Chapter 10
Peak District and north Staffordshire

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Carboniferous rocks within this area occupy the region to the south of, and contiguous with, the Southern Pennines (see Chapter 11). The oldest Tournaisian and Visean strata occur at outcrop within the Peak District, represented by ramp-to-shelf carbonates (Peak Limestone Group) deposited on the Derbyshire High, a promontory of the East Midlands Shelf, and the laterally extensive Staffordshire and Hathern shelves. The platform carbonates of the East Midlands Shelf extend in the sub-surface below Nottinghamshire and Lincolnshire, where the nature of the succession is based largely upon well records and geophysical information (Strank 1987). A 23 m thick succession of platform carbonates is recorded in the base of the Saltfleetby No. 3 Borehole [TF 4246 9135] (Hodge 2003) and at least 100 m is present in the Welton Oilfield (Fig. 10.1). The Derbyshire High platform carbonate rocks pass into more basinal successions in the Edale Basin to the north, the Widmerpool Trough to the south and the Staffordshire Basin to the west, dominated by hemipelagic mudstone and carbonate turbidites (Craven Group). The lithostratigraphical nomenclature for the Tournaisian and Visean strata is that of Waters *et al.* (2009), adapted from Aitkenhead & Chisholm (1982).

The Derbyshire High is flanked to the north, west and east by Namurian and Westphalian strata, occupying the southern extension of the Pennine Anticline (Figure 10.1). The relic Dinantian palaeotopography is partially infilled by hemipelagic mudstone and siliciclastic turbidites (Craven Group). Subsequently, fluvio-deltaic deposits and intervening pro-delta mudstone (Millstone Grit Group) were deposited across the region, the base of the group occurring mainly at the base of the first mappable quartzo-feldspathic sandstone (Waters *et al*. 2009). The overlying Westphalian strata are dominated by fluvio-lacustrine deposits (Pennine Coal Measures Group), with subsequent deposition of late Westphalian to Stephanian red-bed alluvial deposits (Warwickshire Group). On the eastern limb, Westphalian strata form the East Pennine Coalfield of Nottinghamshire, which extends in the sub-surface below strata of Permian and Triassic age. On the western limb, Westphalian to Stephanian strata are preserved in the Potteries and Cheadle coalfields.

Tournaisian

The oldest Tournaisian deposits, mainly proved in deep boreholes, are associated with red alluvial sandstone and/or peritidal to shallow marine dolostone and anhydrite. The Caldon Low Borehole [SK 0804 4822] provides a key record of the succession in Dovedale (Fig. 10.2, Col. 4). It penetrated the Redhouse Sandstone Formation, which although undated is thought to be Tournaisian in age in its upper part (Chisholm *et al*. 1988). The overlying Rue Hill Dolomite Formation includes miospores near the base of the formation (Welsh & Owens 1983), that indicate the VI Subzone [^1]. In the shelf area around Buxton–Matlock (Fig. 10.2, Col. 5) the lower beds of the Middleton Dale Anhydrite Formation, proved in the Eyam Borehole [SK 2096 7603], includes a miospore assemblage between 1735 and 1791 m (Dunham 1973), which indicates the CM Zone [^1]. Thick dolostones, interbedded tuffs and clastic sediments occur in the subsurface near to Lincoln, with Tournaisian strata absent on the East Midlands Shelf

between Nottingham and Lincoln, probably resulting from emergence of the Nocton and Foston highs (Strank 1987).

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The lowermost, Tournaisian, part of the Peak Limestone Group is represented over much of the region by the Milldale Limestone Formation, comprising inter-reef crinoidal biosparites and cherty micrites and massive mud-mounds. Locally, on the Nottingham Shelf, the formation rests unconformably upon deformed Lower Palaeozoic strata (Fig. 10.2, Col. 7). Tournaisian foraminifers are recorded within the formation in the Gun Hill Borehole [SJ 9723 6182] (Fig. 10.2, Col. 2), with diagnostic fauna including *Uriella sp*., *Septaglomospira comblaini* and *Palaeospiroplectammina parva* [O1] (Aitkenhead *et al*. 1985). The lower part of the formation in the Caldon Low Borehole (Fig. 10.2, Col. 4) contains foraminifers indicative of the Cf4α1 Subzone [O2] (Chisholm *et al*. 1988). At outcrop, late Tournaisian conodonts, including *Scaliognathus anchoralis*, have also been recorded at Brownend Quarry, near Waterhouses [SK 0910 5019] (Fig. 10.2, Col. 4 [O2]; Morris 1970) and Wettonmill [SK 0996 5638] (Fig. 10.2, Col. 2 [O1]; Aitkenhead *et al*. 1985). In the shelf area (Fig. 10.2, Col. 5) the Peak Limestone Group is represented by the Woo Dale Limestone Formation, mainly of Visean age.

Visean

Within the Chadian to Holkerian ramp carbonate succession of the Peak Limestone Group, the shallow-water Woo Dale Limestone Formation of the Derbyshire High passes laterally to the south and west into the Milldale Limestone Formation, deposited in the slightly deeper water of the Staffordshire Basin.

The Woo Dale Limestone Formation comprises a lower succession of packstone and grainstone deposited in a shallow open shelf, overlain by mudstone an wackestone deposited in a tidal flat and finally dark grey packstone and grainstone deposited in a restricted lagoon (Schofield & Adams 1985). In the Eyam Borehole (Fig. 10.2, Col. 5) the formation includes foraminifers attributed to the Chadian [O2] (V1a Subzone of Belgium) by R. Conil (in Dunham 1973), with Chadian and Arundian foramanifers found in the lowest 1048 m. At outcrop, the type locality of the Iron Tors Limestone Member includes the foraminifers *Dainella sp*., *Eoparastafella sp*. and *Spinobrunsiina sp*., considered indicative of a Chadian age [O2] (Aitkenhead *et al*. 1985). The basal 157.7 m of the formation proved in the Woo Dale Borehole [SK 0985 7248] include algal and foraminiferal assemblages indicative of an Arundian age [O3] (Strank 1985), as opposed to the Chadian to Arundian age reported for the basal 133.0 m by George *et al*. (1976). The upper part of the formation includes Holkerian brachiopod taxa *Davidsonina carbonaria*, *Daviesiella derbiensis* and *Linoprotonia corrugatohemispherica* [*4] (Aitkenhead *et al*. 1985). This succession is represented by the upper 276 m of the formation proved in the Eyam Borehole (Dunham 1973). The top of the formation may be younger to the north, with the presence of *Dibunophyllum bourtonense* indicating an Asbian age for the topmost part of the formation [*5] (Mitchell in Stevenson & Gaunt 1971).

