U.K. North Sea
Carboniferous Chronostratigraphy

Contents

1.0	**Basic Carboniferous Chronostratigraphy**	**4**
1.1	**Upper Palaeozoic, Carboniferous**	**4**
	1.1.1 Lithology	**4**
	1.1.2 Fauna	**4**
	Fig 1.1 Chronostratigraphical framework for the Carboniferous	6
2.0	**General Geology and Structural Framework**	**7**
2.1	**Introduction**	**7**
2.2	**Hercynian Phase**	**7**
2.3	**Variscan Deformation**	**8**
	Fig 2.1 Basin Platform Topography Resulting from Early Carboniferous Rifting.	8
3.0	**Southern North Sea Stratigraphy and Reservoir Geology**	**8**
3.1	**Carboniferous Reservoirs**	**8**
	Fig 3.1 Carboniferous Petroleum Systems around the Mid North Sea High.	9
3.2	**Carboniferous Formation Identification**	**9**
3.3	**Stephanian / Westphalian**	**10**
	Fig 3.2 Westphalian Palaeogeography Schematic.	10
	3.3.1 General Lithology	**10**
	3.3.2 Barren Red Beds	**10**
	3.3.3 Schooner and Ketch Fields *(Blocks 44/26 & 44/28)*	**11**
	Fig 3.3 Ketch and Cleaver Formations.	11
3.4	**Namurian**	**12**
	Fig 3.4 Early Namurian Palaeogeography Schematic.	12
	3.4.1 General Lithology	**13**
	3.4.2 Ravenspurn Field (Block 43/26)	**13**
	Fig 3.5 Typical Namurian cyclothem sequence in the Ravenspurn Field.	13
3.5	**Visean / Dinantian**	**13**
	3.5.1 Holkerian	**13**
	3.5.2 Asbian	**13**
	3.5.3 Brigantian	**14**
	Fig 3.6 Dinantian Palaeogeography Schematic.	14
	3.5.4 Breagh Field (Block 42/13)	**14**
	Fig 3.7 Breagh Area (Block 42/13) Carboniferous Stratigraphy Summary.	15
3.6	**Tournaisian**	**15**
4.0	**Northern North Sea Stratigraphy and Reservoir Geology**	**16**

4.1 **Carboniferous Limestone Group** (Visean) **16**

4.2 **Firth of Forth Group** (Early Carboniferous) **16**

5.0 **Acknowledgements & References** **17**

1.0 Basic Carboniferous Chronostratigraphy

1.1 Upper Palaeozoic, Carboniferous

Named after widespread occurrence of carbon in the form of coal in the beds, the Carboniferous system covers 345 to 280 million years ago and had a duration of 65 million years. The lower limit of the Carboniferous is taken where the Devonian faunas are replaced by the fauna of Productid brachiopod and corals. The upper limit is difficult to interpret; a marine sequence occurs in Russia and North America and the Foraminifera Pseudoschwagerina marks the beginning of the Permian.

The Carboniferous System in western Europe has traditionally been defined as comprising two sub-systems, an older Dinantian and younger Silesian, corresponding to Lower Carboniferous and Upper Carboniferous, respectively (Figure 1.1). The Dinantian–Silesian boundary was chosen to represent a regional facies transition in Britain from dominantly carbonate (Carboniferous Limestone Supergroup) to terrigenous clastic strata and does not reflect a global change in flora or fauna. The lower boundary of the Silesian was defined as the base of the ammonoid *Cravenoceras leion* Zone. The Mississippian and Pennsylvanian of the USA have become recognised internationally as sub-systems and strictly represent Lower and Upper Carboniferous, respectively, in international usage, with the boundary being approximately 325 million years. The mid-Carboniferous boundary separating the two sub-systems occurs within the Chokierian Substage of the Namurian Regional Stage in western Europe (Figure 1.1). Difficulties in direct comparisons between North America and western Europe has resulted in the UK maintaining usage of the regional western European chronostratigraphical nomenclature.

The Dinantian was subdivided into the Tournaisian and Visean Series, whereas the Silesian was subdivided into three series, Namurian, Westphalian and Stephanian (Figure 1.1). These series do not represent global faunal or floral events, but were chosen to represent prominent facies variations in western Europe. In southern Britain, the Namurian broadly equates with the Millstone Grit lithofacies and the Westphalian with the Coal Measures lithofacies. The base of the Westphalian is taken at the base of the ammonoid *Gastrioceras subcrenatum* Zone, which broadly equates with the first incoming of thick coal seams. The Stephanian Series is restricted to strata of limited geographical extent in onshore Southern Britain. Internationally, the Dinantian and Silesian are now considered obsolete terms and the Tournaisian and Visean are now formally defined as stages.

1.1.1 Lithology

A major transgression during the late Devonian to early Carboniferous times flooded the southern margin of the Old Red Sandstone continent. Block and basin areas were established, with many basins taking the form of gromorphic gulfs during the early Dinantian. Carbonate sediments dominated Dinantian deposition in most area, with major, eustatically controlled cyclicity responsible for regional facies change. Extensive lime-mudbank accretion occurred in many basinal areas, with a major phase of associated 'stratiform' lead-zinc mineralisation. Northern areas show evidence of repeated introductions of fluvio-deltaic clastics and alkali-basaltic volcanism. An extensive hinterland uplift phase in late Dinantian times (recogniseable from Silesia to Illinois) was followed by a copious introduction of clastic debris (Namurian Millstone Grit). By upper Carboniferous times an enormous low-lying fluvio-deltaic pain lay over much of NW Europe, causing many coal bearing cycles.

The period experienced widespread vulcanicity and minor igneous intrusions. Toward the end it saw the commencement of the Variscan orogeny and widespread glaciation became established in the southern hemisphere, especially near what is now the present day equator.

1.1.2 Fauna

In Great Britain the Lower Carboniferous marine sediments predominate and generally two faunal provinces can be seen.

The Lower Carboniferous facies are usually detrital organic limestones, often with the development of coral reefs, these sometimes show abundant crinoids and brachiopods. The other environment is one of black shales containing a reduced fauna of brachiopods and often goniatites, especially in the upper part of the succession. The Upper Carboniferous in Britain is mainly represented by fresh water or lacustrine sediments containing occasional marine bands. The flora of the Upper Carboniferous consisted mainly of primitive vascular plants that could reach a height of 15-20m and were the main contributors of today's Carboniferous coal seams.

