Chapter 2
Definitions of chronostratigraphic subdivisions. geochronology and event stratigraphy

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The term Carboniferous was created as a stratigraphical term by Conybeare & Phillips (1822) for strata present in England and Wales and was first referred to as a System by Phillips (1835). The original definition of the Carboniferous included the Old Red Sandstone. With the establishment of the Devonian System in 1839 the Old Red Sandstone was removed from the Carboniferous and placed in the Devonian.

Broad similarities within the successions of Britain and Ireland with the rest of Western Europe have allowed development of a regionally applicable chronostratigraphy. Munier-Chalmas & de Lapparent (1893) originally divided the Carboniferous of Western Europe into the Dinantian, Westphalian and Stephanian. Later, the lower part of the Westphalian was redefined as the Namurian and both were identified as stages (Jongmans 1928). The Namurian, Westphalian and Stephanian stages do not represent global faunal or floral events, but were chosen to represent prominent facies variations and palaeogeographic separations in Western Europe.

The Dinantian subsequently became a subsystem, with two component series, the Tournaisian and Visean (George & Wagner 1972), whereas the Namurian, Westphalian and Stephanian became series of a Silesian Subsystem. However, George *et al*. (1976) were not prepared to use the terms Tournaisian and Visean in their review of British chronostratigraphy. The stage nomenclature used in the UK, which applies to Western Europe, were based on boundary stratotypes defined by George *et al*. (1976) for the Visean, Ramsbottom (1981) for the Namurian and Owens *et al*. (1985) for the Westphalian, largely from localities in northern England.

Ongoing development of an international chronostratigraphical nomenclature (discussed more fully in Chapter 25) has led to the Mississippian and Pennsylvanian of the U.S.A. being recognised internationally as subsystems (Leckwijck 1960), and should replace usage of the ambiguous Lower and Upper Carboniferous (Heckel & Clayton 2006). The international subsystems are presented in the correlation panels shown in this report. The terms Dinantian and Silesian are not utilised herein, though because of their close approximation to a prominent lithostratigraphical change it is still useful to divide the correlation panels into the two former subsystems.

Six unnamed global series have been proposed for the Carboniferous, comprising Lower, Middle and Upper Mississippian and Lower, Middle and Upper Pennsylvanian (Heckel & Clayton 2006). The five Western European series have been replaced by a chronostratigraphical nomenclature comprising seven global stages (Fig. 2.1), based largely upon that used in western Russia (see Chapter 25), and assigned stage status (Heckel & Clayton 2006). The former European series are now recognised as Western European regional stages and the former Western European stages are now recognised as substages (Heckel & Clayton 2006). As these developments are far from complete and with difficulties in direct comparisons between Russia and Western Europe, this report maintains usage of the Western European regional stage and regional substage nomenclature, though with some modification of some substage definitions (Fig. 2.1).

Tournaisian Stage
The lower boundary of the Tournaisian, and of the Carboniferous, was proposed at the base of the ammonoid *Gattendorfia subinvoluta* Zone (Streel 1972). Conil *et al*. (1977) subdivided the Tournaisian into the Hastarian and Ivorian substages (formerly stages) with Belgian stratotypes. The boundary between these substages corresponds with the boundary between the *Siphonodella* and *Polygnathus communis carina* Biozones in conodonts and the *Chernyshinella* and *Tournayella* Biozones in foraminifers (Ramsbottom & Mitchell 1980). However, these substages have proved difficult to apply in Great Britain and Ireland.

George *et al*. (1976) indicated that the lowest part of the type Tournaisian in Belgium (Tn1a) was of Famennian (Devonian) age and could not correspond to the base of the Dinantian. They also considered that the top of the Tournaisian (or base of the Visean) could not be identified with certainty in Britain. This led George *et al*. (1976) to propose erection of a Courceyan Stage to comprise the part of the Tournaisian of Dinantian age. The base of the Courceyan Stage was taken at the base of the Kinsale Formation above the Old Head Sandstone Formation on the western side of the Old Head of Kinsale, Co. Cork [Irish Grid 16242 04069] (Fig. 2.2a; see Chapter 23). The base of the Courceyan at the stratotype equates with the base of the *Vallatisporites verrucosus*-*Retusotriletes incohatus* (VI) Miospore Zone, which correlates closely with the base of the Carboniferous.

Subsequently, the base of the Tournaisian, and that of the Carboniferous, has been redefined at the transition from the conodont *Siphonodella praesulcata* to *S. sulcata* (Paproth *et al*. 1991). As a result, the base of both the Tournaisian Stage and the Courceyan Regional Substage are now almost coincident.

Ramsbottom & Mitchell (1980) argued that the incoming of the foraminifer *Eoparastaffella* marked the base of both the Chadian Stage (now substage) in Britain and Visean Series (now stage) in Belgium, and consequently that the top of the Tournaisian and Courceyan are also coincident. This simple relationship has become confused by the recognition that the top of the Ivorian and base of the Visean are not equivalent (Conil *et al*. 1989; Conil *et al*. 1991) and debate over the location of the base of the Chadian (see below). The latter has resulted in an unsatisfactory solution in recent years of recognising an early Chadian succession present below the first incoming of *Eoparastaffella* (Cf4α1 foraminifer biozone) and a late Chadian, of Visean age, marked by the base of the Cf4α2 biozone. It is proposed here that early Chadian strata be included within the Courceyan Substage.

In conclusion, usage of a single Courceyan Substage of direct equivalence to the range of the redefined Tournaisian Stage is recommended by this report.

Visean Stage
The Visean comprises five regional substages based upon stratotype boundaries defined by George *et al*. (1976). The bases of the substages are taken largely at the first lithological change below the entry of a diagnostic faunal group.

The **Chadian** stratotype is at Chatburn, Lancashire [SD 7743 4442] (Fig. 2.2b), the site being described fully in Cossey *et al*. (2004, p265-268). The base of the substage (former stage) was defined as the first change in lithology below the entry of the foraminifer *Eoparastaffella* (George *et al*. 1976). At the type locality this was indicated to be within the Chatburn Limestone Formation, (formerly Group; see Chapter 11). However, Cossey *et al*. (2004, p265-268) highlight a number of discrepancies in the description of the stratotype by Ramsbottom (1981) and subsequent work has indicated that *Eoparastaffella* appears some 300 m higher in the succession within the Hodder Mudstone Formation (Riley 1990a). There is a need to redefine the Chadian stratotype for it to agree with the definition of the base of the Visean Stage, which is recommended to occur at the lowermost presence of *Eoparastaffella simplex* (Devuyst *et al*. 2003). This occurs at a regional unconformity within the Craven Basin, well exposed at Salthill Quarry, Clitheroe (see Chapter 11), and as such does not represent an ideal location for a stratotype. Potentially, a more suitable location would be the Blucks Pool to Bullslaughter Bay area of South Wales, at or near the base of the Linney Head Limestone Formation (see Chapter 5).

