Rialtas na hÉireann
Government of Ireland

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

The Lithostratigraphy of the Tournaisian & Viséan of Ireland: Sligo-Ballymoate-Lough Allen Basin

Author: Dr John Kelly

Editors: R. Doyle, Dr. M. Pracht

A Geological Survey Ireland publication in association with:

iCRAG
SFI RESEARCH CENTRE IN APPLIED GEOSCIENCES

Geological Survey Ireland is a division of the Department of the Environment, Climate and Communications

The Lithostratigraphy of the Tournaisian & Viséan of Ireland

Author:

Dr. John Kelly

Editors:

R. Doyle, Dr. M. Pracht

Study Area:

Sligo – Ballymote – Lough Allen Basin

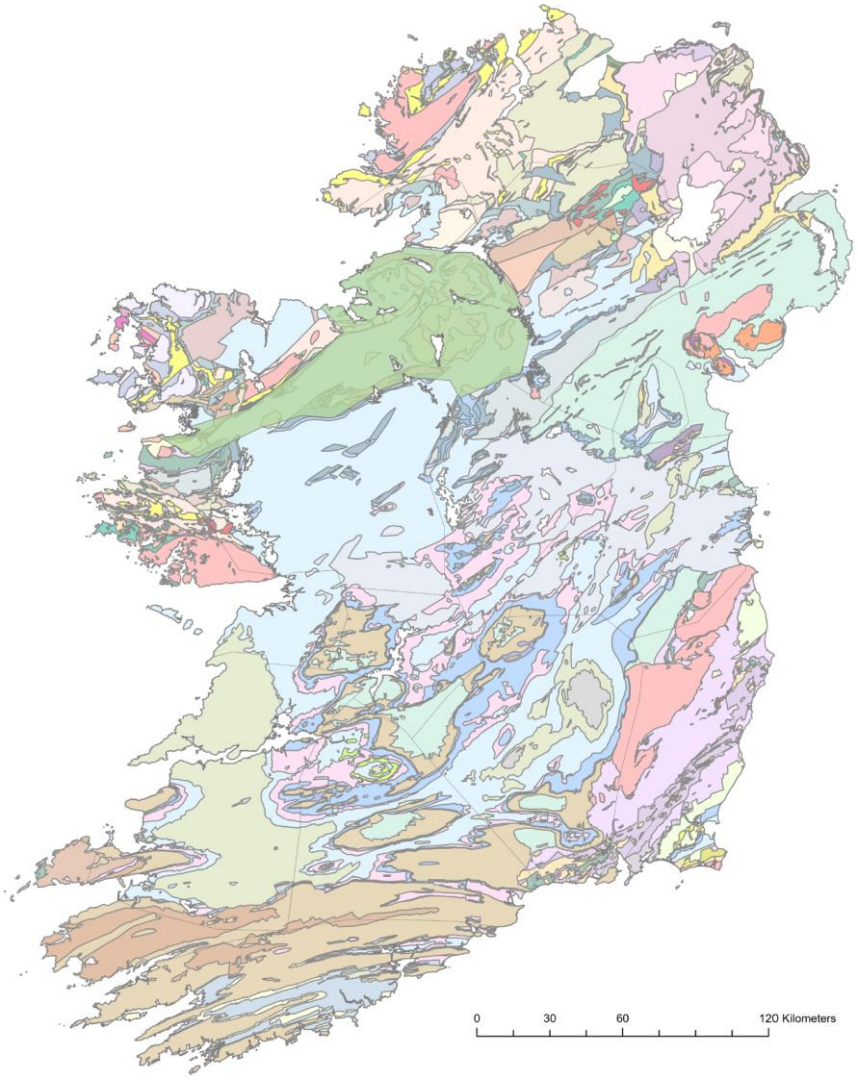


Table of Contents

Introduction 4
Sligo Succession 5
Introduction 5
Lithostratigraphy 5
Twigspark Formation 5
Ballyshannon Limestone Formation 6
Bundoran Shale Formation 6
Mullaghmore Sandstone Formation 7
Benbulben Shale Formation 7
Glencar Limestone Formation 7
Dartry Limestone Formation 8
Meenymore Formation 8
Glenade Sandstone Formation 9
Ballymote Succession 10
Introduction 10
Lithostratigraphy 10
Moy Sandstone Formation 10
Dargan Limestone / Kilbryan Limestone Formation 10
Oakport Limestone Formation 11
Lisgorman Shale Formation 11
Bricklieve Limestone Formation 12
Leitrim Group 13
Lough Allen – West Fermanagh Basin 14
Introduction 14
Lithostratigraphy 15
Ballyshannon Limestone Formation 15
Bundoran Shale Formation 16
Mullaghmore Sandstone Formation 17
Benbulben Shale Formation 17
Glencar Limestone Formation 17
Dartry Limestone Formation 18
Meenymore Formation 18

Glenade Sandstone Formation 19
Bellavally Formation.....20
Carraun Shale Formation 21
List of Figures 22
References and Further Reading.....22

Introduction

The successions in the Sligo, Ballymote and Lough Allen Basins are described here in three sub-sections (Figures 1(a), 1(b), 1(c) and 2). The stratigraphies in each of the areas show broad similarities, but there are significant local variations within and between the three areas (Figures 3, 4 and 5). Previous work and the most relevant publications are summarised in each section.

Borehole data for the three areas is relatively limited, with information in the Sligo Basin restricted to relatively shallow drilling in areas of known mineralisation. In the Ballymote area there are very few cored boreholes and the successions in the Lough Allen Basin are largely known from hydrocarbon exploration wells which were not cored, with a limited number of generally shallow cored boreholes restricted to a small number of areas. The upper parts of the sequences are generally well exposed in upland areas and have been extensively mapped and logged in a number of areas.

Sligo Succession

Introduction

The succession in the Sligo Basin was first established by Oswald (1955) who erected the stratigraphy in the area that has largely been applied to similar formations in the adjacent parts of the Northwest Carboniferous area (Figure 2). Subsequently, a large number of other workers have investigated specific areas or formations within the basin. The distribution of boreholes is limited and largely shallow (<200m), largely concentrated on known deposits or prospects at Abbeytown (Ballysadare), Gleniff, Twigspark (Lurganboy) or Rosses Point (Figures 1(a) and 1(b)).

Lithostratigraphy

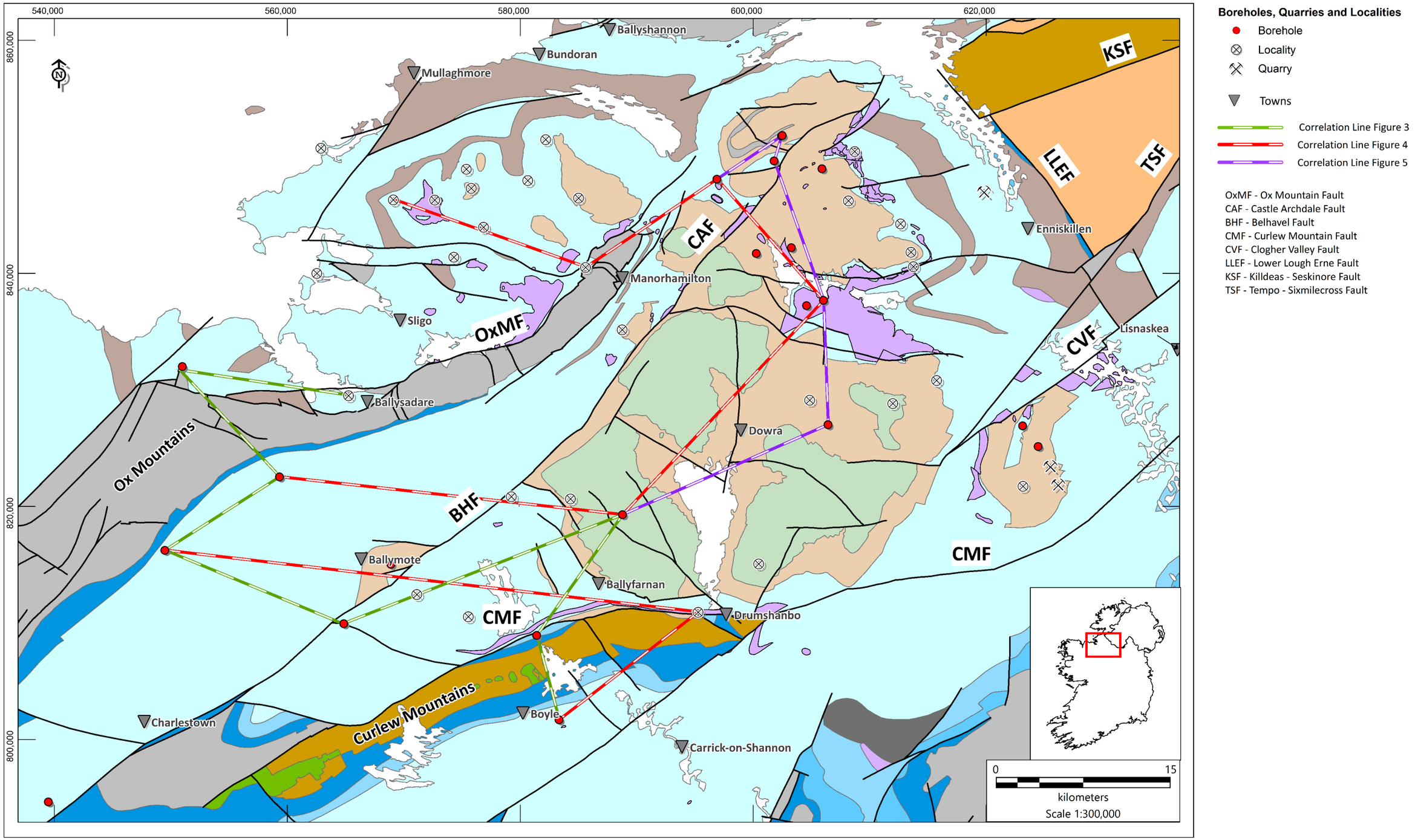
Twigspark Formation

The basal clastics succession in the Sligo Basin is attributed to the Twigspark Formation, with a type section in Twigspark townland near Lurganboy where the formation was intersected at the Twigspark historic Zn-Pb working (Figure 1(b)) by Pennarroya exploration drilling in 1970 (Philcox1983). At Twigspark, the formation was informally sub-divided by Philcox (1983) into four units, the "Basal Sandstone Unit" (which is similar to the Moy / Boyle Sandstone), the "Shaley Beds Unit", The "Upper Sandstone Unit" and the "Sandy Limestone Beds Unit".

The Basal Sandstone Unit is mainly composed of coarse, pale-grey non-calcareous sandstones and subordinate pebbly sandstones, greenish mudstone and shale. The top contact is gradational into the Shaley Beds above while the basal contact is presumed to be unconformable on metamorphic lithologies (quartzites), although the contact is difficult to accurately place in the Twigspark boreholes. The Basal Sandstone is at least 21m in thickness.