Economically the Carboniferous is very important as it contains the bulk of the Worlds coal reserves and important reserves of iron ore, oil shale and oil.

Eon	Era	Period / System	Series (ICS*)	Series (NW Europe)	Epoch	Stage (ICS*)	Stage (NW Europe)	Regional Sub-stage			Offshore UK		Age (Ma)
Phanerozoic	Upper Paleozoic	Carboniferous	Pensylvanian	Silesian	Late / Upper	Gzhelian	Stephanian	C					298.9 ±0.2
								B					
						Kasimovian		A		Barruelian			303.7 ±0.1
					Mid / Middle	Moscovian				Cantabrian	De Lutte Formation Equiv.		307.0 ±0.1
							Westphalian (Coal Measures Facies)	D		Asturian	Boulton Formation		
								C		Bolsovian	Ketch Formation	Upper Ketch Member	
												Lower Ketch 2 Member	
												Lower Ketch 1 Member	
											Cleaver Formation	Upper Cleaver 2 Member	
												Upper Cleaver 1 Member	
					Early / Lower	Bashkirian		B		Duckmantian		Lower Cleaver Member	315.2 ±0.2
											Westoe Formation		
								A		Langsettian	Caister Coal Formation		311.7 ±0.2
							Namurian (Millstone Grit Facies)	C		Yeadonian			
								B		Marsdenian			
										Kinderscoutian			
								A		Alportian			
										Chokierian			
			Mississippian		Late / Upper	Serpukhovian			Yoredale	Arnsbergian	Stainmore Formation		323.2 ±0.4
										Pendleian	Alston Limestone	Great Limestone	
				Dinantian	Mid / Middle	Visean		V3c		Brigantian			327.0 ±0.4
												Quad Peaks Limestone	
												Eelwell Limestone	
												Oxford Limestone	
								V3b	Carboniferous Limestone	Asbian			330.9 ±0.4
												Twin Peaks Limestone	
												Watchlaw Limestone	
											Tyne Limestone	Dun Limestone	
												Scremerston Sandstone	
								V3a V2b		Holkerian	Fell Sandstone Formation		334.0 ±0.4
								V2a V1b		Arundian			
								V1a		Chadian	Cementstone		340.0 ±0.4
					Early / Lower	Tournaisian		Ivorian		Courceyan			346.7 ±0.4
								Hastarian					358.9 ±0.4

ICS* : International Commission on Stratigraphy.

Figure 1.1: Chronostratigraphical framework for the Carboniferous.

2.0 General Geology and Structural Framework

2.1 Introduction

The composition of the sedimentary fill in the North Sea Basin as a whole is the result of a complex series of structural events that have affected the Northwest European shelf since the Palaeozoic Era. The main effect of these structural events has been a highly variable influx of sediment into the basin, both in direction and magnitude. This changing influx reflects the changing positions and relative elevations of the structural units that acted as source areas in adjustment to the stress patterns that effected them. The relative elevation of most of the structural units has changed over geological time to such an extent that almost all have been both source and receiving area. Complete sedimentary sequences representing the entire time span of the North Sea basinal evolution are therefore not found anywhere, however more or less complete sequences over shorter periods can be found in many areas. The most complete sequences are found in the basinal centre.

Two major sedimentary basins are present, the Southern North Sea Basin, and the Northern/Central North Sea Basin. The two basinal areas are separated by a NW-SE trending series of relatively high areas, the Mid North Sea High is the most important high feature in the area of interest to exploration, production and development.

In the Southern North Sea Basin the most important features of the area of exploration, production and development are the NW/SE trending Sole Pit Basin, and Inde Shelf and the Silver Pit Basin to the north of these areas.

It should be realised that the sequence present in the different areas is a layer cake of sediment with each recognisable unit formed to a set of paleo controls uniquely its own. Correlation over large distances and sometimes through the entire basin is usually only possible for those layers or intervals formed in response to major events affecting the entire area.

From the viewpoint of Carboniferous basin development the Hercynian Phase is the most recognised.

2.2 Hercynian Phase

The Hercynian Phase was marked by a major uplift of the areas that still form the southern margin of the North Sea Basin. The London Brabant Massif which was a major stable block during the preceding Caledonian orogenic phase was uplifted and fused with the Hercynian mountain chain which formed in a East-West direction across Southern Britain, France and Central Europe. The North Sea basin became enclosed on all sides with connections to other basins and oceanic areas narrow and perhaps intermittently closed as a results of the various orogenic phases of the Hercynian phase.

The wide shelf that occupied most of the North Sea during the Lower Carboniferous was characterised by shallow marine carbonate and claystone deposition with marine ingressions reaching far to the north into the degraded Caledonian mountain chains. Coal bearing sequences were locally deposited in the Central North Sea and Northern England.

As the basin gradually shallowed sedimentation lost much of its marine character and the thick coal deposits deposited in this period are the source rocks for the gas reservoirs both onshore and offshore in the southern basin.

These upper Carboniferous coal sequences do not extend into the central and northern North Sea. The Carboniferous deposits in the central and northern North Sea were laid down in intramontane basins that had limited or no connection to adjacent basins. As later erosion has removed much of the sediment uncertainty remains on the exact nature and distribution of the deposits of Carboniferous age in these areas. Devonian sediments form most of the Pre-Permian subcrop in the area. Some deposits of Carboniferous age have been drilled, limestone, shale and sandstone have been encountered.

There was pulsed rifting during the Dinantian which was interspersed by quieter, stable tectonic periods. The main periods of rifting and basin formation were:

- Courceyan
- Late Chadian to Late Holkerian
- Late Asbian to Early Brigantian

During the Mid Brigantian a compressive tectonic event resulted in the formation of the Sudetic or Brigantian Unconformity.

2.3 Variscan Deformation

In contrast with the underlying Dinantian, the Namurian to Westphalian section represents a post-rift, thermal sag phase with sedimentation gradually burying the underlying rift topography such that the area was covered by major deltaic systems during the Westphalian.