In the Goyt Trough and on the Staffordshire Shelf (Fig. 10.2) there is a continuation from the Tournaisian of deposition of the Milldale Limestone Formation. The Gun Hill Borehole (Fig. 10.2, Col. 2) includes Arundian [O2] and Holkerian [O3] foraminifers

(Aitkenhead *et al.* 1985). In the Dovedale area (Fig. 10.2, Col. 4) the formation contains foraminifers indicative of the Cf4α2 Subzone [O3] and the presence of the ammonoid *Bollandoceras* cf. *hodderense* suggests a late Holkerian age for the top of the formation [+5] (Chisholm *et al*. 1988).

On the Nottingham Shelf, the dolomitic, locally ooidal limestone of the Belvoir Limestone Formation (Carney *et al.* 2004) is considered to rest unconformably upon the Milldale Limestone Formation in the Vale of Belvoir (Fig. 10.2, Col. 7). A Chadian age is assumed for the topmost part of the Belvoir Limestone Formation in the Plungar 8A Borehole [SK 7745 3336], which yielded bilaminar *Koninckopora*, with no archaediscids present [O1] (Riley 1992). Further to the east, shallow-water limestone and dolostone with mud-mounds and bioherms are identified in the Chadian succession around Lincoln, thinning dramatically over the Nocton and Stixwold highs (Strank 1987). Holkerian carbonate rocks are recorded widely in the subsurface, extending as far as north east Norfolk and developing over the Nocton, Foston and Stixwold highs (Strank 1987).

By Asbian times a further sea-level rise along with syn-rift subsidence led to a clear differentiation between shelf provinces, fringed by apron-reefs (Peak Limestone Group), and off-shelf facies (Craven Group).

The Bowsey Wood Formation (former Astbury Limestone) comprises pale grey massive and thick bedded limestones deposited upon the Market Drayton Horst (Fig. 10.2, Col. 1). Late Asbian foraminifers [O1] are recorded by Earp & Calver (1961a), an age supported by diverse faunal assemblages described by Evans *et al*. (1968) and Rees & Wilson (1998). This passes up into the Astbury Formation (former Astbury Limestone-Shales) a succession of mudstone interbedded with limestone, sandstone, tuff, coal and seatearth palaeosols, the two highest coals including miospores of late Brigantian age [^2] (Evans *et al*. 1968). The formation probably represents a shallow marine, periodically emergent shelf equivalent of the Widmerpool Formation (Waters *et al*. 2009). The Kevin Limestone Formation is lithologically similar to the Bowsey Wood Formation but was deposited upon the adjacent Staffordshire Shelf (Fig. 10.2, Col. 3), with a late Asbian age indicated by coral assemblages [*1] (Chisholm *et al.* 1988).

The shelf province of the Derbyshire High (Fig. 10.2, Col. 5) includes the Asbian Bee Low Limestone Formation and the Brigantian Monsal Dale Limestone and Eyam Limestone formations. The Bee Low Limestone Formation mainly comprises pale grey, thick-bedded biosparite and includes characteristic Asbian coral and brachiopod taxa at outcrop and foraminiferal assemblage recorded in the Lees Barn Borehole [SK 1581 5674], with apron-reef facies containing late Asbian ammonoids of the Upper Beyrichoceras (B_2) Zone [O*+6] (Aitkenhead *et al*. 1985). The Monsal Dale Limestone Formation comprises pale to medium grey, thickly bedded and bioturbated biosparite and pelsparite, to poorly sorted biomicrite. It includes characteristic Brigantian coral and brachiopod taxa at outcrop, with several beds including abundant *Girvanella* or *Saccamminopsis* [O*7] (Aitkenhead *et al.* 1985). The presence of *Koninckopora inflata* and *Davidsonina septosa* in the lowest few metres of the formation (Chisholm *et al*. 1988) suggests, at least locally, a late Asbian age for the base of the formation.

Off-shelf, in the Dovedale area (Fig 10.2, Col. 4) the lower part of the Hopedale Limestone Formation includes mud-mounds with Upper B_2 Zone brachiopods and the ammonoid *Bollandoceras* cf. *micronotum* [+*7] (Aitkenhead *et al.* 1985). Brigantian fauna, including the coral *Diphyphyllum lateseptatum* and brachiopods *Productus hispidus* and *Pugilis pugilis*, are recorded by these authors within the upper part of the formation [*9]. The heterogeneous succession typically comprises medium to dark grey, fine- to course-grained calcarenite.

Internally, the Peak Limestone Group includes local disconformities. Those occurring during the early Visean at the base of the Belvoir Limestone and Plungar Limestone (Fig. 10.2, Col. 7) formations and within the Woo Dale Limestone Formation (Col. 5) may result from localised tectonic uplift. More extensive disconformities developed at the base of the Kevin Limestone (Fig. 10.2, Col. 3), Hopedale Limestone (Col. 4), and Bee Low Limestone (Col. 5) formations during early Asbian times may be eustatically driven. Subaerial palaeokarstic dissolution hollows are common in the Asbian and Brigantian succession (Walkden 1974) and these can be related to eustatic sea-level fluctuations that became important at this time. In the East Midlands Shelf, south of Lincoln and east of Nottingham, boreholes prove Brigantian strata to be absent, removed beneath a sub-Westphalian unconformity (Strank 1987).

The Peak Limestone Group of Derbyshire includes common basaltic lavas, olivine-dolerite sills and pyroclastic rocks, of late Holkerian to late Brigantian age, although the majority of activity occurred during early Brigantian times (Walters & Ineson 1981). The Fallgate Borehole within the Ashover inlier (Fig. 10.2, Col. 6) includes the Fallgate Volcanic Formation, which includes thin limestone beds of Asbian to Brigantian age (D_1 to D_2 coral/brachiopod zones) [*1] (Smith *et al*. 1967, p52). Sills appear to be genetically related to the extrusive rocks and are probably also of Visean age, despite radiometric ages suggesting the sills to be much younger than the lavas (Fitch *et al*. 1970). There are two main centres of igneous activity at Matlock and at Miller's Dale (Francis 1970). K-bentonites are widespread, most notably in the Bee Low Limestone Formation of Asbian age (Walkden 1972; 1977; Aitkenhead *et al*. 1985).

The overlying Craven Group initially developed within the comparatively deep-water of the Goyt Trough as a succession of proximal turbiditic, sharp-based limestone beds of the Ecton Limestone Formation. In the Dovedale area (Fig. 10.2, Col. 4) the lower beds of the formation (Fig. 10.2, Col. 4) yield a diagnostic Arundian foraminiferal assemblage [O4] with less common Holkerian assemblage [O6] (Aitkenhead *et al*. 1985). The formation extended to the Mixon off-shelf area [O4] (Fig. 10.2, Col. 2) during Holkerian–Asbian times with recorded uncommon early Asbian foraminiferal assemblages (Aitkenhead *et al*. 1985).