The succeeding Shaley Beds are 14m thick in borehole LIT-10, composed of medium-grey, weakly calcareous shales with scattered micrite nodules and rare thin beds of black, non-calcareous pyritic shale. Thin sandstone beds are present and are more common towards its base. The Upper Sandstone is described by Philcox (1983) as a fairly uniform pale grey, laminated, non-calcareous sandstone, with thin interbeds of black, non-calcareous pyritic shales, occasionally with plant debris. A distinctive 1.5m thick shaley bed marks the top of the unit in all the Pennarroya boreholes at Twigspark. The unit varies from 5.5m (LIT-12) to 9m (LIT-10) in thickness.

The overlying Sandy Limestone Beds can be clearly defined as the unit base and top are marked by prominent shale beds, the uppermost of which is marked by apparent soft sediment deformation and the lower is a black shale in excess of 0.5m in thickness. The main part of the unit is composed of sandy limestones and bioclastic sandstones and reaches a maximum thickness of 17.0m at Lurganboy.



Boreholes, Quarries and Localities

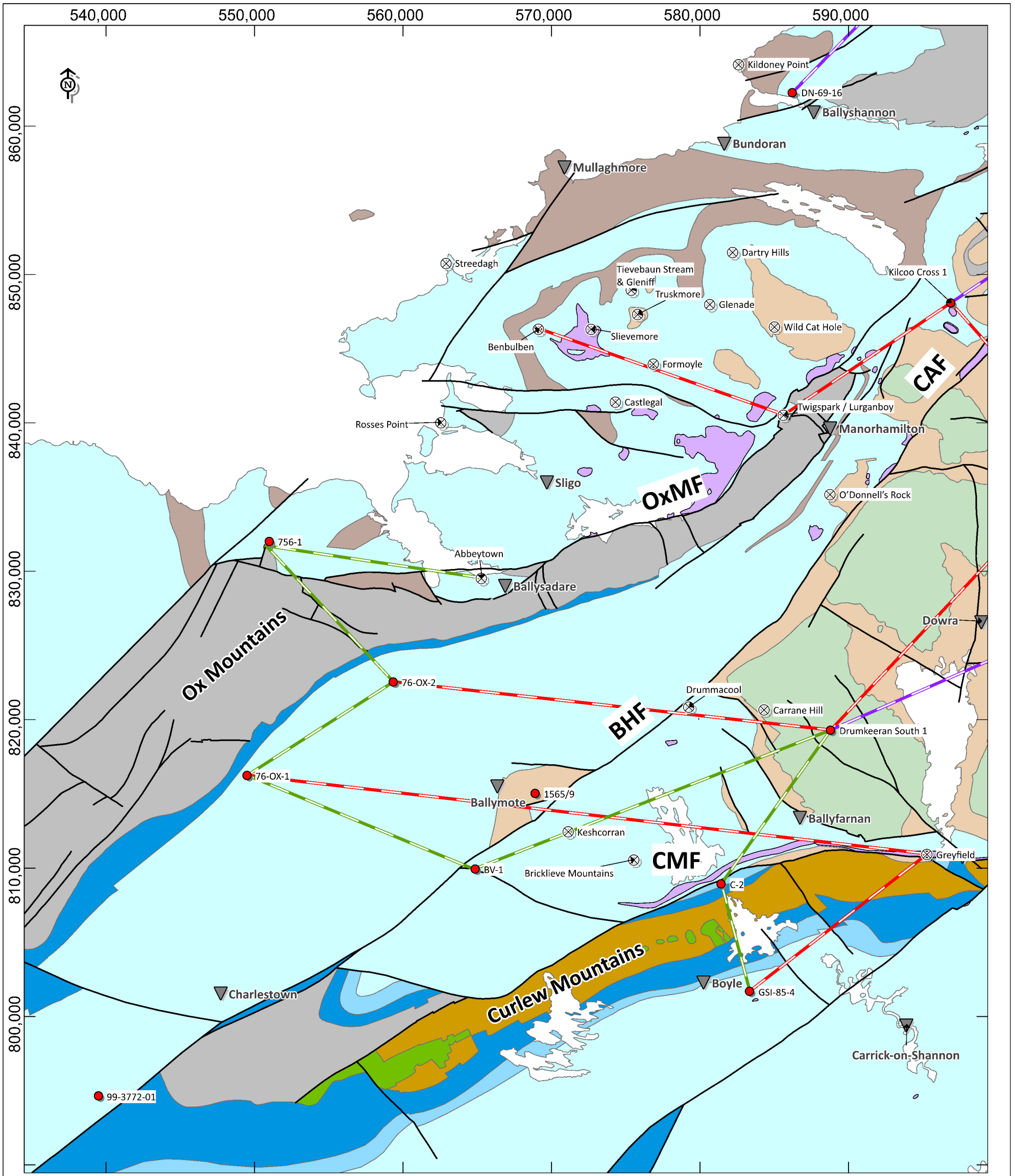
- Borehole
- Locality
- Quarry
- Towns
- Correlation Line Figure 3
- Correlation Line Figure 4
- Correlation Line Figure 5

OxMF - Ox Mountain Fault
CAF - Castle Archdale Fault
BHF - Belhavel Fault
CMF - Curlew Mountain Fault
CVF - Clogher Valley Fault
LLEF - Lower Lough Erne Fault
KSF - Killdeas - Seskinore Fault
TSF - Tempo - Sixmilecross Fault

Map Legend

- Post-Carboniferous
- Carboniferous Redbed Facies
- Fluvio-deltaic & basinal marine clastics
- Viséan Marginal Marine / Sabkha
- Mudbank Limestone
- Viséan Limestone & Shale
- Viséan Sandstones
- Basal Clastics
- Devonian Continental redbed facies
- Devonian Volcanics
- Pre-Devonian

Figure 1(a): Regional Geology map showing the Sligo, Ballymote and Lough Allen Basins, boreholes and site locations.



Map Legend

- Post-Carboniferous
- Carboniferous Redbed Facies (late Viséan to early Westphalian)
- Fluvio-deltaic & basinal marine clastics
- Viséan Marginal Marine / Sabkha
- Mudbank Limestone
- Viséan Limestone & Shale
- Viséan Sandstones
- Basal Clastics
- Devonian Continental redbed facies
- Devonian Volcanics
- Pre-Devonian

Boreholes, Quarries and Localities

- Borehole
- Locality
- Quarry
- Towns
- Correlation Line Figure 3
- Correlation Line Figure 4

OxMF - Ox Mountain Fault
CAF - Castle Archdale Fault
BHF - Belhavel Fault
CMF - Curlew Mountain Fault

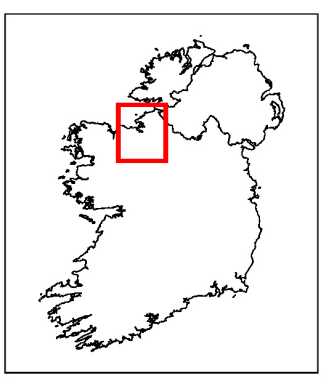
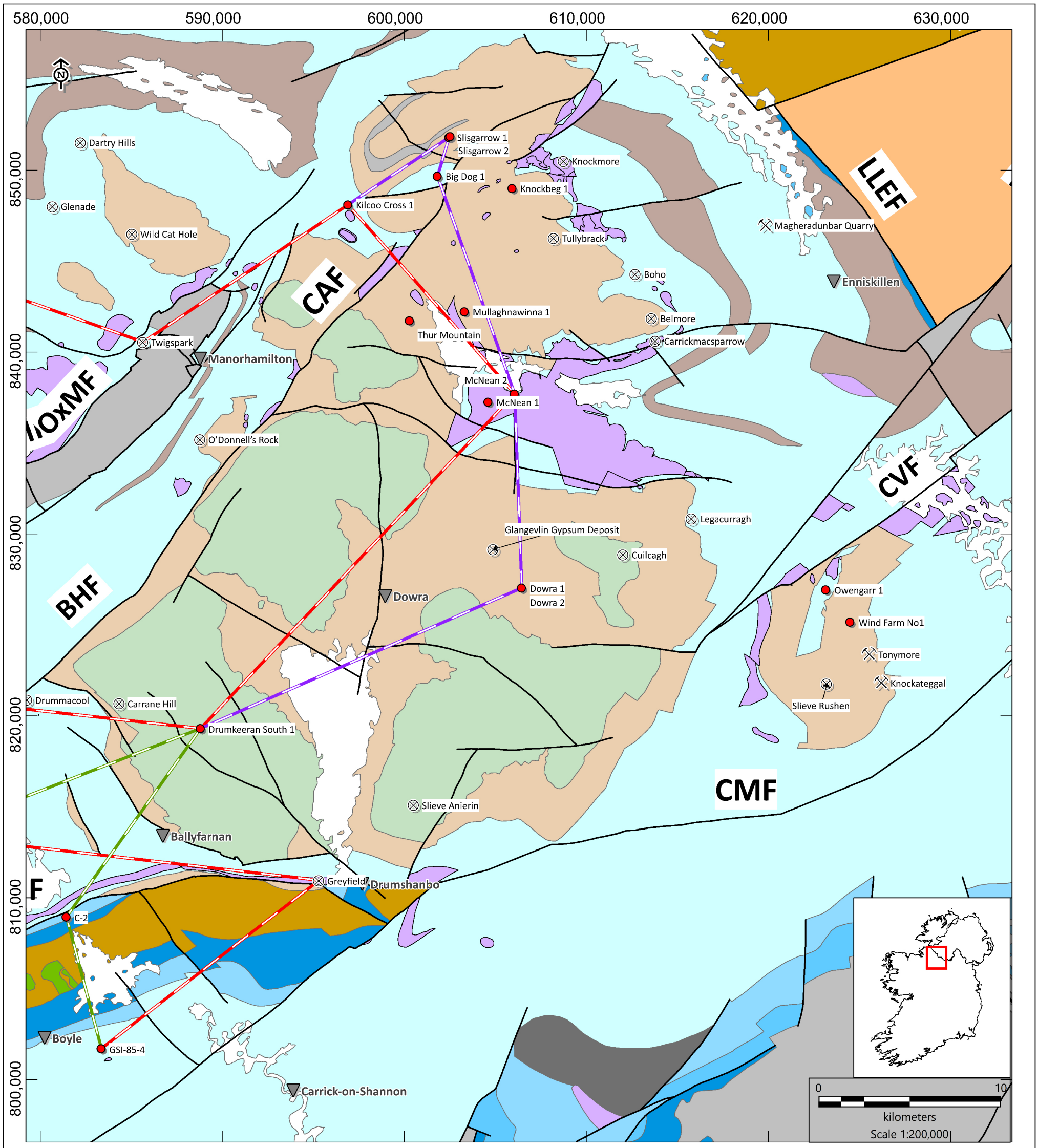


Figure 1(b): Sligo and Ballymote Basins. Bedrock Geology, boreholes and localities.



