, pronounced “*bar-nuck*”. The group was not subdivided due to limited data.

*Age:* Mississippian, Brigantian to Ivorian in the Central Irish Sea Basin, and present as only Ivorian in the Fastnet Basin.

*Type Section:* Well 63/4-1 (1508 – 1645.2 m below KB) in the Fastnet Basin.

*Distribution:* Fastnet Basin and Central Irish Sea Basin.

*Lithology:* The group consists of limestone, locally dolomitic or silicified, and rarely brecciated.

*Depositional Environment:* Shallow marine, inner shelf.

## **CORK GROUP**

The Cork Group was originally described onshore by Sleeman (1991) in the South Munster Basin, and at the type section at the Old Head of Kinsale, Co. Cork (Naylor, 1966). The shallow to deep marine clastic sediments of the onshore Cork Group are dated as Carboniferous, Mississippian (Arnsbergian to Ivorian) and are divided into three formations. The offshore framework only includes the Kinsale Formation, located at the bottom of the Cork Group.

**Kinsale Formation.** The Kinsale Formation is the oldest formation of the equivalent onshore Cork Group. The sequence offshore shares similar age and lithological characteristics with the onshore section. Therefore, the formation name has been incorporated in the offshore due to its presence in two wells.

*Age:* Mississippian, Hastarian.

*Type Section:* Well 48/30-1 (2749 – 2909.32 m below KB).

*Distribution:* North Celtic Sea Basin.

*Lithology:* Claystone and siltstones with local sandstone lenses.

*Depositional Environment:* Shallow marine shelf.

## 14. DEVONIAN

### NOMENCLATURE THEME

The theme of colours was chosen for new names of the offshore Devonian stratigraphy.

### STRATIGRAPHIC UNITS

The Devonian stratigraphy offshore Ireland has not been encountered frequently. As a result of the long distances between the sparse penetrations in the Goban Spur, Fastnet and North Celtic Sea basins, the Devonian succession was kept at formation level only.

**Darrig Formation.** The Irish translation of 'red' was used, *Darrig* or *Dearg*, (pronounced "dar-rig"). Due to the considerable distance between the well penetrations and the onshore Devonian outcrops, the new name was used to represent all of the Devonian succession in the offshore domain.

*Age:* Late Devonian (Famennian) to Middle Devonian (Eifelian).

*Type Section:* Well 55/30-1 (2602.5 – 2800 m below KB) in the Fastnet Basin.

*Distribution:* Four wells only from Goban Spur, Fastnet and North Celtic Sea basins.

*Lithology:* Heterogenous deposits range from interbedded conglomerates, sandstones to claystones and siltstones, with evidence of tuffs. The sequence can be multicoloured including reddish brown, pink and grey.

*Depositional Environment:* Deposits range from marine to continental, with evidence of fluvial deposition within desert and semi-arid environments.

## **15. PRE-DEVONIAN**

### **NOMENCLATURE THEME**

No new names were assigned due to the limited penetrations into the Pre-Devonian rocks.

### **STRATIGRAPHIC UNITS**

Three informal units are included in the framework from the Pre-Devonian stages. Uncertainty remains in the dating of these units due to the lack of biostratigraphic evidence and low-grade metamorphism.

An informally named “18/25-2 Sandstone/Claystone”, located in the Slyne Basin, has been assigned to the Silurian and may possibly correlate to outcrops on Clare Island, Co. Mayo. However, this is uncertain and alternatively the section could be of Carboniferous age.

A unit informally named the “26/28 Conglomerate”, located in the northern Porcupine Basin, was assigned to the Early Ordovician based on lithological similarities to the “American Quartzite”, regionally represented in western France and the Iberian Peninsula.

Finally, a unit encountered in the Kish Bank Basin has been tentatively assigned to the existing onshore Cambrian Bray Group, without further subdivision.

## 16. GUIDELINES FOR NEW NAMES

The stratigraphic nomenclature presented in this publication, and in the Merlin Energy Consortium (2020) Atlas, represent the nomenclature status at the time of writing. However, it is acknowledged that, as new data become available, there will be a need to update and build upon the current stratigraphic framework. A number of unnamed informal units, at different levels in the succession, have already been identified in the Merlin Atlas and with further information some of these may be assigned member status. Some of the units currently defined as members could, in the future, be upgraded to formations.