The **Arundian** stratotype is at Hobbyhorse Bay, Dyfed, South Wales [SR 8880 9563] (Fig. 2.2c). The base of the substage was defined as the first change in lithology below the entry of the foraminifer family Archaediscidae (George *et al*. 1976). At the type locality this was taken at the base of the Pen-y-holt Limestone above the Hobbyhorse Bay Limestone (see Chapter 5). However, the lowermost 16 m of the Pen-y-holt Limestone lacks diagnostic Arundian fauna (Ramsbottom 1981) and is indistinguishable from the late Chadian biostratigraphy. Riley (1993) suggested that the boundary stratotype be redefined as the first entry of primitive archaediscids. The foraminiferal biostratigraphy and sedimentology of the section is provided by Simpson & Kalvoda (1987), the conodont biostratigraphy is described by Austin (1987) and Cossey *et al*. (2004, p425-428) reviewed the entire section.

The **Holkerian** stratotype is at Barker Scar, Holker Hall, Cumbria [SD 3330 7827] (Fig. 2.2d). The base of the substage is defined as the lithological change, which occurs below the incoming of diagnostic fauna, including the brachiopods *Davidsonina carbonaria*, *Composita ficoides* and *Linoprotonia corrugatohemispherica*, the corals *Carcinophyllum (=Axophyllum) vaughani* and *Lithostrotion minus*, the archaediscids *Archaediscus* spp. of the *A. concavus* stage and palaeotextulariids (George *et al*. 1976). The base of the substage occurs at the boundary between what is now recognised as the Dalton Formation and overlying Park Limestone Formation (see Chapter 12). Riley (1993) indicated that a significant non-sequence may be present in the succession at Barker Scar and that the stratotype may need to be relocated. The section is described by Rose and Dunham (1977), Ramsbottom (1981) and Cossey *et al*. (2004, p185-188).

The **Asbian** stratotype is at Little Asby Scar, Ravenstonedale, Cumbria [NY 6988 0827] (Fig. 2.2e). The base of the substage was defined by George *et al*. (1976) as the lithological change which occurs below the incoming of diagnostic fauna, including *Dibunophyllum bourtonense*, *Lithostrotion (=Siphonodendron) pauciradiale*, *L. junceum* and *Palaeosmilia murchisoni*, *Linoprotonia hemisphaerica*, *Daviesiella llangollensis* in the lower part and *Davidsonina septosa* in the upper part. The conodont *Gnathodus bilineatus* appears in the Asbian and the base of the substage appears to coincide with the TC miospore zone of Neves *et al*. (1972). The base of the substage also coincides with the boundary between the Ashfell Limestone Formation and overlying Potts Beck Limestone Formation (see Chapter 12). The base of the substage corresponds with the Belgian foraminiferal biozonal transition from V_{3a} to V_{3b}. Other common foraminifer include *Archaediscus* sp. of the *A. convexus* stage and *Howchinia* sp. Strank, in Ramsbottom (1981) noted that the first diagnostic Asbian foraminifers and the diagnostic coral *Dibunophyllum* occur no lower than 19.6 m above the defined stratotype boundary, whereas White (1992) reported the foraminifer *Vissariotaxis* only 2 m above the boundary. Aretz and Nudds (2005) concluded that the Holkerian/Asbian boundary was purely lithostratigraphical, with typical Holkerian rugose corals present at the boundary and the first diagnostic Asbian coral, *Dibunophyllum bipartitum,* is not recognised until the lower part of the Knipe Scar Limestone Formation, agreeing with the observations of Strank, in Ramsbottom (1981). Riley (1993) has indicated that the base of the substage needs to be repositioned, without needing to relocate the stratotype, whereas Aretz and Nudds (2005) concluded that the faulted nature of the contact between the Potts Beck Limestone and Knipe Scar Limestone formations required that the stratotype be relocated. A review and description of the section is provided by Cossey *et al*. (2004, p223-226).

The **Brigantian** stratotype is at Janny Wood, near Kirkby Stephen, Cumbria [NY 7832 0375] (Fig. 2.2f). The base of the substage was defined by George *et al*. (1976) as the lithological change which occurs below the incoming of diagnostic fauna, including characteristic coral and brachiopod fauna *Diphyphyllum lateseptatum*, *Lonsdaleia (=Actinocyathus) floriformis*, *Nemistium edmondsi*, *Orionatraea* spp., *Palaeosmilia (Palastraea) regia*, *Productus hispidus*, *Productus productus and Pugilis pugilis*. The foraminiferal biostratigraphy of the section is described by White (1992), with characteristic foraminifers include *Neoarchaediscus*, *Asteroarchaediscus* and *Bradyina* (Hallett 1970) and the conodont *Gnathodus (=Lochriea) nodosus*. The base of the substage coincides with the base of the Peghorn Limestone, the lowest limestone of the Yoredale Group in the region (see Chapter 12). However, Riley (1993 and references therein) noted that there is a disconformity at the base of the limestone and that there is a transitional brachiopod and coral fauna between the Asbian and Brigantian substages. Riley (1993) suggested that the boundary stratotype should be relocated and redefined using ammonoid biostratigraphy at the base of the *Arnsbergites falcatus* (P_{1b}) Zone. The stratotype is described in detail by Ramsbottom (1981), with a review of published work provided by Cossey *et al*. (2004, p226-229).

Namurian Regional Stage

Substages have not been established world-wide, the nomenclature used in the UK applying to the Western Europe chronostratigraphic classification. Many of the substages have been defined using ammonoid fauna present in marine bands deposited during marine transgressions.

The Namurian Stage (formerly Series) comprises seven substages (formerly stages) coincident with ammonoid zones Pendleian (E_1), Arnsbergian (E_2), Chokierian (H_1), Alportian (H_2), Kinderscoutian (R_1), Marsdenian (R_2) and Yeadonian (G_1). The Namurian Substage indices were originally proposed by Bisat (1924) to indicate biozones. Boundary stratotypes for all but the Arnsbergian have been defined in northern England (Ramsbottom 1981). It was also agreed that existing substage names be maintained despite the necessity to identify some stratotypes away from the geographical localities indicated by these names.

The **Pendleian** type locality is at Light Clough, Pendle Hill, Lancashire [SD 7516 3764] (Fig. 2.3a), proposed by Ramsbottom (1981). The section, within the hemipelagic claystones of the Bowland Shale Formation (see Chapter 11), is the type locality for *Cravenoceras* (*=Emstites) leion* (Bisat 1930). The lowest occurrence of this fauna was agreed at Heerlen, 1935 to be taken as the base of the Pendleian Stage (now Substage) and the Namurian Series (now Stage).

The **Arnsbergian** is named after Arnsberg, Westphalia, Germany (Hudson & Cotton 1943), although this site is an unsatisfactory stratotype due to the absence of *Cravenoceras cowlingense*, the first appearance of which marks the base of the substage. The most complete section of the basal part of the substage is at Stony River, Slieve Anierin, County Leitrim [H 010 178] (Yates 1962) and has been proposed as the boundary stratotype (Ramsbottom 1969; Fig. 2.3b and see Chapter 19).