Map Legend

- Post-Carboniferous
- Carboniferous Redbed Facies (late Viséan to early Westphalian)
- Fluvio-deltaic & basinal marine clastics
- Viséan Marginal Marine / Sabkha
- Mudbank Limestone
- Viséan Limestone & Shale
- Viséan Sandstones
- Basal Clastics
- Devonian Continental redbed facies
- Devonian Volcanics
- Pre-Devonian

Boreholes, Quarries and Localities

- Borehole
- Locality
- Quarry
- Towns

- Correlation Line Figure 3
- Correlation Line Figure 4
- Correlation Line Figure 5

OxMF - Ox Mountain Fault
BHF - Belhavel Fault
CAF - Castle Archdale Fault
CMF - Curlew Mountain Fault
CVF - Clogher Valley Fault
LLEF - Lower Lough Erne Faults

Figure 1(c): Lough Allen Basin. Bedrock Geology, boreholes and localities.

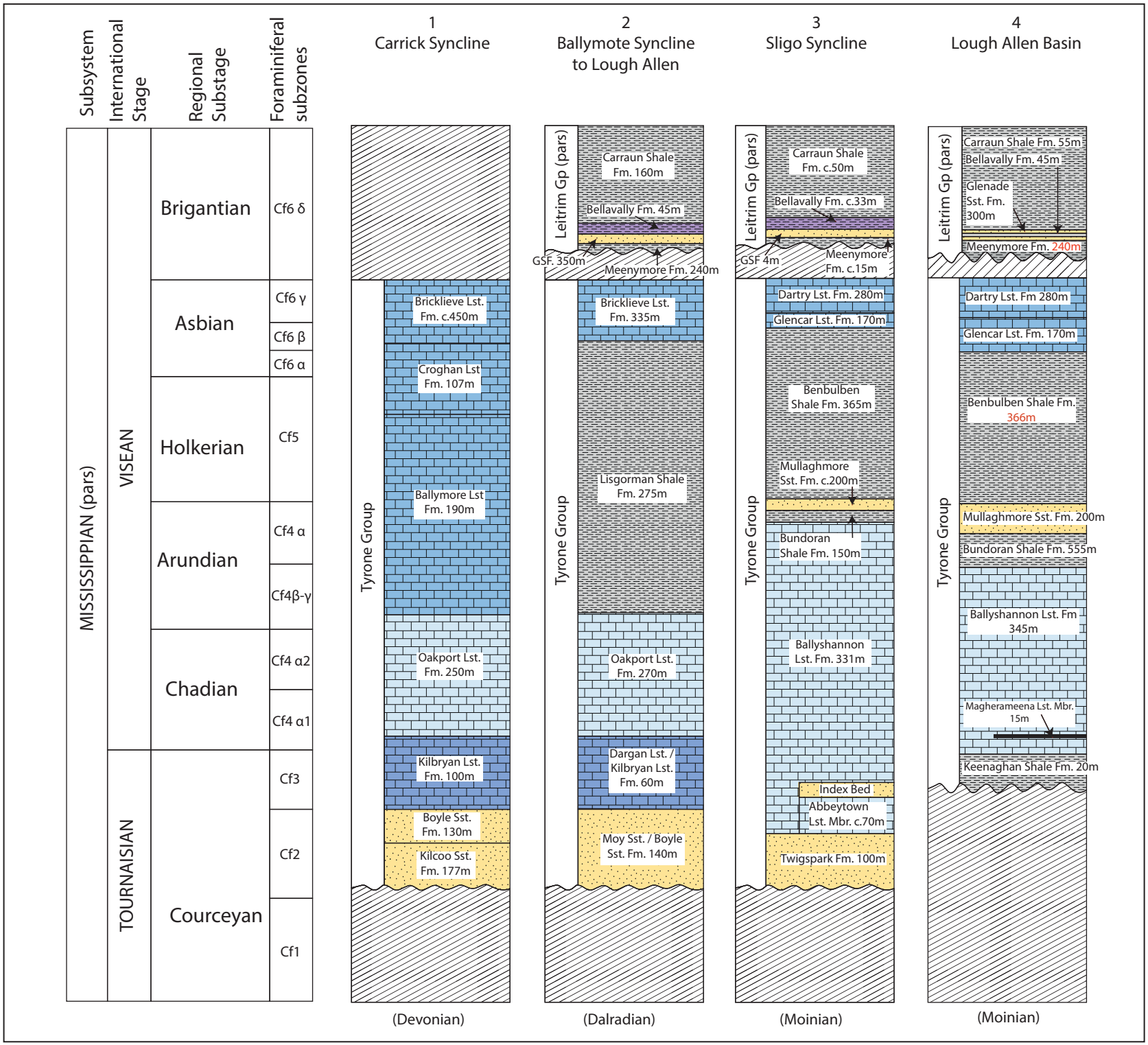


Figure 2:
Modified from Somerville & Waters (2011) and Mitchell & Somerville (2011)

At Abbeytown (Figure 1(b), 2 and 3) the Twigspark Formation is sub-divided into three units, a basal pebbly sandstone overlain by a mixed sequence of 35m of dark argillaceous micritic limestones, fine grainstones/packstones and shale, with an upper unit composed of sandy oolites and calcareous sandstones.

Oswald (1954) included the entire sequence between the basement and the base of the Bundoran Shale as belonging to the Ballyshannon Limestone, but it is now defined (MacDermot et al., 1996) as the thick sequence of pale to mid-grey, generally thick-bedded or massive crinoidal bioclastic limestones between the Twigspark Formation, Kilbryan Limestone and the Bundoran Shale. The formation is argillaceous in its lowermost part and finer-grained, cherty, darker and slightly argillaceous in its upper part in the Sligo area. The formation is estimated to be between 240m to 330m in thickness, it is upper Chadian at the formation base and late Arundian in its upper part.

Ballyshannon Limestone Formation

At Abbeytown, the basal part of the Ballyshannon Limestone is assigned to the Abbeytown Limestone Member, composed of a pebbly coarse-grained grainstone (the “Lower Grit Bed”) overlain by some 60m of dark, fine-grained crinoidal limestones and thin shales, This is overlain by a very distinctive unit, the “Index Bed”, comprising cross-bedded, coarse-grained sandy limestones and calcareous sandstones with quartz pebble coarse-grained calcareous sandstones. Above the Index Bed, the Ballyshannon Limestone consists of some 175m of mid-grey, fine to medium-grained grainstones and packstones, overlain by a unit of cherty bioturbated fine-grained limestones, graded coarse crinoidal limestones and shales termed The Lugawarry Beds by Philcox (1983). The Ballyshannon Limestone in the Sligo Basin is late Courceyan to Arundian in age.

Bundoran Shale Formation

A marked change in sedimentation is marked by the onset of deposition of the Bundoran Shale Formation, first defined by Oswald (1954), the type section was described by Avbovbo (1973) at Bundoran (Figure 1(a), 1(b)). In the type section the formation is 86m in thickness, the lowermost 33m are composed of dark grey laminated shales interbedded with thin fossiliferous limestones and shales – the basal shales are especially fossiliferous. This is overlain by 53m of fossiliferous dark grey shales and micaceous siltstones, the bioclastic content predominantly composed of brachiopods and crinoids. At the eastern margin of the Sligo Basin at Lurganboy, Philcox (1983a) described the sequence in a number of boreholes drilled by Pennarroya in 1970. Here, 100.5m of Bundoran Shale was intersected (95m true thickness) in LIT-13, and the intersected interval was sub-divided into 3 sub-units. The basal unit consists of 26m of interbedded limestones and shales (approximately a 50:50 division), this is overlain by an 46m thick interval of thinly laminated sandstones and siltstones and the uppermost unit is composed of interbedded calcareous shales and fine-grained limestones. The Bundoran Shale Formation is Arundian in age.

Mullaghmore Sandstone Formation

The base of the succeeding Mullaghmore Sandstone marks a change to fluvial and marginal marine siliciclastics and is taken at the point where siliciclastic sedimentation becomes dominant over the preceding calcareous, bioclastic mud deposition. The formation has been described in detail by Graham (2017) who describes the basal contact with the underlying Bundoran Shale as sharp and erosional in area proximal to the sediment source and gradational in more distal areas. Graham (2017) recognises up to 10 sub-facies within the formation, but after a thin interval of cyclic siltstones and shales in the lower part, it passes up into a sequence of medium to coarse-grained arkosic sandstones with abundant trace fossils, deposited in a range of environments identified as fluviatile, distributary fan and delta. The upper part of the formation is more calcareous, with calcareous siltstones, thin limestones and sandy oolites recorded. The formation varies dramatically in thickness, thinning to the south and east in its distal areas. It is estimated to be approximately 200m in the type areas at Mullaghmore but has thinned to 60m at O'Donnell's Rock (Figure 1(b)) and disappears in the Ballymote area. It is Arundian – Holkerian in age.

Benbulben Shale Formation

The Benbulben Shale Formation was first described by Oswald (1954) who did not define a type section: however, a full sequence is exposed in a stream at Tievebaun (Figure 1(b)). Here the formation consists of dark grey laminated calcareous shales interbedded with thin beds of argillaceous fine-grained limestones. Limestones are more common at the base of the formation and the formation passes upwards into the overlying Glencar Limestone Formation due to a gradual increase in limestone content and bed thickness. Bioclastic material is present throughout, consisting of abundant crinoid material, brachiopods, large solitary corals and bryozoans. The Tievebaun section is 99m thick, although it is not possible to determine thickness variations in the formation due to lateral facies variations with the lower Glencar Limestone. The formation is Holkerian to early Asbian in age.

Glencar Limestone Formation

The Glencar Limestone was first described by Oswald (1955). Oswald and Schwarzacher (1964) conducted a statistical analysis on two sections in Glencar to investigate Milankovitch cyclicity in the limestone/shale ratios. Coastal sections have been described by Hubbard (1966) and the section at O'Donnell's Rock was logged and described in detail by Cózar et al. (2005) and Somerville et al. (2009). Where exposed, the Benbulben Shale is seen to pass gradually upwards into the Glencar Limestone Formation and there are significant lateral facies variations between the Benbulben Shale and the Glencar Limestone, limestone proportion and bed thicknesses increase at the expense of the shale/mudstone component. The main part of the formation consists of cyclic interbedded limestones and shales, very fine-grained limestones passing up into argillaceous fine-grained wackestones which pass up into calcareous shales/mudstones. At Streedagh (Figure 1(b)), the basal contact of the formation is

exposed at the southern end of Streedagh Strand and at Streedagh Point limestones with minor shales and abundant solitary corals are present. At O'Donnell's Rock the Glencar Limestone consists of a 6m thick limestone bed overlain by 39m of thin interbedded limestones and mudstones overlain by approximately 12m of non-argillaceous crinoidal, laminated, packstones. Corals are common including *S. pauciradiale*. Oswald (1954) estimated the thickness of the formation at 180m in the type area, but this is likely to be variable due lateral thickness and interdigitation with the Benbulben Shale facies.

