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Stratigraphical framework for Westphalian to Early Permian red-bed successions of the Pennine Basin

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NOTE

The National Grid Reference (NGR) and BGS Reference Number for boreholes and shafts mentioned in the text are listed in Appendix 4.

1 SUMMARY

The lithostratigraphy of the Westphalian to Early Permian rocks of the Pennine Basin has been reviewed. Grey coal-bearing strata pass up into successions containing primary red beds, and two lithostratigraphic units are now defined to recognise this fundamental division. They are the Coal Measures Group (below) and the Warwickshire Group (above). The base of the Coal Measures Group is unchanged from earlier classifications, and the traditional divisions (Lower, Middle and Upper) are retained as formations. The Warwickshire Group comprises, in upward order, the widespread Etruria, Halesowen and Salop formations, overlain by the Tile Hill Mudstone, Kenilworth Sandstone and Ashow formations (in Warwickshire) and the Clent Formation (in south Staffordshire). The main changes from earlier classifications are that large parts of the former Upper Coal Measures now belong to the Warwickshire Group, and that the former Keele Formation is partitioned between the Halesowen and Salop formations. Many other names have been made redundant.

2 PREFACE

The Stratigraphy Committee of the British Geological Survey has undertaken to carry out a review of the stratigraphical classification and nomenclature for all parts of Great Britain for which modern information is available. To this end several Stratigraphical Framework Committees have been established, each with the following terms of reference:

i To carry out a complete review of the lithostratigraphical nomenclature of the designated region, identifying problems in classification, correlation and nomenclature.

ii To propose a stratigraphical framework and lithostratigraphical nomenclature down to formation level for the whole outcrop.

iii To organise peer review of the scheme.

iv To present the results in a document suitable for publication.

v To see that the Lexicon entries are completed for their area of responsibility.

The Westphalian to Early Permian red-bed successions of the Pennine Basin have been the subject of a committee under the chairmanship of Dr J H Powell and are reported on here.

The purpose of all SFCs is to establish a framework down to formation level that can be used as a central reference by all geologists working in the region. The process of erecting a framework requires decisions to be taken about correlations and equivalences leading to a simplified nomenclature. Inevitably many names will be rendered obsolete. The frameworks are lithostratigraphical, and although each is set against a chronostratigraphical reference column the finer points of the chronostratigraphy of the succession are not our prime concern.

The report was reviewed for the Geological Society Stratigraphy Commission by Prof G Kelling and Dr P D Guion, and validated by Dr J E A Marshall on behalf of the Geological Society Stratigraphy Commission, who endorse the scheme proposed in this work.

The lithostratigraphical rules applied are those of the North American Commission on Stratigraphic Nomenclature (Anon., 1983).

It is expected that the frameworks will be refined and improved with time. Indeed, erecting them effectively poses a challenge to stratigraphers which I hope will be taken up to contribute to a better understanding of British stratigraphy.

Dr P M Allen
Chairman
British Geological Survey Stratigraphy Committee

Prof P F Rawson
Chairman
Geological Society Stratigraphy Commission

3 INTRODUCTION

This report evolved after two decades of BGS revision-mapping in the coalfields of central England, most of it associated with applied, thematic mapping projects (e.g. Charsley et al., 1990; Old et al., 1990; Wilson et al., 1992; Powell et al., 1992). These studies were extended to cover component BGS 1:50 000 sheet areas (Sheets 123, 126, 168, 169), and the geology was described in accompanying BGS memoirs (Bridge et al., 1998; Rees and Wilson, 1998; Powell et al., in press; Howard et al., in prep). These studies included detailed re-survey of the Upper Carboniferous and Lower Permian red-bed successions in disparate parts of the Pennine Basin. At the same time as the BGS studies, Dr B M Besly was carrying out research into the stratigraphy and sedimentology of these successions, and the establishment of a BGS Stratigraphical Framework Committee offered an opportunity to combine our efforts in a synthesis of the stratigraphy.

The Stratigraphical Framework Committee was set up in June 1993 and met on three occasions, with the review conducted by correspondence. The original remit was to review the stratigraphy of the uppermost Carboniferous in the Pennine Basin, but this was widened to include the Lower Permian since the highest beds under consideration may be of this age. In addition, we reviewed the nomenclature of the productive Coal Measures in England and Wales. During the working life of the committee, Dr B M Besly (together with Dr C J Cleal) produced a paper on the stratigraphy of the Upper Carboniferous of the West Midlands; the BGS Stratigraphical Framework report was postponed until this work was completed.

Over the last century separate lithostratigraphical schemes had arisen in the coalfields of south Staffordshire, north Staffordshire, Warwickshire, Coalbrookdale, Lancashire and the East Midlands (see Ramsbottom et al., 1978). This was, in part, due to the geographical separation of the coalfields, but also reflects the local, but distinctive, sedimentary fill resulting from variable rates of basin subsidence, uplift and sediment flux in different areas of the Pennine Basin. Furthermore, the strata under consideration are predominantly red beds of alluvial origin, and generally lack well-defined marker beds or biostratigraphical markers which might allow precise lithostratigraphical and chronostratigraphical correlation between the coalfields. The Coal Measures *sensu stricto* (i.e. the productive measures) are only briefly considered in this study; the top of this group is a diachronous boundary with the red-bed Etruria Formation. The recent studies have allowed detailed analysis of the sedimentary succession, integrating

information from new surface mapping, borehole core, geophysical wireline logs, and sedimentological and biostratigraphical studies to produce an overview of the stratigraphy of the basin. This provided an opportunity to rationalise and revise lithostratigraphical nomenclature, and to define clearly the stratigraphical units.

The report covers areas within the Pennine Basin where the BGS has recent experience in surface and subsurface mapping based on the studies noted above; it focuses on the coalfields of south Staffordshire (Black Country), north Staffordshire, and Warwickshire, but includes reference to the Coalbrookdale, Wyre Forest, Denbigh, Lancashire and East Midlands coalfields (Figure 1). The Canonbie Coalfield contains a thick sequence of red beds (Figure 2); if some of these prove to be of primary origin, it may be necessary to extend the new classification to this area also. The report does not cover areas located on or south of the Wales-Brabant High (St George's Land), such as the South Wales, Oxfordshire and Kent coalfields, and Devon and Cornwall.

The chronostratigraphical scope of the report ranges from the diachronous onset of red bed development in Duckmantian to Bolsovian times (Westphalian B to C), to end-Variscan deformation in Stephanian to Early Permian time. However, the precise age of the uppermost strata considered here has not been resolved (see discussion in Waters et al., 1995, and references therein).

4 STRATIGRAPHICAL FRAMEWORK

The strata considered in this report comprise the Westphalian **Coal Measures Group** of England and Wales, and predominantly red-bed formations which overlie it and range in age from Duckmantian (Westphalian B) to Early Permian. The predominantly red-bed strata have, in the past, been referred to collectively by terms such as Barren (Coal) Measures and Red Measures. However, they include the grey, coal-bearing Halesowen Formation, and consequently terms of this type are unsuitable. A new group name, **Warwickshire Group**, is introduced to replace them (see Section 7).

In describing oxidised red strata it is important to distinguish between those that have undergone oxidation at, or close to, the time of deposition (primary red beds — here termed red beds) and those that have been reddened as a result of later oxidative weathering such as the sub-Permian penetrative weathering of Carboniferous strata in Lancashire (Trotter, 1954).

The Warwickshire Group succession consists predominantly of red mudstone and sandstone with pebbly sandstone, conglomerate and breccia; minor components comprise grey mudstone, thin coals, lacustrine limestone ('Spirorbis limestone') and pedogenic limestone (caliche; calcrete). The succession is divided into formations, many of which can be correlated between coalfields; others are geographically

Table 1 Stratigraphical framework for south Staffordshire, Warwickshire and north Staffordshire.

<table>
<tr><th rowspan="2">GROUP</th><th colspan="3">FORMATION</th><th rowspan="2">SERIES/STAGE</th></tr>
<tr><th>South Staffordshire</th><th>Warwickshire</th><th>North Staffordshire</th></tr>
<tr><td rowspan="8">WARWICKSHIRE GROUP

(BARREN MEASURES)</td><td></td><td>Ashow Formation</td><td rowspan="3"></td><td rowspan="2">AUTUNIAN[2]</td></tr>
<tr><td>Clent Formation</td><td>Kenilworth Sandstone Formation</td></tr>
<tr><td></td><td>Tile Hill Mudstone Formation</td><td rowspan="2">STEPHANIAN</td></tr>
<tr><td>Salop Formation</td><td>Salop Formation
(Meriden Formation)</td><td>Salop Formation
(Radwood Formation)</td></tr>
<tr><td colspan="2">red facies[1]
Halesowen Formation</td><td>(Keele Formation)</td><td rowspan="2">WESTPHALIAN D</td></tr>
<tr><td colspan="2"></td><td>(Newcastle Formation)</td></tr>
<tr><td colspan="3">Etruria Formation</td><td rowspan="2">BOLSOVIAN (WESTPHALIAN C)</td></tr>
<tr><td rowspan="3">COAL MEASURES GROUP</td><td colspan="3">Upper Coal Measures Formation</td></tr>
<tr><td colspan="3">Middle Coal Measures Formation</td><td>DUCKMANTIAN (WESTPHALIAN B)</td></tr>
<tr><td colspan="3">Lower Coal Measures Formation</td><td>LANGSETTIAN (WESTPHALIAN A)</td></tr>
</table>

NOTES:
[1] Local red lithofacies in Halesowen Formation
[2] Base Permian is assumed to be below the Clent and Kenilworth formations
Italicised names in brackets are superseded

vertical lines indicate a hiatus
shaded areas indicate predominantly red beds

restricted. An unconformity, below the Halesowen Formation (Westphalian D), is traceable throughout most of the southern part the Pennine Basin, but has not been widely recognised in the northern basinal successions of South Yorkshire and Lancashire. In the south-east part of the Coalbrookdale Coalfield, the stratigraphically older 'Symon Unconformity' occurs between the Coal Measures and the Etruria Formation (Hamblin and Coppack, 1995). This unconformity is also locally developed in Warwickshire (NCB seismic data over the Arley anticline, and the Ballards Green Borehole). A local unconformity within the Halesowen Formation has been inferred at the basin margin in the East Midlands (see below).

The broad geographical distribution of Westphalian and Stephanian strata is outlined in Figure 1. The stratigraphical divisions (groups, formations and members) are listed in Sections 6 and 7, together with stratotype and other relevant information, including bibliographical references. The stratigraphical names of the units, together with their BGS map abbreviations and Lexicon computer codes, are listed alphabetically in Appendix 1, and alphabetically by code in Appendix 2. Redundant names and lexicon codes are listed in Appendix 3. Names that are recommended for future use are shown in **bold** in Appendices 1 and 2.

Correlation of the units in the south and central parts of the Pennine Basin are shown in Figures 2 and 3, and the stratigraphy of the southern part of the basin is summarised in Table 1 (north and south Staffordshire and Warwickshire).

5 CORRELATION AND BIOSTRATIGRAPHICAL FRAMEWORK

5.1 Biostratigraphy

One of the main problems in correlating the Warwickshire Group successions of the Pennine Basin is the paucity of biostratigraphical control (see discussion in Waters et al., 1995, and references therein). This is due to the rarity of useful diagnostic faunas and floras associated with the predominantly red-bed, alluvial strata. The Coal Measures have diagnostic fossils including the basin-wide marine bands which are useful marker beds, but these grey strata pass diachronously upward to red beds of the Etruria Formation at the base of the Warwickshire Group at different stratigraphical levels in different parts of the basin (Figures 2, 3). The passage from grey to red beds becomes stratigraphically younger as the beds are traced towards the central part of the depositional basin (Figure 2). Thus diagnostic marker beds and faunas, including the Cambriense Marine Band, are best preserved in grey measures in the central parts of the basin (Lancashire; north Staffordshire; East Midlands) (Calver, 1968, figure 21). Conversely, in the south of the basin (south Staffordshire; Wyre Forest; Coalbrookdale; Warwickshire) the highest correlatable marker bed is the stratigraphically lower Aegiranum Marine Band, but even this marker is absent in the southernmost part of the South Staffordshire Coalfield where red beds predominate (Whitehead and Eastwood, 1927). Where primary reddening is less intense, non-marine bivalve faunas of the Phillipsi chronozone have been recorded from the Etruria Formation (Ramsbottom et al., 1978).

