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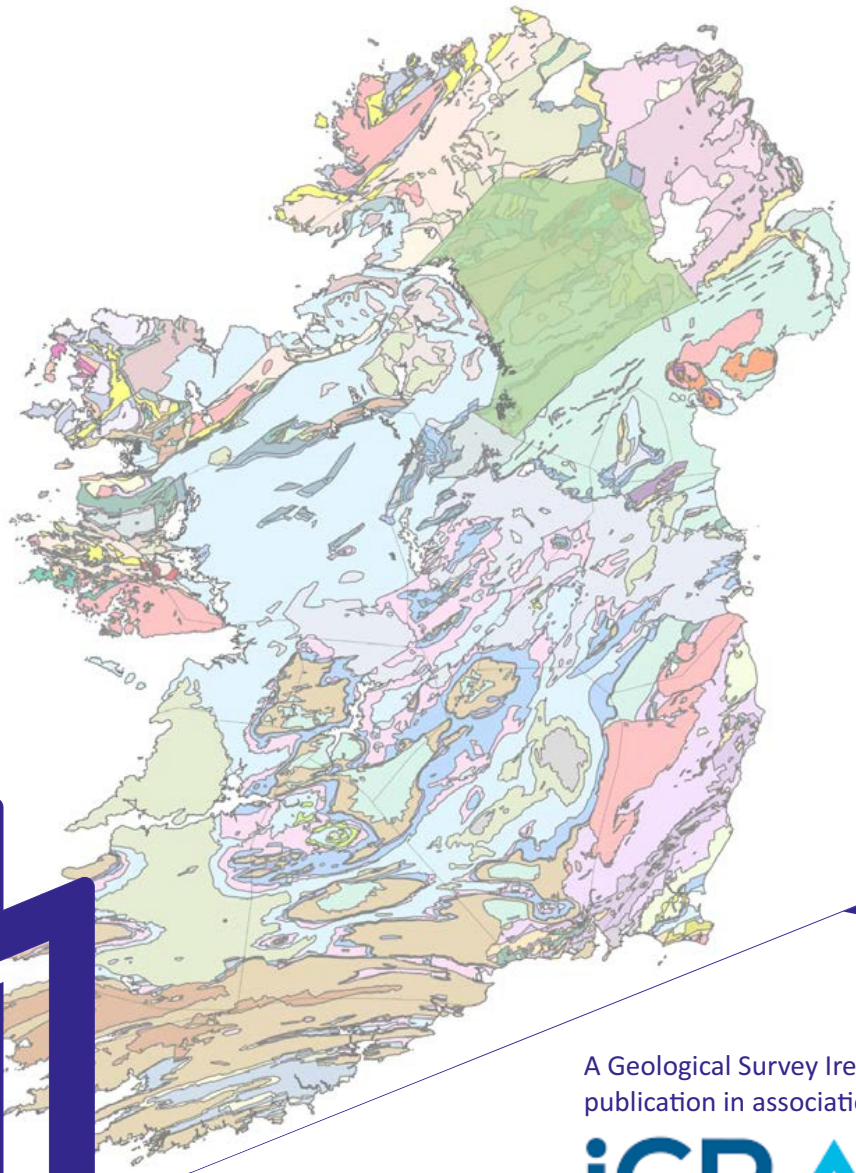
The Lithostratigraphy of the Tournaisian & Viséan of Ireland: East of the River Erne

Author: Dr John Kelly

Editors: R Doyle, Dr M Pracht



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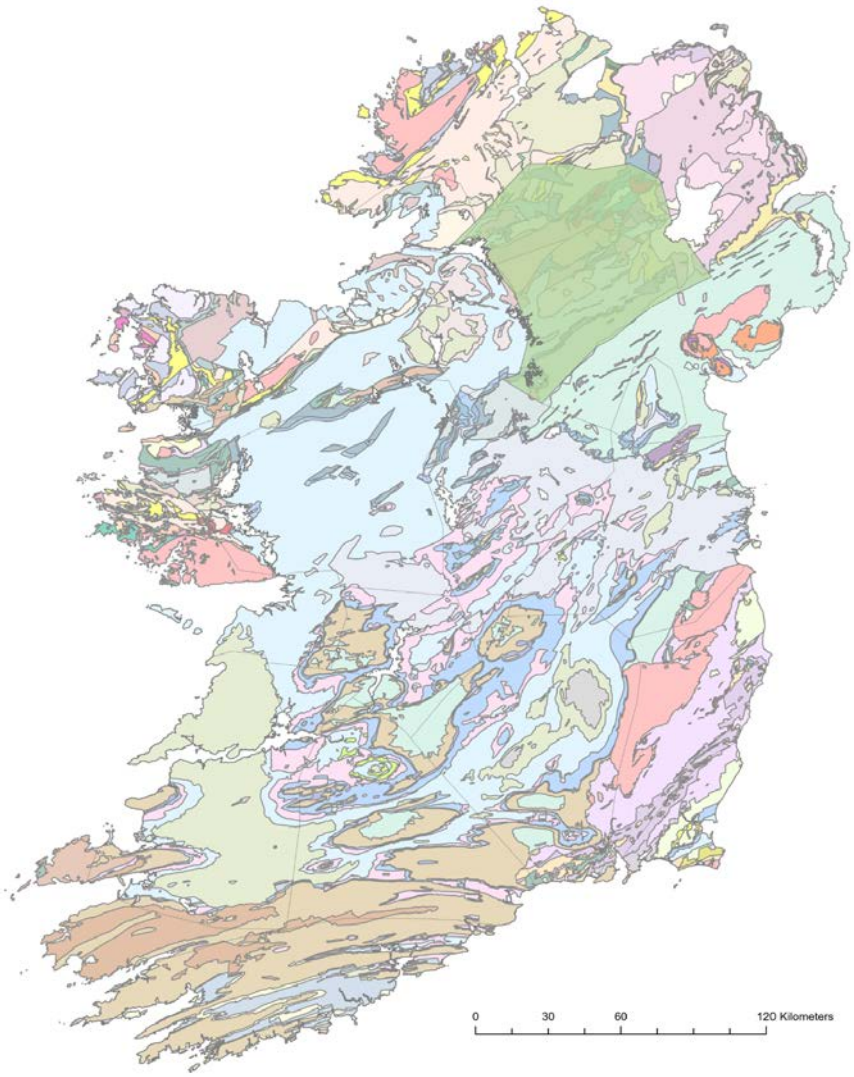
Study Area:

East of the River Erne



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Introduction and Regional Setting

This section details the Mississippian successions located east of Lough Erne and north of the Longford-Down Lower Palaeozoic block (Figures 1 and 2). The area covers an area roughly bounded by Enniskillen, Cavan, Monaghan, Armagh, Cookstown and Dungannon and has previously been sub-divided into several sub-areas (from east to west) termed the Armagh Platform, The Clogher Valley – Aughnacloy – Benburb succession, the Lisnaskea – Slieve Beagh succession and the Cavan - Monaghan Succession. An isolated area to the northwest of the Fintona Uplands is termed the Kesh-Omagh Basin and the Newtownstewart Outlier. Mississippian (Asbian – Brigantian) Redbeds within the Fintona Uplands are also described. Correlation of the various successions is presented in Figure 3 (modified from Mitchell and Somerville 2011).

Carboniferous outliers at Draperstown, Dungiven and Limavady, Co. Londonderry, Cultra and Castle Espie, Co. Down, Cranfield Point/Carlingford, Co. Down and Co. Louth and Ballycastle, Co. Antrim are described elsewhere. The areas underlain by Mississippian (Courceyan – Viséan) rocks east of Lough Erne and immediately north of the Longford – Down Lower Palaeozoic Belt can be divided into a number of sub-areas, based on their lithostratigraphic successions.

The easternmost succession is centred in the Armagh and Cookstown/Dungannon areas, where formations assigned to the Tyrone Group are overlain by a distinctive shallow water, predominantly limestone succession, termed the Armagh Group.

Immediately west, in the Benburb, Aughnacloy and Clogher Valley area the succession is attributed in its entirety to the Tyrone Group. To the south and southwest of the Clogher Valley in the Lisnaskea and adjacent Cavan/Monaghan areas the succession shows a number of similarities.