Dartry Limestone Formation

The Dartry Limestone Formation (Oswald 1955) overlies the Glencar Limestone Formation and forms the dramatic cliffs around the Benbulben – Truskmore, Castlegal and Dartry uplands in North Sligo. The contact with the underlying Glencar Limestone Formation is gradational, marked by the loss of interbedded shales and the appearance of abundant cherts and silicification of the limestone. In the Sligo area, the formation is composed of two main lithofacies, bedded cherty limestones and carbonate mudbank limestones. The bedded cherty limestones are composed of medium to thick bedded, dark grey, fine-grained silicified wackestones / packstones with chert bands or horizons of chert nodules delineating bedding. Certain horizons contain common to abundant fossils, especially colonial and solitary corals but these are restricted and much of the formation is unfossiliferous. The fossils are frequently silicified.

Carbonate mudbanks

Interbedded with the bedded limestones and laterally equivalent to them, are a number of areas of carbonate mudbanks. These mudbanks are lensoid or sheet like in form, composed of largely chert-free pale grey, massive bedded biomicrites of microbial origin. The banks are typically flanked and capped by bedded pale grey biomicrites, which may be cherty. The mudbanks in the Sligo Basin occur in two main areas, forming a belt of mudbanks along the northwestern edge of the Ox Mountains from east of Lough Gill to northeast of Manorhamilton and in the uplands east of Benbulben (Figure 1(b)). A number of scattered mounds are developed in the uplands east of Sligo town. A detailed assessment of two mudbank developments (at Formoyle in Glencar and Slievemore in Gleniff – see Figure 1(b)) was undertaken by Schwarzacher (1961). Although significantly younger, the Asbian Dartry Limestone Formation mudbanks show many sedimentological similarities with the older (Courceyan) Waulsortian carbonate mudbanks of the Irish Midlands. The Dartry Limestone is of upper Asbian age.

Meenymore Formation

In the Sligo Basin, the area underlain by the Meenymore Formation is restricted to small outcrop areas capped by the Glenade Sandstone Formation and a small area capping the high ground south of Glenade Lough (Figure 1(b)). The formation in these areas is generally poorly exposed, Oswald (1955) describes the contact with the Dartry Limestone as sharp and the

formation composed of thin dark shales with rare thin impure limestones. Brandon (1977) located and described a section from Glenade where 36.5m of Meenymore Formation is exposed in a stream. Here, a basal unit of laminated micrites with evaporites is overlain by a mixed sequence of unfossiliferous shales, fossiliferous shales and micrites and dolomicrites, with a thin (0.3m to 0.5m) orthoquartzitic sandstone in the approximate middle of the formation. The uppermost shales immediately underlying the Glenade Sandstone are micaceous and silty. The formation has been determined to be Brigantian in age (Somerville et al. 2009).

Glenade Sandstone Formation

Overlying the Meenymore Formation in the Sligo succession is the Glenade Sandstone Formation, with a type section where the formation occurs to the northeast of Glenade Valley, there are also small outliers on the Truskmore/Benbulben summit areas. The formation was originally defined by Oswald as the upper part of his Glenade Beds. The basal contact is not exposed and the outcrop in the type area is frequently peat covered. Where exposed, the sandstones consist of medium-grained pale grey to buff arkose sandstones (up to 50% feldspar), but exposure is largely restricted to displaced blocks. Based on other areas, the Glenade Sandstone is now considered to be Brigantian in age (Somerville et al. 2009).

Ballymote Succession

Introduction

The Ballymote Succession refers to the rock succession between the south-eastern edge of the Ox Mountains and the north-western edge of the Curlew Mountains (Figures 1(a), 1(b), 2, 3 and 4). The north-eastern edge of the area is bounded by the north-western margins of the Lough Allen Basin where the Mullaghmore Sandstone is still present. The area is roughly centred on the town of Ballymote, although the southwestern margins of the area are poorly defined. The full succession was first established by Dixon (1972) and the upper part of the succession has been significantly refined by Cózar et al. (2004) and Somerville et al. (2009). Boreholes are rare, generally centred on Zn-Pb and Cu anomalies along the Belhavel Fault along the south-eastern edge of the area. One deeper (394m) borehole (99-3772-01) was drilled by Rio Algom southeast of Swinford and intersected a typical Ballymote succession (Figure 1(b)).

Lithostratigraphy

Moy Sandstone Formation

The basal unit of the Ballymote succession is the Moy Sandstone Formation, exposed as a belt of sandstone lying unconformably on high-grade metamorphics along the south-eastern edge of the Ox Mountains. The formation consists of alternating units of conglomerates dominated by quartz pebbles, grey to green coarse pebbly sub-arkose or orthoquartzitic sandstones and finer-grained red to green orthoquartzites and siltstones. The uppermost beds of the formation may consist of bioclastic sandstones with fragmented brachiopods, corals and crinoids. In the western part of the outcrop area of the formation it is estimated to be 140m thick, thinning eastwards to 30m – 60m east of Coolaney, in conjunction with the disappearance of the conglomeratic units. The formation has been intersected in borehole 76-OX-1 (Figures 1(b) and 3). On the southern side of the Ballymote area, the basal clastics are assigned to the Boyle Sandstone Formation (first established with a type locality in the Carrick on Shannon area by Caldwell (1957). Here, the 'basal clastics' are significantly different in character, composed of coarse-grained, grey sandstones with pebbles of quartz, jasper, shale and tuffs. The basal sandstone sequence is interpreted as Courceyan in age.

Dargan Limestone / Kilbryan Limestone Formation

Dixon (1972) subdivided the succeeding Dargan Limestone Formation into three sub-units. The basal unit consists of a dolomitic bioclastic packstone/grainstone, the middle units consists of a medium-grained slightly sandy oolitic packstone/grainstone (the Dargan Oolite) and the uppermost unit is more variable, changing from dark grey to black argillaceous micrites east of Collooney, passing westwards into massive crinoidal grainstones which are locally sandy, this interval is best intersected in 76-OX-2. On the southern side of the Ballymote area, the Dargan Limestone is replaced by an equivalent formation, the Kilbryan Limestone Formation (Philcox

1983) (Figure 3). The Kilbryan Limestone Formation type section is defined in GSI borehole GSI-85-4, drilled in the adjacent Dunmore – Roscommon Province, (Figures 1(b) and 3) in the Roadstone Quarry at Boyle in the Carrick Basin where it consists of bioturbated nodular limestones interbedded with calcareous bioclastic shales and argillaceous limestones. In borehole 99-3772-01 (Figure 1(b)), on the southern edge of the area, some 131.5m of Kilbryan Limestone Formation were intersected between the basal clastics and clean massive limestones of the Oakport Limestone dominated by argillaceous bioclastic wackestones, slightly argillaceous packstones and clean packstones. It has also been intersected in BV-1 in the Ballymote Basin (Figure 1(b)). The Dargan and Kilbryan Limestone Formations are late Courceyan to early Chadian in age.

Oakport Limestone Formation

The Dargan/Kilbryan Limestone is overlain by the Oakport Limestone Formation, an equivalent to the Ballyshannon Limestone, first defined by Caldwell (1959) in the Carrick on Shannon Basin (?)Basin and extended to similar lithologies in the Ballymote sequence by Dixon (1972) (Figures 1(b), 2 and 3). The basal dolomite of Caldwell year has been assigned to the Dargan Limestone by Philcox (1986). In the type section, near Boyle, the lowermost unit consists of 27m of thick-bedded pale-grey, fine-grained grainstone which is overlain by finely laminated limestones with peloids with algal textures. At Boyle the uppermost unit of the formation is composed of fine grainstones, with rare micrites and shelly horizons, but is truncated by a disconformity so all the formation is not present. In the Ballymote area, the uppermost part of the formation is composed of cherty limestones with shales, tentatively correlated (MacDermot et al., 1996) with the Lugawarry Beds at the top of the Ballyshannon Limestone at Ballysadare. In borehole 99-3772-01 the formation is 117.7m thick, composed of typical Oakport lithologies (Figures 1 and 3). The Oakport Limestone Formation is early Chadian to earliest Arundian in age.

Lisgorman Shale Formation

As the Mullaghmore Sandstone thins to the south and was not deposited in the Ballymore area south of the O'Donnell's Rock area, it is not possible to separate the Bundoran and Benbulben Shale Formations. Therefore, the entire shale interval overlying the Oakport Limestone was assigned by Dixon (1972) to a single unit, the Lisgorman Shale Group (now Formation). It is composed of dark grey calcareous shales, interbedded with subordinate thin fine-grained limestone beds (5cm – 20cm). Bioclasts are rare but bioturbation is common. It is more carbonate-rich in the lower part. Rio Algom borehole 99-3772-01 intersected a 4.85m thick unit with sandstones and green shales which has been interpreted as a Mullaghmore

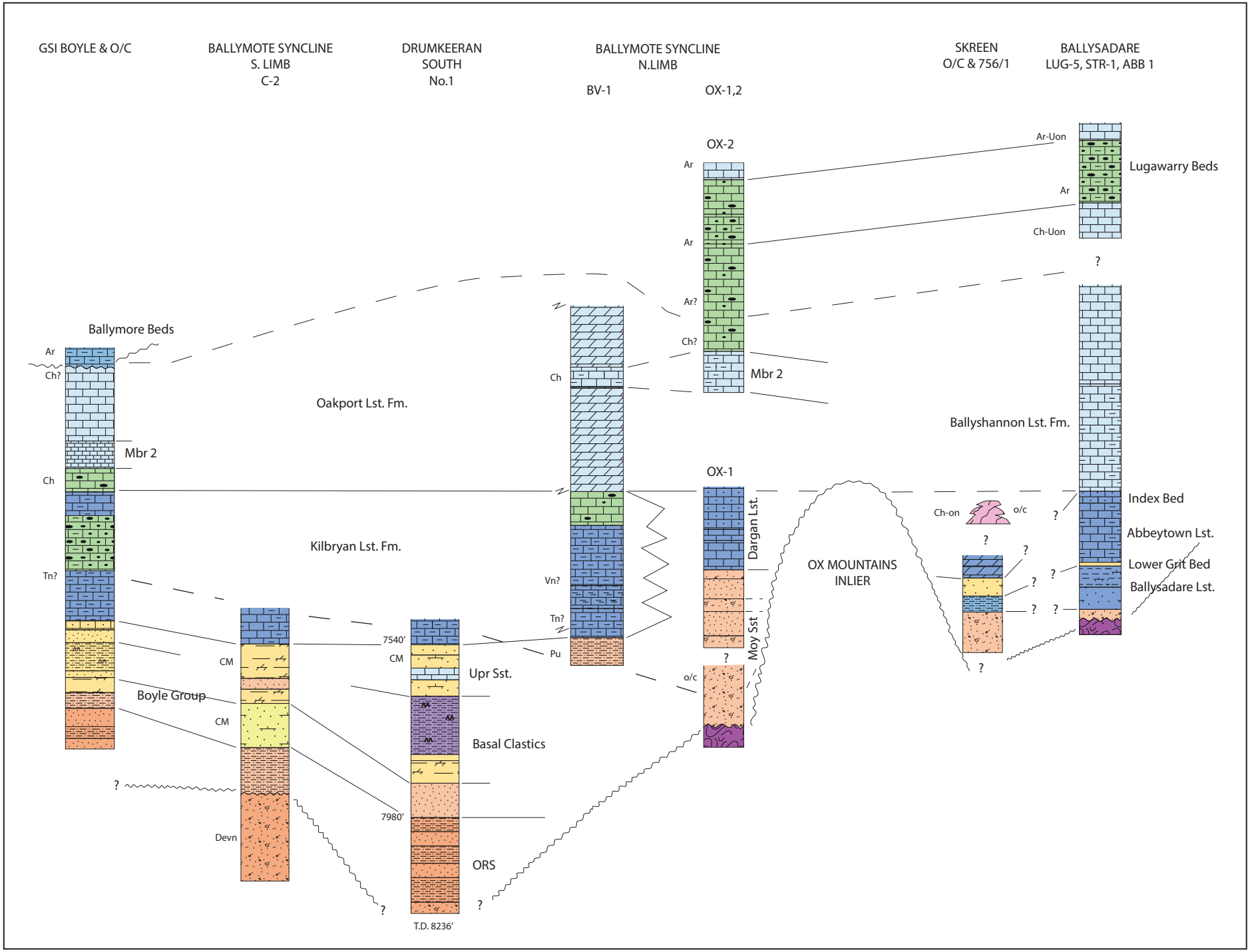


Figure 3: Correlation of Basal Clastics - Oakport/Ballyshannon Limestone in the Carrick-Ballymote-Sligo Basins. (modified from Philcox, M. E. 1986)