The overlying Halesowen Formation, which rests unconformably on the Etruria Formation in the southern part of the basin, marks a return to grey beds, and is better constrained biostratigraphically than the strata above and below (Figure 2). Carbonaceous beds have yielded miospores (Smith and Butterworth, 1967; Butterworth and Smith, 1976; McNestry, 1994; Turner, 1994) and plant macrofossils that indicate a Westphalian D age (Clayton et al., 1977; Cleal, 1984; Besly and Cleal, 1997). Non-marine bivalve faunas (e.g. Edwards, 1951; Trotter, 1952) include records of *Anthraconauta tenuis*, which also suggests a Westphalian D age. However, the basal Main Sulphur Coal at Coalbrookdale has been assigned a late Bolsovian age on the basis of its miospore content (Hamblin and Coppack, 1995).

The predominantly alluvial red beds between the Halesowen Formation and the base of the unconformable Clent Formation (Table 1) are known only in the south part of the basin. Their age is poorly known, but they are generally regarded as late Westphalian D to Stephanian in age (Besly and Cleal, 1997). Evidence for the presence of Stephanian beds is largely indirect, in that an apparently conformable succession from Westphalian D (Halesowen Formation) to Permian (Kenilworth Sandstone Formation) should include beds of that age. Undoubted Stephanian fossils are generally lacking (Waters et al., 1995), though poorly preserved plant material from the Claverley Borehole (Wyre Coalfield) suggests the inclusion of early Stephanian (Cantabrian) beds in the Salop Formation there (Besly and Cleal, 1997).

The Clent Formation (South Staffordshire Coalfield) is generally regarded as Early Permian in age, although there is no fossil evidence for this (see discussion in Waters et al., 1995). In the Warwickshire Coalfield, where the succession is thicker and more complete, the Tile Hill Mudstone Formation and overlying strata have been regarded as Autunian (earliest Permian) in age on the basis of vertebrate fauna and ichnofauna (Vernon, 1912; Shotton, 1929; Dix, 1935; Haubold and Sarjeant, 1973). However, the base of the Permian in Warwickshire is usually drawn higher up, at the base of the 'Kenilworth Breccia Group' (Smith et al., 1974; Ramsbottom et al., 1978) or the Kenilworth Sandstone (Old et al., 1987). This age is based on the occurrence of the pelycosaurs *Sphenacodon brittanicus* and *Haptodus grandis* (Paton, 1974) and the amphibian *Dascyceps bucklandi* (Paton, 1975) in the Kenilworth Sandstone Formation.

5.2 Geophysical wireline log correlation

Geophysical wireline logs have proved very useful in characterising the succession and enable correlation of units within and between coalfields (Besly and Cleal, 1997; Bridge et al., 1998; Rees and Wilson, 1998; Glover and Powell, 1996; Powell et al., in press).

The most useful are the gamma and neutron logs which, since the 1980s, have been routinely recorded for all deep NCB/British Coal boreholes. The Etruria Formation and Halesowen Formation each have distinctive log signatures (see references listed above for discussion). Most notable amongst these is a narrow zone of high gamma-radiation near the top of the Halesowen Formation which is recognisable throughout much of the region (Figure 3). The gamma-ray high was arbitrarily taken as the top of the Halesowen Formation by NCB/British Coal geologists, although it lies about 50 m below the upper mappable boundary recognised at outcrop (Bridge et al., 1998; Powell et al., in press). The alluvial red beds overlying the Halesowen Formation also have distinctive wireline log signatures which permit local correlation and the recognition of alluvial sequences (Glover and Powell, 1996; Besly and Cleal, 1997; Bridge et al., 1998).

6 COAL MEASURES GROUP (CM)

Explanation:
Coal Measures, as now defined in lithostratigraphical terms, are recognised throughout Britain (except for Devon and Cornwall), but the present report refers only to their development in the Pennine Basin, where they pass up conformably into primary red beds. In areas south of the Wales-Brabant High, no large thicknesses of primary red beds overlie the coal-bearing strata and the term Coal Measures Group may remain valid to the top of the Carboniferous sequence. A separate account (Browne et al., 1996, 1999) is available for Scotland, where there are local type sections and some different boundary definitions.

Lithology:
Alternation of sandstone, grey siltstone and grey mudstone, with frequent coal seams and seatearth (palaeosol) horizons.

Nomenclature:
Until 1991 BGS practice was to treat Coal Measures as a time-rock name synonymous with Westphalian plus Stephanian. However, the present report follows more recent BGS practice (1:50 000 Sheets 123, 168, 169) and uses the name in a purely lithostratigraphical sense, to describe the main body of coal-bearing strata in the Westphalian succession. The base remains as defined by Stubblefield and Trotter (1957) but the top is now drawn at the incoming of primary red beds in the Westphalian rather than at the base of the Permian. Thus defined, Coal Measures equates to 'Productive Coal Measures' as used, for example, by Whitehead and Pocock (1947) and Besly (1988), and to 'Grey Measures' (Calver and Smith, 1974).

Rank:
Group

Subdivisions:
Formations (Table 1): Lower Coal Measures; Middle Coal Measures; Upper Coal Measures, as defined by Stubblefield and Trotter (1957), now defined as formations.

Type area:
Pennine coalfields; full development in the Potteries Syncline (north Staffordshire), with numerous borehole and shaft sections but few good exposures (Rees and Wilson, 1998).

Reference sections:
a For the base and lower part: Ridgeway Borehole, from the surface to 1806ft 10ins.

b For the top and upper part: Wolstanton Colliery No. 3 Shaft, from 1142ft 7ins to the base of shaft.

c For the boundary between the Lower and Middle Coal Measures: Mirywood, Locality C [SJ 8118 4942] on map SJ 84 NW, to become a designated RIGS; base of the Vanderbeckei Marine Band is the boundary.

d For the boundary between the Middle and Upper Coal Measures: Parkhouse Colliery No. 1 Underground Borehole; top of the Cambriense Marine Band, at 529ft depth in the borehole, is the boundary.

Geographical extent of group:
Britain except for Devon and Cornwall.

Lower boundary:
Base of the Subcrenatum Marine Band or at the base of the coal-bearing sequence if this marker band cannot be identified.

Upper boundary:
Base of the lowest conformably overlying major red-bed formation — Etruria Formation or lateral equivalent.

Thickness:
Up to 1600 m in the Potteries Syncline.

Age:
Silesian; Westphalian.

Remarks:
Definitions of Lower, Middle and Upper divisions in England and Wales differ slightly from those in Scotland (Browne et al., 1996, 1999).

References:
Besly (1988), Browne et al. (1996, 1999), Calver and Smith (1974), Rees and Wilson (1998), Stubblefield and Trotter (1957), Whitehead and Pocock (1947).

7 WARWICKSHIRE GROUP (WAWK)

Explanation:
The Coal Measures was formalised as a group in the BGS Lexicon in 1991. The status of the overlying strata has been debated widely in the BGS, with opinion divided into two camps, namely: a) those who believe that a name is required for the predominantly red strata of Westphalian B/C to early Permian age, and b) those believing that this stratal interval is too diverse for a group, and that the formations alone reflect the stratigraphy in the various parts of the basin.

Following discussion, the BGS Stratigraphy Committee strongly recommended that a group name be introduced to describe the red-bed succession. Some members of the Stratigraphical Framework Committee were against the adoption of the term Barren Measures, Barren Coal Measures or Red Measures because of the inclusion of the grey Halesowen Formation, and because a geographical prefix is preferred. The names Warwickshire Group or Ardwick Group were suggested.

Ardwick Group is the name formerly used in Lancashire. We regard this name as unsuitable because no thick red-bed sequence is known above the Halesowen Formation in Lancashire, so the area is not representative; and because the succession is known, in detail, only from boreholes without geophysical logs.

The Warwickshire name is preferred, because the Warwickshire Coalfield has the thickest and most complete red-bed succession in the Pennine Basin; outcrop and borehole data are good (including geophysical logs); and it is the area where Vernon (1912) first used terms like Barren Coal Measures.

Lithology:
Sandstone, siltstone and mudstone, predominantly red, brown or purple-grey in colour, but with some grey strata; coal seams not common; locally developed conglomerates and breccias; occasional beds of Spirorbis limestone (traditional name for fine-grained limestone of lacustrine origin; *Spirorbis* is not always present).

Nomenclature:
The group is here defined to include the red-bed formations and the relatively coal-poor, grey formations that overlie the Coal Measures Group (as now defined) in the Pennine Basin and its southern margin. The name derives from the Warwickshire Coalfield where the succession is thickest.

The Warwickshire Group replaces the approximately equivalent names Barren Coal Measures (Vernon, 1912), Red Measures (Edwards, 1951; Calver and Smith, 1974), Barren Measures (Fraser et al., 1990; Rees and Wilson, 1998), Barren Red Measures (Leeder and Hardman, 1990) and Barren Red Beds (Collinson et al., 1993).

Rank:
Group

Subdivisions (Table 2):
Etruria Formation, Halesowen Formation and Salop Formation (general); Tile Hill Mudstone Formation, Kenilworth Sandstone Formation and Ashow Formation (Warwickshire); Clent Formation (south Staffordshire).

Type area:
Warwickshire Coalfield; intermittently exposed outcrops and deep boreholes from the Tamworth area [SK 20 00] southwards to the Warwick area [SP 20 60]. The type area for the informal Barren Measures (Rees and Wilson, 1998) was the Potteries Syncline.

Reference sections:
See details of component formations. The Sandy Lane Borehole provides the most complete section with wireline logs, although the Kenilworth Formation appears to be anomalously thin, perhaps due to faulting.

Geographical extent:
West Midlands, north Wales, Lancashire, South Yorkshire, Nottinghamshire and Lincolnshire.

Table 2 Stratigraphical framework for the Warwickshire Group in south Staffordshire, Warwickshire and north Staffordshire.

<table>
<tr><th>GROUP</th><th colspan="5">FORMATION</th><th>SERIES/STAGE</th></tr>
<tr><td></td><td colspan="2">South Staffordshire</td><td colspan="2">Warwickshire</td><td>North Staffordshire</td><td></td></tr>
<tr><td rowspan="11">WARWICKSHIRE GROUP

(BARREN MEASURES)</td><td colspan="2" rowspan="2"></td><td colspan="2">Ashow Formation</td><td rowspan="2"></td><td rowspan="2">AUTUNIAN[2]</td></tr>
<tr><td colspan="2">Clent Formation</td><td colspan="2">Kenilworth Sandstone Formation</td></tr>
<tr><td colspan="2" rowspan="3"></td><td colspan="2">Tile Hill Mudstone Formation</td><td rowspan="4"></td><td rowspan="5">STEPHANIAN</td></tr>
<tr><td rowspan="4">Salop Formation (Meriden Formation)</td><td>Allesley Member</td></tr>
<tr><td>Keresley Member</td></tr>
<tr><td rowspan="3">Salop Formation</td><td rowspan="2">Enville Member (Enville Fm)</td><td rowspan="3">Whitacre Member</td></tr>
<tr><td rowspan="3">Salop Formation (Radwood Formation)</td></tr>
<tr><td>Alveley Member (Keele Fm)</td><td rowspan="2">WESTPHALIAN D</td></tr>
<tr><td rowspan="2">Halesowen Formation</td><td rowspan="2">Dark Slade Member</td><td>red facies[1]</td><td rowspan="2">(Keele Formation)</td></tr>
<tr><td colspan="2">(Newcastle Formation)</td></tr>
<tr><td colspan="5">Etruria Formation</td><td>BOLSOVIAN
(WESTPHALIAN C)</td></tr>
</table>

NOTES:
[1] Local red lithofacies in Halesowen Formation
[2] Base Permian is assumed to be below the Clent and Kenilworth formations
Italicised names in brackets are superseded


vertical lines indicate a hiatus
shaded areas indicate predominantly red beds

Lower boundary:
Generally taken at the base of the lowest red-bed formation (generally Etruria Formation) above the Coal Measures; or at the base of red beds of late Carboniferous age if Coal Measures are absent. In some areas, where both the Coal Measures and Etruria Formation are absent, the basal unit of the group consists of grey beds of the Halesowen Formation.