The youngest part of the geological column (Pleistocene-Pliocene) is currently defined at Group level, with no constituent formations or members yet. This succession is most likely to see new litho- and bio-stratigraphic data emerging in the near to medium future resulting from site survey work associated with offshore wind energy development. In addition to new data from any future oil and gas exploration and production, research and development of deep geothermal energy or CCS (carbon capture and storage) is likely to provide valuable new information that may justify modification of the deeper part of the sedimentary succession in some of the basins.

It is, therefore, important to ensure appropriate protocols for the definition or revision of parts of the stratigraphic succession and for the formal definition of new stratigraphic units, ensuring that they follow the themes established in the current framework. The Standard Stratigraphic Nomenclature of Offshore Ireland will be updated periodically. The guidelines on the formalisation of proposed new units are given in Appendix A: *Application Form for Proposed New Units for the Standard Stratigraphic Nomenclature of Offshore Ireland*. These guidelines provide instructions on the procedures to be followed to request formal approval and inclusion in future versions of the Stratigraphic Framework.

## 17. ACKNOWLEDGEMENTS

The authors wish to acknowledge, with thanks, the contributions made by a large number of people and institutions that ultimately led to this publication. It would not have been possible without the lithostratigraphic and biostratigraphical data and analysis provided in the Merlin Energy Consortium Atlas, completed in 2020 and published as PAD Special Publication 1/21. That large project was funded by the Irish Shelf Petroleum Studies Group (ISPSG), with a steering group comprising representatives of the DCCAE and a number of the ISPSG member companies, and with the assistance of the members of the Petroleum Infrastructure Programme (PIP) Secretariat.

The nomenclature themes and the names themselves in the publication come from the authors but we were guided, informed and kept in check by a Stratigraphic Committee that oversaw the development and integration of the themes, names and litho/biostratigraphy data and seismic into the Merlin Energy Consortium Atlas. We wish to thank our colleagues and fellow members of the Stratigraphic Committee for their expertise and guidance: Dr Philip Copestake, Dr Nigel Ainsworth, Clare Morgan, Professor Peter Haughton, Professor George Sevastopulo, Dr David Naylor, Dr Shane Tyrrell and Dr Tony Doré. We also acknowledge the advice and very helpful contributions and comments received from a large number of other scientists including Dr Martyn Stoker, Professor Peter Coxon, Professor Stephen Daly and Dr Stephen McCarron.

The report is published by the Department of the Environment, Climate and Communications.



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# Appendix A. Application Form for Proposed New Units for the Standard Stratigraphic Nomenclature of Offshore Ireland



An Roinn Comhshaoil,  
Aeráide agus Cumarsáide  
Department of the Environment,  
Climate and Communications

The *Standard Stratigraphic Nomenclature of Offshore Ireland* will be updated periodically. Where work has been carried out to define a new unit, please complete the following form. Not all fields will relate to every unit being defined. The criteria and notes below will give a general guide of the criteria requested to define a new unit.

Submit the completed information to: [GSRO@decc.gov.ie](mailto:GSRO@decc.gov.ie)

***Refer to the following for various types of data previously used to describe a new unit:***

Merlin Energy Resources Consortium, 2020. *The Standard Stratigraphic Nomenclature of Offshore Ireland: An Integrated Lithostratigraphic, Biostratigraphic and Sequence Stratigraphic Framework*. Project Atlas. Petroleum Affairs Division, Department of Communications, Climate Action & Environment, Special Publication 1/21.

***For information on themes to guide future naming:***

Shannon, P.M., English, K.L., and Hanrahan, M., 2021. *The Stratigraphic Nomenclature of the Irish Offshore Basins*. Department of the Environment, Climate and Communications, PAD Special Publication 2/21.