To the northwest of the Clogher Valley, Mississippian redbed successions have been identified in the Fintona Block, separated from Devonian redbeds by a series of major faults.

To the northwest of the Fintona Block is the Kesh – Omagh area, with a succession similar to that of the Tyrone Group, but with a significantly greater clastic input. To the north of the Kesh – Omagh area is the Newtownstewart Outlier, with a succession that can be correlated to the Omagh area, but almost totally clastic dominated due to its proximity to the main Carboniferous clastic sources to the north and west.

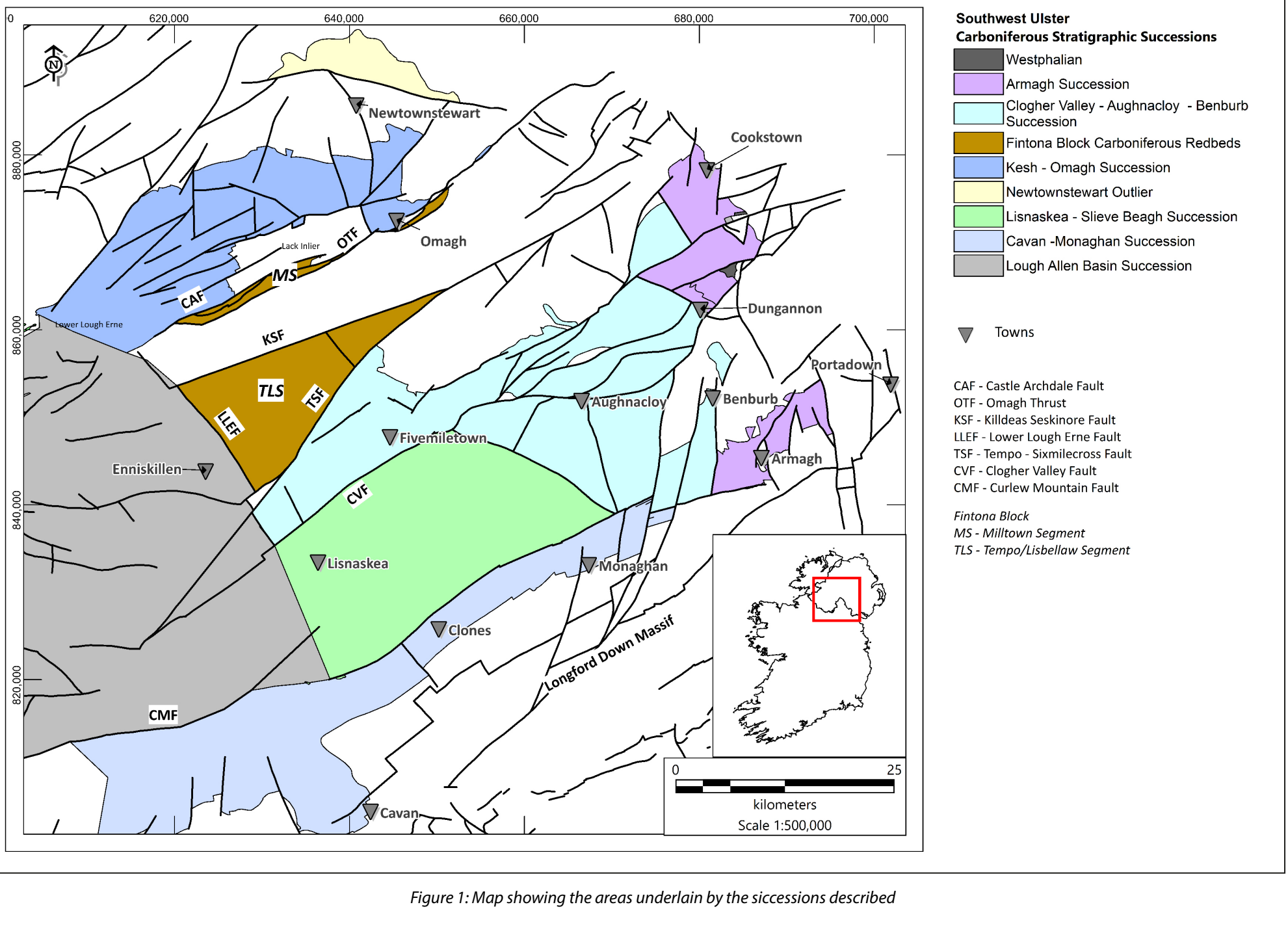

Figure 1: Map showing the areas underlain by the siccessions described

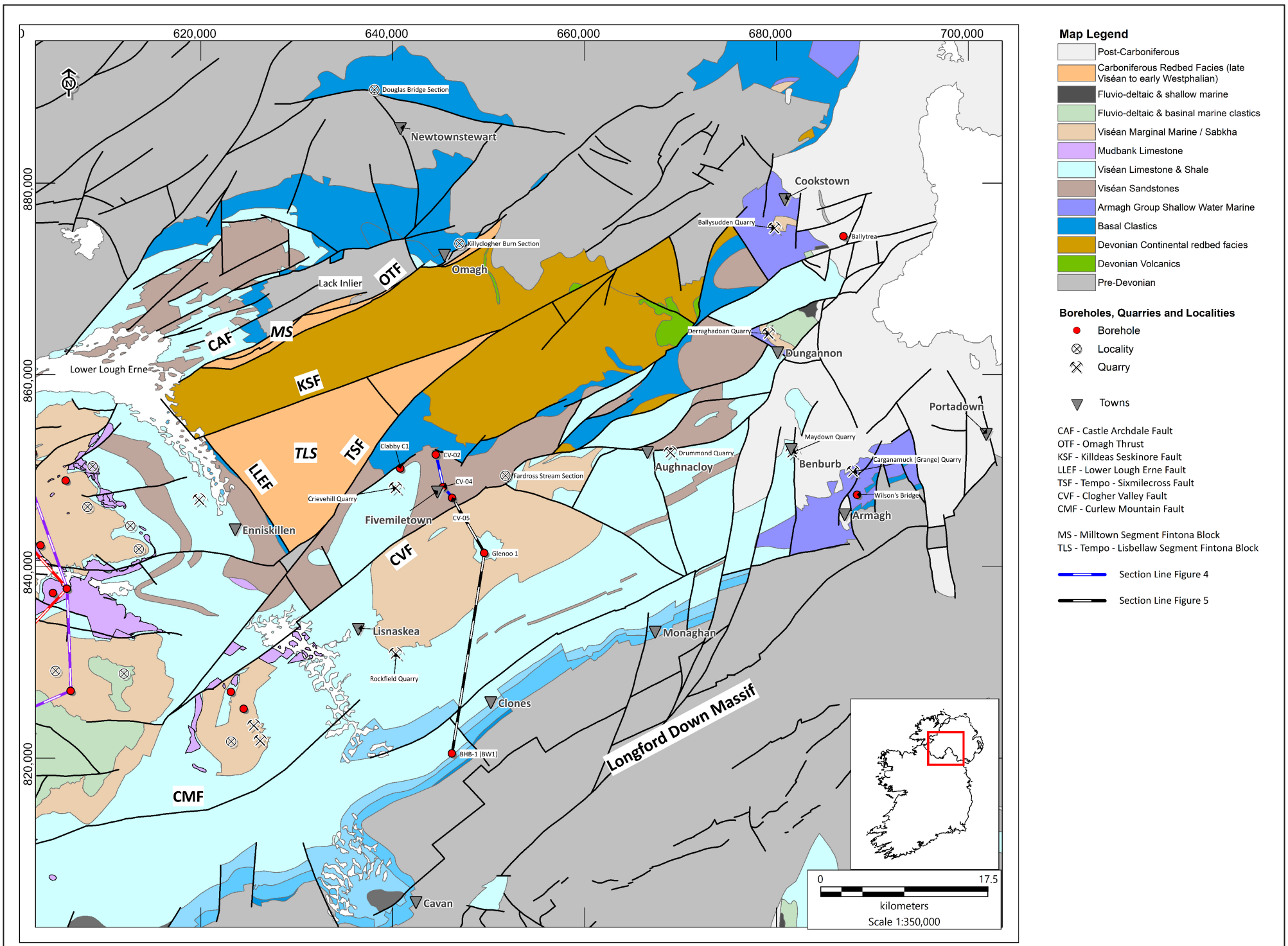

Figure 2: Regional Geology map showing the areas described with borehole and site locations