Upper boundary:
Taken at the base of unconformable (post-Variscan) Permian or younger strata.

Thickness:
About 1225 m in the Warwickshire area; up to 1192 m in the Stoke-on-Trent area.

Age:
Silesian (Duckmantian, Westphalian B) to Early Permian (Autunian).

Remarks:
The group is newly defined to replace informal terms like Barren Measures and the formal name Ardwick Group. The latter was used in Lancashire (sometimes as Ardwick Formation) to include both red beds (Etruria equivalents) and overlying mixed grey and red beds (Halesowen equivalents), up to the unconformable base of the Permo-Triassic beds. However, Lancashire is unsuitable for a type area because no thick red-bed sequence is known above the Halesowen Formation there, and because the succession is known only from old borehole records. Terms like Barren Measures and Red Measures are unsuitable because they lack a geographical prefix and parts of the succession are grey, with coals (e.g. Halesowen Formation).

The type Warwickshire Coalfield area has the thickest and most complete succession in the Pennine Basin, outcrop and borehole data are good (including geophysical logs), and it is the area where Vernon (1912) first used the term Barren Coal Measures (also Barren Measures and Red Barren Coal Measures). However, Vernon only included the Etruria, Halesowen and lower part of the Salop units (as defined in this report) in this 'group', excluding the overlying red beds with conglomerates.

Five characteristic areas (Figures 1, 2) of the Warwickshire Group are described:

Area A: South Staffordshire, Coalbrookdale, Wyre Forest, Shrewsbury, Denbigh, Cannock and South Derbyshire/Leicestershire coalfields
Area B: North Staffordshire Coalfield
Area C: Warwickshire Coalfield
Area D: Lancashire Coalfield
Area E: East Midland coalfields (South Yorkshire, Lincolnshire and Nottinghamshire)

The nomenclature in Areas A, B and C has been rationalised to reduce the number of formation names (see below). Lithostratigraphical units in each area are listed in upward stratigraphical order.

7.1 Area A: South Staffordshire and adjacent areas

7.1.1 Etruria Formation (ETM)

Lithology:
Mudstone, red, purple, brown, ochreous, green and grey, commonly mottled, with lenticular sandstones and conglomerates (locally known as 'espleys'). Some sandstones and conglomerates consist mostly of volcanic and lithic clasts. Pedogenic horizons are common. Thin coal seams are locally present; volcaniclastic rocks are present in south Staffordshire and south Nottinghamshire.

Nomenclature:
The name is derived from the Etruria area of the North Staffordshire Coalfield (Gibson, 1899; 1901). It was formerly referred to as the Etruria Marl, but the lithological epithet was dropped (Besly, 1988) because the rocks are mostly mudstone with subordinate sandstone and conglomerate.

Many local names exist for the unit (Ramsbottom et al., 1978): it was formerly known as the Old Hill Marl in south Staffordshire; Kinlet Formation in the Wyre Forest; Hadley Formation in Coalbrookdale; and Ruabon Marl in the Shrewsbury and Denbigh coalfields. The lower part of the Ardwick Group of Lancashire (Area D) comprises red beds (Ardwick Marls: Magraw, 1960) attributable to the Etruria Formation. We recommend these local names be dropped in favour of the name Etruria Formation.

Rank:
Formation in the Warwickshire Group.

Type area:
Potteries syncline (North Staffordshire Coalfield) in numerous boreholes and some quarries [SJ 70 30 to SK 00 60].

Reference sections:
a Original type locality, Etruria [SJ 86 46], near Stoke-on-Trent (Gibson, 1899, p.125).

b For the whole formation: Sidway Mill Borehole from 1210.84 m depth (base) to 779.07 m depth (top).

c Barker's Wood Borehole from 461.93 m depth (base) to 151.79 m (top).

d For the base only: Wolstanton Colliery No. 3 Shaft at a depth of 348.26 m.

Geographical extent:
Central and northern England and north Wales (Pennine Basin).

Lower boundary:
Passage by alternation from grey strata of the Coal Measures to red and varicoloured, mottled mudstone interbedded with sandstone and conglomerate which contains common volcanic and lithic clasts. The base is locally erosional on grey Coal Measures in Warwickshire (Arley anticline), Coalbrookdale (Hamblin and Coppack, 1995, figure 13), and Lincolnshire (Berridge et al., 1999).

Upper boundary:
Overlain by predominantly grey strata of the Halesowen Formation. This boundary is unconformable in the southern part of the Pennine Basin (e.g. south Staffordshire) where it is termed the 'sub-Halesowen unconformity', but is conformable to the north in the North Staffordshire and Lancashire coalfields and appears to be conformable in South Yorkshire and Nottinghamshire (Edwards, 1951; Smith et al., 1973; Howard et al., in prep).

Thickness:
Up to 300 m, but typically 50–100 m in the southern part of the Pennine Basin.

Age:
Silesian; late Duckmantian (Westphalian B) to Bolsovian (Westphalian C).

Remarks:
The lower boundary is highly diachronous, because primary red beds started to form earlier in the southern part of the Pennine Basin. However, in the southernmost part of the South Staffordshire Coalfield, close to the palaeo-high of the Wales-Brabant High, some of the lowermost Coal Measures are locally reddened (due to a localised lowering of the palaeo water-table); these strata are not regarded as Etruria Formation. In addition to the red colour, recognition of the formation is also dependant on the presence of characteristic sandstones and conglomerates (see lithology). As a rule of thumb the base, where it is a conformable passage, occurs at about the level of the Aegiranum Marine Band (Duckmantian to Bolsovian boundary) in the south of the basin, but lies at higher stratigraphical levels in the north.

References:
Berridge et al. (1999), Besly (1988), Besly and Fielding (1989), Besly and Cleal (1997), Bridge et al. (1998), Edwards (1951), Gibson (1899), Gibson (1901), Gibson (1905), Glover et al. (1993), Hamblin and Coppack (1995), Howard et al. (in prep), Magraw (1960), Powell et al. (in press), Rees and Wilson (1998).

7.1.2 Halesowen Formation (HA)

Lithology:
Grey-green, micaceous sandstone (litharenite) and grey-green mudstone, with thin coals, beds of Spirorbis limestone, local intraformational conglomerate, and caliche. Red beds are known from the parts of the South Staffordshire and North Staffordshire coalfields. In Cannock Chase the entire succession comprises red beds. Sandstones in the southern part of the basin have a notable content of foliated mudrock clasts.

Nomenclature:
The name derives from the town of Halesowen, which is located in the southern part of the South Staffordshire Coalfield. Previous names in this area are: Halesowen Beds (Whitehead and Eastwood, 1927), Halesowen Group (Eastwood et al., 1925) and Halesowen Sandstone Series (Kay, 1913). Local names, now redundant, for equivalent strata in other areas are as follows: Highley Formation (Wyre Forest Coalfield); Coalport Formation (Coalbrookdale Coalfield); Coed-yr-Allt Formation (Shrewsbury and Denbigh Coalfield); Newcastle Formation (North Staffordshire Coalfield); Ardwick Limestones (Lancashire Coalfield). In north Staffordshire and Cannock Chase the formation includes much of the formerly defined Keele Beds (or Keele Formation).

Rank:
Formation in the Warwickshire Group.

Subdivisions:
Dark Slade Member (Besly and Cleal, 1997).
Butterton Sandstone Bed, Springpool Sandstone Bed, Hanchurch Sandstone Bed: units locally mapped in the North Staffordshire Coalfield.
Holt Town Sandstone Bed: a very local unit in Lancashire.
First Limestone Bed to Twelfth Limestone Bed: units in Lancashire.

Type area:
Halesowen Town, Metropolitan Borough of Dudley [SO 97 84]; South Staffordshire Coalfield.

Reference sections:
a Composite stratotype. Base, The Rumbow (River Stour) [SO 967 836]; Oldnall, disused tramway track [SO 8318 8401]. General composite section, Illey Brook, Halesowen [SO 975 816 to 977 813]. Upper boundary, Uffmoor Wood, stream section [SO 956 811 to 951 811].

b Daleswood Farm Borehole: middle and upper part of the formation (from 147.4 m depth to the bottom of the borehole (Glover and Powell, 1996).

c Allotment-1 Borehole, Stafford (continuously cored with a full suite of wireline logs): base at 352.0 m, top at 176.0 m.

d Whittington Heath Borehole: continuous red beds in a 100% sandstone lithofacies.

e Sidway Mill Borehole: north Staffordshire succession including the former Newcastle and Keele units (red beds, in part); base at 779.1 m, top at 472.8 m.

Geographical extent:
Central and northern England (Oxfordshire to Lancashire and Nottinghamshire) and north Wales.

Lower boundary:
In the type area, a sharp, unconformable junction between red mudstones of the Etruria Formation and overlying, grey-green, locally pebbly sandstones. Elsewhere, the boundary may be conformable. If the Halesowen Formation is red, the base is drawn at the base of the first litharenite sandstone above the Etruria mudstones.

Upper boundary:
Drawn where the Dark Slade Member is overlain by the Salop Formation. In boreholes the gamma ray log character locates the boundary and at outcrop an associated colour change from grey to orange-red can be used, except where the Halesowen Formation is itself red. In such areas the Dark Slade Member cannot usually be recognised, and the boundary is based on general lithology and drawn above the top of the highest litharenite sandstone. A regional gamma radiation peak recognised on wireline logs about 50 m below the boundary (and within the Dark Slade Member) was formerly taken by NCB/British Coal as the top of the Halesowen Formation in some deep boreholes in the Warwickshire Coalfield.

Thickness:
About 110 m in the type area; 76–152 m in south Staffordshire; 70–127 m in Warwickshire; up to c.200 m in the Wyre Forest and 350 m in north Staffordshire (Besly and Cleal, 1997). Further north the top is eroded but remaining thicknesses are up to c.125 m in the East Midlands and up to about 200 m in Lancashire.

Age:
Silesian; mainly Westphalian D (see discussion in Waters et al., 1995); basal coal may be late Bolsovian at Coalbrookdale (Hamblin and Coppack, 1995, p.78).

Remarks:
It is proposed that the local names for equivalent strata in

the disparate coalfields (see nomenclature, above, and Figure 2) be dropped in favour of Halesowen Formation. In Lancashire, the former Ardwick Group included red beds (Ardwick Marls, now Etruria Formation) below and mixed grey and red beds (Ardwick Limestones, now Halesowen Formation), above. The Halesowen Formation is the highest unit of the Warwickshire Group so far recognised in the more northern parts of the Pennine Basin (Lancashire, Nottinghamshire).

References:
Besly (1988), Besly and Cleal (1997), Eastwood et al. (1925), Edwards (1951), Glover and Powell (1996), Howard et al. (in prep), Kay (1913), Magraw (1960), Powell et al. (in press), Waters et al. (1995), Whitehead and Eastwood (1927).

7.1.2.1 Dark Slade Member (DAR)

Lithology:
Mudstone with subordinate sublitharenite sandstones and thin beds of Spirorbis limestone. Colour mainly grey (though with mottled grey/brown palaeosols) in Shropshire, south Staffordshire and Warwickshire; red elsewhere. Distinctive geophysical log character, due to the higher gamma radiation response of mudstones compared to sandstones, with one or more gamma peaks.

Nomenclature:
Informally called the 'Palustrine Unit' and formalised as the Dark Slade Member by Besly and Cleal (1997).

Rank:
Member in the Halesowen Formation.

Subdivisions:
Index Limestone Bed: a Spirorbis limestone of regional extent in the South Staffordshire and Warwickshire coalfields.

Type section:
Dark Slade Borehole: base at 241.8 m, top at 181.3 m (Besly and Cleal, 1997, figure 10).

Reference section:
Radwood Borehole: base at 284.9 m, top at 204.3 m (Besly and Cleal, 1997, figure 6).

Geographical extent:
Staffordshire, Shropshire and Warwickshire.

Lower boundary:
At the base of a mudstone-dominated succession resting on litharenites of the lower Halesowen Formation; or at a change of gamma log character.

Upper boundary:
At the base of the overlying Salop Formation. In places where the member is grey there is a change to orange-red colours. The boundary is also marked by a change of gamma log character.

Thickness:
Between 40 and 90 m; 60.5 m in type section.

Age:
Silesian; probably Westphalian D.