The Variscan Orogeny which occured towards the end of the Carboniferous was a results of continental collision between Gondwana with Laurentia to the west and Iberia to the south to form the super continent of Pangaea. The effects of this orogeny commenced in late Westphalian C times and continued until the end of the Carboniferous. The major effect of this compression was the inversion and erosion of the pre-existing Dinantian basins. In contrast, the platform areas remained relatively undeformed with a preserved section of younger Westphalian to Stephanian rocks.

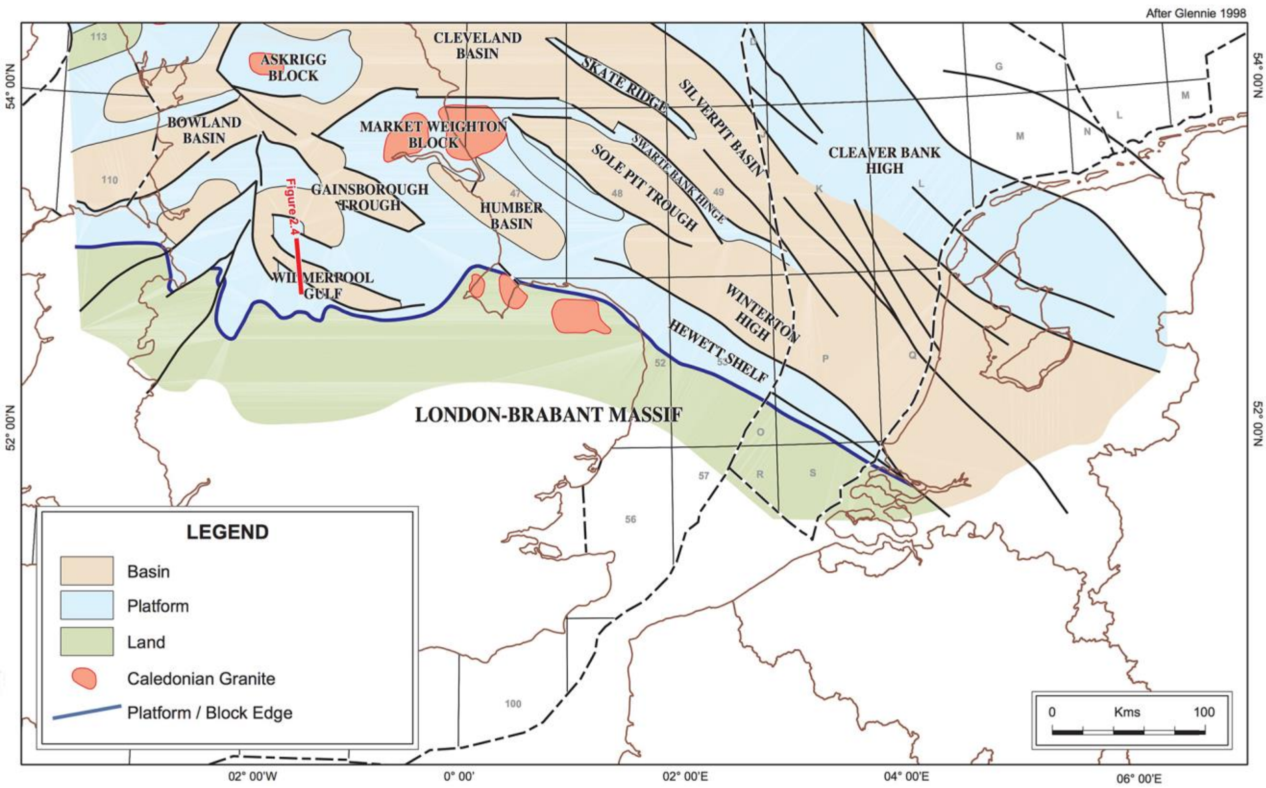

Figure 2.1: Basin Platform Topography Resulting from Early Carboniferous Rifting.

3.0 Southern North Sea Stratigraphy and Reservoir Geology

3.1 Carboniferous Reservoirs

The source for all the reservoirs in the southern North Sea area are Carboniferous coals and shales deposited in a range of environments (shallow/deep marine, lagoon, delta, lake). The gas migrated either into Permian sand bodies sealed by Zechstein evaporites, or Carboniferous sands sealed by Lower Permian clays.

Westphalian and Stephanian reservoirs occur in the Silverpit area where fluvial sand/shale sequences lie unconformably below sealing shales of the Lower Permian Silverpit formation. The Westphalian consists of a mixture of interbedded coastal, swamp (coal), fluvial and shallow marine deposits.

Above the Westphalian deposits is a further sand/shale sequence called the Barren Red Beds, of indeterminate age (but considered to be Westphalian D and/or Stephanian) due to the lack of coal seams and destruction of spores by oxidation.

High sand to shale ratios occur at two levels in the Carboniferous and these generally form the best reservoirs;

- Barren Red Beds (Westphalian D/Stephanian)
- Middle Coal Measures (Lower Westphalian B)

These comprise high energy, laterally extensive braided river deposits. Sands in intermediate shale rich horizons were generally laid down in low energy meandering rivers and tend to be local, laterally discontinuous and in poor communication. Some of the ticker shales are thought to be intra-formational seals.

A period of uplift and erosion occurred at the end of the Carboniferous. In general reservoir quality decreases away from the unconformity thus formed. The stratigraphic level of good reservoir sands at any one locality varies depending on the structural level of the unconformity.