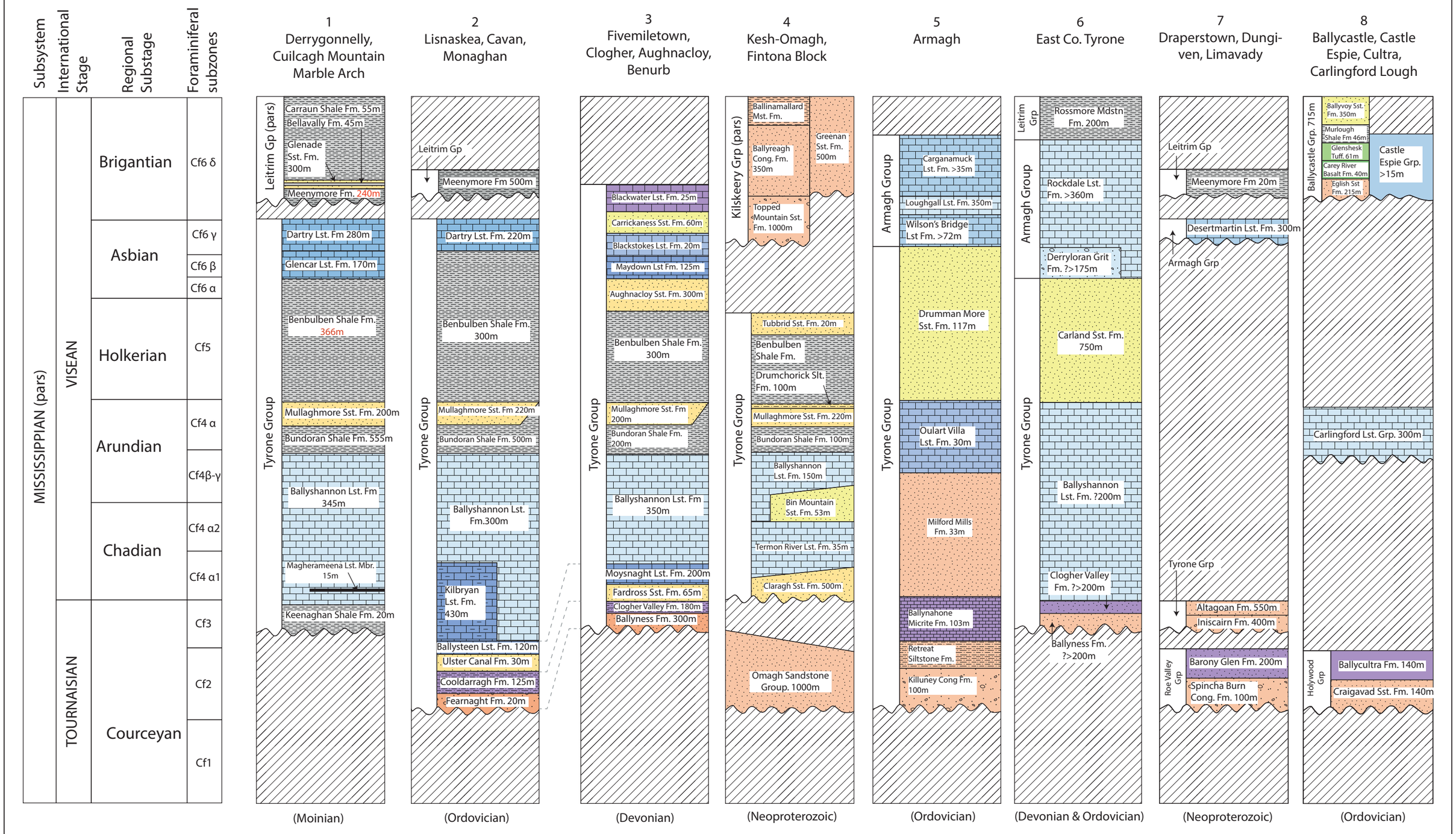

Figure 3: Correlation of Carboniferous Sequences East of the River Erne
(Modified from Mitchell and Somerville, 2011)

Armagh Succession

The area underlain by the Armagh Platform succession is heavily glaciated, with thick superficial deposits so the succession is mainly derived from drilling undertaken by a Glencar Explorations Ltd./Aquitaine Oil (UK) Ltd. Joint Venture at Wilson's Bridge in 1976 and described by Somerville et al. (2001). The lowermost part of the succession is exposed at Killuney and Retreat and the uppermost part of the succession is exposed in quarries at Carganamuck and Loughgall. Successions attributed to the Armagh Group also occur at Cookstown and Dungannon, Co. Tyrone.

Armagh Area

The Armagh area succession is largely based on the Wilson's Bridge drilling (Figure 2). The lowermost six Formations are attributed to the Tyrone Group (Killuney Conglomerate Formation, Retreat Siltstone Formation, Ballynahone Micrite Formation, Milford Mills Formation, Oulart Villa Formation and the Drumman More Sandstone Formation), while the upper three Formations are attributed to the Armagh Group (Wilson's Bridge Limestone Formation, Loughgall Limestone Formation and the Carganamuck Limestone Formation; Somerville et al., 2001; Mitchell, 2004).

The base of the succession has not been intersected by drilling, but the unconformable contact between the lowermost Carboniferous unit, the Killuney Conglomerate Formation, and Ordovician metasediments (termed the Acton Group by GSNI (1984), and undifferentiated Northern Belt by GSI (Geraghty, 1997) is exposed in the Killuney Stream. The Killuney Conglomerate Formation is a red-bed succession, some 80 to 100m thick, composed of red-purple microconglomerates, fine- to coarse-grained red sandstones and banded red siltstones and clays. The Killuney Conglomerate Formation is overlain by the Retreat Siltstone Formation.

The lower part of the Retreat Siltstone Formation is exposed in the Killuney stream section and the best exposures are in a stream section northwest of Retreat House. The upper part of the Formation (42.95m) is intersected in borehole WB3 at Wilson's Bridge, the total thickness is estimated at 75 – 90 m. This unit consists of alternating thinly-bedded, green-brown to purple-red sandstones, siltstones and mudstones with arenaceous dolomites at the top of the Formation. In WB3, the Formation can be sub-divided into two units, the lower unit is similar to the type section at Retreat House, the upper unit is distinguished by the presence of thick beds of medium- to coarse-grained grey sandstones with conglomerate bands and sandy micrites and dolomites in the uppermost part of the Formation. The top contact is sharp and taken at the top of a medium-grained sandstone overlain by a black shale.

A significant change from predominantly clastic sedimentation to carbonates is marked by the deposition of the Ballynahone Micrite Formation, some 102.95m thick in WB3. The Ballynahone Micrite consists of grey, predominantly micritic limestones, interbedded with green and black mudstones. The limestones are variable, including massive micrites, dolomicrites, bioturbated and laminated micrites, with desiccation cracks, fissures and fenestrae recorded, along with evidence of evaporites in the form of rare pseudomorphs after gypsum in the lowermost beds. Some coarser limestones are present, comprising skeletal,

peloidal, intraclastic packstones and grainstones in which calcareous algae and foraminifers may be locally abundant. Variable amounts of clastic grains of feldspar and quartz occur. The formation is Chadian in age.

The Ballynahone Micrite is overlain by the Milford Mills Formation, some 42.7m thick in WB3, representing a return to clastic-dominated deposition. The formation comprises predominantly non-marine lithologies, varying from polymict sandstones, siltstones, dolomites, and mudstones with calcretes. The conglomerates contain pebbles of sandstones, micrite and green mudstone flakes, the sandstones are predominantly green, medium- to coarse-grained and laminated, occasionally red or white with cross-lamination and grading. The mudstones and siltstones are red and green. The top of the formation is marked by rare grey and black shales, containing skeletal debris with coal fragments and plant material, and thin limestones and dolomites with rare crinoids. A thinner (15m), but lithologically similar succession has been intersected in the Milford Mills borehole (3 km southwest of Armagh).

The Milford Mills Formation is overlain in WB3 by about 9m of limestones interbedded with thin black mudstones/shales, termed the Oulart Villa Limestone Formation. The limestones are composed of thinly-bedded, pale grey bioclastic packstones and wackestones, dolomitised in the lower part of the interval and sandy in the upper part.