The Widmerpool Formation (including the former Mixon Limestone-Shales) developed within the off-shelf areas during late Asbian times and became extensive across off-shelf and drowned shelf areas by Brigantian times. It comprises calcareous mudstone, thinly interbedded with turbiditic cherty limestone and quartzose siltstone and sandstone beds. The proportion of limestone to mudstone increases northwards,

with the formation passing laterally into the Hopedale Limestone Formation of the Derbyshire platform. In the Gun Hill Borehole (Fig. 10.2, Col. 2), basal shales contain typical Asbian foraminifers and the New Mixon Hay Borehole [SK 0369 5713] includes ammonoids of the B_2 Zone [O+5] (Aitkenhead *et al.* 1985). Within Dovedale (Fig. 10.2, Col. 4) the presence of *Beyrichoceras* cf. *vesiculiferum*, *Goniatites moorei* and *G. struppus* indicates that locally the basal part of the formation is within the B_2 Zone [+8] (Chisholm *et al*. 1988). The progressive flooding of shelf areas across the region is evident by the diachronous base of the Widmerpool Formation, which on the Derbyshire High (Fig. 10.2, Col. 5) is of late Brigantian (P_2 Zone) age [+8], including the ammonoids *Neoglyphioceras sp*., *Lyrogoniatites sp*. and *Sudeticeras sp*. (Aitkenhead *et al.* 1985). Locally, the upper part of the formation in the Widmerpool Trough includes late Brigantian subaqueous basaltic lava, tuff, agglomerate and hyaloclastite, such as in the Duffield No. 1 Borehole [SK 3428 4217] (Aitkenhead 1977).

Namurian

During the early Pendleian, the hemipelagic mudstone of the Bowland Shale Formation (Craven Group) extended across most of the region. In Staffordshire, the Morridge Formation (Millstone Grit Group) conformably overlies, and interleaves with, the Bowland Shale Formation. The Morridge Formation comprises dominantly turbiditic quartzose sandstone derived from the Wales-Brabant High to the south (Trewin & Holdsworth 1973). The sandstone beds are typically sharp-based and graded, interbedded with mudstone, siltstone and subordinate chert (Chisholm *et al*. 1988). The first influx into the region of feldspathic sandstone of northern provenance is associated with the late Kinderscoutian turbiditic Longnor Sandstone (Hebden Formation), which rests conformably upon the Morridge Formation in Staffordshire and the Bowland Shale Formation in north Derbyshire. In the Widmerpool Trough, intermixing obscures the distinction between late Namurian sandstone of southern and northern provenance (Chisholm & Hallsworth 2005). In the Welton and Saltfleetby oilfields, late Namurian sandstone rests unconformably upon probable Visean carbonate rocks (Hodge 2003; Rothwell & Quinn 1987)

The Bowland Shale Formation of the Staffordshire Basin (former Lask Edge or Edale Shales) is proved in the Werrington Borehole [SJ 9434 4856] in the Stoke-on-Trent area (Fig. 10.2, Col. 1). The *Cravenoceras (=Emstites) leion* ($E_{1a}1$) and *Tumulites pseudobilinguis* ($E_{1b}2$) marine bands are present in the Whiston–Hamps Valley section [+2] (Fig. 10.2, Col. 3; Chisholm *et al*. 1988), in the Gun Hill Borehole [+6] (Fig. 10.2, Col. 2; Aitkenhead *et al.* 1985) and in the Alport Borehole [SK 1360 9105] (Fig. 10.2, Col. 9; Hudson & Cotton 1945). In the Alport/Kinder Scout (Fig. 10.2, Col. 9; Stevenson & Gaunt 1971) and Ashover (Fig. 10.2, Col. 6; Smith *et al*. 1967) areas a comprehensive development of marine bands of Pendleian [+1], Arnsbergian [+2], Chokierian [+3], Alportian [+4] and Kinderscoutian [+5] age is recorded. The uppermost marine band of the Bowland Shale Formation within the Alport Borehole contains *Reticuloceras reticulatum* (R_{1c} Zone), and is immediately overlain by the Mam Tor Sandstones (Hebden Formation). Further to the south in the Ashover area (Fig. 10.2, Col. 6), the top of the Bowland Shale Formation extends into the Marsdenian, with strata of the R2a1 and R2b1 Zones recorded [+6] (Smith *et al*. 1967). The formation decreases in the thickness from the Alport Borehole to the Ashover area despite the

longer duration of the formation in the south, probably a result of the southern area being a bathymetric high during deposition.

The Morridge Formation ranges from Pendleian to late Marsdenian in age. The oldest sandstone in the formation is typically the Minn Sandstone, of late Pendleian to early Arnsbergian (E_{1b} to E_{2a} Zone) age (Aitkenhead *et al.* 1985). The youngest sandstone of the Morridge Formation, the Brockholes Sandstones, is of mid-Marsdenian (R_{2b}) age and interdigitates with the Roaches Grit, the local basal sandstone of the Millstone Grit Group (Chisholm *et al*. 1988; Rees & Wilson 1998). In the Stoke-on-Trent area (Fig. 10.2, Col. 1) the formation includes marine bands of the $E_{2b}3$-$E_{2c}1$ [+3], R_{1a}-R_{1c} [+4] and $R_{2a}1$-$R_{2b}1$-$R_{2b}5$ [+5] biozones (Rees & Wilson 1998). Arnsbergian marine bands [+7] are recorded in the upper part of the Gun Hill succession (Fig. 10.2, Col. 2; Aitkenhead *et al.* 1985). In the Whiston–Hamps Valley section (Fig. 10.2, Col. 3) marine bands of the $E_{1c}1$ [+2] and $E_{2a}1$-$E_{2b}1$ [+3] biozones are recorded (Chisholm *et al*. 1988). In a key section at Blake Brook [SK 055 610 to 067 613] (Fig. 10.2, Col. 8), marine bands with diagnostic ammonoids of the $E_{1c}1$ [+1], $E_{2a}1$-$E_{2a}2$-$E_{2b}1$-$E_{2b}3$-$E_{2c}1$ [+2], $H_{1a}3$ [+3], $H_{2a}1$-$H_{2b}1$-$H_{2c}1$-$H_{2c}2$ [+4] and $R_{1a}1$-$R_{1a}2$-$R_{1b}1$-$R_{1b}2$-$R_{1b}3$ [+5] biozones are recorded (Aitkenhead *et al.* 1985), with the section taken as the stratotype of the Alportian Substage, at the base of the *Hudsonoceras proteum* ($H_{2a}1$) Marine Band (see Chapter 2). The top of the section, within the $R_{2a}1$ Subzone [+6], occurs above the Longnor Sandstone. The Morridge Formation is absent to the north and east of the area.