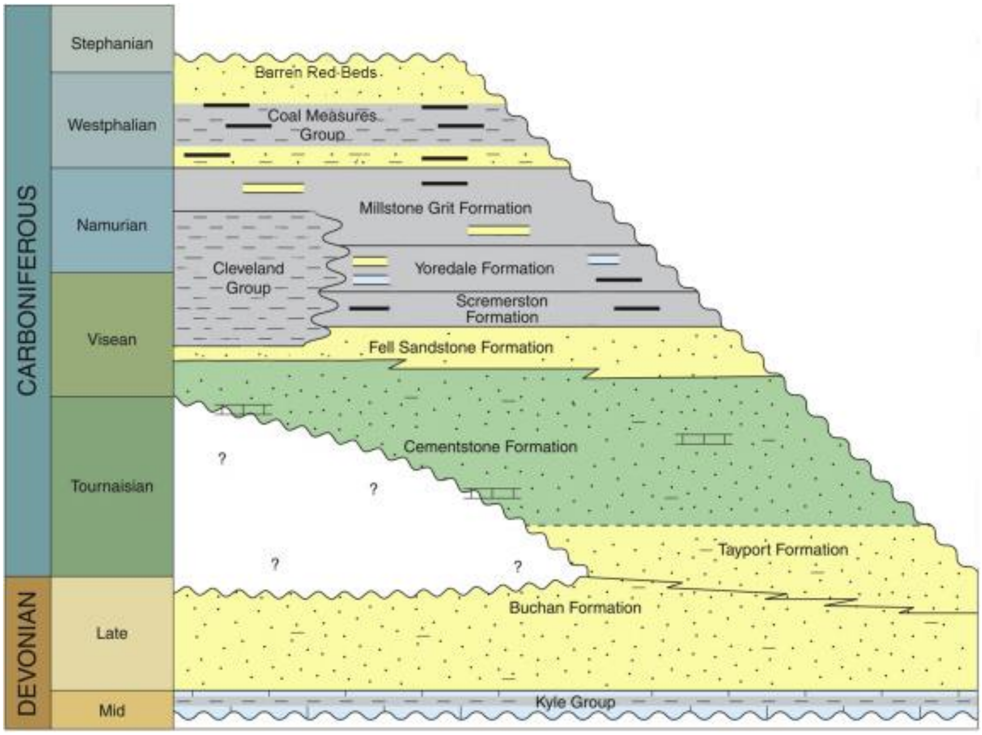

Figure 3.1: Carboniferous Petroleum Systems around the Mid North Sea High.

3.2 Carboniferous Formation Identification

These guidelines are intended to aid identification of formation tops and to provide general information on the stratigraphy of the area. The descriptions are very general, describing briefly the main points of some of the more diagnostic lithologies that comprise a stratigraphic unit. Faulting and/or unconformities may remove part of the sequence of any well. The Carboniferous tends to be hard with reduced ROP throughout. Any sands may be gas bearing. The Carboniferous lies unconformably below the Rotliegendes and may be entered at any level down to the Westphalian A.

3.3 Stephanian / Westphalian

The early Westphalian A section includes distributory channels and shallow fresh-brackish lakes that were infilled by lacustrine deltas, crevasse splays and overbank deposits. The upper part of the Westphalian is characterised by coal swamps and meandering fluvial channels.

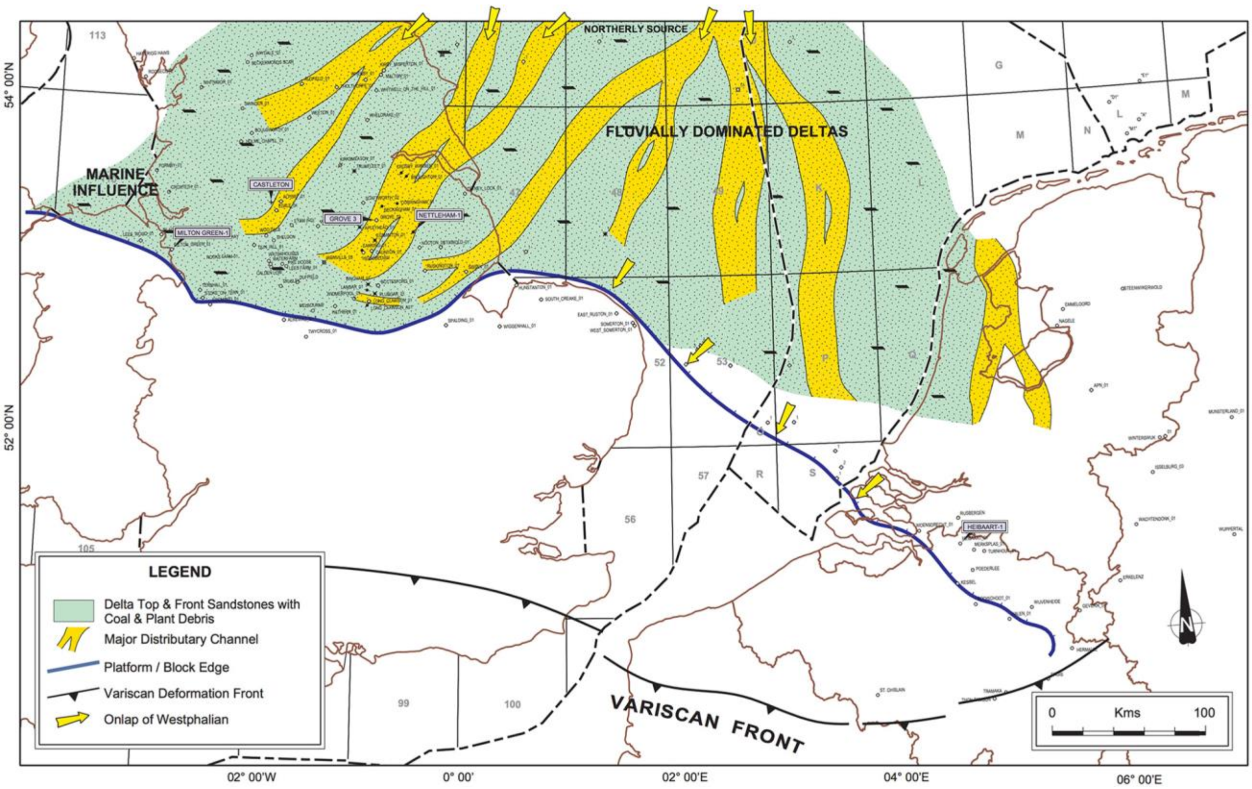

Figure 3.2: Westphalian Palaeogeography Schematic.

3.3.1 General Lithology

Typically white to grey in colour (with the finer sediments being darker) as opposed to the Barren Red Beds. Similar lithologies with the addition of coals and fragments. A transition zone exists above the top coal and the top is difficult to define from cuttings.