The succeeding formation, the uppermost unit of the Tyrone Group, is the Drumman More Sandstone Formation, first referred to by GSNI (1984), and was subsequently formally defined in WB3 by Somerville et al. (2001). In WB3 it is a 117 m-thick deltaic succession, largely composed of red and green, medium-grained, non-calcareous, micaceous sandstones interbedded with red, purple, green or yellow mudstones. Mudstone clasts and black coal streaks or organic bands are present in the sandstones, particularly on cross-bedding foresets, accentuating the sedimentary fabric. The lowermost part of the formation is partially marine, rare calcareous sandstones and thin fossiliferous limestones.

The Tyrone Group in the Armagh platform is overlain by the Armagh Group, distinguished by being composed of generally pale, open marine, shallow water limestones with subordinate sandstones and mudstones, and marked by the presence of palaeokarst surfaces and reddish-brown clay palaeosols resting on the palaeokarst surfaces.

The basal formation in the Armagh Group is the Wilson's Bridge Limestone Formation, in which most of the Wilson's Bridge boreholes collared. The maximum recorded thickness is 81.2m in WB6, but a total thickness of only 26.5m was intersected in WB5, which collared in the overlying Loughgall Limestone Formation. It is evident, therefore, that the thickness of this formation can be highly variable or that there are significant lateral facies variations over very short distances. The Wilson's Bridge Limestone is described by Somerville et al. (2001) as being composed of pale to dark grey, frequently red-stained, thick bedded bioclastic limestones with abundant colonial and solitary corals interbedded with thin calcareous, bioturbated bioclastic shales, locally rich in brachiopods or red clay bands. The limestones are dominated by skeletal, peloidal packstones and grainstones, typically more sandy or argillaceous in the basal part of the formation.

The succeeding formation, the Loughgall Limestone Formation is composed of pale grey thick- (typically 2.5m) bedded oolitic, skeletal grainstones, typically with abundant fossils, comprising crinoids, brachiopods and *in situ* colonial rugose corals of Asbian age. Thin channel sandstones, shales and palaeokarst surfaces are recorded in quarry exposures (Figure 2). In WB5, an incomplete succession of 118m was intersected, but GSNI estimate a thickness of 350m in the Loughgall area. The formation is likely an equivalent of the lower part of the Rockdale Limestone Formation in the Cookstown area.

The highest preserved unit in the Armagh Group is the Carganamuck Limestone Formation, exposed in Carganamuck Quarry, 4.25 km north of Armagh City (Figure 2). This unit is composed of dark grey, thinly- bedded wackestones with purple shale parting and colonial corals, overlain by paler, thick bedded grainstones with palaeokarst marked by erosion surfaces and red palaeosols. The base of the formation is not exposed, and the top of the formation is marked by a major disconformity, overlain by the Triassic Milltown Conglomerate Formation and Deerycreevy Sandstone Formation. The macro- and microfaunas indicate that this formation is Brigantian in age and is likely an equivalent of the upper part of the Rockdale Limestone in the Cookstown area.

Dungannon and Cookstown

East of Pomeroy, the Carboniferous lies unconformably on Ordovician rocks of the Tyrone Igneous Complex (Mitchell, 2004) or on Devonian rocks of the Fintona Block and are overlain to the east by Mesozoic and Cenozoic rocks (GSNI, 1960, Cameron & Old, 1997, Mitchell, 2004).

The lower part of the succession is poorly exposed and has not been drilled. The lower part of the succession is assigned to the Tyrone Group (Mitchell, 2004), the lowermost unit is composed of red bed conglomerates, sandstone and siltstones of the Ballyness Formation, overlain by the Clogher Valley Formation. The limestones immediately overlying the Clogher Valley Formation are attributed to the Ballyshannon Limestone Formation and succeeding sandstones of Holkerian to Asbian age (based on miospores) are assigned to the Carland Sandstone Formation.

In the Cookstown/Dungannon area, the Carland Sandstone Formation is overlain by a succession assigned to the Armagh Group. The lowermost unit is composed of non-marine sandstones and interbedded fossiliferous marine sandstones of the Derryloran Grit Formation. The Derryloran Grit Formation is overlain by the Rockdale Limestone Formation which is, in turn, overlain by the Rossmore Mudstone Formation.

The upper Viséan succession has been best intersected in the Ballytrea Borehole (Fowler & Robbie, 1961), some 4.5 km southeast of Cookstown (Figure 2), which intersected some 46.3m of the Rossmore Mudstone Formation (306.0m to 352.3m) and 258m of Carboniferous limestones, here assigned to the Rockdale Limestone Formation (352.3m to end of hole at 611.3m). The lowest unit of the succession intersected at Ballytrea (523.0m to 611.3m) is composed of dark grey, occasionally pale-grey, fossiliferous bioclastic limestones with *Siphonodendron martini, S. pauciradiale, S. junceum* and *Gigantoproductus* sp. This is overlain by a 108.9 m-thick interval (414.1m to 523m) of dark grey to pale grey bioclastic limestones,

occasionally oolitic, with seven recorded sandstone intervals, the thickest of which is about 6.5 m. The uppermost limestone interval is composed of 61.8m (352.3m to 414.1m) of dark grey to pale grey, fossiliferous (abundant brachiopods) bioclastic limestones and nodular limestones (described as "pseudo-breccias" by Fowler & Robbie, 1961). Rare thin mudstones may be present, as are two sandstone intervals in this part of the succession.

At Ballysudden Quarry, 2 km south of Cookstown (Figure 2, the lowest unit exposed consists of non-marine and marine (fossiliferous) sandstones, possibly belonging to the Derryloran Grit Formation, but likely to be a sandstone horizon in the Rockdale Limestone Formation. The overlying unit is composed of pale grey to cream packstones and oolitic peloidal grainstones with subordinate sandstones and mudstones. The mudstones are frequently brown, brown-red or green, occurring above palaeosols developed on palaeokarstic surfaces in the limestone succession. The age of the formation is well constrained here, being of Asbian and lower Brigantian age (Mitchell, 2004).

At Dungannon exposures are very sparse due to extensive drift, GSNI map a small area of Armagh Group limestones dipping to the northeast in the Dungannon town area.

The Rossmore Mudstone Formation is typically composed of dark grey to almost black mudstones, thin siltstones and fine-grained sandstones and is 46.3m thick in the Ballytrea borehole (306.0m to 352.3m). The lower part of the Formation contains the ammonoid *Sudeticeras crenistriatus* indicating a Brigantian (P2a) age, but the upper part of the Formation is undated. It is well exposed at Derraghadoan Quarry, near Dungannon (Figure 2), where shales are extracted for cement manufacture at Cookstown.

Clogher Valley – Aughnacloy – Benburb Succession

This area includes a belt of Mississippian rocks north of the Clogher Valley Fault (CVF) and south of the Fintona Block (trending from Carry Bridge through the Tempo/Fivemiletown/Clogher area to Aughnacloy and Benburb). The western areas are described in Kelly and Jones (2020 in press) and the eastern area is described by Mitchell and Mitchell (1983).

Clogher Valley

In the west of the area the lower part of the Tyrone Group is well known from borehole intersections drilled by The Mission Exploration Company at Clabby and Carry Bridge in 1974 and in the Tempo and Fivemiletown area by Ivernia West plc. in 1998 to 2000. The upper part of the succession is known from exposures and quarries only (Mitchell, 2004)

The basal Carboniferous Formation in this area is the Ballyness Formation, estimated by Michell (2004) to be 300m thick, composed of red and purple-red sandstones and conglomerates with white quartz pebbles. The formation is well exposed in the Cole Bridge stream section and the uppermost few metres of the formation have been intersected in the Mission and Ivernia drilling. The uppermost part of the Ballyness Formation is distinctively different, composed of mottled green, red and buff-grey sandstones with common grey or grey-green nodular micrites or dolomicrites interpreted as calcrete deposits, and termed the Cole Bridge Member by Kelly and Jones (2020). It is 6.7m thick in the type interval in borehole 98-IW/CV-05 (typically abbreviated to CV-05 etc.) and varies from 1.2m to 12.0m in the Ivernia drilling.