The earliest onset of deposition of the Hebden Formation in the area to the north of the Derbyshire Massif (Fig. 10.2, Col. 9) comprises a thick turbidite to slope succession, the Mam Tor Sandstones, Shale Grit and Grindslow Shales, overlain by the fluvial Kinderscout Grits (Walker 1966; Collinson 1969). The full succession, 460 m thick, is present entirely within the R_{1c} Zone [+6] (Stevenson & Gaunt 1971). In the Staffordshire Basin (Fig. 10.2, Col. 8), the base of the formation is taken at the base of the Longnor Sandstone, equivalent to the Upper Kinderscout Grit (R_{1c} Zone). This indicates that none of the 460 m thick sequence north of the Derbyshire Massif extended into the Staffordshire Basin, demonstrating spectacular bathymetric control on deposition.

More generally, the base of the influx of northerly sourced quartz-feldspathic sands occurs within the R_{2b} Zone, at the base of the turbiditic Five Clouds Sandstone (Aitkenhead *et al*. 1985), or lower turbiditic part of the Ashover Grit (Smith *et al.* 1967). In addition to these units, the overlying part of the Marsden Formation comprises the fluvial Roaches/Ashover and Chatsworth Grits, separated by a mudstone containing the *Bilinguites superbilinguis* ($R_{2c}1$) Marine Band proved in the Weaver Hills [+4] (Fig. 10.2, Col. 3; Aitkenhead *et al*. 1985). In the Morridge [+6] (Fig. 10.2, Col. 8; Chisholm *et al*. 1988) and Nottingham [+2] (Fig. 10.2, Col. 10; Carney *et al*. 2004) areas the *Bilinguites gracilis*, *B. bilinguis* and *B. superbilinguis* marine bands are all present.

The Rossendale Formation is marked by a distinctive lower mudstone-dominated succession with the *Cancelloceras cancellatum* ($G_{1a}1$) and *C. cumbriense* ($G_{1b}1$) marine bands, overlain by the sandstone-dominated Rough Rock. Both marine bands and sandstone are widespread within the Stoke-on-Trent [+6] (Fig. 10.2, Col. 1; Rees & Wilson 1998), Weaver Hills [+5] (Fig. 10.2, Col. 3; Aitkenhead *et al*. 1985), Morridge [+7]

(Fig. 10.2, Col. 8; Chisholm *et al*. 1988), Ashover $^{+7}$ (Fig. 10.2, Col. 6; Smith *et al.* 1967) and Nottingham $^{+3}$ (Fig. 10.2, Col. 10; Carney *et al*. 2004) areas, although the Rough Rock is locally absent in the Chesterfield area (Smith *et al.* 1967).

Westphalian

During the Langsettian to early Bolsovian, grey, mudstone-dominated fluvio-lacustrine deposits of the Pennine Coal Measures Group were deposited across the region. Subsequent tectonism has isolated the outcrop into separate coalfields. The thickest development of Westphalian strata in the area is within the Potteries Coalfield (Fig. 10.2, Col. 1; Fig. 10.3). Immediately to the east of the Potteries Coalfield, the small Cheadle Coalfield (Fig. 10.2, Col. 3; Fig. 10.3) includes only Langsettian and Duckmantian strata. To the north, the small outliers of Pennine Coal Measures within the Goyt Syncline (Fig. 10.2, Col. 8) are limited to Langsettian strata. The southern part of the Yorkshire-Nottingham Coalfield extends across the eastern part of the area (Fig. 10.2, Col. 10; Figure 10.3), and includes Pennine Coal Measures of Langsettian to early Bolsovian age. The subsurface expression of this coalfield is proved in Lincolnshire in the Welton and Saltfleetby oilfields (Fig. 10.1 & 10.3). The late Bolsovian and Asturian (Westphalian D) red, mudstone- and sandstone-dominated alluvial successions of the Warwickshire Group are recorded in this region within the Potteries and South Nottinghamshire coalfields (Fig. 10.2, Cols. 1 & 10; Fig. 10.3).

The base of the Subcrenatum Marine Band defines the base of the Langsettian Substage and Pennine Lower Coal Measures Formation. The lower part of the formation, up to the King Coal (i.e. the non-marine bivalve Lenisulcata and lower part of the Communis chronozones) is marked by numerous marine bands and thin coals within the Potteries Coalfield (Fig. 10.3). The sandstones within this interval, up to the Grenoside Sandstone, are mainly of northerly provenance (Chisholm & Hallsworth 2005). In the Potteries Coalfield (Fig. 10.2, Col. 1), only the Subcrenatum $^{+7}$, Honley and Listeri marine bands contain ammonoids, whereas the Holbrook, Springwood, Parkhouse and Meadow Farm marine bands include *Lingula* (Rees & Wilson 1998). Of these marine bands, only the Parkhouse is not recorded within the Cheadle Coalfield (Fig. 10.2, Col. 3; Fig 10.3; Chisholm *et al*. 1988), the Subcrenatum Marine Band again forming the base of the formation $^{+6}$. Within the Goyt Syncline (Fig. 10.2, Col. 8; Fig. 10.3) the Subcrenatum $^{+8}$, Holbrook, Honley and Listeri Marine bands are recorded (Aitkenhead *et al.* 1985), with strata above the Listeri Marine Band absent. In the Nottingham Coalfield (Fig. 10.2, Col. 10; Fig. 10.3) the Subcrenatum Marine Band $^{+4}$ contains diagnostic fauna in the Wilds Bridge Borehole [SK 6738 3248] (Carney *et al*. 2004). In the Welton and Saltfleetby (Fig. 10.3) oilfields a thick sandstone, representing the main hydrocarbon reservoir, occurs in the lower part of the formation, the Subcrenatum Marine Band being absent (Hodge 2003; Rothwell & Quinn 1987). The Amaliae Marine Band occurs above this sandstone in Saltfleetby (Fig. 10.3). The upper part of the formation, including the upper part of the Communis and lower part of the Modiolaris chronzones is devoid of marine bands, but includes thick coals. The sandstones within this interval, and of Duckmantian age, are mainly of westerly provenance (Chisholm & Hallsworth 2005).