3.3.2 Barren Red Beds

During the mid-late Westphalian C times a major phase of basin inversion commenced to the north of the London-Brabant Massif radically changing the sedimentary depocentres and facies patterns across the region. The sediments derived from the inverted and eroded areas are often referred to as the Barren Red Measures or Barren Red Beds. These red-coloured rocks are thought to represent alluvial fan complexes with medium to coarse grained fluvial sandstones, overbank silts and clays, and lateritic palaeosols. However, the base Permian unconformity (BPU) cuts across the late Carboniferous stratigraphy of the region and much of the evidence for the deposition of the sediments has been removed by erosion.

Interbedded red-brown sandstones, siltstones and shales. Occasional gravel and pebble beds. The barren Red Beds may be subdivided into three zones:

- Zone 3 - Sand Prone
- Zone 2 - Shale Rich
- Zone 1 - Sand Rich

3.3.3 Schooner and Ketch Fields *(Blocks 44/26 & 44/28)*

The oldest rocks penetrated by the Schooner and Ketch Field wells are the Carboniferous (Westphalian) Coal Measures; a succession of sandstones, shales and siltstones with some coal seams, which form the primary source rock interval for most of the Southern North Sea region. These are overlain by the Ketch Formation (formerly known as the “Barren Red Group”), also of Westphalian age, which comprises alternating sandstones and shales and forms the major reservoir of the Schooner Field. Towards the close of the Carboniferous, the Variscan orogeny led to uplift in the region. Subsequent erosion of the interval resulted in an angular unconformity at the base of the Permian. In the Schooner Field this unconformity produces a subcrop pattern in which progressively older horizons in the Ketch Formation and Cleaver Formation (Coal Measures) underlie the Permian towards the west.

The reservoir in the Schooner and Ketch Fields is mainly formed by fluvial channel and overbank sandstones in the Ketch Formation. (A very small proportion of the gas in place is reservoired in channel sandstones in the underlying Cleaver Formation.

Channel sandstone development in the Ketch Formation is variable, the proportion of major sandstones to non-reservoir ranging from <20% to *c.* 40% in different areas of the field and stratigraphic horizons. Individual channel bodies typically range in thickness from *c.* 5ft to *c.* 18ft. The channels are locally stacked to form larger multistory and multilateral sand bodies that commonly reach thicknesses of 25-30ft, and in exceptional cases may be as thick as 50ft. Channel sand bodies are formed of well-cemented, fine to very coarse grained sandstone that locally contains conglomeratic beds characterized by quartzite pebbles.

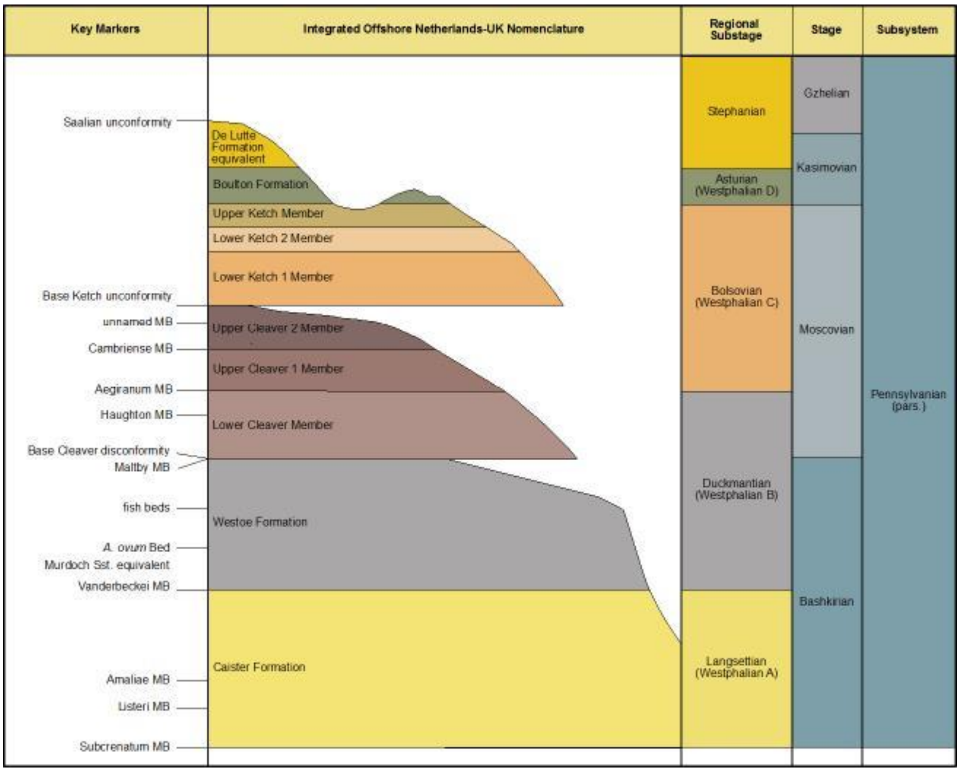

Figure 3.3: Ketch and Cleaver Formations.

The channel sand bodies form narrow elongate features that generally have an N-S to NE- SW orientation. The simple, single storey channel sands are expected to have widths proportional to their thicknesses, in the range 120 – 900m (400 – 2950ft). The lateral extents of the stacked multiple channel units are more difficult to predict, because of the multilateral architecture of these bodies. In general these bodies are likely to have similar widths to the single channels, but wider, sheet-like sand layers may be present. These may contain marked lateral heterogeneities, with intercalations of finer grained rocks. The larger, stacked sand bodies are likely to form a reasonably well connected network, while smaller sand bodies may be isolated.

Within the Schooner and Ketch Fields, sand development is generally better in terms of sand body thickness and lateral continuity, in the basal 500ft stratigraphic thickness of the Ketch Formation.

In addition to the major channels, thin (generally not greater than 5ft) sand bodies of non-channel origin (levee, crevasse splay and lacustrine mouth bar) are likely to be randomly distributed though these will generally be fine grained and tight.