The interval between the top of the Ballyness Formation and the base of the Ballyshannon Limestone Formation was assigned in its entirety by GSNI (1983) and Mitchell (2004) to the Clogher Valley Formation, but this has been sub-divided by Kelly and Jones (2020) into three formations based on lithology and depositional environment into: the Clogher Valley Formation *sensu stricto*, the Fardross Sandstone Formation and the Moysnaght Limestone Formation.

In borehole CV-05 at Fivemiletown, the Ballyness Formation is succeeded by an interval of highly variable lithologies, comprising calcareous shales, siltstones, sandstones and evaporates, with subordinate limestones, primarily composed of micrites, algal laminate micrites, evaporitic micrites and dolomicrites, with minor grainstones, packstones and argillaceous wackestones. This 117.1 m-thick interval in CV-05 matches the description of the Clogher Valley Formation by GSNI (1983) and Mitchell (2004), and has been termed the Clogher Valley Formation *sensu stricto* by Kelly and Jones (2020). Of note, are three horizons of massive to semi-massive evaporites, predominantly gypsum above -82m OD and predominantly anhydrite below this depth.

Two persistent and recognisable marker horizons are present in the Clogher Valley Formation, a distinctive fine- to medium-grained sandstone/siltstone and calcareous mudstone, finely laminated with a distinctive flaser-bedded appearance and containing abundant ostracods, formally termed the Blessingbourne Member, and a widespread sandstone unit, informally

termed the 2-3 Sandstone Marker, primarily composed of calcareous bioclastic sandstones, but also containing siltstones, calcareous mudstones, shales or micrites. The Blessingbourne Member is located below the lowest massive evaporite unit, while the 2-3 Sandstone Marker is located between the Lower and Middle Evaporite Units. The Clogher Valley Formation exhibits major thickness and facies variations, generally thinner on the northern side of the Clogher Valley, thickening significantly southeast towards Fivemiletown and southwest towards Carry Bridge (Figure 4).

The Clogher Valley Formation *sensu stricto* is overlain by a thick (64.8m in CV-05) unit dominated by sandstones, termed the Fardross Sandstone Formation by Kelly and Jones (2020). The lower part of the formation is marked by massive bedded, well sorted, laminated, pale to mid-grey calcareous sandstone, composed of straight extinction quartz dominated with minor fresh microcline, rare micas and a calcite cement. This massive sandstone unit is termed the Murley Sandstone Member. The upper part of the Fardross Sandstone Formation is more variable, sandstone dominated, but with thin siltstones, mudstones, argillaceous micrites and micrites. Again, the Fardross Sandstone Formation shows significant thickness variations between the northern and southern areas in the Clogher Valley but does not exhibit the facies variations seen in the Clogher Valley Formation.

The Fardross Sandstone Formation is overlain by an interval of interbedded limestones and black, unfossiliferous, non-calcareous highly fissile shales, termed the Moysnaght Limestone Formation. The limestones vary from rare biomicrites (especially near the base of the formation to the north) to bioclastic, fossiliferous packstone and grainstones. The formation is only fully intersected in Mission borehole **C1** at Clabby (Figure 2), where it is 156m thick, but borehole CV-05 collared in the Moysnaght Limestone Formation and 195.4m was intersected, indicating thickening of the formation from north to south, as with the Clogher Valley and Fardross Sandstone formations.

The Moysnaght Limestone Formation is overlain by the Ballyshannon Limestone Formation, composed of thick-bedded, pale to mid-grey bioclastic, micritic cyclic packstones/grainstones, where cycle tops may be marked by a thin palaeosol or thin, fine-grained sandstones/siltstones. In borehole C1 at Clabby, a 14-m-thick sandstone unit, mineralogically and texturally similar to the Fardross Sandstone Formation, occurs 8.8m above the base of the Formation. Surface exposures of the Ballyshannon Limestone Formation are restricted to some 40 – 50m at Crievehill Quarry northwest of Fivemiletown (Figure 1), a heavily disturbed roadcutting exposure at Brookeborough, some outcrops in small stream sections and a small disused quarry at Mullaghsillogagh. The remainder of the succession in this area is exposed in a stream at Fardross forest (Figure 2), where the units are well-exposed, as they have been strongly tilted by later Variscan(?) movement on the Clogher Valley Fault. Here, the Bundoran Shale Formation, the Mullaghmore Sandstone Formation, the Benbulben Shale Formation, the Glencar Limestone Formation and the Dartry Limestone Formation are exposed. Mitchell (2004) gives no details on the lithological composition or thickness of these units, but the Bundoran Shale Formation, the Mullaghmore Sandstone Formation and the lower Benbulben Shale Formation are recorded as being of mid to late-Arundian, while the upper Benbulben

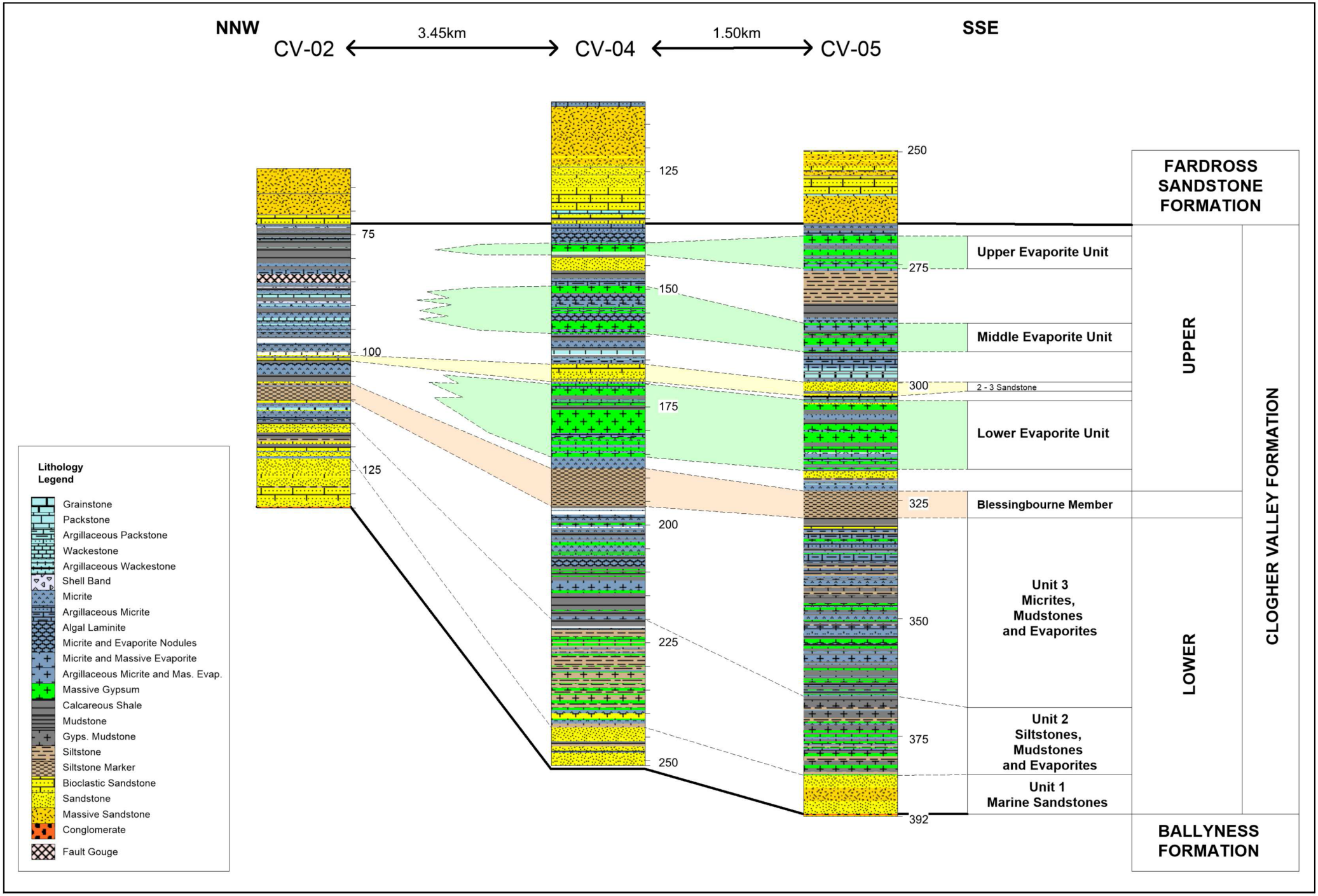

Figure 4. Clogher Valley Facies and Thickness Variations. (Extract from Kelly and Jones, 2020)

Shale Formation, the Glencar Limestone Formation and the Dartry Limestone Formation contain an early Asbian macrofauna.