The base of Vanderbeckei Marine Band defines the bases of the Duckmantian Substage and the Pennine Middle Coal Measures Formation. The marine band is proved in the Potteries $^{+8}$ (Fig. 10.2, Col. 1), Cheadle $^{+7}$ (Fig. 10.2, Col. 3) and Nottingham $^{+5}$ (Fig. 10.2, Col. 10; Fig. 10.3) coalfields. The lower part of the

formation, between the Vanderbeckei and Maltby marine bands consists of thick coal seams, but is devoid of further marine bands (Fig. 10.3), whereas the upper part includes five regionally developed marine bands in the Potteries Coalfield (Rees & Wilson 1998). The base of one of these, the Aegiranum Marine Band, defines the base of the Bolsovian Regional Substage. This marine band is present in the Potteries Coalfield [+9] (Fig. 10.2, Col.1), where overlying coals are typically thicker and include clayband ironstones in their roof measures (Fig. 10.3). In east Derbyshire the Bolsovian succession includes sandstones introduced into the region from the south-east (Chisholm & Hallsworth 2005). South of Nottingham [+6] (Fig. 10.2, Col.10) the Aegiranum Marine Band is up to 12 m thick (Carney *et al*. 2004). The top of the formation is defined at the top of the Cambriense Marine Band, found extensively across the Potteries Coalfield [+10] (Fig. 10.2, Col.1; Rees & Wilson).

The Pennine Upper Coal Measures Formation, present in the Potteries Coalfield (Fig. 10.2, Col. 1; Fig. 10.3), is devoid of marine bands and includes strata of the Phillipsii Chronozone [~11]. The lower part of the formation, below the Bassey Mine Coal, is characterised by clayband ironstones, whereas the upper part contains blackband (carbonaceous) ironstones, in addition to seatearth palaeosols, coal and mudstone (Rees & Wilson 1998). In the east of the region the formation includes thick development of sandstone (including the Ackworth Rock) in the Saltfleetby (Fig. 10.3) and Welton areas, although the thickness is variable and locally absent beneath the Sub-Permian Unconformity.

There is a complex interdigitating conformable transition from the grey, coal-rich Pennine Coal Measures Group into the overlying red, coal-poor Warwickshire Group in the Potteries Coalfield (Fig. 10.2, Col. 1; Fig. 10.3). The base of the Etruria Formation occurs at a lower stratigraphical level in the south of the coalfield. The formation is of late Bolsovian age, based upon the presence of *Anthraconauta phillipsi* and *Anthraconaia* cf. *saravana* [~12] (Gibson 1901). A thinner development of the formation is recorded in the Nottinghamshire Coalfield (Fig. 10.2, Col. 10). The overlying Halesowen Formation was formerly defined in the Potteries Coalfield as the Newcastle Formation for the lower grey, coal-bearing beds and Keele Formation for the overlying red, sandstone-dominated succession (Rees & Wilson 1998). Besly & Cleal (1997) proposed a revision of the nomenclature, recognising that the grey and red units displayed a markedly diachronous relationship, with the coal-bearing succession passing laterally into red beds to the southeast and that both facies included sandstone characterised as lithic arenites. Mudstone at the base of the Halesowen Formation in the Potteries Coalfield [~^13] (Fig. 10.2, Col. 1) includes the bivalve *Anthraconauta tenuis* (Myers 1954). Asturian miospores of the OT Zone are also recorded from coals higher in the formation (Butterworth & Smith, 1976). The top 50 to 80 m of the formation are marked by a distinctive 'Palustrine Unit', comprising carbonate-bearing lacustrine deposits that have been modified by pedogenesis, referred to as the Dark Slade Member by Besly & Cleal (1997). The formation is also recognised in the Nottingham Coalfield, with non-marine bivalves of the *A. tenuis* Zone proved in the Ollerton area [~7] (Fig. 10.2, Col. 10; Edwards 1967).

Stephanian

Strata of possible Stephanian age within the region are limited to the Salop Formation of the Warwickshire Group, within the Potteries Coalfield (Fig. 10.2, Col. 1). The

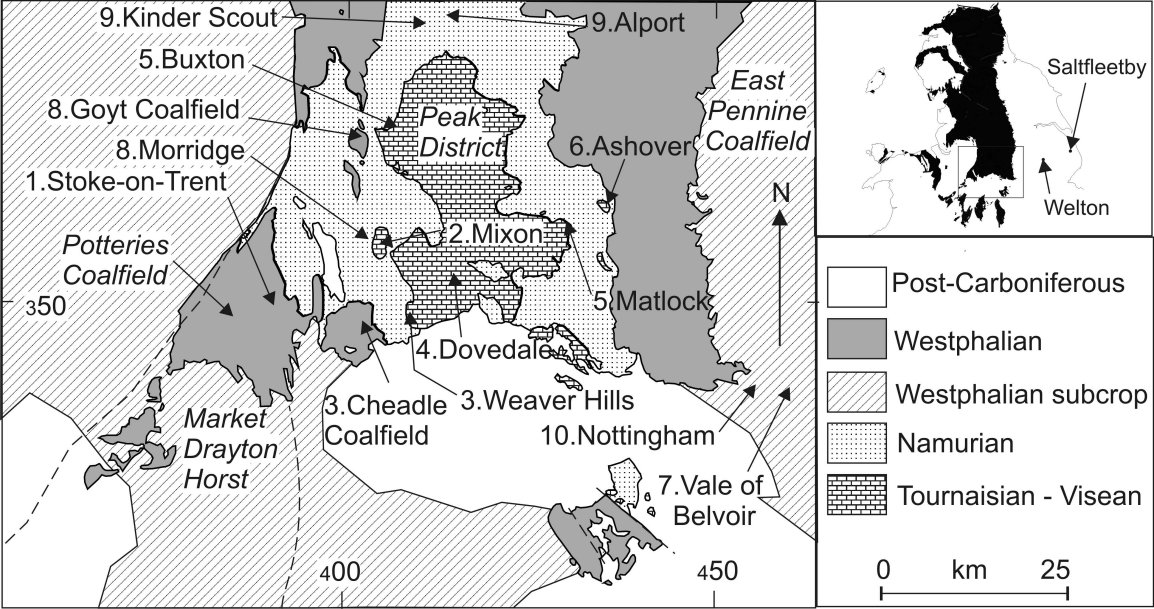
formation, formerly referred to as the Radwood Formation (Rees & Wilson 1998) comprises red mudstone and siltstone with minor sandstone. No biostratigraphically diagnostic taxa have been determined for the formation within the coalfield, but an Asturian to Cantabrian age is presumed, from comparison with the formation in the South Staffordshire and Oxfordshire coalfields (see Chapters 7 and 9). The main fauna determined include the bivalves *Anthraconaia prolifera* and *A. saravana*, the gastropod *Anthracopupa britannica*, the annelid *Spirorbis*, *Leia*, *Estheria* and ostracods (Rees & Wilson 1998).