3.4 Namurian

Post rift subsidence at the end of the Dinantian led to the drowning of the carbonate platforms and the cessation of carbonate deposition. Outcrop and well data indicate that during the Early Namurian the area immediately to the north of the London-Brabant Massif is characterised by the deposition of pro-delta organic-rich shales. These shales typically show a high gamma ray and low sonic log response. This interval is thickest in the deeper parts of the basins and gradually thins and onlaps the surrounding carbonate platforms. Black organic-rich shales are known to occur immediately to the north of the London-Brabant Massif in a connecting belt extending from Belgium through the UK and into the Dublin Basin in Ireland.

During the middle part of the Namurian (Arnsbergian to Alportian) course siliclastics gradually infilled the basins in the north of England in response to major southerly prograding delta sysatems. Whilst the more southerly basins are characterised by contemporaneous distal pro-delta mudstones.

By Kinderscoutian times much of the underlying rift topography had been buried beneath the advancing delta systems resulting in widespread shallow-water an d delta top conditions. Much of the Namurian is characterised by high frequency cyclicity, comprising goniatite-bearing marine mudstones passing upwards into channel sandstones and delta top deposits associated with colas and palaeosols. Typically, these shallow-water delta cycles are 10m to 50m thick and each cycle is characterised by a major fluvial sandbody. It is generally accepted that these cycles result from high frequency glacio-eustatic sea-level changes. The goniatite-bearing marine mudstones (marine bands) reflect maximum flooding surface condensed sections and the overlying delta front to delta top succession progradation of a HST (high stand systems tract).

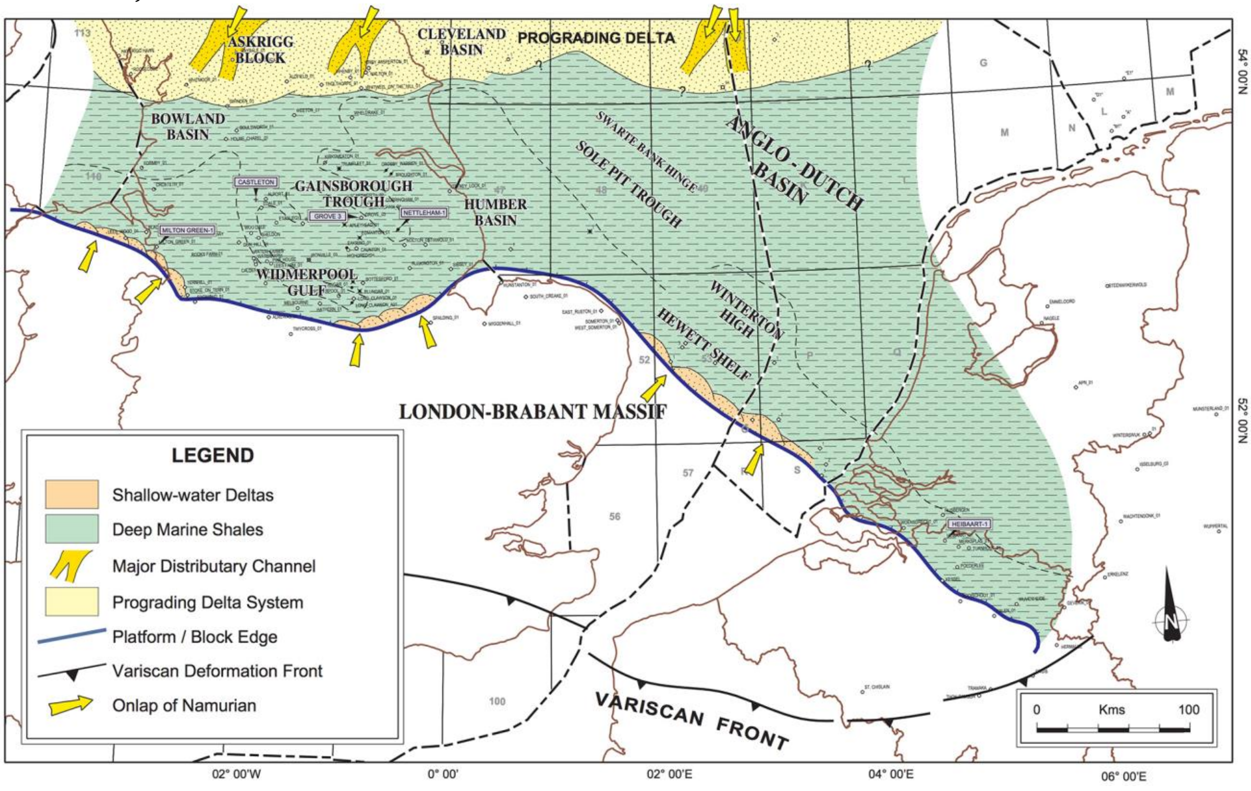

Figure 3.4: Early Namurian Palaeogeography Schematic.

3.4.1 General Lithology

Interbedded Sandstones, Siltstones and Shale cyclothems. Medium to dark grey, dark blue-grey, hard, blocky, silty, carbonaceous and micromicaceous Claystones. Very pale grey to pale yellow-brown, very fine to medium , rarely coarse grained Sandstones. Non or very rare Coal seams.