LITHOSTRATIGRAPHIC UNIT	
<b>Name of Unit:</b> New unit names must be within the defined themes. Ensure that the name has not been used for another geological unit in Ireland or the UK (refer to Offshore Ireland Nomenclature, Geological Survey of Ireland onshore bedrock nomenclature, British Geological Survey Lexicon).	
<b>Status of Unit:</b> New name; variation of published name; redefinition of unit	
<b>Rank:</b> Group, formation, member, bed	
<b>Proposer:</b> Name and organisation	<b>Definition Date:</b> dd-mm-yyyy
<b>Proposed publication:</b> Where do you intend to publish this lithostratigraphic unit definition?	
<b>DEFINITION</b>	
<b>Derivation of name:</b> Following the established theme, describe how the name was derived.	
<b>Name history</b> (if any): Any variations on the name, or other names used that include descriptions of this unit, prior to this definition, i.e. history of recognition and description of this unit.	
<b>Subdivisions:</b> Essential only for groups and formations which have named members at the time of definition. <b>Note:</b> no unit above the rank of 'formation' should be established without having constituent units.	
<b>Parent unit:</b> Describe how this unit falls within an existing parent unit (i.e. group, formation).	
<b>Type locality:</b> Geographic and geological designation of type section or type locality. Include well reference if relevant.	
<b>Description at type locality:</b> The International Stratigraphic Guide requires "a statement summarizing the total content of a lithostratigraphic unit". May include a type section illustration, or seismic section (interpreted and uninterpreted). Use the following fields to define the new unit.	
<b>Lithology:</b> Describe lithology of the unit, and proportions of different types of rocks.	
<b>Wireline log character:</b> Describe wireline character if encountered by wells.	
<b>Upper Boundary:</b> Describe relationship and transition from overlying unit.	
<b>Lower Boundary:</b> Describe relationship and transition to underlying unit.	
<b>Thickness:</b> At type locality/type section. If thickness not known, this should be stated. Can be estimated from seismic data, with calibration to well data.	
<b>Biostratigraphic evidence</b> ( <i>if relevant</i> ): Essential if fossils are diagnostic or noteworthy. Detailed species descriptions may be given if available but are not required. Can be described according to biozones relevant to offshore Ireland.	

<b>Distinguishing features:</b> Any particularly identifying features of the unit which differentiate it from surrounding units. May be extended to also describe any distinguishing features found elsewhere in the unit.	
<b>Age and evidence:</b> The age range of the unit, and how that age was determined (e.g. fossils in this unit or surrounding units, numerical age determinations made by isotopic or other means, age inferred from relationships with other units, or by correlation with other units, of known age).	
<b>Depositional environment:</b> Describe depositional setting, with reference to evidence (fossils, lithology, correlation, seismic facies etc.).	
<b>Distribution:</b> Description of the geographic extent or distribution of the unit.	
<b>Seismic expression:</b> Note key seismic horizons and internal seismic character.	
<b>Regional correlation with other units:</b> Correlated or equivalent units and the reasons for relating them (e.g. fossils, age, lithology, geochronology, structural style, seismic character).	
<b>Regional aspects, geological significance:</b> Criteria to identify and extend the unit geographically away from the type section or type locality. Include any distinctive regional aspects not found at the type locality.	
<b>Geochemistry:</b> Summary description of the geochemical composition of the unit, if available.	
<b>Comments/Other:</b> Any additional information deemed significant about the unit, such as geological or environmental hazards, geotechnical data that may be of interest, or other information not mentioned above.	
<b>References:</b> If published articles, reports or maps exist, give full bibliographic reference details.	
<b>LITHOSTRATIGRAPHIC UNIT</b>	
<b>Name of Unit:</b>	
<b>Status of Unit:</b>	
<b>Rank:</b>	
Proposer:	Definition Date:
Proposed publication:	
<b>DEFINITION</b>	
Derivation of name:	
Name history (if any):	
Subdivisions (if any):	
Parent unit:	
Type locality:	

Description at type locality:
Lithology:
Wireline log character:
Upper Boundary:
Lower Boundary:
Thickness:
Biostratigraphic evidence:
Distinguishing features:
Age and evidence:
Depositional environment:
Distribution:
Seismic expression:
Regional correlation with other units:
Regional aspects, geological significance:
Geochemistry:

Comments/Other:
References:

## **Enclosure 1.**

**Regional Chronostratigraphic Summary Chart of the  
Groups, Formations and Members in the Irish Offshore.**

**(from Merlin Energy Resources Consortium, 2020)**