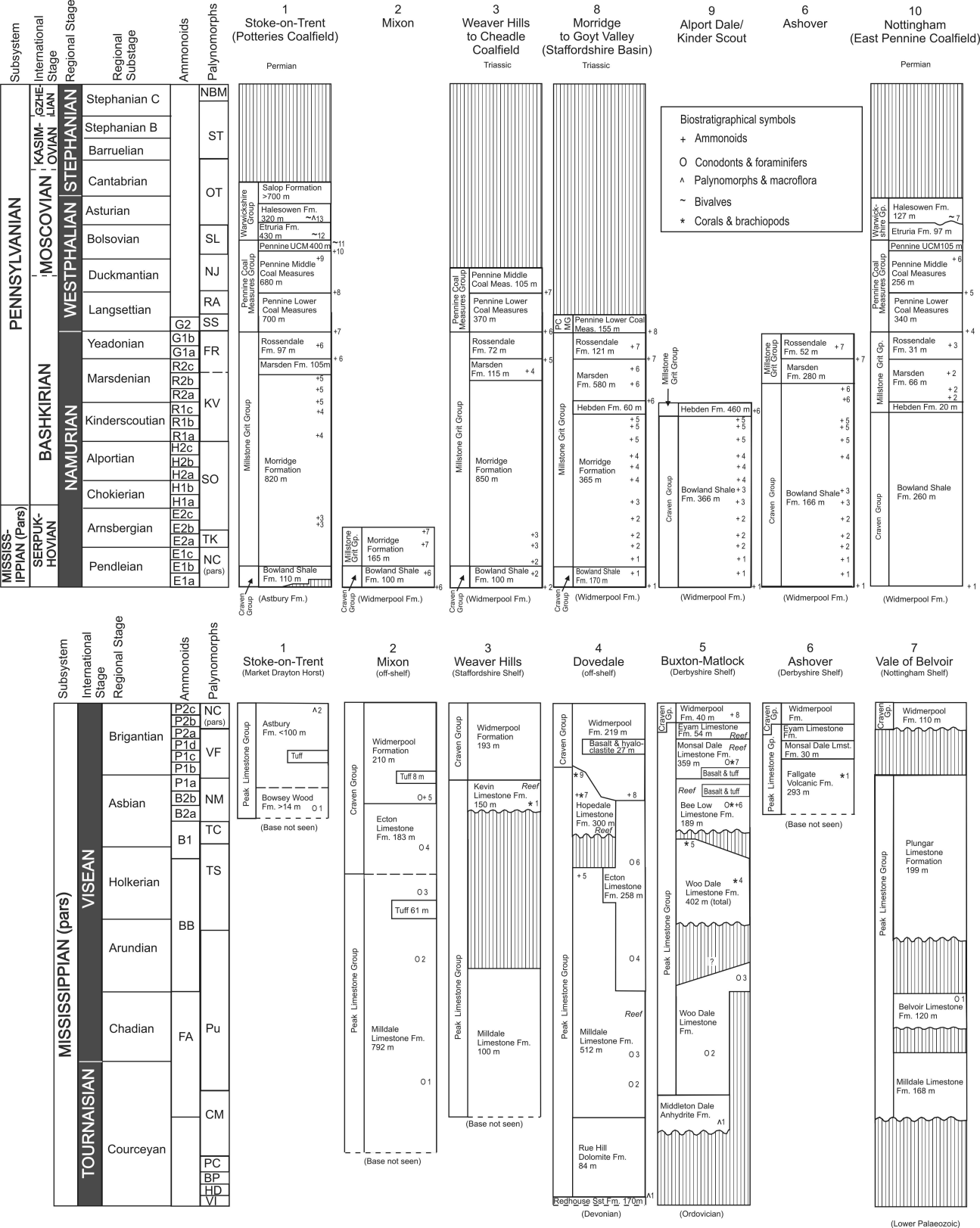
Figures

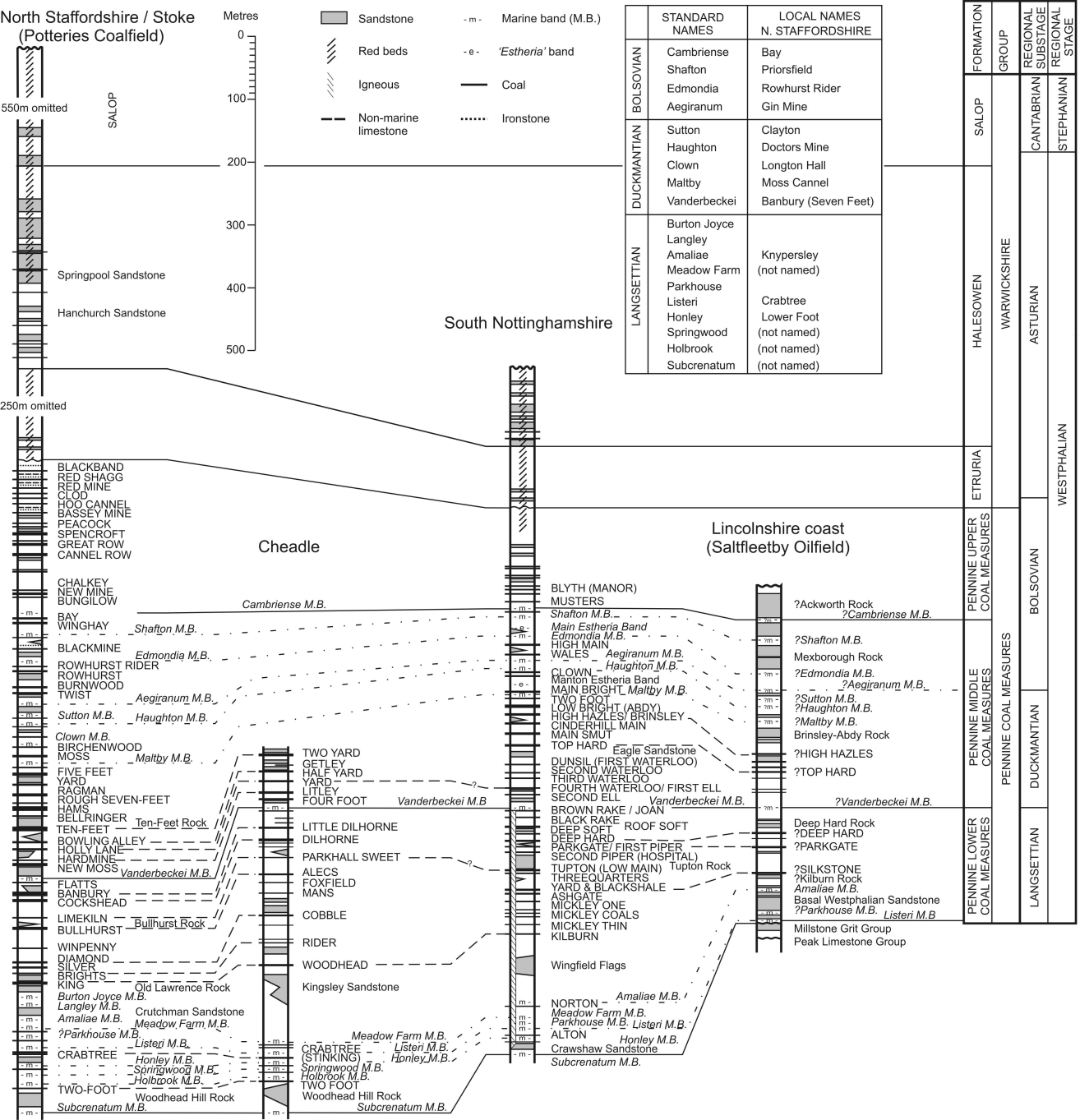
Fig. 10.1. Geological map showing the distribution of Carboniferous strata of the East Midlands and north Staffordshire adapted from IGS (1979).