3.4.2 Ravenspurn Field *(Block 43/26)*

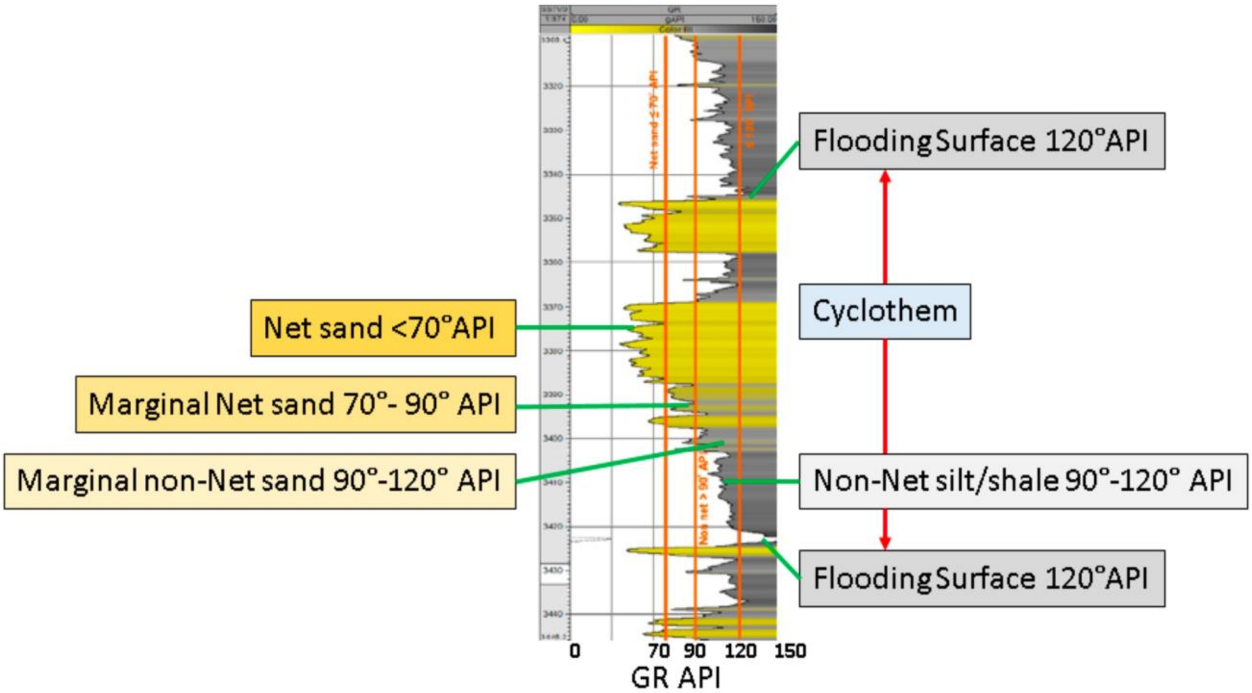

Figure 3.5: Typical Namurian cyclothem sequence in the Ravenspurn Field.

3.5 Visean / Dinantian

During the Dinantian, the area to the north of the London-Brabant Massif comprised either shallow water carbonate deposition over the structural highs or deep-marine mudstones and calci-turbidites in the intervening basins. Sediment input from the London-Brabant Massif was minimal and the basins were largely starved of sediment supply. Further north, major deltas were prograding southwards burying the underlying rift topography and at the same time terminating carbonate deposition. The deltaic system continued to prograde southwards eventually terminating all carbonate deposition by the end of the Dinantian.

3.5.1 Holkerian

The Holkerian represents the start of the transition from carbonate ramp systems fringing areas of exposed basement to the development of carbonate platform systems and rimmed margins. The carbonate system became differentiated into carbonate shelves and basins. Basement highs were finally covered by carbonate deposition therefore cutting off the local supply of siliclastic sediment. This sequence often shows distinctive log character, consisting of a high gamma ray maximum flooding surface overlain by a relatively thick aggradational HST (high stand systems tract) that comprises a lower, low gamma interval and an upper, high gamma interval.

3.5.2 Asbian

The Asbian marks the first fully developed rimmed carbonate shelf systems nucleated over basement highs and fringing the margins of the London-Brabant Massif. These carbonate shelves were surrounded by deep-marine basins in which distal carbonate turbidites and deep-marine mudstones were deposited. Outcrop evidence from Northern England shows that the Asbian shelf carbonates consist of shallowing-upward glacio-eustatic carbonate shelf cycles. The cycles consist of argillaceous packstones and grainstones representing late TST (transgressive system tract) to TST deposits. These cycles are capped by calcrete and karstic surface overlain by K bentonites that represent volcanic ash deposits modified by soil processes.

3.5.3 Brigantian

The Brigantian also comprises a number of glacio-eustatic shallowing-upwards carbonate shelf cycles with palaeosols and palaeokarst at sequence boundaries. Potential reservoirs occur at the carbonate platform margins with the development of grainstone carbonate bodies and re-sedimented carbonates in base of slope setting. The Brigantian is often eroded at the carbonate platform margins with the development of a karstic surface at the top of the carbonate platform.