Remarks:
The sandstone lithology links the member with the overlying Salop Formation; its inclusion in the Halesowen Formation is discussed by Besly and Cleal (1997, p.113). The unit is recognised easily in boreholes but is not currently mapped at outcrop.

References:
Besly and Cleal (1997).

7.1.3 Salop Formation (SAL)

Lithology:
Interbedded mudstone and sandstone, red and red-brown, with beds of pebbly sandstone and conglomerate; thin Spirorbis limestone beds and caliche in the lower part. Sparse, thin coals in the lower part. Sandstone mostly sublitharenite. Conglomerate clasts include Carboniferous Limestone and chert.

Nomenclature:
The name is taken from a colloquial regional term used for the Staffordshire/Shropshire area, and derives from the term 'Lower Permian, Salopian type' used by Hull (1869) for these rocks (Besly and Cleal, 1997). The new name has no chronostratigraphical connotation. It is also to be distinguished from the term 'Salopian' which was formerly used as a stage name for part of the Silurian.

Rank:
Formation in the Warwickshire Group.

Subdivisions:
The Alveley and Enville members in South Staffordshire and Wyre Forest coalfields; three other members in Warwickshire (see below, Area C).

Type area:
The area around Alveley village, Bowhills and Enville Sheepwalks, from the River Severn north-eastwards to the Bobbington area [SO 75 83 to SO 80 88].

Reference sections:
a Alveley No. 1 Borehole: from the surface to 76.8 m depth (Besly and Cleal, 1997).

b Penn No. 5 Borehole: from 562.4 m depth (base) to 202.6 m depth (top) (Powell, 1991b).

c Daleswood Farm Borehole: from 147.4 m depth (base) to 3.7 m depth (close to top of unit) (Glover and Powell, 1996).

d Romsley Borehole: upper boundary at 8.85 m depth, to 67.35 m depth (in upper part of formation) (Glover and Powell, 1996).

e Gravelly Way (Four Ashes) Borehole: base at 509.1 m depth (equivalent to the base of the Keele Group of Mitchell, 1945: see Besly and Cleal, 1997, figure 14).

There are two more reference sections in Warwickshire (see below, Area C).

Geographical extent:
Staffordshire, Shropshire and Warwickshire.

Lower boundary:
Conformable, gradational boundary taken at the base of the

first major red-bed strata overlying the grey or mottled mudstone dominated Dark Slade Member at the top of the Halesowen Formation; this grey interval can be recognised in boreholes by its gamma ray log character, which includes a regional gamma high. Where the Halesowen Formation is also red, the Dark Slade Member cannot usually be recognised at outcrop and the base of the Salop Formation is based on general lithology and is drawn above the top of the highest litharenite sandstone.

Upper boundary:
Drawn in the type area at the base of the Clent Formation: this is an unconformable (disconformable) boundary beneath breccia lithofacies in the Clent Hills, but a gradational boundary into a mudstone-dominated facies in the Wolverhampton and Cannock areas. In the Gospel End area (West Midlands) [SO 90 95] the boundary is taken at the base of the first red sandstone with volcanic clasts, intercalated with red mudstone. In Warwickshire the boundary is conformable below the Tile Hill Mudstone Formation (see below, Area C).

Thickness:
Between 200 and 360 m in the type area; over 450 m in north Staffordshire (Besly and Cleal, 1997); much thicker in Warwickshire (see below, Area C).

Age:
Silesian; Westphalian D to Stephanian or Early Permian (see discussion in Waters et al., 1995; Besly and Cleal, 1997).

Remarks:
The formation was established in the West Midlands to include all the red-bed strata between the Halesowen Formation and the Clent Formation. It includes the former Keele Formation of some areas (now the Alveley Member) in its lower part, and the former Enville Formation (now Enville Member) in its upper part. The Alveley and Enville units are reduced to member status since it is difficult to distinguish a mappable boundary between them over much of the area. In north Staffordshire, the Salop Formation replaces the term Radwood Formation (used by Rees and Wilson, 1998); the former Keele Formation now forms the upper (red) part of the Halesowen Formation. In the Shrewsbury area most of the former Erbistock Formation (or Group) is now assigned provisionally to the Salop Formation. The thin Alberbury Breccia at the top of the Erbistock Formation is now regarded as a basal breccia to the Permo-Triassic sequence. In Warwickshire the name Salop Formation replaces the Meriden Formation of Bridge et al. (1998).

References:
Bridge et al. (1998), Besly and Cleal (1997), Eastwood et al. (1925), Glover and Powell (1996), Powell (1991b), Powell et al. (in press), Rees and Wilson (1998), Waters et al. (1995), Whitehead and Eastwood (1927).

7.1.3.1 Alveley Member (ALY)

Lithology:
Interbedded red mudstone and red to red-brown, fine- to medium-grained sandstone; thin beds of Spirorbis limestone and pedogenic caliche (calcrete). Sparse, thin coals in the lower part. Sandstone mostly sublitharenite.

Nomenclature:
The name is derived from the village of Alveley, north-west of Kidderminster (Besly and Cleal, 1997).

Rank:
Member of the Salop Formation.

Subdivisions:
No formal subdivisions.

Type area:
Quarries and stream sections around Alveley, from the River Severn north-east to Bobbington area [SO 75 83 to SO 77 84].

Reference sections:
a Alveley No. 1 Borehole: from the surface to 76.8 m depth (Besly and Cleal, 1997).

b Daleswood Farm Borehole: from 147.4 m depth (base) to 97.7 m depth (top) (Glover and Powell, 1996).

Geographical extent:
Staffordshire and Shropshire.

Lower boundary:
As for the base of the Salop Formation: conformable, gradational boundary, taken at the base of the first major red-bed strata overlying the grey mudstone-dominated Dark Slade Member at the top of the Halesowen Formation.

Upper boundary:
Poorly defined, but arbitrarily taken at the base of a sandstone-dominated succession (Enville Member) which is characterised by conglomerates and pebbly sandstones with extrabasinal clasts, commonly of Carboniferous Limestone and chert.

Thickness:
Between 152 and 247 m in the type area (Alveley); 50–140 m in south Staffordshire.

Age:
Silesian; Westphalian D (see discussion in Waters et al., 1995).

Remarks:
The Alveley Member replaces the name Keele Formation (or Beds). The name was introduced (Besly and Cleal, 1997) because the Keele Beds outcropping near Keele in north Staffordshire have been shown to be red-bed equivalents of the Halesowen Formation (see below, Area B).

References:
Besly and Cleal (1997), Eastwood et al. (1925), Glover and Powell (1996), Waters et al. (1995), Whitehead and Eastwood (1927), Whitehead and Pocock (1947), Powell et al. (in press), Ramsbottom et al. (1978), Rees and Wilson (1998).

7.1.3.2 Enville Member (EN)

Lithology:
Interbedded red mudstone and red-brown, fine- to coarse-grained sandstone, locally pebbly; lenticular beds of conglomerate. Sandstone mostly sublitharenite; conglomerate clasts mostly Carboniferous Limestone and chert.

Nomenclature:
The name is derived from the village of Enville, c.10 km north

of Kidderminster (Whitehead and Eastwood, 1927; Besly and Cleal, 1997). The status of the unit has been reduced to member (see remarks under Alveley Member). The unit was formerly known as Enville Beds (Whitehead and Eastwood, 1927), Calcareous Conglomerate Group (Eastwood et al., 1925), Bowhills Formation (Ramsbottom et al., 1978; Old et al., 1991), and Enville Formation (Besly, 1988).

Rank:
Member of the Salop Formation.

Subdivisions:
No formal subdivisions.

Type area:
Enville Sheepwalks and Bowhills, between Alveley and Enville villages (Shropshire and West Midlands, respectively) [SO 77 84 to SO 77 85 and SO 78 87 to SO 80 88].

Reference sections:
a Daleswood Farm Borehole: from 97.7 m depth (base) to 3.7 m depth (close to top of member) (Glover and Powell, 1996).

b Romsley Borehole: from the upper boundary at 8.85 m depth to 67.35 m depth (upper part of member) (Glover and Powell, 1996).

Geographical extent:
Staffordshire and Shropshire.

Lower boundary:
Poorly defined, but arbitrarily taken at the base of a sandstone-dominated succession which overlies the Alveley Member, and which is characterised by conglomerates and pebbly sandstones with extrabasinal clasts, commonly of Carboniferous Limestone and chert.

Upper boundary:
At the base of the Clent Formation, as for upper boundary of Salop Formation (see above).

Thickness:
Between 100 and 247 m in the West Midlands.

Age:
Silesian; Westphalian D to ?Stephanian or Early Permian (Waters et al., 1995).

Remarks:
The Enville unit has been reduced to member status because it is difficult to map a boundary with the underlying Alveley Member (formerly Keele Formation) over much of the outcrop.

References:
Besly (1988), Bridge et al. (1998), Besly and Cleal (1997), Eastwood et al. (1925), Glover and Powell (1996), Old et al. (1991), Powell et al. (in press), Waters et al. (1995), Whitehead and Eastwood (1927), Whitehead and Pocock (1947), Ramsbottom et al. (1978), Rees and Wilson (1998).

7.1.4 Clent Formation (CLT)

Lithology:
Breccia, subangular, with red-brown mudstone matrix in the type area; northwards from the type area red mudstone and sandstone with sparse pebbles predominate. Clasts are diagnostic; they mostly consist of Uriconian (Precambrian) volcanic and volcaniclastic rocks, and subordinate Lower Palaeozoic limestone and shale.

Nomenclature:
The name is derived from the type area, Clent Hills, West Midlands. Previous names include: Clent Hills Breccia (King, 1893); Trappoid Breccia (King, 1923); Breccia Group (Eastwood et al. 1925); Clent Group (Wills, 1956); Clent Breccias (Old et al., 1991). It also includes the Northfield Breccia (Whitehead and Eastwood, 1927), Nechells Breccia (Boulton, 1924) and Quartzite Breccia (Wills and Shotton, 1938).

The term breccia has been dropped from the name because the lithology changes northwards over a few kilometres from breccia-dominated lithofacies in the type area (proximal) to mudstone/sandstone lithofacies in the Wolverhampton area (more distal) (Figure 3).

Rank:
Formation in the Warwickshire Group.

Subdivisions:
No formal subdivisions.

Type area:
Clent Hills, near Hagley; from the Country Park Visitors Car Park [SO 935 807] to the summit of the Clent Hills (present-day erosion surface; upper boundary not seen).

Reference sections:
a Breccia lithofacies: Romsley Borehole; lower boundary at 8.85 m depth (Glover and Powell, 1996).

b Mudstone/sandstone lithofacies: Penn No. 5 Borehole; from 83 m depth (base) to 20 m depth (top) (Glover and Powell, 1996).

c Mudstone-dominated lithofacies: Penn Common, Penn Brook stream section [from SO 913 955 to SO 893 940].

Geographical extent:
South Staffordshire; also identified on seismic sections in the subsurface to the west of Stratford-on-Avon (Peace and Besly, 1997).

Lower boundary:
Rests on Salop Formation (Enville Member); the boundary is unconformable (or disconformable) at the base of coarse breccia in the Clent Hills type area, but gradational at the base of mudstone-dominated Clent Formation in the Wolverhampton and Cannock areas. In the Gospel End area [SO 90 95] the boundary is taken at the base of red sandstone with volcanic clasts, intercalated with red mudstone.

Upper boundary:
A present-day erosion surface in the type area means that the top is not seen. Elsewhere, the formation is overlain unconformably by Triassic Sherwood Sandstone.

Thickness:
About 138 m in the type area; c.240 m in the Wolverhampton and Baggeridge areas to the north.

Age:
Probably Early Permian; possibly late Stephanian (see discussion in Waters et al., 1995).

Remarks:
Breccias of the Clent Formation mark a major change in provenance and lithofacies from the underlying Salop Formation. The proximal breccias of the type area pass rapidly northwards (basinwards) to mudstones and sandstones which overlie similar rocks attributed to the Salop Formation. Consequently, the boundary between these two formations is difficult to trace at outcrop in distal areas. In these mudstone-dominated areas the base of the Clent Formation is arbitrarily taken at the incoming of volcanic clasts in thin sandstone beds. The angular unconformity at the base of the Clent Formation can be demonstrated in a line of boreholes between Wolverhampton and Cannock Chase (Gravelly Way, Bangley, Lodgerail, Ashflats).