Fig. 10.2. Correlation of Carboniferous successions in the East Midlands and north Staffordshire. The nomenclature is that of Waters *et al*. (2007; 2009), with details from the following publications: Col. 1 from Rees & Wilson (1998); Col. 2 from Aitkenhead *et al*. (1985); Col. 3 from Chisholm *et al*. (1988); Col. 4 from Chisholm *et al*. (1988); Col. 5 from Aitkenhead *et al*. (1985); Col. 6 from (Smith *et al*. 1967); Col. 7 from Carney *et al*. (2004); Col. 8 from Aitkenhead *et al*. (1985); Col. 9 from Stevenson & Gaunt (1971); Col. 10 from Carney *et al*. (2004).

Fig. 10.3. Correlation of Westphalian successions in the East Midlands and north Staffordshire with the nomenclature that of Waters *et al*. (2007; 2009). Details modified from the following: Potteries Coalfield- Rees & Wilson (1998); Cheadle Coalfield- Chisholm *et al*. (1988); Nottingham Coalfield- Carney *et al*. (2004); Saltfleetby- Hodge (2003).


9.Kinder Scout
9.Alport
5.Buxton
8.Goyt Coalfield
Peak District
East Pennine Coalfield
8.Morridge
6.Ashover
1.Stoke-on-Trent
N
Potteries Coalfield
2.Mixon
350
5.Matlock
4.Dovedale
3.Cheadle Coalfield
3.Weaver Hills
Market Drayton Horst
10.Nottingham
7.Vale of Belvoir
400
450
Saltfleetby
Welton
Post-Carboniferous
Westphalian
Westphalian subcrop
Namurian
Tournaisian - Visean
0
km
25


Subsystem
International Stage
Regional Stage
Regional Substage
Ammonoids
Palynomorphs
PENNSYLVANIAN
MISSISSIPPIAN (Pars)
GZHELIAN
KASIMOVIAN
MOSCOVIAN
SERPUKHOVIAN
BASHKIRIAN
STEPHANIAN
WESTPHALIAN
NAMURIAN
Stephanian C
Stephanian B
Barruelian
Cantabrian
Asturian
Bolsovian
Duckmantian
Langsettian
Yeadonian
Marsdenian
Kinderscoutian
Alportian
Chokierian
Arnsbergian
Pendleian
G2
G1b
G1a
R2c
R2b
R2a
R1c
R1b
R1a
H2c
H2b
H2a
H1b
H1a
E2c
E2b
E2a
E1c
E1b
E1a
NBM
ST
OT
SL
NJ
RA
SS
FR
KV
SO
TK
NC (pars)
1 Stoke-on-Trent (Potteries Coalfield)
2 Mixon
3 Weaver Hills to Cheadle Coalfield
8 Morridge to Goyt Valley (Staffordshire Basin)
9 Alport Dale/ Kinder Scout
6 Ashover
10 Nottingham (East Pennine Coalfield)
Permian
Triassic
Biostratigraphical symbols
+ Ammonoids
O Conodonts & foraminifers
^ Palynomorphs & macroflora
~ Bivalves
* Corals & brachiopods
Warwickshire Group
Salop Formation >700 m
Halesowen Fm. 320 m
Etruria Fm. 430 m
Pennine Coal Measures Group
Pennine UCM 400 m
Pennine Middle Coal Measures 680 m
Pennine Lower Coal Measures 700 m
Millstone Grit Group
Rossendale Fm. 97 m
Marsden Fm. 105m
Morridge Formation 820 m
Bowland Shale Fm. 110 m
Craven Group
(Astbury Fm.)
Millstone Grit Gp.
Morridge Formation 165 m
Bowland Shale Fm. 100 m
(Widmerpool Fm.)
Pennine Middle Coal Meas. 105 m
Pennine Lower Coal Measures 370 m
Rossendale Fm. 72 m
Marsden Fm. 115 m
Morridge Formation 850 m
Bowland Shale Fm. 100 m
PC
MG
Pennine Lower Coal Meas. 155 m
Rossendale Fm. 121 m
Marsden Fm. 580 m
Hebden Fm. 60 m
Morridge Formation 365 m
Bowland Shale Fm. 170 m
Hebden Fm. 460 m
Bowland Shale Fm. 366 m
Millstone Grit Gp.
Rossendale Fm. 52 m
Marsden Fm. 280 m
Bowland Shale Fm. 166 m
Halesowen Fm. 127 m
Etruria Fm. 97 m
Pennine UCM105 m
Pennine Middle Coal Measures 256 m
Pennine Lower Coal Measures 340 m
Rossendale Fm. 31 m
Marsden Fm. 66 m
Hebden Fm. 20 m
Bowland Shale Fm. 260 m
Subsystem
International Stage
Regional Stage
Ammonoids
Palynomorphs
MISSISSIPPIAN (pars)
VISEAN
TOURNAISIAN
Brigantian
Asbian
Holkerian
Arundian
Chadian
Courceyan
P2c
P2b
P2a
P1d
P1c
P1b
P1a
B2b
B2a
B1
BB
FA
NC (pars)
VF
NM
TC
TS
Pu
CM
PC
BP
HD
VI
1 Stoke-on-Trent (Market Drayton Horst)
2 Mixon (off-shelf)
3 Weaver Hills (Staffordshire Shelf)
4 Dovedale (off-shelf)
5 Buxton-Matlock (Derbyshire Shelf)
6 Ashover (Derbyshire Shelf)
7 Vale of Belvoir (Nottingham Shelf)
Peak Limestone Group
Astbury Fm. <100 m
Tuff
Bowsey Wood Fm. >14 m
(Base not seen)
Craven Group
Widmerpool Formation 210 m
Tuff 8 m
Ecton Limestone Fm. 183 m
Tuff 61 m
Milldale Limestone Fm. 792 m
Widmerpool Formation 193 m
Kevin Limestone Fm. 150 m
Reef
Milldale Limestone Fm. 100 m
Widmerpool Fm. 219 m
Basalt & hyaloclastite 27 m
Hopedale Limestone Fm. 300 m
Ecton Limestone Fm. 258 m
Milldale Limestone Fm. 512 m
Rue Hill Dolomite Fm. 84 m
Redhouse Sst Fm. 170m
(Devonian)
Widmerpool Fm. 40 m
Eyam Limestone Fm. 54 m
Monsal Dale Limestone Fm. 359 m
Basalt & tuff
Bee Low Limestone Fm. 189 m
Woo Dale Limestone Fm. 402 m (total)
Woo Dale Limestone Fm.
Middleton Dale Anhydrite Fm.
(Ordovician)
Widmerpool Fm.
Eyam Limestone Fm.
Monsal Dale Lmst. Fm. 30 m
Fallgate Volcanic Fm. 293 m
Widmerpool Fm. 110 m
Plungar Limestone Formation 199 m
Belvoir Limestone Fm. 120 m
Milldale Limestone Fm. 168 m
(Lower Palaeozoic)