Aughnacloy – Benburb

The Mississippian stratigraphy in the Aughnacloy area is not well understood as exposure is poor in this area (Mitchell, 2004). The oldest Carboniferous rocks exposed are the Bundoran Shale Formation at Drummond Quarry, 2.5 km east of Aughnacloy (GSNI 1983) (Figure 2). The Bundoran Shale Formation is succeeded by the Benbulben Shale Formation (the Mullaghmore Sandstone Formation appears to be absent). The Benbulben Shale is overlain by the Aughnacloy Sandstone Formation, considered an equivalent to the Carland Sandstone Formation in east Tyrone and the Drumman More Sandstone in Armagh. It has been determined to be of Holkerian to early Asbian age, based on miospores from thin interbedded mudstones and rare early Asbian corals and brachiopods from a thin calcareous sandstone in Carricklongfield Quarry. The Aughnacloy Sandstone Formation is overlain by the Maydown Limestone Formation, which contains an Asbian macrofauna.

In the Benburb area, the succession is much better understood and is summarised from Mitchell and Mitchell (1983). Here the lowest unity exposed is the Maydown Limestone Formation, composed of at least 130m of blue-grey thinly bedded argillaceous limestones, dark grey silty limestones, calcareous siltstones and calcareous shales is exposed at the type section at Maydown Quarry (Figure 2) and adjacent outcrops. The proportion of limestone increases consistently towards the top of the formation and thinly-laminated, cross-bedded sandstones with plant debris and a fine-grained sandstone capping the cycle may be present. In the upper part of the formation, a 5.5m mixed unit of conglomerates, coarse sandstones, micaceous siltstones and a bioclastic limestones are present, termed the Crow Hill Conglomerate and Sandstone Member. This member is thought to be about 12m below the top of the formation.

The Maydown Limestone Formation is overlain by the Blackstokes Limestone Formation, which although not exposed in its entirety, is calculated to be about 20m in thickness. It is sub-divided into two members, the basal Gorestown Mudstone Member consisting of some 9m of highly fossiliferous calcareous indurated mudstones and thin dark micrites and the overlying Rookwood Member, composed of dark grey-brown argillaceous biomicrites and thin dark grey shales and estimated to be 11m in thickness.

The Blackstokes Limestone Formation is overlain by the Carrickaness Sandstone Formation comprising a minimum of 60m of sandstones, siltstones and mudstones which, with the exception of plant debris and rare bivalves, is unfossiliferous. A thin (1m) unit of calcareous sandstone and sandy limestone is present near the top of the formation and contains a sparse macrofauna (brachiopods, bryozoa, bivalves and crinoids. The sandstones are white to pale grey, fine- to medium-grained and quartzose with cross-bedding and ripple marks. The siltstones are laminated, show small-scale rippling and cross-bedding and are bioturbated in places. The mudstones are dark grey to fawn and blocky in nature, containing ironstones.

The youngest Carboniferous unit is the Blackwater Limestone Formation, estimated to be 26m thick, but not completely exposed. It has been sub-divided into 6 members, from base to top,

the Tullymore Limestone Member with 4m of fossiliferous biomicrite and micrite exposed, the Glenview Limestone Member (3m exposed) composed of pale, orange-brown oolitic peloidal grainstones, the Drumflugh Limestone Member (3.4m exposed), pale-grey, rubbly bioturbated micrite and dark grey calcareous shales, the Benburb Mudstone Member (1.4m exposed) composed of dark grey to brown highly fossiliferous mudstone and a thin argillaceous limestone, the Island Sandstone Member (1m), pale purple, unfossiliferous calcareous sandstone and subordinate siltstone and finally, the Outlet Limestone Member of which some 1.3m of pale yellow to fawn, thinly-laminated dolomitic micritic algal laminite with algal nodules and bioturbated with scattered bioclastic fragments is exposed.

Fintona Block Redbeds Succession

The redbeds of the Fintona Block (Clayton et al., 1980) were originally attributed in their entirety to the Devonian Old Red Sandstone (Simon, 1984; House et al., 1985). However, based on new detailed mapping by GSNI and palynological dating (Mitchell & Owens, 1990), large blocks of Carboniferous redbeds between the Castle Archdale and Cloghfin Faults have been dated as Asbian to Pendleian age.

The Milltown Segment (MS), (25 km^2) is located on the northwestern margin of the Fintona Block (Figure 2) and a much larger triangular wedge, the Tempo - Lisbellaw Segment (TLS), (215 km^2) is located at the southwestern part of the Fintona Block (Figure 2) and is bounded by the Lower Lough Erne Fault to the southwest, the Killadeas – Seskinore Fault to the northwest and the Tempo – Sixmilecross Fault to the southeast. The two areas contain distinctly different redbed units of Asbian and Brigantian age and descriptions from Mitchell and Owens (1990) and Mitchell (2004) are summarised here.

Milltown Segment

The Greenan Sandstone Formation is the oldest unit in this area, it is seen to unconformably overlie Dalradian metasediments at the northeastern limit of the outcrop, but all other contacts are bounded by northeast to southwest trending faults. It is in fault contact with the Tyrone Group and Dalradian to the northwest and the other Carboniferous redbeds in this area, the Slievebane Group, to the southeast. The basal part of the Greenan Sandstone Formation is described as a basal breccia, some 30m thick in the type section and composed of an unsorted mix of fine metamorphic debris with angular boulders of psammitic and phyllitic schist and vein and pegmatite quartz, clast size decreases upwards. This basal unit is overlain by some 5m of red mudstone and siltstones with pedogenic carbonate. The rest of the formation is composed of purple-grey, medium- to coarse-grained arkose sandstones, with purple-red and green mudstone laminae. The formation is in excess of 500m in thickness and miospores present indicate a Brigantian to Pendleian age.

To the southeast of the Greenan Sandstone Formation exposure the Slievebane Group is present, the southeastern edge of the outcrop marked by the Omagh Thrust, which thrusts Devonian redbeds over the Slievebane Group. The group has been subdivided by Mitchell and Owens (1990) into two formations, The Tullanaglare Mudstone Formation composed of mottled purple-brown to green-grey mudstones with palaeosols and calcretes and the overlying Drumlish Conglomerate Formation composed of greyish-purple conglomerates with clasts of basaltic and andesitic volcanics and minor metamorphics interbedded with upward-fining coarse- to fine-grained sandstones and green mudstones. Miospores indicate a Westphalian A to B age.

Tempo - Lisbellaw Segment

Within the Tempo - Lisbellaw Segment, the succession youngs to the northwest and the youngest Carboniferous redbeds identified belong to the Topped Mountain Sandstone Formation, composed of over 1000m of grey, red-brown weathering, fine- to coarse-grained

sandstones with greyish-red, purple and green mudstones with calcretes and mud-flake conglomerates. Two distinctive sub-units have been recorded, the Glen Member, some 20m of unfossiliferous grey calcareous siltstone and the Coolcran Conglomerate Member, composed of 40m of pebbly sandstone and conglomerate with lamina of green mudstones which yield miospores. The miospore data indicates the Topped Mountain Sandstone Formation is Asbian to lower Brigantian in age.

This is overlain by the Ballyreagh Conglomerate Formation, composed of 350m of purple-brown to grey conglomerates, pebbly sandstones, sandstones, thin siltstones and mudstone. The succession fines upwards, is unfossiliferous, and the coarse clastic component is largely derived from greywacke sandstones. Miospore data indicates the formation is of Brigantian age. The Ballyreagh Conglomerate is, in turn, overlain by the Ballinamallard Mudstone Formation, composed of greyish-red to greyish- green mudstones and siltstones, with three distinct sandstone units, the Corkill Sandstone, Errington Sandstone and Coa Sandstone Members. Miospores indicate a Pendleian age.