The depositional setting (proximal alluvial fan) of the breccia lithofacies in the Clent Hills and the Birmingham area had a profound influence on the clast content; pebble clasts were derived locally from uplifted hinterland blocks and thus reflect local provenance. Consequently, a number of lithostratigraphical units have been erected locally, in the West Midlands, named after the dominant clast type or locality e.g. Quartzite Breccia, Tessall Lane Breccia (Wills and Shotton, 1938), Northfield Breccia, Nechells Breccia (Boulton, 1924). These breccias are now regarded as correlatives of the Clent Formation (Powell et al., in press).

The Clent Formation has not been recognised in the Warwickshire Coalfield. It may be equivalent, in part, to the Tile Hill Mudstone Formation which includes the Beechwood Conglomerate Bed, rich in volcanic clasts, and/or to the overlying Kenilworth Sandstone and Ashow formations which are thought to be late Stephanian to Early Permian in age (Bridge et al., 1998).

References:
Bridge et al. (1998), Besly (1988), Boulton (1924), Eastwood et al. (1925), Glover and Powell (1996), King (1893), King (1923), Old et al. (1991), Powell (1991a), Powell et al. (in press), Smith et al. (1974), Waters et al. (1995), Whitehead and Eastwood (1927), Whitehead and Pocock (1947), Wills and Shotton (1938).

7.2 Area B: North Staffordshire

The red-bed succession in north Staffordshire (Figure 1) is similar to that in south Staffordshire (Figures 2, 3), although different names were formerly used for broadly coeval strata. It is proposed that the nomenclature is rationalised, as shown in Table 1.

The Etruria Formation has its type area in north Staffordshire, so the name is retained there and used, as before, in south Staffordshire also. The Newcastle Formation corresponds lithologically with the Halesowen Formation, which is recognised regionally and is better defined, so it is proposed to extend the latter name to north Staffordshire. Recent work (Besly and Cleal, 1997; Rees and Wilson, 1998) has shown that the Keele Formation is a composite unit; the lower part is a red-bed lithofacies of the Halesowen Formation, while the upper part (Radwood Formation of Rees and Wilson, 1998) is equivalent to the Salop Formation. The latter name is preferred.

7.3 Area C: Warwickshire

The Warwickshire Group succession is at its thickest here. The lithostratigraphical nomenclature (Table 1; Figures 2, 3), up to the level of the top of the Halesowen Formation, is the same as that for south Staffordshire and adjacent areas (Area A). The nomenclature of the higher beds, recently revised by Bridge et al. (1998), is further revised here, in that the name Meriden Formation introduced by these authors is replaced by the regional name Salop Formation. This unit includes higher beds than any in south Staffordshire, and is overlain conformably by formations unique to Warwickshire. The succession lacks any certain correlative of the Clent Formation of south Staffordshire (Figure 3).

7.3.1 Salop Formation (SAL)

Lithology:
As for Area A, but the formation is subdivided into members based on the recognition of upward-coarsening cycles (Bridge et al., 1998).

Nomenclature:
The formation includes both the former Keele Formation and Coventry Sandstone (Old et al., 1987) of the Warwickshire area, and replaces the Meriden Formation of Bridge et al. (1998).

Subdivisions:
Whitacre, Keresley and Allesley members, unique to Warwickshire.

Additional reference sections in Warwickshire:
a Rough Close Borehole: uncored borehole, but a full suite of geophysical logs is available; base defined at c.718 m depth; top at 109 m depth (Bridge et al., 1998, figure 32).

b Birch Tree Farm Borehole (lower part of formation): cored from 300 m to base of formation at 519.5 m depth (Bridge et al., 1998, figure 32).

Lower boundary:
As for Area A, at the top of the Dark Slade Member of the Halesowen Formation. At outcrop, at an upward colour change from grey to orange-red; in boreholes, at a change of gamma log character. The boundary is therefore c.50 m above the gamma high proposed as the criterion for the base of the Meriden Formation in boreholes (Bridge et al., 1998).

Upper boundary:
Conformable, taken at the top of the highest mappable persistent sandstone beneath the Tile Hill Mudstone Formation.

Thickness:
About 625 m.

Remarks:
The Salop Formation replaces the former Keele Formation and Coventry Sandstone (Old et al., 1987). A change in nomenclature was necessary for two reasons. First, the Keele Formation in the type area is now redundant, having been split between the Halesowen and Salop formations. Second, the Coventry Sandstone, as defined by Old et al. (1987), includes substantial thicknesses of mudstone, and in many areas there is no clearly mappable boundary with the former Keele Formation. Three new formal members are recognised, and an informal nomenclature (after Eastwood et al., 1923) is retained for the sandstone-dominated, upper parts of the two lowest members. Given that neither of these units is particularly conglomeratic, the preferred names are Arley and Exhall sandstones (for the upper part of the Whitacre Member) and Corley sandstone

(for the upper part of the Keresley Member). Use of the term Corley Member (Old et al., 1990) is discontinued.

References:
Bridge et al. (1998), Eastwood et al. (1923), Old et al. (1987), Old et al. (1990).

7.3.1.1 Whitacre Member (WIT)

Lithology:
Red and red-brown mudstone and red-brown sandstone. Mudstone-dominated in lower part, with characteristic caliche-bearing mudstones and breccias; sandstone-dominated in upper part (60–130 m) of the member. Thin Spirorbis limestone beds at some levels; impersistent conglomerate beds in upper part. Conglomerate clasts include chert, sandstone and limestone, mostly of Lower Carboniferous type (Shotton, 1927), and caliche.

Nomenclature:
The name derives from the village of Whitacre, Warwickshire, and was introduced by Bridge et al. (1998) for the first upward coarsening red-bed succession overlying the grey Halesowen Formation. It is equivalent to the former Keele Formation and the lowermost part of the Coventry Sandstone (Old et al., 1987).

Rank:
The lowest member of the Salop Formation in Warwickshire.

Subdivisions:
Pebbly sandstones, the Arley and Exhall sandstones, lie at the top of the Whitacre Member.

Type area:
Warwickshire Coalfield; poorly exposed terrain between Whitacre and Baxterley [SP 25 91 to SP 27 97].

Reference sections:
a Birch Tree Farm Borehole: base taken at 519.5 m; top taken at 238 m depth.

b Old quarry [SP 2815 8893] at Tippers Hill Lane: exposes granule to pebble grade breccia-conglomerate, composed mostly of mudstone clasts; typical of lower part of member.

Geographical extent:
Warwickshire Coalfield; outcrops in northern part.

Lower boundary:
Same as the base of the Salop Formation.

Upper boundary:
Taken at the top of the highest mappable sandstone unit (Arley and Exhall sandstones) below the basal mudstone-dominated part of the Keresley Member.

Thickness:
Between 280 and 357 m (based on borehole geophysical log data).

Age:
Silesian; Westphalian D to Stephanian.

Remarks:
Similar lithologically to the Keresley Member. The lower part is mudstone-dominated, and includes feature-forming breccias and caliche-bearing mudstones. The upper part is sandstone dominated. Thin beds of Spirorbis limestone can be traced over part of the outcrop.

References:
Bridge et al. (1998), Eastwood et al. (1923), Old et al. (1987), Old et al. (1990).

7.3.1.2 Keresley Member (KRS)

Lithology:
Red and red-brown mudstone and red-brown sandstone. Mudstone-dominated in the lower part, becoming increasingly sandy in the upper part. Thin Spirorbis limestone beds at some levels; impersistent conglomerate beds occur in the upper part. Conglomerate clasts include chert, sandstone and limestone, mostly of Lower Carboniferous type (Shotton, 1927).

Nomenclature:
The name derives from the village of Keresley, Warwickshire, and was introduced by Bridge et al. (1998) for the middle, upward-coarsening red-bed succession of the Meriden (now Salop) Formation. The member is equivalent to the middle part of the former Coventry Sandstone (Old et al., 1987).

Rank:
Middle member of the Salop Formation in Warwickshire.

Subdivisions:
The Corley sandstone, a pebbly sandstone at the top of the Keresley Member, was formerly the Corley Member of the Coventry Sandstone Formation (Old et al., 1987).

Type area:
Warwickshire Coalfield; centred on the village of Corley [SP 30 85]; poorly exposed terrain extending from the Western Boundary Fault to northwest Coventry.

Reference sections:
a Staircase Lane Borehole: an uncored borehole but good quality geophysical logs available; the base is taken at 363 m depth, and the top at 78 m depth.

b Cliff section at Corley [SP 3040 8520], a roadside exposure 200 m northeast of Corley village: Corley sandstone; representative of sandstones in the upper part of the member.

c Websters, Hemming and Sons. Ltd. Brickworks [SP 3423 8050]: laterally impersistent sandstones in lower part of member (Besly, 1988, figure 15.13b). Quarry backfilled c.1994.

Geographical extent:
Warwickshire Coalfield; outcrops in northern part.

Lower boundary:
Taken immediately above the Arley and Exhall sandstones at the top of the underlying Whitacre Member (Bridge et al., 1998).

Upper boundary:
Taken at the top of the highest mappable sandstone (Corley sandstone) below the basal mudstone-dominated succession of the overlying Allesley Member.

Thickness:
Between 197 and 306 m (based on borehole geophysical log data).

Age:
Silesian; Westphalian D to Stephanian.

Remarks:
Similar lithologically to the Whitacre Member. The argillaceous lower part is dominated by red mudstone with subordinate reddish brown or greyish green sandstone beds and pellet-rich, mudstone conglomerate. The upper 85 m consists of thickly bedded sandstones and lenticular conglomerates, best developed in the prominent escarpment between Corley village and the outskirts of Coventry.

References:
Bridge et al. (1998), Eastwood et al. (1923), Old et al. (1987), Old et al. (1990).

7.3.1.3 Allesley Member (ASY)

Lithology:
Red and red-brown mudstone and red-brown sandstone. Mudstone-dominated in the lower part, becoming increasingly sandy in the upper part. Impersistent conglomerate beds at some levels. Conglomerate clasts include chert, sandstone and limestone, mostly of Lower Carboniferous type (Shotton, 1927).

Nomenclature:
The name derives from the village of Allesley, Warwickshire, and was introduced by Bridge et al. (1998) for the uppermost red-bed succession in the Meriden (now Salop) Formation; the upper part of the member includes the Allesley sandstones and conglomerates of Eastwood et al. (1923). The member is equivalent to the upper part of the former Coventry Sandstone (Old et al., 1987).

Rank:
Uppermost member of the Salop Formation.

Type area:
Warwickshire Coalfield: poorly exposed outcrops centred on the village of Allesley and extending from the Western Boundary Fault to the western suburbs of Coventry [SP 24 81 to SP 33 78].

Reference sections:
a Mount Nod No. 2 Borehole: base of member at 170.5 m depth, top at 38.3 m depth.

b Wainbody Wood Borehole: base of member at 275.4 m depth, top at 160.2 m depth. Full suite of wireline logs.

Geographical extent:
Warwickshire Coalfield.

Lower boundary:
Taken at the junction between the highest sandstone package in the Keresley Member and the overlying mudstone unit.

Upper boundary:
Defined at the incoming of mudstone of the essentially argillaceous Tile Hill Mudstone Formation.

Thickness:
About 140 m.

Age:
Silesian; Westphalian D to Stephanian.

Remarks:
A persistent mudstone interval, about 75 m thick, is developed in the lower part of the member. A bed yielding silicified wood forms a local marker horizon about 97 m above the base.

References:
Bridge et al. (1998), Eastwood et al. (1923), Old et al. (1987), Old et al. (1990).

7.3.2 Tile Hill Mudstone Formation (TLM)

Lithology:
Mudstone, red-brown, with subordinate thin red-brown and green flaggy sandstones; sparse thin conglomeratic lenses.

Nomenclature:
The name is taken from Tile Hill, west of Coventry. It was previously known as the Tile Hill Marl Group (Shotton, 1929; Old et al., 1987).

Rank:
Formation in the Warwickshire Group.

Subdivisions:
The Beechwood Conglomerate Bed is a lensoid, conglomeratic bed lying about 120 m above the base.

Type area:
Extensive poorly exposed outcrop in the southern part of the Warwickshire Coalfield [SP 28 78].