The **Chokierian** is named after Chokier, Belgium (Hodson 1957), though the site lacks a good section (Ramsbottom 1969). The type locality is at Stonehead Beck (formerly Gill Beck), North Yorkshire [SD 9474 4330 to SD 9470 4326] (Ramsbottom 1981; Fig. 2.3c and see Chapter 11). The site is described fully by Riley *et al*. (1987), Varker *et al*. (1991) and Riley *et al*. (1995). The exposure comprises more than 40 m of hemipelagic claystone of the Sabden Shales, and includes the *Isohomoceras subglobosum* Marine Band, the base of which marks the base of the substage. This was also the British proposed stratotype for the Mississippian–Pennsylvanian boundary. The first appearance of the conodont *Declinognathodus*, which defines the internationally recognised Mid-Carboniferous Boundary, occurs 9.4 m above the base of the Chokierian.

The **Alportian**, originally based upon the Alport Borehole in Derbyshire has a type locality at Blake Brook, Staffordshire [SK 0625 6119] (Ramsbottom 1981; Fig. 2.3d). The base of the substage is taken at the base of the *Hudsonoceras proteum* horizon. The entire thickness of Alportian strata is 10 m, present within hemipelagic claystone within the Morridge Formation (see Chapter 10).

The **Kinderscoutian** was originally named by Bisat (1928) from the Kinder Scout area of Derbyshire, associated with the ammonoid genus *Reticuloceras*. However, no good section in the basinal hemipelagic shales is present at Kinder Scout. The type locality of Samlesbury Bottoms, Lancashire [SD 6183 2916] was proposed by Ramsbottom (1969; Fig. 2.3e). The exposure comprises more than 35 m of hemipelagic claystone of the Sabden Shales (see Chapter 11), and includes the *Hodsonites magistrorum* Marine Band, the base of which marks the base of the substage.

The **Marsdenian**, erected by Bisat (1928), has a proposed basal stratotype at Park Clough, Marsden, West Yorkshire [SE 0299 1246] (Ramsbottom 1981; Fig. 2.3f and see Chapter 11). The base of the substage is defined as the base of marine strata containing *Bilinguites gracilis* (basionym: *Reticuloceras gracile* Bisat).

The **Yeadonian** was originally named from Yeadon, West Yorkshire, type locality of *Cancelloceras cancellatum* (formerly *Gastrioceras cancellatum*). The first appearance of this ammonoid marks the base of the substage. The section has been lost and a new basal stratotype at Orchard Farm, Derbyshire [SK 0226 6903] has been proposed (Ramsbottom 1981; Fig. 2.3g and see Chapter 10).

Westphalian Regional Stage

The Westphalian was defined as a series (George & Wagner 1972) divided into four stages, continuing to use the informal nomenclature of A, B, C and D originally proposed at the Heerlen Congress in 1935. Three stages (now substages) have been formally named, the

Langsettian (Westphalian A), Duckmantian (B) and Bolsovian (C) with boundary stratotypes present in the East Pennines Coalfield of England (Owens *et al*. 1985). The Westphalian D, introduced by Bertrand (1937), has as yet no formally defined stratotype, although a proposal to replace Westphalian D with Asturian, with a stratotype in Asturias, northwest Spain, has been recently made (Wagner *et al*. 2002).

The **Langsettian** stratotype is at Langsett, River Little Don, South Yorkshire [SE 2215 0041] (Fig. 2.4a and see Chapter 11). The base of the substage, and hence also the base of the Westphalian Regional Stage (former Series), is defined as the base of marine strata containing *Gastrioceras subcrenatum*.

The **Duckmantian** stratotype is at Duckmanton, north Derbyshire [SK 4237 7040] (Fig. 2.4b and see Chapter 11). The type section includes the uppermost 75 m of Langsettian strata and 50 m of Duckmantian strata. The base of the substage is defined as the base of marine strata containing *Anthracoceratites vanderbeckei*.

The **Bolsovian** stratotype is in the River Doe Lea, Bolsover, north Derbyshire [SK 4590 6930] (Fig. 2.4c and see Chapter 11). The base of the substage is defined as the base of marine strata containing *Donetzoceras aegiranum*.

Stephanian Regional Stage

The Stephanian was originally defined in the intramontane basins of the Massif Central of France as a series with three stages, referred to as Stephanian A, B and C. The Stephanian A was formally renamed the Barreulian Stage (now Substage), with a boundary stratotype in northern Spain (Wagner & Winkler Prins 1985). The Stephanian B and C are yet to be renamed. The recognition of a non-sequence in the Massif Central and the identification of strata older than Barreulian in Cantabria, northern Spain, led to the establishment of the Cantabrian Stage (now Substage) as the lowest division of the Stephanian (George & Wagner 1972; Wagner & Winkler Prins 1985), again with a boundary stratotype in northern Spain.

The Carboniferous-Permian boundary is defined in the South Ural Mountains. The current tentative correlation with Western Europe suggests the basal Permian equates with mid-Autunian Regional Stage (Wagner 1998). The basal Permian is associated with a sudden increase in the conifer pollen *Protonieisporites*, representing an amelioration of climate at the end of the Pennsylvanian ice-age (Wagner & Winkler Prins 1991).

Stephanian strata are mainly absent within the British Isles. Only strata of lowermost Cantabrian have been found in South Wales and southern England and of Stephanian C (lower Autunian) in the Midland Valley of Scotland (Wagner 1983).

Geochronology

Radiometric ages for the Carboniferous have been derived principally from thin beds of tuff, tonstein or bentonite, providing ages of eruption of deposits accumulating rapidly within sedimentary successions with good biostratigraphical control. Much reliance has been made in the UK of numerous K-Ar dates determined from intrusive dolerites (Fitch *et al*. 1970). Many of these dates have been affected by subsequent argon mobility, giving spurious ages and are consequently of little significance in calibrating the Carboniferous Period.

The main sources of internationally recognised ages are U-Pb zircon and Ar-Ar sanidine (Davydov *et al*. 2004), although inconsistencies are recognised between sources and laboratory techniques (Menning *et al*. 2000). Radiometric ages attributed to the international stages are shown in Chapter 25. Many of the published Ar-Ar data for the Namurian and Westphalian comes from Central and Western Europe, though as chronostratigraphical correlations with England and Wales are well established, these ages are applicable in the UK.

A significant SHRIMP ion microprobe $^{238}U/^{206}Pb$ zircon date of 314.5 ± 4.6 Ma has been determined for biostratigraphically well contrained Arnsbergian bentonites from the northern part of the Pennine Basin, north of Leeds (Riley *et al*. 1995). $^{40}Ar/^{39}Ar$ dates have been determined in the Midland Valley of Scotland, giving an age for the Garleton Hills Volcanic Formation (late Tournaisian to early Visean) of 342.1 ± 1.3 and 342.4 ± 1.1 Ma, for the Clyde Plateau Volcanic Formation (mid Visean) of between 335 ± 2 and 329.2 ± 1.4 Ma and for late Carboniferous to early Permian alkaline intrusives from 298.3 ± 1.3 to 292.1 ± 1.1 Ma (Monaghan & Pringle 2004; Monaghan & Parrish 2006).