Kesh – Omagh Successions

The Kesh – Omagh Basins lie to the northwest of the Fintona Block and east of Lower Lough Erne. The area has not been drilled and the succession is known entirely from outcrop mapping (Mitchell & Owens 1990; GSNI 1994, 1995, Mitchell, 2000, Mitchell, 2004). This area has been interpreted as lying close to the northern margin of the Carboniferous shoreline in the early and mid-Viséan (Michell, 2004).

The lowermost unit exposed is the Omagh Sandstone Group, of Courceyan age and seen at Killyclogher Burn (Figure 2), where it is composed of a thin basal conglomerate overlain by up to 100m of red sandstones with reworked calcretes and white quartz pebbles. Further east, to the west of the Lack Inlier, the formation is composed of channel sandstones and siltstones with interbedded mudstones containing miospores of Courceyan/ (CM Biozone) miospores. An interbedded marine unit composed of algal micrites with evaporite textures and bioturbation and a crinoidal sandstone has been recorded and is correlated with the Douglas Burn Limestone Member in the Newtownstewart Outlier.

The Omagh Sandstone Group is succeeded by a number of formations assigned to the Tyrone Group. The basal formation is the Claragh Sandstone Formation, which lies unconformably on the Omagh Sandstone Group and oversteps it westwards to rest directly on the Dalradian. The Claragh Sandstone Formation is estimated to be 320 – 500m thick (Mitchell, 2004).

Newtownstewart Outlier

The Newtownstewart Outlier (Figure 1, Figure 3 Column 7) is an outlier of Carboniferous rocks, predominantly non-marine clastics lying to the north of Newtownstewart. The southern margin is bounded by a west-northwest to east-southeast trending, northerly downthrowing unnamed normal fault, while the western, northern and eastern margins of the outlier are unconformable on the Dalradian succession.

The succession in the outlier was assigned originally to the Owenkillew Sandstone Group (Mitchell, 2004) but has been subsequently amended (GSNI, 2008) to the Roe Valley Group (as defined to the northeast in Co. Londonderry, cf. Mitchell & Somerville, 2011). This consists of two formations, the Spincha Burn Conglomerate Formation and the Barony Glen Formation, which is a lateral equivalent of the Omagh Sandstone Group. The Roe Valley Group is shown by GSNI (2008) as being of Courceyan age.

The Spincha Burn Conglomerate Formation is composed of conglomerates, the clasts are composed of pebbles and cobbles of vein quartz, rounded pale grey and rounded greenish-grey quartzites in a matrix of coarse sandstone and very coarse-grained arkosic sandstones. The formation shows significant thickness variations within the outlier and is estimated by GSNI (2008) to vary from 0 to 850m in thickness, thinning to the eastern side of the outlier, where the Barony Glen Formation is seen to rest unconformably on the Dalradian.

The Barony Glen Formation overlies the Spincha Burn Conglomerate Formation and consists of approximately 1000m of feldspathic redbed sandstones, siltstones and mudstones with purplish-red, pink, green and grey palaeosols and calcrete nodule horizons. In the area

immediately south and east of Douglas Bridge (Figure 2), some 15 to 50m of dark grey algal laminated and fenestrate micrites interbedded with thick, dark grey calcareous mudstones has been recorded (the Douglas Burn Limestone Member).

SOUTH

NORTH

Glenoo No.1

(m)

1316.7

Ballyshannon Lst. Fm

Limestone & Shale lithofacies

1758.6

Sandstone lithofacies

1911

Mixed clastic, carbonate & evaporite lithofacies

2090.8

Basal Clastics

?

ORS

T.D @ 2,106.1m

ORS

CV-05
(Fivemiletown, Clogher Valley)

(m)

8.4

Moysnaght Lst Fm

201.4

223.

Fardross Sst. Fm

Murley Sst Mbr

266.2

268.9

Upper Evaporite

275.8

Upper Clogher Valley Fm

287.4

292.4

Middle Evaporite

303.8

Lower Evaporite

318.3

323

Chadian

Blessingbourne Mbr

328.7

Courceyan

Lower Clogher Valley Fm

383.2

Cole Bridge Mbr

389.9

Ballyness Fm

392

Ballyhoe Bridge
(Clones) BHB-1

(m)

8.5

Ch?

Ballyhoe Mudstone

65.5

Sill

85.5

Chadian

Courceyan

?

Ch-U/Ch

Ballysteen Fm.

130

mehli

165.5

189.6

Ulster Canal Fm.

220.5

mehli

250

286.5

Cooldaragh Fm.

381

Fearnaght Fm.

394.5

Lower Palaeozoics

T.D. 400.9m

100m

21km

6.7km

Figure 5: Correlation of the Ballyhoe Bridge, Glenoo No.1 and CV-05 Boreholes.
BHB-1 after Pracht & Somerville (pers. comm.),
Glenoo No.1 reinterpreted from Sheridan (1972),
CV-05 after Kelly and Jones (2020).

Lisnaskea-Slieve Beagh and Monaghan - Cavan Succession

The Lisnaskea – Slieve Beagh succession is mainly based on the succession intersected by the Glenoo Borehole (Sheridan, 1972) and GSNI mapping in the Lisnaskea area (Mitchell, 1995, GSNI, 2005, see Figure 3 Column 2). The Cavan and Monaghan area successions, located along the northern margin of the Longford-Down Lower Palaeozoics, are largely based on several historic boreholes examined in detail by Philcox (1988) and revised by Ní Bhroín (1993). Geraghty (1997) sub-divided this area into three successions, The Erne Succession, the Cavan Succession and The Monaghan Succession, but it is considered that variations between the successions are localized and are herein considered as one area, with minor sub-areas.

Lisnaskea – Slieve Beagh

The Lisnaskea – Slieve Beagh succession (Figure 5) is largely based on a reinterpretation of the lower part of the succession intersected in the Glenoo Borehole (Sheridan, 1972) and the upper part of the succession described by Mitchell (1995), who mapped the areas along the southern margin of the Slieve Beagh Uplands (the oldest part of the succession exposed in Fermanagh is the Ballyshannon Limestone Formation).

In the Glenoo Borehole, drilled by Marathon in 1965 – 1966, the borehole was terminated at a final depth of 2106.1m. The lowermost 15.2m intersected consists of redbed lithologies termed Old Red Sandstones by Sheridan (1972). This unit consists of bright red, iron stained, non-calcareous mudstones and micaceous siltstones with subordinate light green non-calcareous mudstones and micaceous siltstones interbedded with fine-grained to locally conglomeratic sandstones with rounded and sub-rounded quartz grit and white quartz pebbles. No fauna was recovered from this unit to confirm a Devonian age, and it is most likely that it represents a basal sandstone interval in the Carboniferous, analogous to the Ballyness Formation to the north and the Fearnaght Formation to the south, in counties Cavan and Monaghan (Geraghty, 1997).

The basal clastics are overlain by a 179.8m-thick interval (1911.0m to 2090.8m) composed of mudstones, siltstones, sandstones, carbonates and evaporites. The lower 137.2m of this formation is composed of pale grey-green mudstones with traces of anhydrite, slightly pink at base, passing up into dark grey rarely bioclastic silty shales. The upper part of the formation (42.7m, 1911.0m to 1953.7m) consists of dark grey unfossiliferous shales and limestones interbedded with anhydritic limestones and beds of grey white, clayey anhydrite.

This highly variable interval is overlain by unit 152.4m thick (1758.6m to 1911.0m), composed of grey white, very fine-grained, silty, micaceous sandstones, interbedded with calcareous shales and silty, very argillaceous limestones.

This is in turn overlain by 138.7m (1619.9m to 1758.6m) of light to dark grey calcareous shales and mudstones, generally unfossiliferous, interbedded with silty, very argillaceous limestones and light to medium grey fine-grained calcareous sandstones and siltstones.

The succeeding interval includes an interval termed the Lower Shale and Limestone by Sheridan (1972) and part of the underlying unit, it consists of 441.9m (1316.7m to 1758.6m) of dark grey, argillaceous crinoidal limestones, noticeably very shaley in the lower 34.5m.