Reference sections:
a Tile Hill Railway Station Borehole: mudstone with subordinate sandstones recorded to 211.3 m depth; top not seen.

b Stream section [SP 2789 7975 to SP 2800 7975], north of Broad Lane, Tile Hill: flaggy, red-brown sandstone and interbedded mudstone.

c Mount Nod No. 2 Borehole: basal 38.3 m of formation recorded as ‘hard red marl with sandy beds’.

d Ashow Borehole: base taken at 239.9 m depth; top at 104.3 m depth. Full suite of wireline logs.

Geographical extent:
Southern part of the Warwickshire Coalfield.

Lower boundary:
Taken at the top of the highest mappable persistent sandstone of the Salop Formation.

Upper boundary:
Taken at the change from mudstone to the predominantly arenaceous sequence of the Kenilworth Sandstone Formation.

Thickness:
About 280 m in the Warwickshire Coalfield.

Age:
Silesian; Westphalian D to Stephanian, or possibly Autunian (Permian).

Remarks:
The boundaries of the formation are unchanged from those defined by Shotton (1929).

References:
Bridge et al. (1998), Eastwood et al. (1923), Old et al. (1987), Old et al. (1990), Shotton (1929).

7.3.3 Kenilworth Sandstone Formation (KHS)

Lithology:
Sandstone, red-brown with subordinate thin beds of red mudstone; towards the base, conglomerate is locally present (Gibbet Hill Conglomerate), and lenses of breccia occur toward the top of the formation. Pebbles in the conglomerate comprise mostly 'Valentian' sandstone/quartzite and red Carboniferous chert; other quartzites, vein quartz, Carboniferous limestones and Precambrian tuffs occur in minor amounts (Shotton, 1929). Breccia clasts comprise mudstone, siltstone and ironstone, with sparse quartzite, limestone and red chert (Old et al., 1987).

Nomenclature:
The name is derived from the village of Kenilworth, Warwickshire, and was defined by Old et al., (1987). It includes the Kenilworth Breccia Group and the Gibbet Hill (Conglomerate) Group as defined by Shotton (1929).

Rank:
Formation in the Warwickshire Group.

Subdivisions:
The Gibbet Hill Conglomerate Bed is a unit near the base; unnamed breccias occur at higher levels.

Type area:
Kenilworth area, from Hurst Farm through Gibbet Hill to Stoneleigh [SP 27 74 to SP 33 71].

Reference sections:
a Gibbet Hill: 'Middle Quarry' [SP 3045 7521], type locality for the Gibbet Hill Conglomerate, described by Shotton (1929, p.174); see also Old et al. (1987, p.16).

b Weston Colony Borehole (Old et al., 1987): proved the upper 20 m of the formation.

c Sandy Lane Borehole: base at 317.6 m; top at 253.8 m.

d Love Lane Quarry [SP 2866 7284] (Shotton, 1929, p.127): breccias in the upper part of the formation.

e Castle Quarry, Kenilworth [SP 2778 7191] (Shotton, 1929, p.117): sandstones and breccias in the upper part of the formation.

Geographical extent:
Kenilworth area, southern part of the Warwickshire Coalfield.

Lower boundary:
The base is marked by the incoming of thick sandstones above the argillaceous Tile Hill Mudstone Formation. These beds form a strong north-facing scarp from Hurst Farm [SP 28 74] through Gibbet Hill [SP 30 75] to Stoneleigh [SP 33 72].

Upper boundary:
The top is taken at the base of a thick red mudstone of the overlying Ashow Formation.

Thickness:
About 100 m.

Age:
Autunian (Permian).

Remarks:
Although quartz, quartzite and micaceous siltstone form the most common clasts in the formation, the presence of rhyolite, andesite and basalt together with some chlorite-mica-schist suggests an igneous/metamorphic source area, in part (Shotton, 1929; Old et al., 1987). Shotton concluded that these clasts were derived from Precambrian and Lower Palaeozoic rocks of the Lickey Ridge, and proposed a correlation between the breccias of the Kenilworth Sandstone Formation and the 'Uriconian' breccias of the Clent Formation of the West Midlands. This correlation is open to debate, since stratigraphically lower conglomerates and breccias such as the Beechwood Conglomerate (Salop Formation) also contain volcanic clasts.

References:
Bridge et al. (1998), Eastwood et al. (1923), Old et al. (1987), Old et al. (1990), Shotton (1929).

7.3.4 Ashow Formation (AW)

Lithology:
Red-brown mudstone with subordinate, but locally thick, beds of red-brown and grey-green, fine- to medium-grained sandstone.

Nomenclature:
The formation is equivalent to the Ashow Group of Shotton (1929); the name is derived from the village of Ashow, located south-east of Kenilworth. The lower part of the formation was termed the Whitmoor Marls and Whitemoor Sandstone (Richardson and Fleet, 1926).

Rank:
Formation; uppermost subdivision of the Warwickshire Group.

Type area:
Warwick and the southern part of the Warwickshire Coalfield [SP 28 65 to 32 72]. The upper part of the formation around Warwick is poorly exposed, and occurs in fault-bounded inliers; as a result details of the succession and thickness are uncertain.

Reference sections:
a Whitemoor Brickworks [SP 295 717] and Cherry Orchard Brickworks [SP 295 722], Kenilworth (Richardson and Fleet, 1926; Shotton, 1929; Old et al., 1987): lower part of the formation.

b Chesford Bridge [SP 311 693] (Old et al., 1987): sandstones in the middle part of the formation.

c Guys Cliffe Chapel pit [SP 2883 6674]: upper part of the formation.

d Tachbrook Mallory Borehole (Richardson, 1928).

e Sandy Lane Borehole: from the surface to the base of the formation at 253.8 m.

Geographical extent:
Southern part of the Warwickshire Coalfield.

Lower boundary:
Taken at the incoming of a thick succession of red mudstones (50 to 65 m thick) above the Kenilworth Sandstone Formation.

Upper boundary:
Taken at the base of the unconformable Bromsgrove Sandstone Formation (Triassic) in the type area.

Thickness:
Up to 250 m in the Sandy Lane and Barford boreholes.

Age:
Autunian (Permian).

References:
Bridge et al. (1998), Eastwood et al. (1923), Old et al. (1987), Old et al. (1990), Richardson (1928), Richardson and Fleet (1926), Shotton (1929).

7.4 Area D: Lancashire

In the Lancashire area (Figures 2, 3), the strata above the grey Coal Measures have been termed the Ardwick Group (Tonks et al., 1931) or Ardwick Formation (Ramsbottom et al., 1978). The strata are known mostly from NCB boreholes (Trotter, 1953; 1954), of which the Farnworth (A3/4) Borehole is typical (Figure 3). They consist of primary red beds (Ardwick Marls) overlain by the Ardwick Limestones, mixed red, varicoloured and grey strata, including thin coals and Spirorbis limestones (Magraw, 1960). In addition, the strata immediately below the unconformable Permo-Triassic beds are intensely reddened, supposedly a result of complete oxidation (secondary reddening) prior to deposition of the Permo-Triassic strata (Trotter, 1954). A strong unconformity was at one time thought to exist beneath the red beds (Jones et al., 1938) but this was disproved by drilling (Trotter, 1954).

It is proposed that the Ardwick Marls are referred to the Etruria Formation, and the overlying Ardwick Limestones to the Halesowen Formation. The term Ardwick Group is now replaced by Warwickshire Group (see discussion above; Section 7).

The upward transition from grey Coal Measures to Etruria Formation is strongly diachronous, as at the southern margins of the basin; it rises in the sequence from west to east, being less than 50 m above the Cambriense Marine Band near St. Helens (Trotter, 1954: Farnworth Borehole A3/4), but over 350 m above that horizon in the Manchester/Stockport area (Poole and Whiteman, 1955; BGS sheets 85, 98).

7.5 Area E: East Midlands (South Yorkshire, Lincolnshire and Nottinghamshire)

Red-bed strata of late Westphalian age are known to lie beneath an unconformable cover of Permian beds in this region (Edwards, 1951, figure 36). In south Nottinghamshire a lower unit of primary red beds is assigned to the Etruria Formation and a higher unit of mixed grey and red strata is equated with the Halesowen Formation (Howard et al., in prep). Further north a probable equivalent of the Etruria Formation has been identified (Edwards, 1951, figure 36; Smith et al., 1973). The base of the red beds is strongly diachronous, lying at progressively lower levels in the sequence towards the south. In the north, near Doncaster, this boundary lies 100 to 250 m above the Cambriense Marine Band (Edwards, 1951, figure 36; Smith et al., 1973, plate 9) and is gradational, but at the basin margin, in the south-east, it is apparently erosional, resting on much older (Duckmantian and Langsettian) strata (Howard et al., in prep; Berridge et al., 1999). The highest strata are sandstones (Howard et al., in prep) beneath which an unconformity has been inferred to develop as the sequence thins at the basin margin (Edwards, 1967).

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APPENDIX 1

Alphabetical list of Westphalian to Early Permian lithostratigraphical units used by BGS.

The letter codes, shown in brackets after the lithostratigraphical unit, refer to the area/coalfield in which the stratigraphical name was commonly used; these are listed below:
(C) Cannock; (CB) Coalbrookdale; (DB) Denbigh; (SD) South Derbyshire; (SH) Shrewsbury; (SS) South Staffordshire; (NS) North Staffordshire; (W) Warwickshire; (WF) Wyre Forest; (L) Lancashire.

The second column gives the current status, as shown in the following chart:

Status	Group	Formation	Member	Bed	undefined
Abbreviation	G	F	M	B	U

Bold text indicates recommended lithostratigraphical names

LITHOSTRATIGRAPHICAL UNIT	CURRENT STATUS	LEXICON CODE	BGS MAP CODE	CURRENT EQUIVALENT
Alveley Member (SS; WF)	M	ALY	Aly	√
Allesley Member (W)	M	ASY	Asy	√
Allesley sandstones and conglomerates (W)	B	AYC		√
Allesley Conglomerate		AYC		see item above
Ardwick Formation (L)		ARG		Warwickshire Group
Ardwick Group (L)		ARG		Warwickshire Group
Ardwick Marl (L)		AM		Etruria Formation
Arley and Exhall sandstones (W)	B	ARSA		√
Arley Conglomerate (W)		ARLC		see item above
Arley Sandstone (W)		ARSA		see item above
Ashow Formation (W)	F	AW		√
Barren Measures		BME	BME	Warwickshire Group
Beechwood Conglomerate Bed (W)	B	BCWC		√
Bowhills Formation (SS)		BWH		Enville Member
Butterton Sandstone Bed (NS)	B	BUTS	BtS	√
Calcareous Conglomerate Group (SS)		CAGG		Salop Formation
Clent Formation (SS)	F	CLT	Cle	√
Clent Breccias (SS)		CLE		Clent Formation
Coal Measures Group (Pennine Basin)	G	CM		√
Coalport Formation (CB)		CP		Halesowen Formation
Coed-yr-Allt Formation (DB; SH)		CYAF		Halesowen Formation
Corley sandstone (W)	B	CRSA		√
Corley Conglomerate (W)		CC		Corley sandstone
Corley Member (W)				Corley sandstone
Coventry Sandstone Formation (W)		CYS		Salop Formation (part)
Dark Slade Member	M	DAR	Dar	√
Enville Member (SS; DB)	M	EN	En	√
Enville Formation (SS; CB)		EB		Enville Member
Enville Group (SS; W)				Enville Member
Erbistock Formation (SH)		ERB		mainly Salop Formation
Etruria Formation (C; NS; W; SD; SS)	F	ETM	Et	√
Etruria Marl				Etruria Formation
Gibbet Hill Conglomerate Bed (W)	B	GHC		√