The Kelso Volcanic Formation, alkaline basalts of the Inverclyde Group, of Tournaisian age, have been dated by K-Ar methods at 361 ± 7 Ma (de Souza 1982). In Derbyshire, K-Ar ages typically indicate intrusion during Bolsovian to Autunian times, despite an absence of dolerite intrusions in strata younger than Visean age. An Ar-Ar plateau age of c. 321 Ma obtained from groundmass plagioclase of the Waterswallows Sill by M. Timmerman (pers comm., 2002), reported in Waters (2003), suggests a Namurian age of intrusion. In southeast Wales, a K-Ar date of 336 ± 7 Ma (Fitch *et al*. 1969) on a biotite separate from the Golden Hill diatreme pipe is in agreement with Visean age fossils found in a block of limestone within the pipe.

A whole-rock K-Ar date of 308 ± 10 Ma has been determined on a dolerite from Barrow Hill, near Dudley (Fitch *et al*. 1970). Extrusive volcaniclastic deposits associated with the vent are interbedded with sedimentary strata of Bolsovian age. This suggests that the radiometric age probably represents a close minimum for the true intrusive age.

Event stratigraphy

The subdivision of British Carboniferous successions using event stratigraphy was initiated by Ramsbottom (1973, 1977, 1978c 1979). He identified cyclical facies changes (mesothems) and associated faunal variations that formed the basis of the Carboniferous of Great Britain and Ireland into distinct stages (now substages), as described above. He argued that the mesothems resulted from eustatic transgressive/regressive pulses with the boundaries of each major cycle occurring as widespread disconformities in shelf areas. Over recent decades sequence stratigraphic methodology has evolved to use the interaction of depositional systems in response to relative sea-level fluctuations as a powerful tool to aid correlation. The technique uses a range of key surfaces, including flooding surfaces, the marine bands described in Chapter 3) and regionally widespread surfaces of erosion and emergence, referred to as sequence boundaries, to examine facies relationships. A description of the application of sequence stratigraphy to Carboniferous successions is beyond the scope of this publication, but Hampson *et al*. (1997) provide a valuable appraisal.

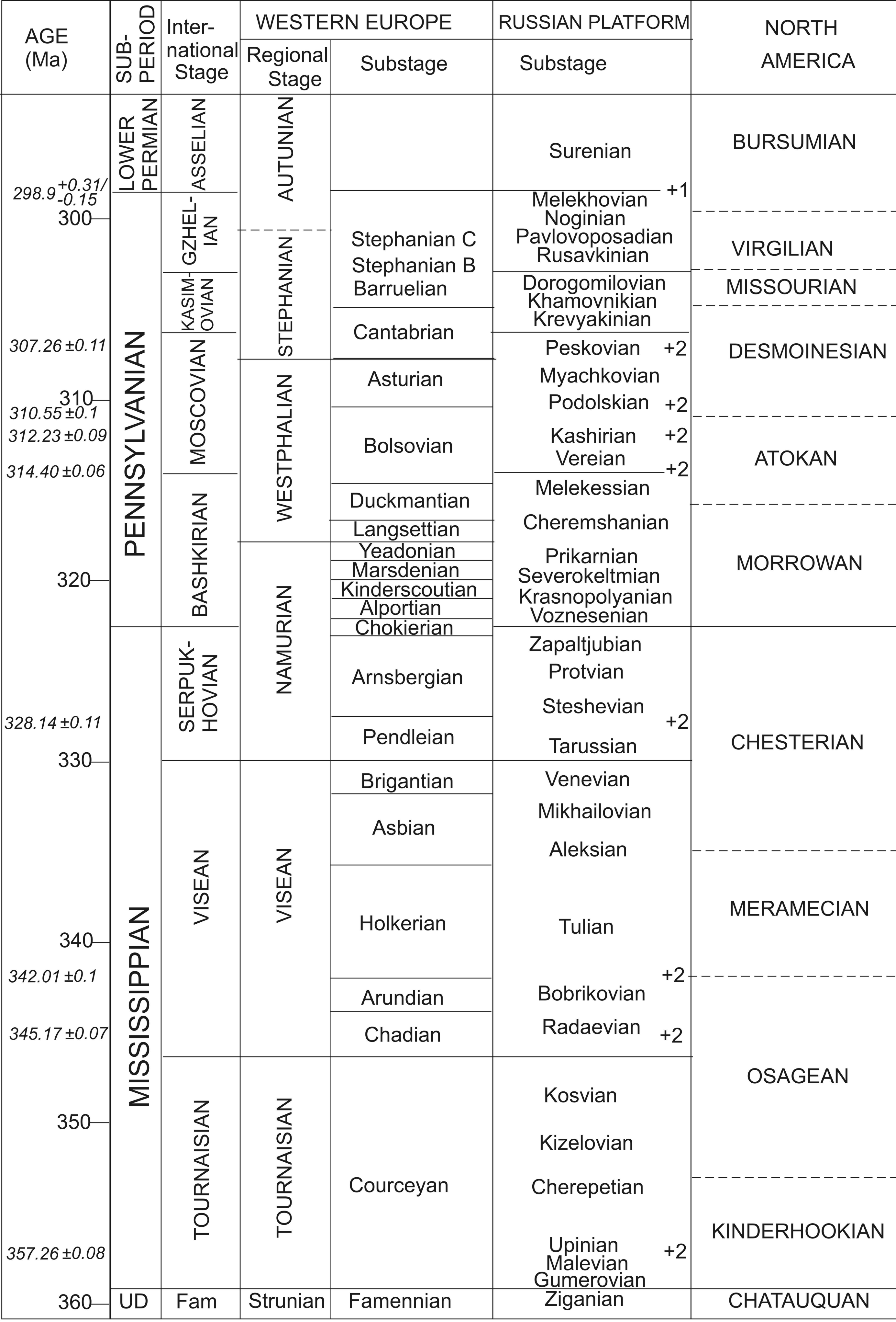
A seismostratigraphical classification for the Carboniferous of northern England (Fraser & Gawthorpe 1990) and for the Tournaisian to Visean of the East Midlands (Ebdon *et al.* 1990) used mainly reflection seismic data suggested that many of the cyclical and widespread facies changes reflect discrete periods of rifting and subsidence alternating with episodes of tectonic quiescence. Six sequences (EC1-6), of broadly Late Devonian to late Brigantian age, separated by seismic sequence boundaries, were interpreted by these authors as part of a syn-rift megasequence. The late Brigantian to late Bolsovian post-rift megasequence is characterised by up to four sequences (LC1a-c & LC2) formed during the phase of thermal subsidence with minor fault reactivation. Finally, the inversion megasequence of late Bolsovian to early Permian age comprises two sequences (V1-2). The classification has been particularly relevant in basin investigations by the hydrocarbons industry.