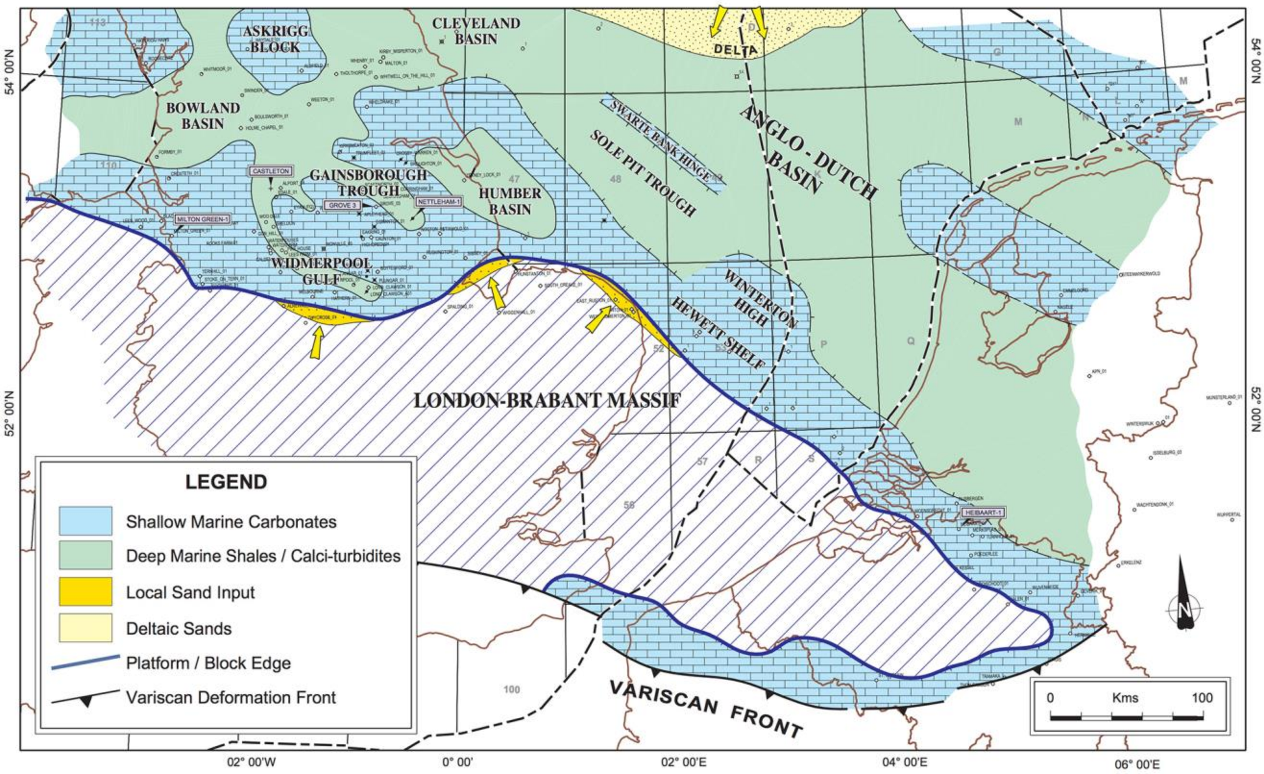

Figure 3.6: Dinantian Palaeogeography Schematic.

3.5.4 Breagh Field *(Block 42/13)*

The Breagh gas field is on the southern margin of the Dogger Shelf in the northwest part of the Southern Gas Basin, a previously under-developed region of the Southern North Sea. To the southeast, several Carboniferous-age fields have been developed over the past 30 years, but all from younger stratigraphic intervals (Westphalian and Namurian). Breagh is the first field development of Dinantian age (i.e. Lower Carboniferous) and is located at the edge of the play fairway and has different reservoir and source to the other Carboniferous fields.

The Breagh Field trap configuration is a combined tilted fault block with dip closure. There is a predominantly NW-SE structural grain in the western part of the accumulation and an almost E- W, to ENE-WSW trend present in the eastern area of the field. Although the Breagh structure is mapped as an independent closure it is envisaged that the complex fault pattern within the field will exert a degree of influence on reservoir architecture by either baffling fluid flow or by altering the juxtaposition of sand bodies from their original depositional configuration.

The Carboniferous in the Breagh area consists of a thick sequence of Yoredale Group clastics (shales, siltstone and sandstone), marine limestones and thin coal beds that subcrop the Base Permian

Unconformity. The Carboniferous penetrated in the Breagh area has been dated as Late Asbian to Middle Brigantian in age. For development purposes the Breagh wells have been zoned and correlated using marker limestone horizons, as indicated in the following figure 3.3;

Stage	Sub-stage	Group	UKOOA Group	BGS Group	UKOOA Formation		Member	Marine Bands	Age (Ma)
Namurian A	Amsbergian	Yoredale	Farne Group	Yoredale Group	Stainmore Formation	Upper Limestone			324
									325
	Pendleian				Alston Limestone		Great Limestone		327
Visean	Brigantian					Middle Limestone		Breagh Zone 1C	
							Quad Peaks Limestone		
								Breagh Zone 1B	
							Eelwell Limestone		
								Breagh Zone 1A Upper	
							Zone 1 Coal		
								Breagh Zone 1A Lower	
							Oxford Limestone	Breagh Zone 2	330
	Asbian	Carboniferous Limestone				Lower Limestone			
							Twin Peaks Limestone		
								Breagh Zone 3	
							Watchlaw Limestone	Breagh Zone 4	
					Tyne Limestone		Dun Limestone		
						Scremerston Sandstone			334
	Holkerian			Border Group	Fell Sandstone	Fell Sandstone			337
	Arundian								340
	Chadian			Cementstone	Cementstone	Cementstone			344
Tournaisian	Courceyan								359

Figure 3.7: Breagh Area (Block 42/13) Carboniferous Stratigraphy Summary.

3.6 Tournaisian

The Tourinasian to Arundian sequences are interpretted as a series of off-lapping carbonate ramp units that onlap the emergent basement. Each sequence consists of a basal mixed siliclastic-carbonate marginal marine sequence passing up into a progradational ramp. Sequences separated by sequence boundaries are often karstified. Outcrop evidence from the UK and Belgium indicates that in the deeper water parts of the carbonate ramp setting Waulsortian mud mounds occur and these are generally of Chadian to Arundian in age. These build-ups range from isolated mounds a few tens of metres high to complexes hundreds of metres high that cover several square kilometres. In general, these build-ups are not reefal frameworks and they comprise micrite with low permeability and vuggy porosity. Being situated in a more seaward location they are less susceptible to karstification processes. Well data show that Tournaisian to Arundian carbonates are often dololimitised results from fluids derived from connate waters expelled from compacting mudstone sequences.

4.0 Northern North Sea Stratigraphy and Reservoir Geology

4.1 Carboniferous Limestone Group *(Visean)*

Some scattered deposits have been encountered in the northern North Sea. The limestones are recrystallised, very hard and can in places be very vuggy. Thin black shale partings are found in the limestone.

4.2 Firth of Forth Group *(Early Carboniferous)*

Carbonaceous vary coloured shales with interbedded coal seams, silty shales and sandstones.

5.0 Acknowledgements & References

Compiled from a series of Geology notes, well programs, manuals and various texts including;

D. F. Lapidus. (1990). Collins Dictionary of Geology. AbeBooks.

R. Anderton, P. Bridges, *et.al.* (1979). A Dynamic Stratigraphy of the British Isles: A Study in Crustal Evolution. HarperCollins.

K. W. Glennie. (1990). An Introduction to the Petroleum Geology of the North Sea. Wiley-Blackwell.

M. E. Tucker. (1981). Sedimentary Petrology: An Introduction to the Origin of Sedimentary Rocks. Wiley-Blackwell.

R. C. Selley. (1978). Ancient Sedimentary Environments and their Sub-surface Diagnosis. Routledge.

C. N. Waters, R. A Waters. *et.al.* (1991). British Geological Survey (BGS) Research Report RR/09/01: A lithostratigraphical framework for the Carboniferous successions of southern Great Britain.

Total E&P UK. (2007). A Regional Review of the Dinantian Carbonate Play: Southern North Sea and Onshore UK.

Journals of the Geological Society.

Wikipedea.

www.dxcgeological.co.uk