Sandstone equivalent, but as it is only 12.5m from the base of the Lisgorman Shale, it may represent a clastic depositional event close to the base of the Bundoran/Lisgorman, similar to other coarse clastic events close to the base of the Bundoran Shale such as the Dowra/Drumkeeran Sandstones in the Lough Allen Basin (Philcox, 1986, MacDermot et al. 1996) or the Mullynagowan Sandstone Member in the Lisnaskea area (Mitchell, 1995). The Lisgorman Shale Formation is early Arundian to early Asbian in age.

Bricklieve Limestone Formation

A significant change in sedimentation pattern occurs at the top of the Lisgorman Shale, which is overlain by the Bricklieve Limestone Formation. The Bricklieve Limestone Formation of Dixon (1972) is an equivalent of the Cavetown Limestone Formation of Caldwell (1957) in the Carrick on Shannon (?)Basin and the Dartry Limestone Formation of Oswald (1955) in the Sligo Basin (Figures 2 and 3). The Bricklieve Limestone Formation was first defined by Caldwell and Charlesworth (1962) who described the sequence in the Bricklieve Mountains (Figure 1(b)). Dixon examined the formation across the area and sub-divided the formation into 6 informal sub-units (termed “Groups”) and MacDermot et al. (1996) sub-divided the formation into an informal “Lower Bricklieve Limestone Formation” and an “Upper Bricklieve Limestone Formation”, based on a first appearance of cerioid lithostrotiontid rugose corals. Cózar et al. (2004) and Somerville et al. (2009) examined several well exposed sections in detail for biostratigraphy, carbonate facies and biostromal distribution and provided detailed lithological logs of the Bricklieve Limestone successions at Keshcorran and several localities in the Bricklieve Mountains, Carrane Hill and Clogher Lough (Figure 1(b)).

The lower Bricklieve Limestone Formation is roughly coincident with the two lowermost units of Dixon (1972). The lowermost unit predominantly consists of packstones and grainstones, partially dolomitised in places and locally cherty or peloidal, with subordinate argillaceous biomicrites, sometime laminated. The top of the unit is taken at the base of a major, widespread biostrome of colonial coral-rich limestones dominated by *Siphonodendron pauciradiale* which forms the basal beds of unit 2. Above this coral rich interval, unit 2 consists mainly of thick-bedded packstones and grainstones, locally cherty, with solitary corals in places. The top of the unit is marked by another coral-rich biostrome dominated by *Siphonodendron martini*. The Lower Bricklieve Limestone is Asbian in age and Somerville et al. (2009) have correlated the Lower Bricklieve Limestone with the Glencar Limestone Formation in the Sligo and Lough Allen Successions. The Bricklieve Limestone Formation can be correlated with the Burren Limestone Formation on the Galway-Roscommon shelf (Pracht this publication).

The Upper Bricklieve Limestone Formation largely consists of thick-bedded, pale to mid-grey, medium to coarse-grained packstone and grainstones, with abundant silica as chert in a range of forms (bands, nodular bands, nodules, diffuse masses) or siliceous replacement of fossil material. Chert free intervals of crinoidal grainstones are present and the Upper Bricklieve

Limestone is split into sub-units by the presence of a number of thin (much thinner than the *S. pauciradiale* and *S. martini* beds in the Lower Bricklieve) biostromes dominated by *S. junceum*. The topmost beds of the formation, where preserved are composed of pale micrites (e.g. at Carrane Hill). Carbonate mudbank facies, interbedded with the typical limestones of the Bricklieve Limestone Formation, are present in the Drummacool area, some 5km northwest of Arigna (Figure 1(b)). The Upper Bricklieve Limestone is Asbian in age and Somerville et al. (2009) have correlated the Upper Bricklieve Limestone with the Dartry Limestone Formation in the Sligo and Lough Allen Successions.

The top of the formation is not exposed in the type area, but it is exposed at Carrane Hill where the formation is overlain by the Meenymore Formation (originally termed the Roscunnish Shales by Caldwell, 1959). The formation is at least 300m thick in the Keshcorran – Bricklieve area and a similar thickness at Carrane Hill. It is late Asbian in age.

Leitrim Group

An outlier of Leitrim Group sediments, presumed to be restricted to the Meenymore Formation, although not well-defined, is present in the Ballymote area, northwest of the Belhavel Fault and to the immediate southeast of Ballymote and Navan Resources borehole 1565/9 was completed in this area in 1999 (Figure 1(b)). Immediately overlying the Bricklieve Limestone is a 50m variable interval composed of interbedded calcareous shales and mudstones, argillaceous calcarenites, argillaceous micrites, thin, clean micrites and cherty limestones with minor evaporitic bands, with a 4.1m thick massive gypsum horizon. This variable interval is overlain by at least 65m of dark grey to black calcareous mudstones, black pyritic mudstones and dark grey sandy mudstones. Thin evaporite bands or horizons of evaporite nodules are common. The Meenymore Formation has been established as Brigantian in age (Somerville et al. 2009).

Lough Allen – West Fermanagh Basin

Introduction

For the purposes of this description, the Lough Allen Basin is defined as the area bounded by the following structures (see Figures 1(a) and 1(c)):

- East of the Lower Lough Erne Fault (LLEF)which downthrows to the west (i.e. west of Upper and Lower Lough Erne
- North of the Curlew Mountain Fault (CMF) which downthrows to the north
- East of the Ox Mountains or Ox Mountains Fault (OxMF) to the northwest of Dromahair - Killarga, including the West Fermanagh Highlands in the Garrison – Lough Navar Area
- Northeast of an unnamed structure trending from Ballyfarnan to Drummacool which downthrows to the northeast

Lithostratigraphic data is largely derived from drilling data restricted to a number of deep hydrocarbon exploration wells with limited drillcore recovery and a number of relatively shallow rotary cored mineral exploration boreholes along the Curlew Mountain Fault, i.e. along the southern edge of the basin. This drilling data is supplemented by surface outcrop mapping.

The lithostratigraphic units in the Lough Allen Basin largely follow the terminology established in the Sligo Basin by Oswald (1955) to the top of the Dartry Limestone Formation (Tyrone Group) and that of Brandon and Hodson (1984) between the top of the Dartry Limestone Formation and the base of the Namurian (Leitrim Group) (see Figures 2 and 5). The most relevant studies on the Lough Allen Basin sequences are those of Brandon and Hodson (1984), Philcox (1986), Philcox et al. (1992), Cózar et al. (2004) and Somerville et al. (2009).

In the early (Courceyan – Chadian) phases of the development of the Lough Allen Basin, a more stable area is present in the eastern area of the basin in the area of the Macnean and Dowra boreholes, with depocentres in the southwest and west of the basin in the Drumkeeran and Big Dog/Slisgarrow/Kilcoo Cross areas. The basin subsidence is more uniform in the late Chadian – lower Asbian, but reactivation of faults in the Asbian led to development of various depocentres and ramp developments. Again, deposition was more rapid in the northwest, west and southwest of the basin and in the Slieve Rushen area a pull apart basin developed in a transfer zone between the Curlew Mountain and Clogher Valley Fault systems.

Lithostratigraphy

Within the Lough Allen Basin, two distinct Basal Clastic succession types have been identified (Philcox, 1986, Philcox et al. 1992), a "Thin Succession" and a "Thick Succession" (Figure 4). In the "Thin" successions, limestones attributed to the Ballyshannon Limestone Formation lie directly on a mixed interval of sandstones, siltstones, mudstones and thin limestones with evaporites. In many of the boreholes, a tripartite division can be identified in the Basal Clastics, comprising a lower sandstone unit, overlain by evaporitic silty, sandy evaporitic mudstones, which are in turn overlain by an upper sandstone unit. This is particularly evident in the Kilcoo Cross, and Macnean No. 2 wells. It is less distinct in Dowra No. 1 and Drumkeeran No. 1 but is still recognisable. In the "Thick" successions, an interval of highly argillaceous carbonates, primarily composed of calcareous shales and argillaceous limestones is developed between the top of the Basal Clastics and the base of the Ballyshannon Limestones. This interval has been assigned by Philcox to the Kilbryan Limestone Formation, using the terminology of Dixon (1972) from the adjacent Ballymote Succession. This unit is particularly well developed in the Slisgarrow, Big Dog No.1 and Drumkeeran wells. Available dating indicates the Basal Clastics are of Courceyan age and the Kilbryan Limestone, where developed, is of Courceyan to lowermost Chadian in age. Just northwest of Lower Lough Erne, a black mudstone unit, the Keenaghan Shale Formation has been recorded (Mitchell, 2004), and is shown my Mitchell (2004) to be a lateral equivalent to the Kilbryan Limestone in this area.

Ballyshannon Limestone Formation

The Basal Clastics/Kilbryan Limestone Formation package is overlain by the Ballyshannon Limestone Formation. In the Lough Allen Basin, the Ballyshannon Limestone is significantly different from the Donegal and Sligo Basins and is different from it's equivalent in the Ballymote succession, the Oakport Limestone Formation. The contact with the underlying Basal Clastics/Kilbryan Limestone Formation tends to be gradational over several 10s of metres and rather than being largely composed of pale to mid-grey grainstones, packstones and micrites, in the western part of the Lough Allen Basin, the Ballyshannon is significantly more argillaceous, composed of fine-grained dark argillaceous limestones and thin calcareous shale interbeds. In the eastern part of the basin, the formation is less argillaceous and is composed of dark grey, medium to thick bedded limestones and thin shales, as seen in a number of quarries (e.g. Magheradunbar Quarry, Figure 1(c)) developed in the Ballyshannon outcrop belt paralleling the western shore of Lower Lough Erne northwest of Enniskillen. The Ballyshannon Limestone Formation shows dramatic thickness variations, in the depocentres up to 750m has been recorded at Slisgarrow and 450m at Drumkeeran. In the Macnean, Big Dog and Kilcoo Cross areas, the formation is between 265m to 350m in thickness. Mitchell (2004) also records early Chadian carbonate mudbanks at the base of the Ballyshannon limestone at Belleek and Bellanaleck, Co. Fermanagh, considered to be Waulsortian mudbanks and the most northerly examples of this facies in Ireland. Available limited dating indicates the Ballyshannon Limestone in the basin is of Chadian to early Arundian in age.