Fig. 2.1 Correlation of the international chronostratigraphy with regional nomenclatures used in Western Europe, U.S.A. and Russia, adapted from Davydov *et. al.* (2004) with radiometric dates from Ramezani *et al.* 2007 and Davydov *et al.* 2010. UD = Upper Devonian; Fam = Famennian. Details are described in Chapter 25.

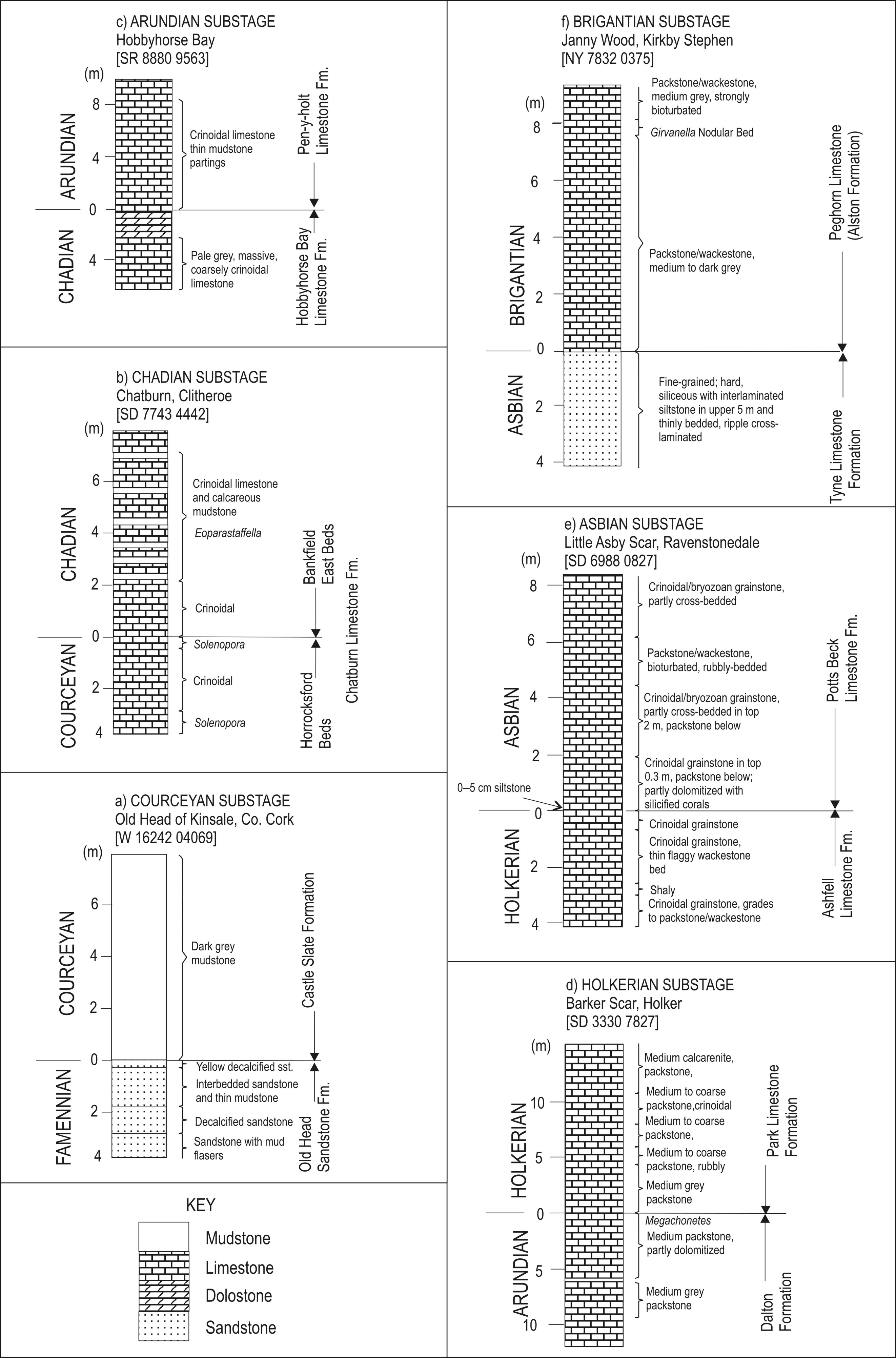
Fig. 2.2 Details of the substage stratotypes for the Tournaisian and Visean successions of Western Europe (from George *et al.* 1976).

Fig. 2.3 Details of the substage stratotypes for the Namurian successions of Western Europe (from Ramsbottom 1969 & 1981).

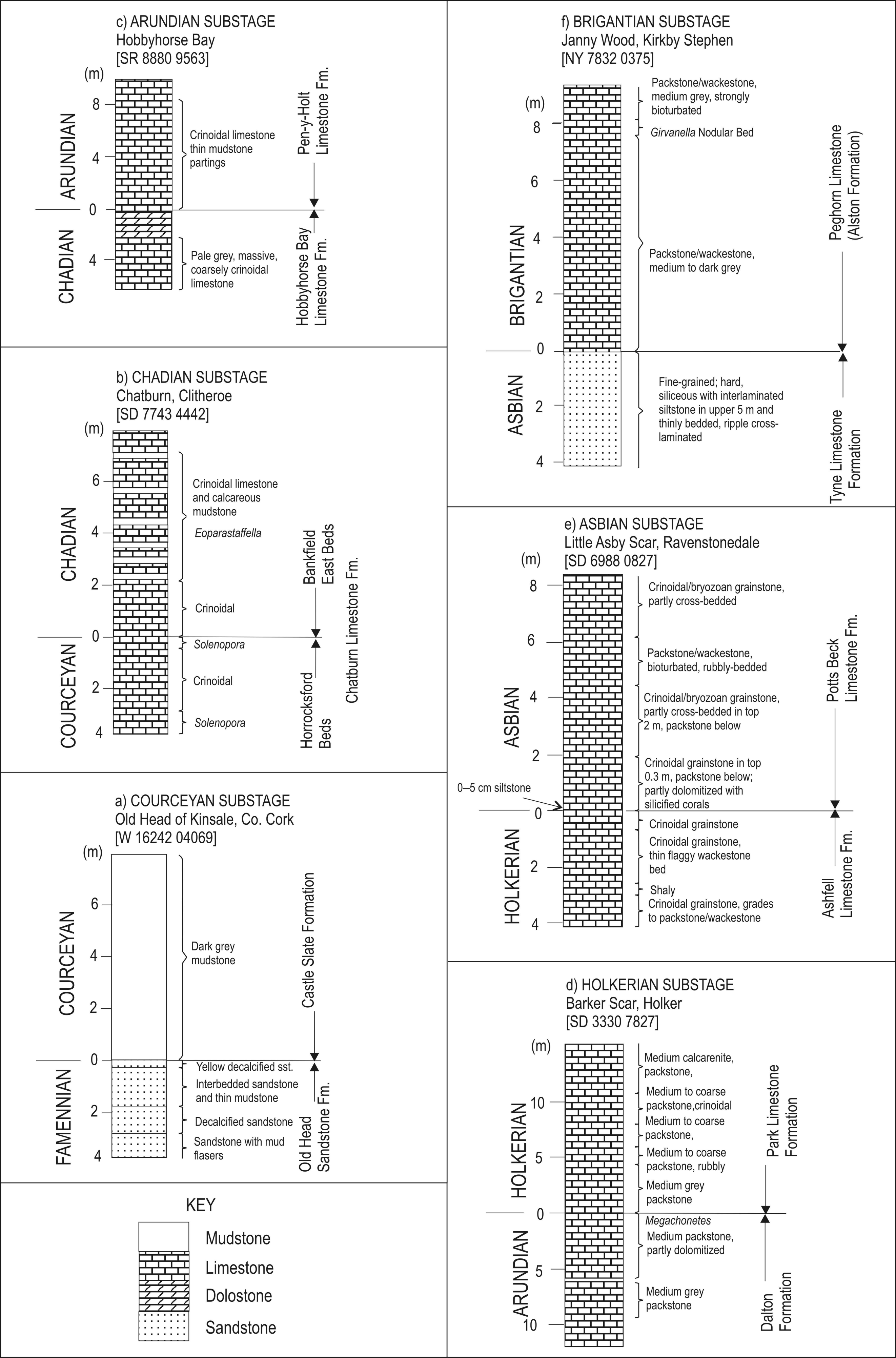
Fig. 2.4 Details of the substage stratotypes for the Westphalian successions of Western Europe (from Owens *et al.* 1985).