North Staffordshire / Stoke
(Potteries Coalfield)
Metres
0
100
200
300
400
500
Sandstone
Red beds
Igneous
Non-marine limestone
Marine band (M.B.)
'Estheria' band
Coal
Ironstone
STANDARD NAMES
LOCAL NAMES N. STAFFORDSHIRE
BOLSOVIAN
Cambriense
Bay
Shafton
Priorsfield
Edmondia
Rowhurst Rider
Aegiranum
Gin Mine
DUCKMANTIAN
Sutton
Clayton
Haughton
Doctors Mine
Clown
Longton Hall
Maltby
Moss Cannel
Vanderbeckei
Banbury (Seven Feet)
LANGSETTIAN
Burton Joyce
Langley
Amaliae
Knypersley
Meadow Farm
(not named)
Parkhouse
Listeri
Crabtree
Honley
Lower Foot
Springwood
(not named)
Holbrook
(not named)
Subcrenatum
(not named)
FORMATION
GROUP
REGIONAL SUBSTAGE
REGIONAL STAGE
SALOP
HALESOWEN
ETRURIA
WARWICKSHIRE
CANTABRIAN
ASTURIAN
STEPHANIAN
WESTPHALIAN
PENNINE UPPER COAL MEASURES
PENNINE MIDDLE COAL MEASURES
PENNINE LOWER COAL MEASURES
PENNINE COAL MEASURES
BOLSOVIAN
DUCKMANTIAN
LANGSETTIAN
550m omitted
SALOP
Springpool Sandstone
Hanchurch Sandstone
250m omitted
South Nottinghamshire
Cheadle
Lincolnshire coast
(Saltfleetby Oilfield)
BLACKBAND
RED SHAGG
RED MINE
CLOD
HOO CANNEL
BASSEY MINE
PEACOCK
SPENCROFT
GREAT ROW
CANNEL ROW
CHALKEY
NEW MINE
BUNGILOW
BAY
WINGHAY
BLACKMINE
ROWHURST RIDER
ROWHURST
BURNWOOD
TWIST
Sutton M.B.
Clown M.B.
BIRCHENWOOD
MOSS
FIVE FEET
YARD
RAGMAN
ROUGH SEVEN-FEET
HAMS
BELLRINGER
TEN-FEET
BOWLING ALLEY
HOLLY LANE
HARDMINE
NEW MOSS
FLATTS
BANBURY
COCKSHEAD
LIMEKILN
BULLHURST
WINPENNY
DIAMOND
SILVER
BRIGHTS
KING
Burton Joyce M.B.
Langley M.B.
Amaliae M.B.
?Parkhouse M.B.
CRABTREE
(STINKING)
Springwood M.B.
Holbrook M.B.
TWO-FOOT
Subcrenatum M.B.
Cambriense M.B.
Shafton M.B.
Edmondia M.B.
Aegiranum M.B.
Haughton M.B.
Maltby M.B.
Ten-Feet Rock
Vanderbeckei M.B.
Bullhurst Rock
Crutchman Sandstone
Meadow Farm M.B.
Listeri M.B.
Honley M.B.
Woodhead Hill Rock
TWO YARD
GETLEY
HALF YARD
YARD
LITLEY
FOUR FOOT
LITTLE DILHORNE
DILHORNE
PARKHALL SWEET
ALECS
FOXFIELD
MANS
COBBLE
RIDER
WOODHEAD
Kingsley Sandstone
Meadow Farm M.B.
CRABTREE
(STINKING)
Springwood M.B.
Holbrook M.B.
TWO FOOT
Woodhead Hill Rock
Subcrenatum M.B.
BLYTH (MANOR)
MUSTERS
Shafton M.B.
Main Estheria Band
Edmondia M.B.
HIGH MAIN
WALES
Aegiranum M.B.
Haughton M.B.
CLOWN
Manton Estheria Band
MAIN BRIGHT
Maltby M.B.
TWO FOOT
LOW BRIGHT (ABDY)
HIGH HAZLES/ BRINSLEY
CINDERHILL MAIN
MAIN SMUT
TOP HARD
Eagle Sandstone
DUNSIL (FIRST WATERLOO)
SECOND WATERLOO
THIRD WATERLOO
FOURTH WATERLOO/ FIRST ELL
SECOND ELL
Vanderbeckei M.B.
BROWN RAKE / JOAN
BLACK RAKE
DEEP SOFT
ROOF SOFT
DEEP HARD
PARKGATE/ FIRST PIPER
SECOND PIPER (HOSPITAL)
TUPTON (LOW MAIN)
Tupton Rock
THREEQUARTERS
YARD & BLACKSHALE
ASHGATE
MICKLEY ONE
MICKLEY COALS
MICKLEY THIN
KILBURN
Wingfield Flags
Amaliae M.B.
NORTON
Meadow Farm M.B.
Parkhouse M.B.
Listeri M.B.
ALTON
Honley M.B.
Crawshaw Sandstone
Subcrenatum M.B.
?Ackworth Rock
?Cambriense M.B.
?Shafton M.B.
Mexborough Rock
?Edmondia M.B.
?Aegiranum M.B.
?Sutton M.B.
?Haughton M.B.
?Maltby M.B.
Brinsley-Abdy Rock
?HIGH HAZLES
?TOP HARD
?Vanderbeckei M.B.
Deep Hard Rock
?DEEP HARD
?PARKGATE
?SILKSTONE
?Kilburn Rock
Amaliae M.B.
Basal Westphalian Sandstone
?Parkhouse M.B.
Listeri M.B
Millstone Grit Group
Peak Limestone Group