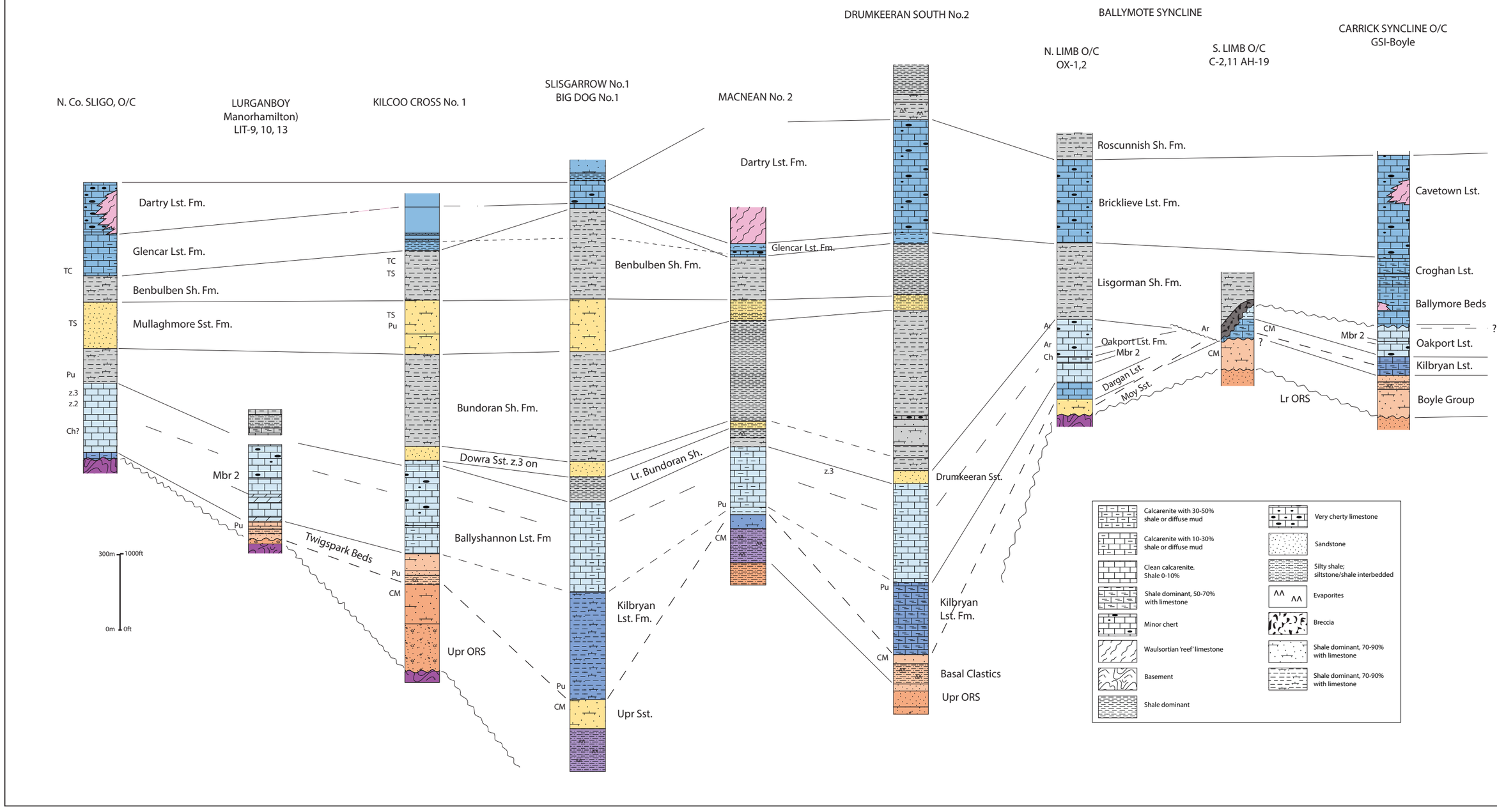


Figure 4: Correlation of successions in the Sligo, Ballymote and Lough Allen Areas Modified from Philcox, 1986.

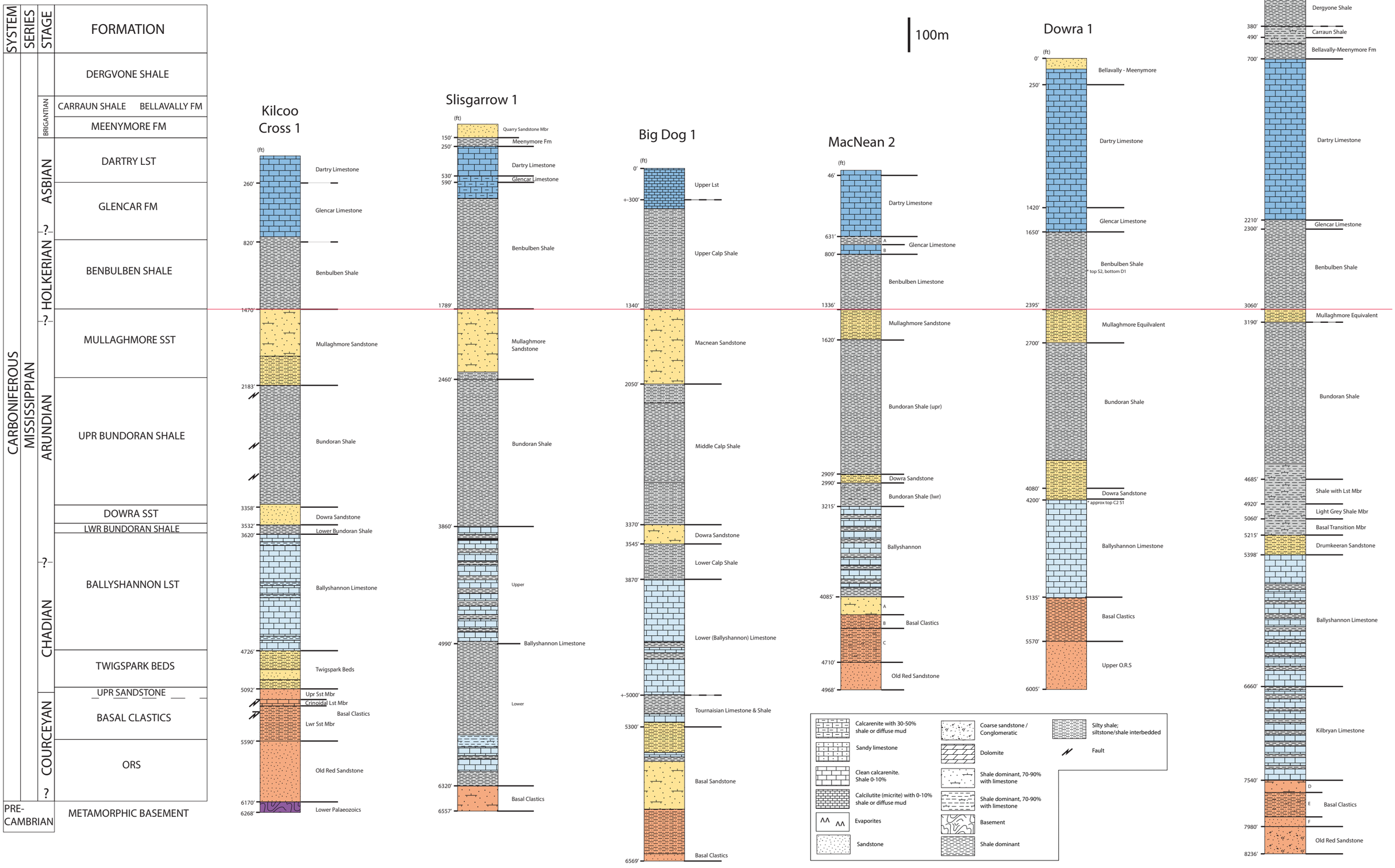


Figure 5: Correlation of selected hydrocarbon wells in the Lough Allen Basin. Modified from Philcox, 1986.

Bundoran Shale Formation

The Ballyshannon Limestone is overlain by the Bundoran Shale Formation which has two significant sandstone units, the Dowra Sandstone Member and the Drumkeeran Sandstone Member developed in the lower part of the formation (Figure 4). The bulk of the Bundoran Shale Formation is primarily composed of dark calcareous shales/mudstones with thin limestone interbeds, although a limestone interval with anhydrite of approximately 15m has been recorded in the Drumkeeran and Macnean No. 2 wells. The Formation is typically about 350m to 450m in thickness in most wells, with a localised thickening to about 680m (including the Dowra Sandstone) in the Drumkeeran No. 1 well. No diagnostic microfossils were obtained from the various hydrocarbon well chippings, but the formation is interpreted as mid to late-Arundian in age.

Dowra Sandstone Member

The Dowra Sandstone Member is only known from wells in the Lough Allen Basin and was first intersected in the Dowra No. 1 well (Sheridan 1972) and has also been intersected in the Kilcoo Cross, Big Dog and Macnean wells. It is developed within the Bundoran Shale, with a thin interval (45m to 50m in the Dowra No. 1 and No. 2 wells but varying from 30m to 90m in other wells) of Bundoran Shale type lithologies between the top of the Ballyshannon Limestone and the base of the Dowra Sandstone. In the north-western part of the basin (Kilcoo Cross No. 1 and Big Dog No. 1), the Dowra Sandstone is composed of up to 53m of sandstones, locally coarse-grained and pebbly, thinning to approximately 25m of finer-grained sandstones in Macnean No.2 and approximately 9.5m of silty mudstone in Dowra No. 1. The variation in thickness and grain size indicates a source from the northwest, thinning and fining to the south and east.

Drumkeeran Sandstone Member

The Drumkeeran Sandstone Member lies directly on the underlying Ballyshannon Limestone, the contact between the two units is sharp, but the top of the member is gradational into a sequence of dolomicrite and silty shale before the onset of typical Bundoran Shale Formation shales and mudstones. The Drumkeeran Sandstone is best developed in the Drumkeeran No.1 well where the type section has been defined. Here it is composed of some 56m of pale grey, fine-grained sandstone with intervals of coarser sandstones and some thin interbedded silty mudstones. The Drumkeeran Sandstone is believed to be sourced from the south, i.e. from the Curlew Mountains area, and has been tentatively correlated with the Greyfield Formation of Philcox et al. (1992).