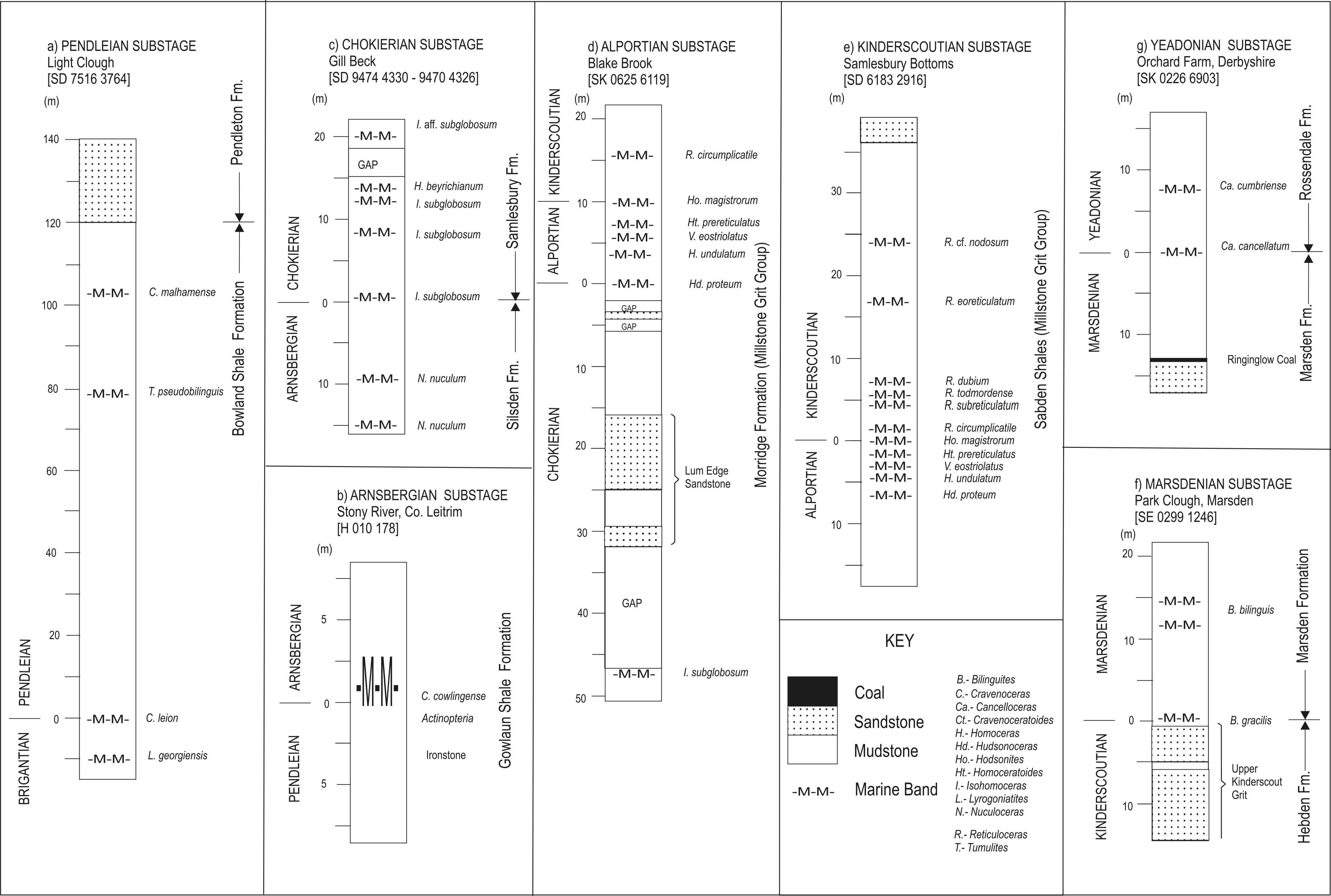
+1 - Ramezani et al. (2007) +2 - Davydov et al. (2010)