Above 1316.7m (not shown in Fig. 5), the succession can be sub-divided into recognisable units typical of the upper part of the Tyrone Group. From 1042.4m to 1316.7m is 274.3m of distinctive light grey bioclastic limestones, predominantly bioclastic micrites and biomicrites, with locally abundant crinoids, bryozoans, brachiopods and coral debris, and with rare interbeds of dark grey argillaceous limestone with localised cherts and pelsparite of the Ballyshannon Limestone Formation, considered to be of late (possibly early) Chadian to lower Arundian in age.

The succeeding Bundoran Shale Formation (470.9 m, 571.5m to 1042.4m) is composed of very dark grey, very argillaceous bioclastic limestones, predominantly crinoidal micrites and biomicrites, interbedded with light grey to medium grey shales, noticeably more limestone-dominated than in the type area and wells drilled further west in the Lough Allen Basin etc. Overlying this formation is white to light grey, very fine- to medium-grained, poorly sorted, quartz-rich sandstones, interbedded with thin siltstones and shales of the Mullaghmore Sandstone Formation (228.6m thick, 342.9m to 571.5m). Some beds of dark grey, dolomitic argillaceous bioclastic micrite are present within the sandstones. The Bundoran Shale Formation is Arundian in age.

The overlying Benbulben Shale Formation (306.3m thick, 36.6m to 342.9m) is of late Arundian to early Asbian age in this area and is composed of grey-brown calcareous shales, with minor silty or micaceous shales. It is very bioclastic, with corals, crinoids, bryozoans, brachiopods and bioturbation. Rare thin limestone bands and rare thin sandstones are present in the lower part from 167.7 m.

The borehole collared into a 15.2m interval (21.4m to 36.6m) of brown-grey, argillaceous micrite and biomicrite, interbedded with calcareous bioclastic shales (up to 30% of the rock), which has been attributed to the Dartry Limestone Formation, but the high shale content and argillaceous nature of the interval is more reminiscent of a Glencar Limestone Formation type facies.

The higher units of the Tyrone Group (Figure 3 column 2) are known from surface exposures detailed in Mitchell (1995). Mitchell considered the Benbulben Shale Formation to be directly overlain by the Dartry Limestone Formation. The Dartry Limestone Formation is described as consisting of thinly- to thick-bedded medium grey to grey-brown and blue-grey very fine to fine-grained packstones interbedded with thin silty calcareous shales. Nodular and bedded cherts are present throughout the formation, becoming more well developed in the upper part of the Formation, carbonate mudbanks typical of the formation to the west of the Erne are absent (Legg et al., 1998).

Where exposed, the upper contact of the formation is conformable, but lateral thickness variations, suggest that the contact with the overlying Meenymore Formation is diachronous. At Rockfield Quarry (approximately 5.5 km southeast of Lisnaskea, Figure 2) some 90m of the upper part of the Dartry Limestone and the basal Meenymore Formation are exposed. The

Dartry Limestone Formation is estimated to vary in thickness from 210m north of Lisnaskea to 300m in the Donagh area, southwest of Lisnaskea, where a distinctive 6m thick pale grey grainstone unit termed the Ballagh Limestone Member, atypical of the rest of the formation, is present.

The Dartry Limestone, as mentioned above, is overlain by the Meenymore Formation, the youngest unit in this area and the only unit of the Leitrim Group present east of Lough Erne. The Meenymore Formation is highly variable, consisting of thinly-bedded deltaic unfossiliferous shales, mudstones, siltstones and sandstones, with interbedded fossiliferous marine mudstones and limestones (composed of unlaminated micrites, thinly laminated algal micrites and rare bioclastic micrites.

One thick distinctive sandstone unit, the Carnmore Sandstone Member is present. This member is composed of pale grey to fawn, very coarse-grained to medium-grained lithic quartzitic sandstones with feldspars absent and with scattered pebbles occasionally concentrated in layers.

The Meenymore Formation is estimated at 575m in thickness, the lower part at 150 m, the Carnmore Sandstone at 75m and the upper part of the formation above the Carnmore Sandstone at 350 m. The Dartry Limestone is Asbian and the Meenymore Formation is Brigantian in age.

Monaghan - Cavan Area

Philcox (1988) examined a number of boreholes along the northern margin of the Longford-Down Lower Palaeozoic rocks and erected an informal succession, attempting to correlate the succession with the main Irish Midlands successions south of the Longford-Down. This was amended by Ní Bhroín (1993), who erected a formal stratigraphy which was incorporated into GSI 1:100,000 digital mapping (Geraghty, 1997) and referred to in Mitchell (2004).

The most easterly borehole of interest, referred to by Philcox as Ballyhoe Bridge Borehole or BHB-1, is BW5 (Figure 2 and 5), drilled by Aquitaine in the Monaghan area some 6.7 km southwest of Clones. In BHB-1, some 13.5m of Carboniferous basal sandstone clastics, termed the Basal Sandstone by Philcox and formally named the Fearnaght Formation by GSI (Geraghty, 1997), lie unconformably on Lower Palaeozoic metasediments of the Coronea Formation. The base of the formation is conglomeratic, overlain by light grey, coarse-grained with shale partings in the upperpart of this unit. This is then succeeded by pink and light grey sandstones with green and black mudstones and some minor calcrete horizons.

The Fearnaght Formation is overlain by the Cooldaragh Formation (the Evaporitic Mudstone Unit of Philcox), described as being composed of calcareous mudstones and siltstones with subordinate thin micrites, occasionally algal laminites, and occasional thin bioclastic and fossiliferous limestones. The siltstones, mudstone and micrites frequently contain evaporite minerals or pseudomorphs after evaporites (gypsum/anhydrite/dolomite) and thick evaporite beds. In the Ballyhoe Bridge area it is 160.5m thick. It is Courceyan in age.

This is succeeded by the Ulster Canal Formation (the Upper Sandstone of Philcox), composed of 30.9m of marine sandstones, alternating between light grey, calcareous fine- to medium-grained sandstones, variably laminated and yellow-grey sandstones, non-calcareous or weakly calcareous but otherwise similar to the paler sandstones. The base of this unit is more calcareous and bioclastic. The upper part of the Ulster Canal Formation is more variable, composed of laminated and cross-bedded, silty and sandy limestones, interbedded with fine-grained limestones and shales. This upper interval was sub-divided by Philcox into a lower "Pale Beds" and upper "Shaley Pales". It is Courceyan in age.

The uppermost units intersected at Ballyhoe Bridge are an interval of 104.1m of interbedded limestones and fossiliferous shales and a more uniform dark grey, poorly fossiliferous bioturbated mudstone with subordinate beds of argillaceous micrite. The two units are separated by a 20m thick dolerite sill, presumably of Tertiary age. The lower unit is termed the Argillaceous Bioclastic Limestone and the upper unit the Ballyhoe Mudstone Formation by Philcox (1988), both units have been assigned to the Ballysteen Formation by GSI (Geraghty, 1997), it is also Courceyan in age.

Diachroneity between the Cavan/Monaghan, Lisnaskea/Slieve Beagh and the Clogher Valley Successions

The lowermost Carboniferous intervals in Cavan/Monaghan, Lisnaskea/Slieve Beagh and the Clogher Valley show a similar lithofacies succession, but this can be shown to be of significantly different ages in the various areas. Between the basal clastic interval and the base of the Ballyhoe Mudstone in BHB-1 or the Ballyshannon Limestone Formation (Glenoo No.1 and the Clogher Valley) is an interval which can be divided into three sub-units, a lowermost variable clastic/carbonate/evaporite lithofacies, a sandstone-dominated lithofacies and an interbedded limestone shale lithofacies.

In the BHB-1 area this has been determined to be entirely Courceyan (Pracht *pers. comm*.), while in the Clogher Valley area it has been shown to be almost entirely Chadian (Kelly and Jones *in press*). Available biostratigraphic data for the Glenoo No.1 borehole is insufficient to accurately place the Courceyan – Chadian Boundary (Sample intervals in the borehole are in excess of 70m), but there is sufficient information in Sheridan (1972) to infer it is within the sandstone lithofacies unit. Unit thicknesses are greater in the Glenoo area as it appears to have been an area with higher subsidence rates than the other areas drilled.

A lithofacies correlation of the various lithofacies, in relation to the position of the Courceyan / Chadian boundary in each area, shows a clear diachroneity and younging of the various lithofacies from north to south, presumably related to the Mississippian northwards transgression (Figure 5).

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