The Greyfield Formation was first defined by Philcox et al. (1989) from drillcore intersections obtained from exploration drilling along the northern edge of the Curlew Mountains inlier between Lough Key and Drumshanbo by Gortdrum Exploration and Irish Base Metals in the 1960s and 1970s (Figures 1(c) and 4). The formation is a highly complex mix of sandstones, conglomerates (containing clasts of Basal Clastic sandstones), breccias and mudbank

limestones. The base of the formation is erosional and disconformable, it may lie directly on Oakport Limestone or Basal Clastics. It is overlain by Lisgorman Shale Formation/Bundoran Shale facies. The formation is attributed to large scale erosion and northwards deposition resulting from Arundian uplift on the Curlew Mountains Fault. The formation is interpreted as an equivalent to the Drumkeeran Sandstone and the same interval is represented by a marked disconformity between the Oakport Limestone Formation and the overlying Ballymore Limestone Formation in the Roadstone quarry at Boyle (Figure 4, Picture 8 in Pracht this volume), (Philcox et al., 1989, Kelly, 1989 and Kelly and Somerville, 1992).

Mullaghmore Sandstone Formation

As in the Sligo succession, the Bundoran Shale is overlain in the Lough Allen Basin by the Mullaghmore Sandstone Formation. In the northwest of the basin (Kilcoo Cross, Big Dog and Slisgarrow) it is composed of some 195m – 217m of pale grey, medium to fine-grained sandstones and silty mudstones with rare limestones. To the east at Macnean No. 2 it is composed of 87m of finer-grained clastic lithologies (fine-grained sandstones, siltstones and mudstones) and to the south in Dowra No. 1 it is composed of 93m of silty mudstones. Further south again, in Drumkeeran No. 1, it is composed of 48.8m of silty mudstones. The pattern of thinning and fining from northwest to the south and east indicates a sediment source to the north and northwest of the Lough Allen Basin. Miospore analysis (Higgs, 1984) indicates an Arundian – Holkerian age for the Mullaghmore Sandstone.

Benbulben Shale Formation

The Mullaghmore Sandstone is succeeded by the Benbulben Shale Formation, similar to the Bundoran Shale in being predominantly composed of calcareous shales and mudstones with thin interbedded subordinate limestones, but more calcareous and fossiliferous. Within the basin, the formation varies in thickness between 170m (Macnean No. 2) and 365m (Slisgarrow No. 1). Where the formation is thinner, the succession is typical of the formation (i.e. shale dominated with subordinate limestones) but in the intervals, the upper part of the formation is much more calcareous and includes thick limestone units. It is considered likely that this is due to the upper part of the Benbulben Shale in the thicker sequences is a lateral equivalent of the Glencar Limestone and the thickness variations are due to lateral facies variations.

Glencar Limestone Formation

The succeeding Glencar Limestone Formation is distinguished from the underlying Benbulben Shale where the succession becomes limestone dominated with subordinate shales, but in the Lough Allen Basin it is a highly variable unit. In the Slisgarrow No. 1 and Macnean No. 2 wells a 50m thick interval underlying the Dartry Limestone has been assigned to the Glencar Limestone and in the Drumkeeran No. 1 well, a 27m interval of shaley limestone has also been assigned to the Glencar. As referred to above, it is considered that the Glencar and the upper Benbulben are lateral equivalents.

Dartry Limestone Formation

In the Lough Allen Basin, the Dartry Limestone Formation is composed of two main facies, although a number of distinctive members have been defined by GSNI at, or near, the top of the formation in parts of west Fermanagh. The bulk of the formation is composed of dark, fine-grained limestones with abundant chert beds, bands and nodular horizons. The limestones are generally partly silicified and intact fossils, especially corals, are frequently silicified. Interbedded with the "typical" bedded cherty limestones are extensive microbial carbonate mudbank limestones. These are particularly well developed on the north and west flanks of Cuilcagh Mountain, the southern side of Belmore Mountain and to the east of Tullybrack in the Boho – Knockmore area. Other occurrences are found to the west, north and northeast of Slieve Rushen and in the Cashel – Kilcoo area.

In the eastern part of the Dartry Outcrop in Co. Fermanagh, GSNI have identified a number of members at or near the top of the Dartry Limestone (Legg et al. 1996). The Carrickmacsparrow Limestone Member is a 4m thick massive peloidal grainstones, interbedded with typical bedded cherty limestones. The type section is on the southern flank of Belmore Mountain. The Legacurragh Member consists of cherty limestones with abundant silicified colonial rugose corals which can be traced across the northern side of Cuilcagh Mountain and has been correlated with the coral biostromes in the Bricklieve Mountains (Somerville et al. 2009). The Carn Limestone Member consists of interbedded limestones and shales and is restricted to the area immediately north of Boho.

The Dartry Limestone Formation shows significant facies and thickness variations within the Lough Allen Basin. In the East Cuilcagh and Boho areas it is likely at its thinnest and composed largely of bedded cherty limestones, although evidence for shallow water deposition in brackish lagoons and as grainstone shoals has been recorded at East Cuilcagh (Kelly 1989, 1995, Legg et al. 1996). The formation thickens significantly eastwards across the Clogher Valley Fault into the Slieve Rushen depocentre (Figure 1(c)) and thickens dramatically westwards across Cuilcagh Mountain, attributed to sedimentation on a variable subsiding carbonate ramp (Kelly 1989, 1995, Legg et al. 1996). The formation also thickens northwards from the Boho area and southwards to Dowra and Drumkeeran. Thickening is largely associated with the development of thick biostromal carbonate mudbank facies within the formation. On North and West Cuilcagh and in the Tullybrack area of the Fermanagh highlands (Figure 1(c)), the formation is almost entirely composed of mudbank limestones, with the cherty facies forming a thin cap to the formation. In the Lough Allen Basin, the Dartry Limestone is of uppermost Asbian age.

Meenymore Formation

The Meenymore Formation originally formed the lower part of the Aghagrania Formation of West et al. (1968) but was given formation status by Brandon (1972). Within the Lough Allen Basin, Brandon (1977) described the formation in detail in the Leitrim uplands, Slieve Rushen

and Cuilcagh areas and Brunton and Mason (1979) and Brunton (1980) described the formation in the Fermanagh Highlands.

The contact between the Dartry Limestone and the Meenymore Formation is generally sharp and there is evidence in a number of areas for erosion of the Dartry Limestone prior to deposition of the Meenymore Formation (Kelly 1989, 1996, Legg et al. 1998, Somerville et al. 2009). The formation is largely composed of grey calcareous shales, frequently fossiliferous, interbedded with limestones in its lower part. The limestones are predominantly micritic or dolomicritic, frequently laminated and commonly contain evaporite minerals or, more commonly, pseudomorphs after evaporites. Thich sandstones are developed in the middle of the formation in a number of localities (e.g. Slieve Rushen, Fermanagh Highlands, Glangevlin) and the upper part of the formation is more clastic dominated with common sandstones, siltstones and micaceous mudstones and carbonate beds are much rarer.

On Slieve Rushen, an unusually thick development of Meenymore Formation is present, estimated at up to 244m in thickness (Brandon, 1977). The lower part of the formation is 90m thick, largely composed of grey, partly fissile poorly fossiliferous calcareous shales with thin poorly fossiliferous limestones at the base and evidence of? evaporites. The lower Meenymore Formation is separated from the upper part of the formation here by the Sralahan Shale Member, some 6m of distinctive blue-grey poorly fossiliferous shale with rare thin micrite beds. Evaporite bearing beds have been recorded within the shale at a number of localities on Slieve Rushen. The upper part of the formation is 120m to 150m thick, marine shales are rarer but fine-grained, thin-bedded sandstones and siltstones are common, reaching a significant (>20 – 30m) thickness in places (these are worked at Knockateggal and Tonymore Quarries on the east flank of Slieve Rushen, Figure 1(c)).

To the northwest of Glangevlin (Figure 1(c)) on the southwestern side of Cuilcagh mountain, up to three thick evaporite intervals were recorded in the Dowra No.1 well and were extensively drilled in the mid-1980s (Kelly, 1989 and Grennan, 1992). The evaporite horizons are largely composed of gypsum above 16mOD, but anhydrite dominated below that elevation. The evaporite horizons are up to 6m in thickness. The gypsum horizons are interbedded with typical Meenymore shales, laminated stromatolitic limestones and argillaceous limestones. A sandstone wedge thinning out to the southeast is present in the northwestern part of the drilled area.

The Meenymore Formation was originally considered to be upper Asbian in age based on Goniatite faunas, but recent work on foraminifera, calcareous algae, rugose corals and a review of previous work on conodonts has assigned the Meenymore to the Brigantian, with the Dartry/Meenymore contact at the Asbian/Brigantian boundary (Cózar et al. 2004).

Glenade Sandstone Formation

The overlying Glenade Sandstone Formation outcrops extensively in the upland areas in the Lough Allen Basin and has been described in detail by Brandon and Hodson (1984). Within the

Lough Allen Basin, the Glenade Sandstone is typically composed of brown to buff thick-bedded, medium-grained sandstones. They are generally homogeneous and orthoquartzitic in nature, differing mineralogically from the formation in the type area where it is an arkose with up to 50% feldspar. Mitchell (2004) notes that on Cuilcagh Mountain, where the formation is approximately 30m thick, it is cyclic in nature, made up of 3 approximately 10m thick cycles. The formation, like the Mullaghmore Sandstone, thins from the northwest of the area to the south and southwest and is absent in the Drumkeeran No. 1 well. These variations in formation thickness and mineralogy indicate a sediment source from the north and northwest.

Bellavally Formation

The Bellavally Formation is composed of a similar lithofacies package as the Meenymore Formation but is noticeably cyclic and can be sub-divided by Brandon and Hodson year into a total of nine members which are laterally extensive and can be traced across much of the formations outcrop area. The formation originally formed the upper part of the Aghagrania formation of West et al. (1968). The formation generally consists of four lithofacies; grey calcareous shales with thin micrites and marine fossils, laminated stromatolitic micrites and dolomicrites with grey shale and evaporites, green grey and grey silty mudstones and micaceous ripple bedded sandstones, siltstones and mudstones with desiccation cracks.

The basal member lying directly on the Glenade Sandstone is the Tullyskeherny Member, composed of up to 1.5m of stromatolitic micrite and dolomicrite, occasionally with an oolite bed. This is overlain by up to 3.0m of grey calcareous shale with thin micrite beds with a marine fauna, the Larkfield Shale Member. The overlying Sraduffy member consists of laminated micrites which mark the top and base of the member, separated by a thick sequence of shale, mudstone, siltstone and sandstones, the sandstones contain up to 90% quartz. The Sraduffy Member is overlain by the Lugasnaghta Shale Member, 4.6m to 6.1m of grey calcareous highly fossiliferous shales containing thin micrite beds or nodular micrite bands, which is in turn overlain by up to 3.8m of stromatolitic micrite and thin shale, named the Drummangarvagh Member. A major change in sedimentation pattern is marked by the deposition of the Doobally Sandstone Member, composed of pale brown, medium-grained thick-bedded sandstones, with occasional pebble beds, siltstones and mudstones. It is lithologically similar to the Glenade Sandstone, is 17m thick in the Fermanagh Highlands (Brandon 1972), approximately 15m thick at Cuilcagh, but only 1.5m thick at Aghagrania. As with the Mullaghmore and Glenade Sandstones, it clearly thins from northwest to the south and southeast indicating a source similar to the other formations. The Doobally Sandstone is overlain by a thin stromatolitic limestones, the Glenkeel Member, which is succeeded by the Sheena Shale Member, similar in lithofacies to the Lugasnaghta and Larkfield Shales. The uppermost unit in the Bellavally Formation is the Corry Member, consisting of two beds of stromatolitic dolomicrite separated by a grey shale and with common pseudomorphs after gypsum and anhydrite at the base of the member.