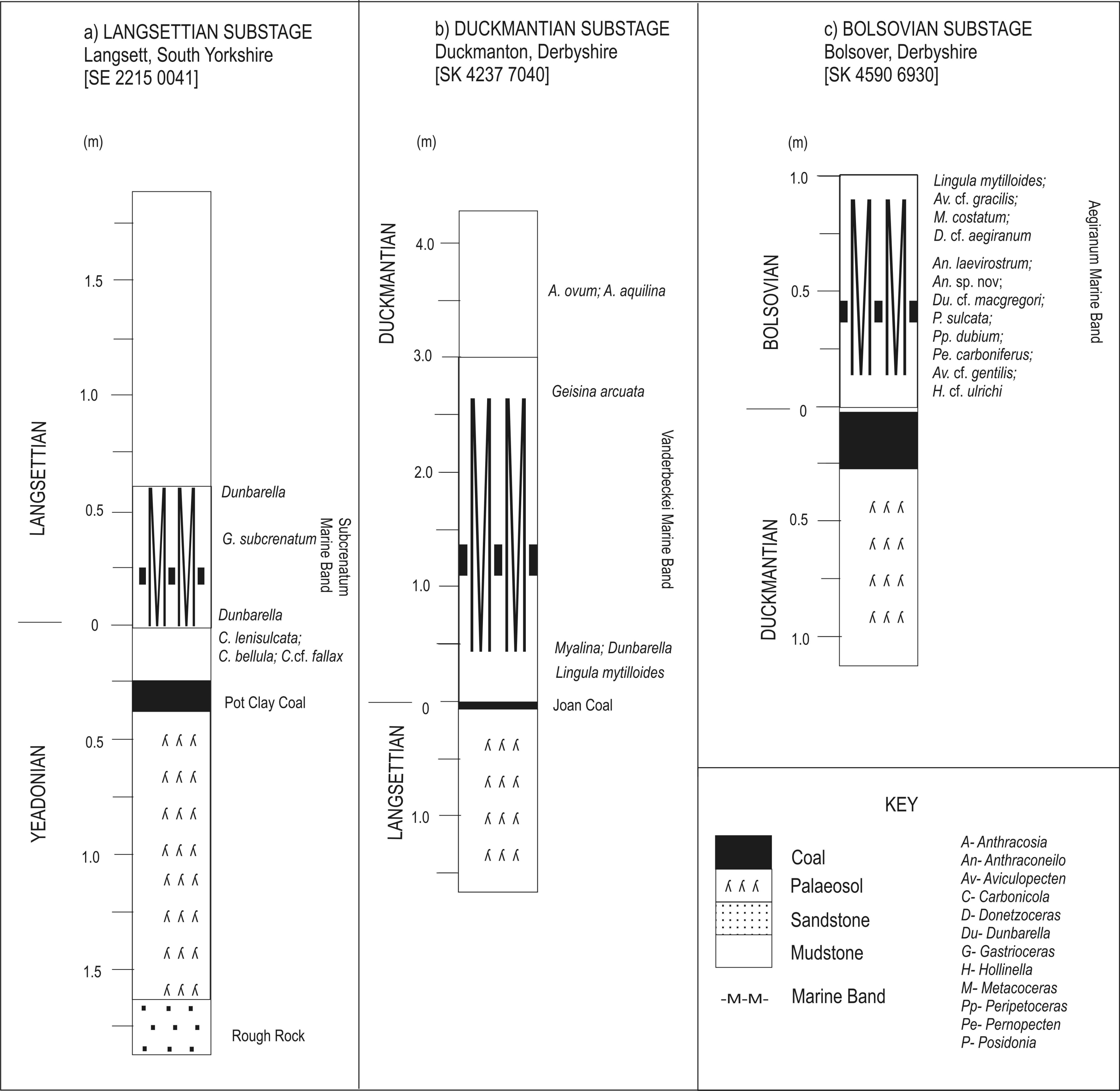
c) ARUNDIAN SUBSTAGE
Hobbyhorse Bay
[SR 8880 9563]
(m)
ARUNDIAN
CHADIAN
8
4
0
4
Crinoidal limestone thin mudstone partings
Pale grey, massive, coarsely crinoidal limestone
Pen-y-holt Limestone Fm.
Hobbyhorse Bay Limestone Fm.
b) CHADIAN SUBSTAGE
Chatburn, Clitheroe
[SD 7743 4442]
(m)
CHADIAN
COURCEYAN
6
4
2
0
2
4
Crinoidal limestone and calcareous mudstone
Eoparastaffella
Crinoidal
Solenopora
Crinoidal
Solenopora
Bankfield East Beds
Horrocksford Beds
Chatburn Limestone Fm.
a) COURCEYAN SUBSTAGE
Old Head of Kinsale, Co. Cork
[W 16242 04069]
(m)
COURCEYAN
FAMENNIAN
6
4
2
0
2
4
Dark grey mudstone
Yellow decalcified sst.
Interbedded sandstone and thin mudstone
Decalcified sandstone
Sandstone with mud flasers
Castle Slate Formation
Old Head Sandstone Fm.
KEY
Mudstone
Limestone
Dolostone
Sandstone
f) BRIGANTIAN SUBSTAGE
Janny Wood, Kirkby Stephen
[NY 7832 0375]
(m)
BRIGANTIAN
ASBIAN
8
6
4
2
0
2
4
Packstone/wackestone, medium grey, strongly bioturbated
Girvanella Nodular Bed
Packstone/wackestone, medium to dark grey
Fine-grained; hard, siliceous with interlaminated siltstone in upper 5 m and thinly bedded, ripple cross-laminated
Peghorn Limestone (Alston Formation)
Tyne Limestone Formation
e) ASBIAN SUBSTAGE
Little Asby Scar, Ravenstonedale
[SD 6988 0827]
(m)
ASBIAN
HOLKERIAN
8
6
4
2
0
2
4
Crinoidal/bryozoan grainstone, partly cross-bedded
Packstone/wackestone, bioturbated, rubbly-bedded
Crinoidal/bryozoan grainstone, partly cross-bedded in top 2 m, packstone below
Crinoidal grainstone in top 0.3 m, packstone below; partly dolomitized with silicified corals
0–5 cm siltstone
Crinoidal grainstone
Crinoidal grainstone, thin flaggy wackestone bed
Shaly
Crinoidal grainstone, grades to packstone/wackestone
Potts Beck Limestone Fm.
Ashfell Limestone Fm.
d) HOLKERIAN SUBSTAGE
Barker Scar, Holker
[SD 3330 7827]
(m)
HOLKERIAN
ARUNDIAN
10
5
0
5
10
Medium calcarenite, packstone,
Medium to coarse packstone,crinoidal
Medium to coarse packstone,
Medium to coarse packstone, rubbly
Medium grey packstone
Megachonetes
Medium packstone, partly dolomitized
Medium grey packstone
Park Limestone Formation
Dalton Formation