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Hadley Formation (CB)		HD		Etruria Formation
Halesowen Formation (SS; W; SD)	F	HA	Ha	√
Halesowen Beds (SS; W; SD)				Halesowen Formation
Halesowen Group (SS; W; SD)				Halesowen Formation
Halesowen Sandstone Series (SS; W; SD)				Halesowen Formation
Hanchurch Sandstone Bed (NS)	B	HANS	HaS	√
Highley Formation (WF)		HYG	Hyg	Halesowen Formation
Holt Town Sandstone Bed (L)	B	HTS		√
Index Limestone Bed (SS; W)	B	ILS		√
Keele Formation (NS; SS; W; WF; CB)		KE	Ke	partly red lithofacies of Halesowen Formation, partly Salop Formation
Keele Beds				
Keele Group				
Keele Sandstone Series				
Keresley Member (W)	M	KRS	Krs	√
Kenilworth Sandstone Formation (W)	F	KHS		√
Kinlet Formation (WF)		KTB		Etruria Formation
Lower Coal Measures Formation (Pennine Basin)	F	LCM	LCM	√
Meriden Formation (W)		MRD		Salop Formation
Middle Coal Measures Formation (Pennine Basin)	F	MCM	MCM	√
Newcastle Formation (NS)		NCL	Ncl	Halesowen Formation
Newcastle Beds				Halesowen Formation
Newcastle Group				Halesowen Formation
Newcastle-under-Lyme Series				Halesowen Formation
Old Hill Marl (SS)				Etruria Formation
Radwood Formation (NS)		RWD	Rwd	Salop Formation
Ruabon Marl Formation (DB; SH)		RM		Etruria Formation
Salop Formation (SS; WF; C; W; NS)	F	SAL	Sal	√
Springpool Sandstone Bed (NS)	B	SPPS	SpS	√
Tile Hill Mudstone Formation (W)	F	TLM	TLM	√
Tile Hill Marl Group (W)				Tile Hill Mudstone Formation
Upper Coal Measures Formation (Pennine Basin)	F	UCM	UCM	√
Warwickshire Group (Pennine Basin)	G	WAWK	Wk	√
Whitacre Member (W)	M	WIT	Wit	√

APPENDIX 2

Alphabetical list of BGS Lexicon computer codes

The letter codes, shown in brackets after the lithostratigraphical unit, refer to the area/coalfield in which the stratigraphical name was commonly used; these are listed below:
(C) Cannock; (CB) Coalbrookdale; (DB) Denbigh; (SD) South Derbyshire; (SH) Shrewsbury; (SS) South Staffordshire; (NS) North Staffordshire; (W) Warwickshire; (WF) Wyre Forest; (L) Lancashire.

Bold text indicates recommended lithostratigraphical names

LEXICON CODE	LITHOSTRATIGRAPHICAL UNIT
ALY	**Alveley Member** (SS; WF)
AM	Ardwick Marls (L)
ARG	Ardwick Group (L)
ARLC	Arley Conglomerate (W)
ARSA	**Arley and Exhall sandstones** (W)
ASY	**Allesley Member** (W)
AW	**Ashow Formation** (W)
AYC	**Allesley sandstones & conglomerates (W)**
BCWC	**Beechwood Conglomerate Bed** (W)
BME	Barren Measures
BUTS	**Butterton Sandstone Bed** (NS)
BWH	Bowhills Formation (SS)
CACG	Calcareous Conglomerate Group (SS)
CC	Corley Conglomerate (W)
CLE	Clent Breccias (SS)
CLT	**Clent Formation** (SS)
CM	**Coal Measures Group**
CP	Coalport Formation (CB)
CRSA	**Corley sandstone** (W)
CYAF	Coed-yr-Allt Formation (DB; SH)
CYS	Coventry Sandstone Formation (W)
DAR	**Dark Slade Member**
EN	**Enville Member** (SS; DB)
ERB	Erbistock Formation (SH)
ETM	**Etruria Formation (C; NS; W; SD; SS)**
GHC	**Gibbet Hill Conglomerate Bed** (W)
HA	**Halesowen Formation** (SS; W; SD; NS)
HANS	**Hanchurch Sandstone Bed** (NS)
HD	Hadley Formation (CB)
HTS	**Holt Town Sandstone Bed** (L)
HYG	Highley Formation (WF)
ILS	**Index Limestone Bed** (SS; W)
KE	Keele Formation (NS; SS; W; WF; CB)
KHS	**Kenilworth Sandstone Formation** (W)
KRS	**Keresley Member** (W)
KTB	Kinlet Formation (WF)
LCM	**Lower Coal Measures Formation**
MCM	**Middle Coal Measures Formation**
MRD	Meriden Formation (W)
NCL	Newcastle Formation (NS)
RM	Ruabon Marl Formation (DB; SH)
RWD	Radwood Formation (NS)
SAL	**Salop Formation** (SS; WF; C)
SPPS	**Springpool Sandstone Bed** (NS)
TLM	**Tile Hill Mudstone Formation** (W)
UCM	**Upper Coal Measures Formation**
WAWK	**Warwickshire Group**
WIT	**Whitacre Member** (W)

APPENDIX 3

List of redundant names and codes

REDUNDANT LITHOSTRATIGRAPHICAL NAMES	REDUNDANT LEXICON CODES
Allesley Conglomerate (W)	
Ardwick Formation (L)	ARG
Ardwick Group (L)	ARG
Ardwick Marl (L)	AM
Arley Conglomerate (W)	ARLC
Arley Sandstone	
Barren Measures	BME
Bowhills Formation (SS)	BWH
Calcareous Conglomerate Group (SS)	CACG
Clent Breccias (SS)	CLE
Coalport Formation (CB)	CP
Coed-yr-Allt Formation (DB; SH)	CYAF
Corley Conglomerate (W)	CC
Corley Member (W)	
Coventry Sandstone Formation (W)	CYS
Enville Formation (SS; CB)	EB
Enville Group (SS; W)	
Erbistock Formation (SH)	ERB
Etruria Marl	
Hadley Formation (CB)	HD
Halesowen Beds (SS; W; SD)	
Halesowen Group (SS; W; SD)	
Halesowen Sandstone Series (SS; W; SD)	
Highley Formation (WF)	HYG
Keele Beds	
Keele Formation	KE
Keele Group	
Keele Sandstone Series	
Kinlet Formation (WF)	KTB
Meriden Formation (W)	MRD
Newcastle Beds (NS)	
Newcastle Formation (NS)	NCL
Newcastle Group (NS)	
Newcastle-under-Lyme Series (NS)	
Old Hill Marl (SS)	
Radwood Formation (NS)	RWD
Ruabon Marl Formation (DB; SH)	RM
Tile Hill Marl Group (W)	

APPENDIX 4

List of boreholes and shafts mentioned in the text

Borehole or shaft name	National grid reference	BGS 1:10k quarter sheet records number
Allotment-1 Borehole, Stafford	[SJ 9467 2679]	SJ 92 NW/35
Alveley No.1 Borehole	[SO 7818 8608]	SO 78 NE/2
Ashflats Borehole	[SJ 9177 1935]	SJ 91 NW/15
Ashow Borehole	[SP 3035 7161]	SP 37 SW/100
Ballards Green Borehole	[SP 2748 9137]	SP 29 SE/6
Bangley Borehole	[SJ 9444 1398]	SJ 91 SW/41
Barford Borehole	[SP 2833 6209]	SP 26 SE/95
Barker's Wood Borehole	[SJ 8221 4516]	SJ 84 NW/68
Birch Tree Farm Borehole	[SP 3101 8288]	SP 38 SW/161
Daleswood Farm Borehole (BGS)	[SO 9511 7913]	SO 97 NE/452
Dark Slade Borehole	[SJ 9764 1649]	SJ 91 NE/16
Farnworth A3/4 Borehole	[SJ 5256 8731]	SJ 58 NW/26
Gravelly Way (Four Ashes) Borehole	[SJ 9153 0954]	SJ 90 NW/8
Lodgerail Borehole	[SJ 9459 1538]	SJ 91 NW/19
Mount Nod No.2 Borehole	[SP 2922 7927]	SP 27 NE/46
Parkhouse Colliery No.1 Underground Borehole	[SJ 8396 5029]	SJ 85 SW/19
Penn No.5 Borehole	[SO 8925 9654]	SO 89 NE/6
Radwood Borehole	[SJ 7753 4176]	SJ 74 SE/28
Ridgeway Borehole	[SJ 8922 5381]	SJ 85 SE/14
Romsley Borehole No.31	[SO 9501 7893]	SO 97 NE/216
Rough Close Borehole	[SP 2648 7851]	SP 27 NE/9
Sandy Land Borehole	[SP 3058 6757]	SP 36 NW/82
Sidway Mill Borehole	[SJ 7603 3934]	SJ 73 NE/3
Staircase Lane Borehole	[SP 3036 8129]	SP 38 SW/97
Tachbrook Mallory Borehole	[SP 3226 6225]	SP 36 SW/13
Tile Hill Railway Station Borehole	[SP 2781 7755]	SP 27 NE/1
Wainbody Wood Borehole	[SP 3139 7419]	SP 37 SW/60
Weston Colony Borehole	[SP 3662 6907]	SP 36 NE/5
Whittington Heath Borehole	[SK 1478 0800]	SK 10 NW/3
Wolstanton Colliery No.3 Shaft	[SJ 8606 4800]	SJ 84 NE/29

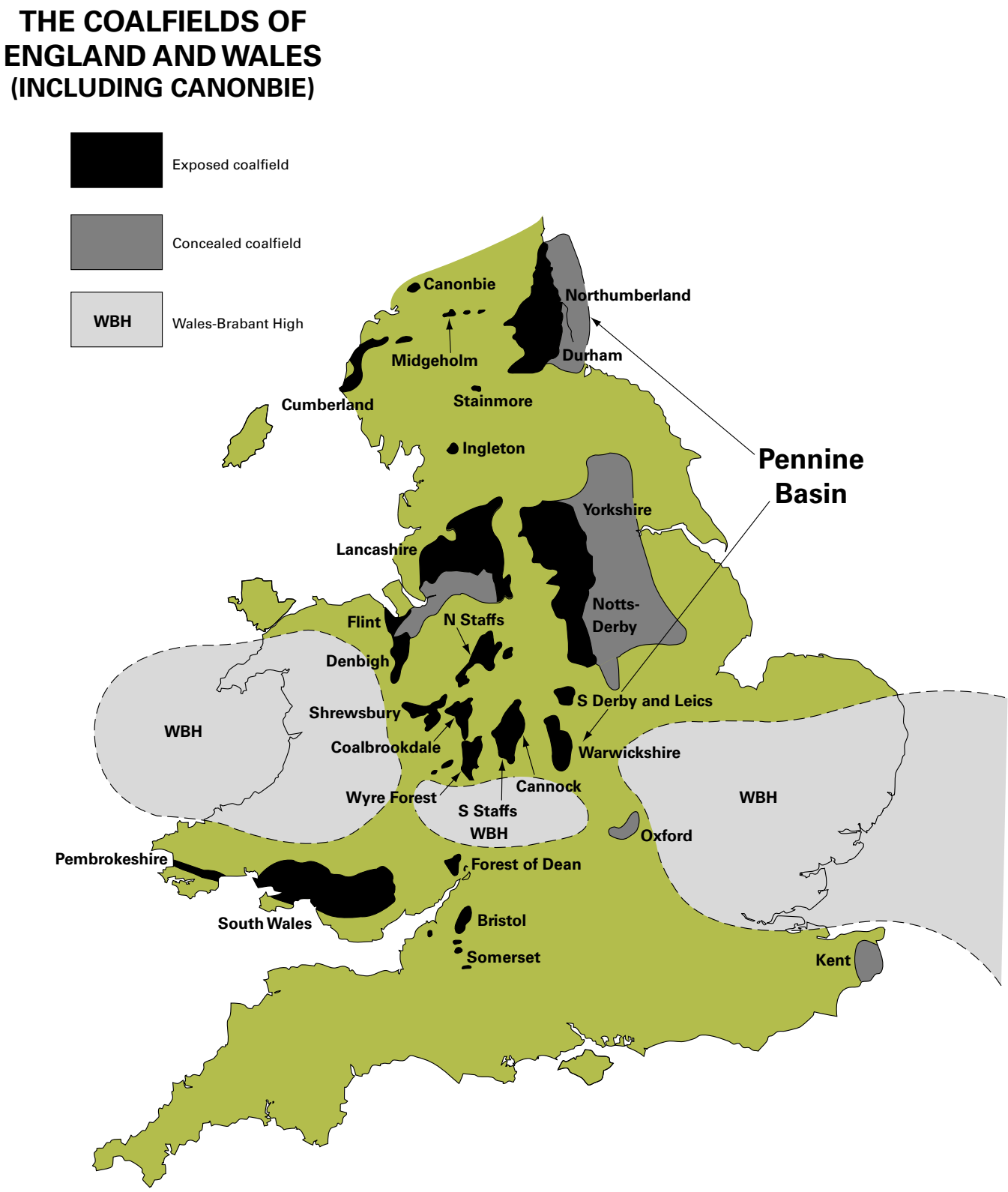

Figure 1 The coalfields of England and Wales in relation to the Pennine Basin (after Ramsbottom et al. 1978, with additions).