Carraun Shale Formation

The youngest formation of Viséan age in the Lough Allen Basin is the Carraun Shale Formation, described in detail by Brandon and Hodson (1984). The Carraun Shale is a relatively uniform sequence of mid to dark-grey, sometimes greenish grey, very fossiliferous calcareous mudstones and shales with common thin laterally persistent micritic limestones. The lowermost part of the formation contains numerous limestones beds and is termed the Derreens Limestone Member. This is overlain by a shale/mudstone dominated sequence, which is capped by a distinctive, laterally persistent stromatolitic limestone bed some 1.95m thick, named the Tawnyunshinagh Limestone Member. In the Lackagh, Arigna and Slieve Anierin areas, the Tawnyunshinagh Limestone is overlain by a thick (0.85m) fine-grained calcareous sandstone, the Graffy River Sandstone Member. The upper part of the formation, above the Tawnyunshinagh Limestone is composed of dark grey, fossiliferous calcareous shales with three laterally persistent limestone/dolomite beds with diagnostic goniatite faunas termed the Ardvarney (0.3m thick), Sranagross (0.15m to 0.6m thick) and Camderry (0.3m to 1.2m thick) Members. In the Fermanagh Highlands the formation is some 160m thick, but is thinner further south, estimated at 52m in the Dough/Thur Mountain area and 46m thick at Slieve Anierin. The Carraun Shale Fortmation is uppermost Brigantian in age and the top of the formation is defined by a marked change in sedimentation pattern to a sequence dominated by fore-delta non-calcareous unfossiliferous shales (with thin fossiliferous marine bands) of the Dergvone Shale Formation.

List of Figures

Figure 1(a): Regional Geology map showing the Sligo, Ballymote and Lough Allen Basins, boreholes and site locations.

Figure 1(b): Sligo and Ballymote Basins. Bedrock Geology, boreholes and localities.

Figure 1(c): Lough Allen Basin. Bedrock Geology, boreholes and localities.

Figure 2: Correlation of Carboniferous successions described. Modified from Somerville and Waters (2011) and Mitchell and Somerville (2011).

Figure 3: Correlation of basal successions in the Sligo, Ballymote and Lough Allen Areas. Modified from Philcox, 1986.

Figure 4: Correlation of successions in the Sligo, Ballymote and Lough Allen Areas Modified from Philcox, 1986.

Figure 5: Correlation of selected hydrocarbon wells in the Lough Allen Basin. Modified from Philcox, 1986.

References and Further Reading

Avbovbo, A.A. 1973. Sedimentary analysis of Viséan clastics in North Western Ireland. Unpublished Ph.D. thesis, University of London.

Brandon, A. 1972: The Upper Viséan and Namurian shales of the Doagh outlier, County Fermanagh, Northern Ireland. Irish Naturalists Journal 17, 159-170.

Brandon, A. 1977: The Meenymore Formation - An extensive intertidal evaporitic formation in the Upper Viséan (B_2 of Northwest Ireland, Report of the Institute of Geological Sciences No. 77/23, 1-14.

Brandon, A. and Hodson 1984: The stratigraphy and palaeontology of the late Viséan and early Namurian Rocks of Northeast Connaught. Geological Survey of Ireland Special Paper No. 6, 1-54.

Brunton, C.H.C. and Mason, T.R., 1979. Palaeoenvironment and correlations of the Carboniferous rocks in west Fermanagh, Ireland. Bull. Br. Mus. Nat. Hist. (Geol.), v. 32, no. 2, p. 91-108.

Clayton, G., Graham, J. R., Higgs, K., Holland, C. H. & Naylor, D. 1980. Devonian rocks in Ireland: a review. Journal of Earth Sciences, Royal Dublin Society 2, 161-83.

Cózar, P. Somerville, I.D., Aretz, M. and Herbig, H-G. 2005. Biostratigraphical Dating of Upper Viséan Limestones (NW Ireland) using Foraminiferans, Calcareous Algae and Rugose Corals. Irish Journal of Earth Sciences, 23. 1 – 23.

Dixon, O. A. 1972: Lower Carboniferous rocks between the Curlew and Ox Mountains, Northwestern Ireland. Journal of the Geological Society of London 128, 71-101

Graham, J.R. 2017. The Mullaghmore Sandstone Formation of North-West Ireland: A Regional Mississippian Lowstand Deposit. Irish Journal of Earth Sciences 35, 19-34

Grennan, E. 1992. The Glangevlin gypsum deposit, Co. Cavan. In Bowden, A.A. et al. (eds), The Irish Minerals Industry 1980 – 1990. Irish Association for Economic Geology.

Higgs, K. 1984. Stratigraphic palynology of the Carboniferous rocks in NorthWest Ireland. *Bulletin of the Geological Survey of Ireland*, 171-201.

Hitzman, M. W. (1986). Geology of the Abbeytown Mine, Co. Sligo, Ireland. In: Andrew, C. J., Crowe, R. W. A., Finlay, S., Pennell, W. M. and Pyne, J. F. (Eds), Geology and Genesis of Mineral Deposits in Ireland, Irish Association for Economic Geology, Dublin, Ireland p449 - 456.

Hubbard, W. F. 1966: Geology of part of the Northwest Carboniferous Basin with special reference to the Lough Macnean - Lower Lough Erne Region, Ireland . Unpublished Thesis. National University of Ireland.

Kelly, J. G., 1986: The geology of northern Cuilcagh Mountain, Co. Fermanagh. Unpublished B. Sc. Thesis, Queens University of Belfast.

Kelly, J.G., 1989: The late Chadian to Brigantian Geology of the Carrick-on-Shannon and Lough Allen Basins, Northwest Ireland. Unpublished Ph. D. Thesis, National University of Ireland.

Kelly, J. G. and Somerville, I. D. 1992. Arundian (Dinantian) carbonate mudbanks in north-west Ireland. Geological Journal, 27, 221-241.

Kelly, J. G. 1995. The Asbian geology of the Cuilcagh Mountain area, Co.'s Fermanagh and Cavan, Ireland. Initiation, growth and decline of a tectonically controlled carbonate ramp. In Somerville, Jones and Strogen (eds) European Dinantian Environments II. Special publication of the Geological Society of London 107.

Legg, I. C., Johnston, T. P., Mitchell, W. I. and Smith, R. A. 1998. Geology of the country around Derrygonnelly and Marble Arch. Memoir of the Geological Survey of Northern Ireland, Sheets 44, 56 and 43 (Northern Ireland).

Legg, I.C., Johnston, T.P., Mitchell, W.I. and Smith, R.A. 1998. *Geology of the country around Derrygonnelly and Marble Arch.* Memoir of the Geological Survey of Northern Ireland, Sheets 44, 56 and 43 (Northern Ireland).

MacDermot, C.V., Long, C.B. and Harney, S.J. 1996. Geology of Sligo-Leitrim. A geological description of Sligo, Leitrim and adjoining parts of Cavan, Fermanagh, Mayo and Roscommon, to accompany bedrock geology 1:100,000 scale map series, Sheet 7, Sligo-Leitrim with contributions by K. Claringbold, G. Stanley, D. Daly and R. Meehan. Geological Survey of Ireland, 100pp.

Mason, T.R., 1978 Revision of the Stratigraphy of the Doagh Outlier, County Fermanagh, Northern Ireland. The Irish Naturalists' Journal, Vol. 19, No. 5, pp. 162-163

Mitchell, W.I. 2004. Carboniferous. In Mitchell, W.I. (ed.), *The Geology of Northern Ireland – Our Natural Foundation.* 79-116. Belfast. Geological Survey of Northern Ireland.

Morris, J.H., Somerville, J.D. and MacDermot, C.V. 2003. A geological description of Roscommon, Longford, Westmeath, and adjoining parts of Cavan, Leitrim and Galway, to accompany the Bedrock Geology 1:100,000 Scale Map Series, sheet 12, Longford Roscommon, with contributions by D. G. Smith, M. Geraghty, B. McConnell, K. Claringbold, W Cox and M. Lee Geological Survey of Ireland.

Oswald, D. H. 1954: The Carboniferous rocks between the Ox Mountains and Donegal Bay. Quarterly Journal of the Geological Society of London 111, 167-182.

Philcox, M.E. 1983a. Carboniferous Succession in Penarroya' s LIT- cores, Manorhamilton, Co. Leitrim. Unpublished Rep.

Philcox, M.E. 1983b. Drilled Carboniferous Succession in the Ballymote Basin, Counties Sligo and Mayo. Unpublished Rep.

Philcox, ME. 1983c. Carboniferous Succession in Basin Exploration Holes (RP-), Rosses Point, Co. Sligo. Unpublished Rep.

Philcox, ME. 1983d. The Drilled Carboniferous Successions near Ballysadare and Skreen, Co. Sligo Unpublished Rep.

Philcox, M. E., Sevastopulo, G. D. and MacDermot, C. V. 1989: Intra-Carboniferous tectonic activity on the Curlew Fault, northwest Ireland. In "The Role of Tectonics in Devonian and Carboniferous sedimentation in the British Isles. Eds. Arthurton, R.S., Gutteridge, P. and Nolan, S.C. Occasional Publication No.6, Yorkshire Geological Society.

Philcox, M. E., Baily, H., Clayton, G. and Sevastopulo, G. D. 1992. Evolution of the Carboniferous Lough Allen Basin, Northwest Ireland. From Parnell, J. (ed.), 1992, Basins on the Atlantic Seaboard: Petroleum Geology, Sedimentology and Basin Evolution. Geological Society Special Publication No 62, pp 203 - 215.

Schwarzacher, W. 1961: Petrology and structure of some Lower Carboniferous reefs in Northwest Ireland. Bulletin American Association of Petroleum Geologists 45 1481-1503.

Somerville, I.D., Cózar, P., Aretz, M., Herbig, H., Mitchell, W.I. and Medina-Varea, P. 2009. Carbonate facies and biostromal distribution in a tectonically controlled platform in northwest Ireland during the late Viséan (Mississippian). Proceedings of the Yorkshire Geological Society, Vol. 57, Parts 3–4, pp. 165–192.

Waters, C. N. and Somerville, I.D. 2011. Northern Ireland. *In* Waters, C.N. et al. *A Revised Correlation of Carboniferous Rocks in the British Isles.* Geological Society Special Report No. 26. 119-127.

West, I. M., Brandon, A. and Smith, M. 1968: A tidal flat evaporitic facies in the Viséan of Ireland. Journal of Sedimentary Petrology 38 1079-1093.