c) ARUNDIAN SUBSTAGE
Hobbyhorse Bay
[SR 8880 9563]
(m)
8
4
0
4
ARUNDIAN
CHADIAN
Crinoidal limestone thin mudstone partings
Pale grey, massive, coarsely crinoidal limestone
Pen-y-Holt Limestone Fm.
Hobbyhorse Bay Limestone Fm.
b) CHADIAN SUBSTAGE
Chatburn, Clitheroe
[SD 7743 4442]
(m)
6
4
2
0
2
4
CHADIAN
COURCEYAN
Crinoidal limestone and calcareous mudstone
Eoparastaffella
Crinoidal
Solenopora
Crinoidal
Solenopora
Bankfield East Beds
Horrocksford Beds
Chatburn Limestone Fm.
a) COURCEYAN SUBSTAGE
Old Head of Kinsale, Co. Cork
[W 16242 04069]
(m)
6
4
2
0
2
4
COURCEYAN
FAMENNIAN
Dark grey mudstone
Yellow decalcified sst.
Interbedded sandstone and thin mudstone
Decalcified sandstone
Sandstone with mud flasers
Castle Slate Formation
Old Head Sandstone Fm.
KEY
Mudstone
Limestone
Dolostone
Sandstone
f) BRIGANTIAN SUBSTAGE
Janny Wood, Kirkby Stephen
[NY 7832 0375]
(m)
8
6
4
2
0
2
4
BRIGANTIAN
ASBIAN
Packstone/wackestone, medium grey, strongly bioturbated
Girvanella Nodular Bed
Packstone/wackestone, medium to dark grey
Fine-grained; hard, siliceous with interlaminated siltstone in upper 5 m and thinly bedded, ripple cross-laminated
Peghorn Limestone (Alston Formation)
Tyne Limestone Formation
e) ASBIAN SUBSTAGE
Little Asby Scar, Ravenstonedale
[SD 6988 0827]
(m)
8
6
4
2
0
2
4
ASBIAN
HOLKERIAN
Crinoidal/bryozoan grainstone, partly cross-bedded
Packstone/wackestone, bioturbated, rubbly-bedded
Crinoidal/bryozoan grainstone, partly cross-bedded in top 2 m, packstone below
Crinoidal grainstone in top 0.3 m, packstone below; partly dolomitized with silicified corals
0–5 cm siltstone
Crinoidal grainstone
Crinoidal grainstone, thin flaggy wackestone bed
Shaly
Crinoidal grainstone, grades to packstone/wackestone
Potts Beck Limestone Fm.
Ashfell Limestone Fm.
d) HOLKERIAN SUBSTAGE
Barker Scar, Holker
[SD 3330 7827]
(m)
10
5
0
5
10
HOLKERIAN
ARUNDIAN
Medium calcarenite, packstone,
Medium to coarse packstone,crinoidal
Medium to coarse packstone,
Medium to coarse packstone, rubbly
Medium grey packstone
Megachonetes
Medium packstone, partly dolomitized
Medium grey packstone
Park Limestone Formation
Dalton Formation



a) PENDLEIAN SUBSTAGE
Light Clough
[SD 7516 3764]
(m)
140
120
100
80
60
40
20
0
-M-M- C. malhamense
-M-M- T. pseudobilinguis
-M-M- C. leion
-M-M- L. georgiensis
PENDLEIAN
BRIGANTIAN
Pendleton Fm.
Bowland Shale Formation
c) CHOKIERIAN SUBSTAGE
Gill Beck
[SD 9474 4330 - 9470 4326]
(m)
20
10
0
10
-M-M- I. aff. subglobosum
GAP
-M-M- H. beyrichianum
-M-M- I. subglobosum
-M-M- I. subglobosum
-M-M- I. subglobosum
-M-M- N. nuculum
-M-M- N. nuculum
CHOKIERIAN
ARNSBERGIAN
Samlesbury Fm.
Silsden Fm.
b) ARNSBERGIAN SUBSTAGE
Stony River, Co. Leitrim
[H 010 178]
(m)
5
0
5
-M-M-
C. cowlingense
Actinopteria
Ironstone
ARNSBERGIAN
PENDLEIAN
Gowlaun Shale Formation
d) ALPORTIAN SUBSTAGE
Blake Brook
[SK 0625 6119]
(m)
20
10
0
10
20
30
40
50
-M-M- R. circumplicatile
-M-M- Ho. magistrorum
-M-M- Ht. prereticulatus
-M-M- V. eostriolatus
-M-M- H. undulatum
-M-M- Hd. proteum
GAP
GAP
Lum Edge Sandstone
GAP
-M-M- I. subglobosum
KINDERSCOUTIAN
ALPORTIAN
CHOKIERIAN
Morridge Formation (Millstone Grit Group)
e) KINDERSCOUTIAN SUBSTAGE
Samlesbury Bottoms
[SD 6183 2916]
(m)
30
20
10
0
10
-M-M- R. cf. nodosum
-M-M- R. eoreticulatum
-M-M- R. dubium
-M-M- R. todmordense
-M-M- R. subreticulatum
-M-M- R. circumplicatile
-M-M- Ho. magistrorum
-M-M- Ht. prereticulatus
-M-M- V. eostriolatus
-M-M- H. undulatum
-M-M- Hd. proteum
KINDERSCOUTIAN
ALPORTIAN
Sabden Shales (Millstone Grit Group)
g) YEADONIAN SUBSTAGE
Orchard Farm, Derbyshire
[SK 0226 6903]
(m)
10
0
10
-M-M- Ca. cumbriense
-M-M- Ca. cancellatum
Ringinglow Coal
YEADONIAN
MARSDENIAN
Rossendale Fm.
Marsden Fm.
f) MARSDENIAN SUBSTAGE
Park Clough, Marsden
[SE 0299 1246]
(m)
20
10
0
10
-M-M-
-M-M- B. bilinguis
-M-M- B. gracilis
Upper Kinderscout Grit
MARSDENIAN
KINDERSCOUTIAN
Marsden Formation
Hebden Fm.
KEY
Coal
Sandstone
Mudstone
-M-M- Marine Band
B.- Bilinguites
C.- Cravenoceras
Ca.- Cancelloceras
Ct.- Cravenoceratoides
H.- Homoceras
Hd.- Hudsonoceras
Ho.- Hodsonites
Ht.- Homoceratoides
I.- Isohomoceras
L.- Lyrogoniatites
N.- Nuculoceras
R.- Reticuloceras
T.- Tumulites


a) LANGSETTIAN SUBSTAGE
Langsett, South Yorkshire
[SE 2215 0041]
(m)
1.5
1.0
0.5
0
0.5
1.0
1.5
LANGSETTIAN
YEADONIAN
Dunbarella
G. subcrenatum
Dunbarella
C. lenisulcata;
C. bellula; C.cf. fallax
Subcrenatum Marine Band
Pot Clay Coal
Rough Rock
b) DUCKMANTIAN SUBSTAGE
Duckmanton, Derbyshire
[SK 4237 7040]
(m)
4.0
3.0
2.0
1.0
0
1.0
DUCKMANTIAN
LANGSETTIAN
A. ovum; A. aquilina
Geisina arcuata
Myalina; Dunbarella
Lingula mytilloides
Vanderbeckei Marine Band
Joan Coal
c) BOLSOVIAN SUBSTAGE
Bolsover, Derbyshire
[SK 4590 6930]
(m)
1.0
0.5
0
0.5
1.0
BOLSOVIAN
DUCKMANTIAN
Lingula mytilloides;
Av. cf. gracilis;
M. costatum;
D. cf. aegiranum
An. laevirostrum;
An. sp. nov;
Du. cf. macgregori;
P. sulcata;
Pp. dubium;
Pe. carboniferus;
Av. cf. gentilis;
H. cf. ulrichi
Aegiranum Marine Band
KEY
Coal
Palaeosol
Sandstone
Mudstone
-M-M-
Marine Band
A- Anthracosia
An- Anthraconeilo
Av- Aviculopecten
C- Carbonicola
D- Donetzoceras
Du- Dunbarella
G- Gastrioceras
H- Hollinella
M- Metacoceras
Pp- Peripetoceras
Pe- Pernopecten
P- Posidonia