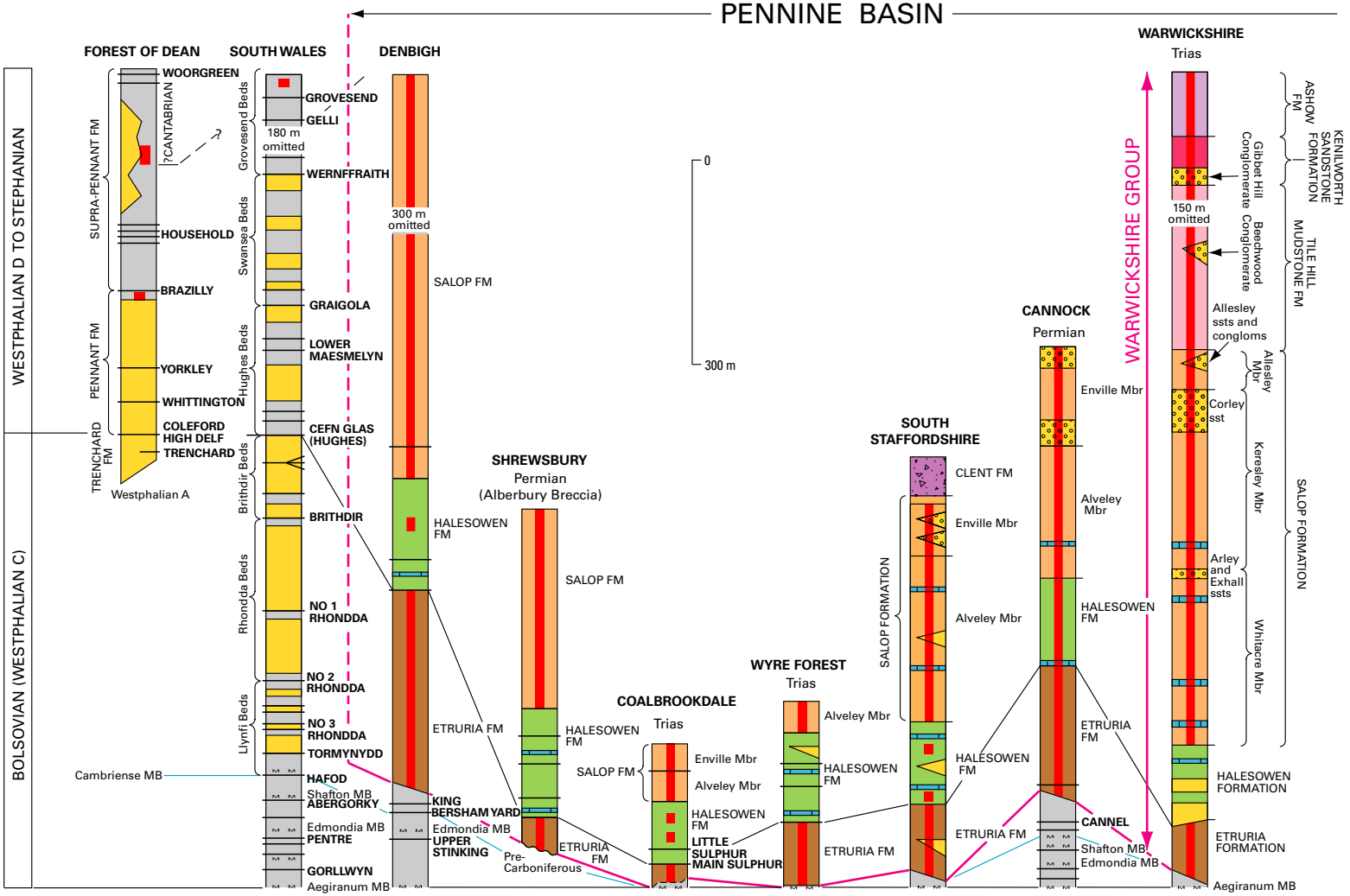

Figure 2a Correlation of the uppermost Westphalian and lowest Permian strata in parts of the Pennine Basin (after Ramsbottom et al., 1978, with additions). See Figure 4 for key.

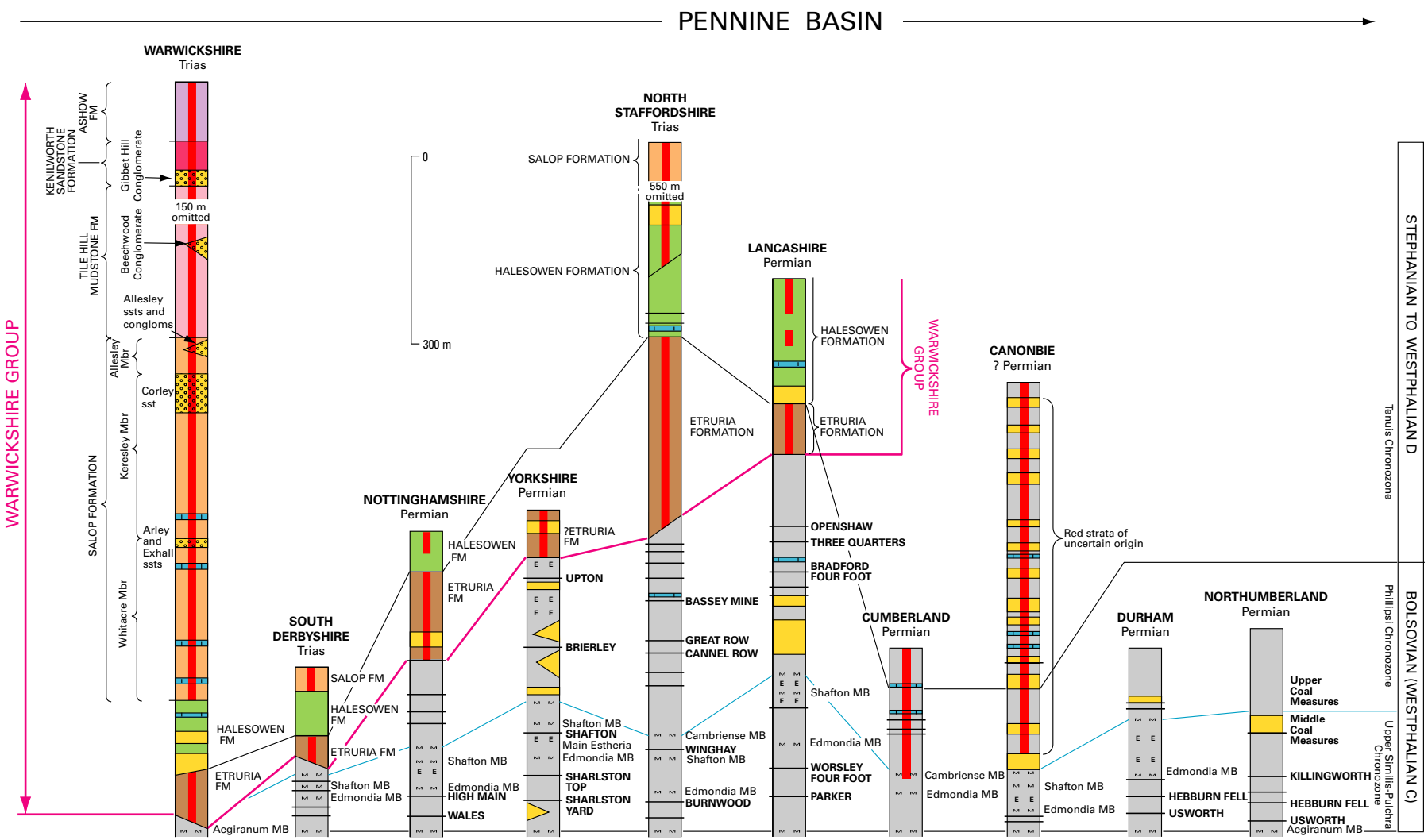

Figure 2b Correlation of the uppermost Westphalian and lowest Permian strata in parts of the Pennine Basin (after Ramsbottom et al., 1978, with additions). See Figure 4 for key.

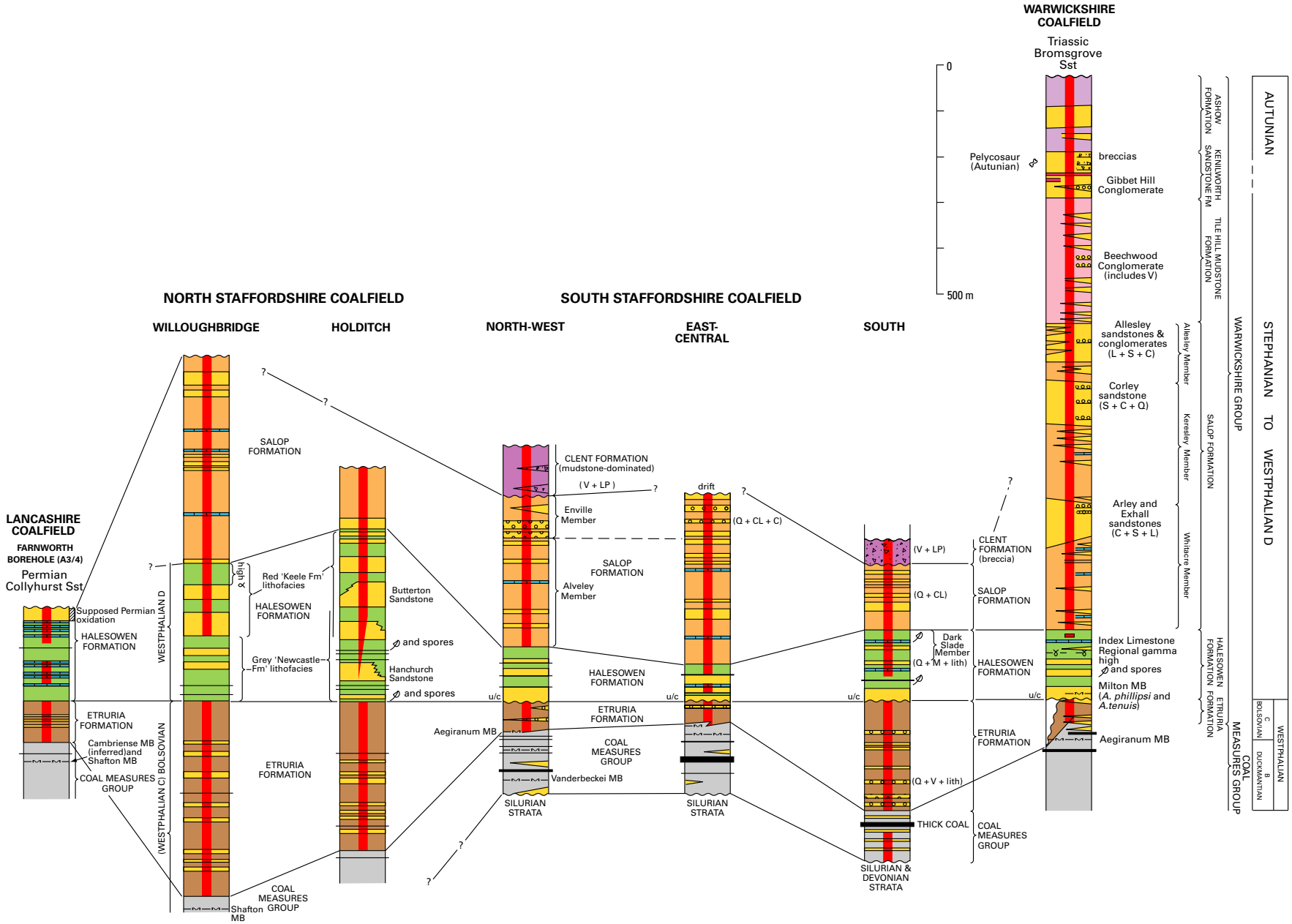

Figure 3 Detailed correlation of lithofacies and formations in key areas of the Pennine Basin. See Figure 4 for key.

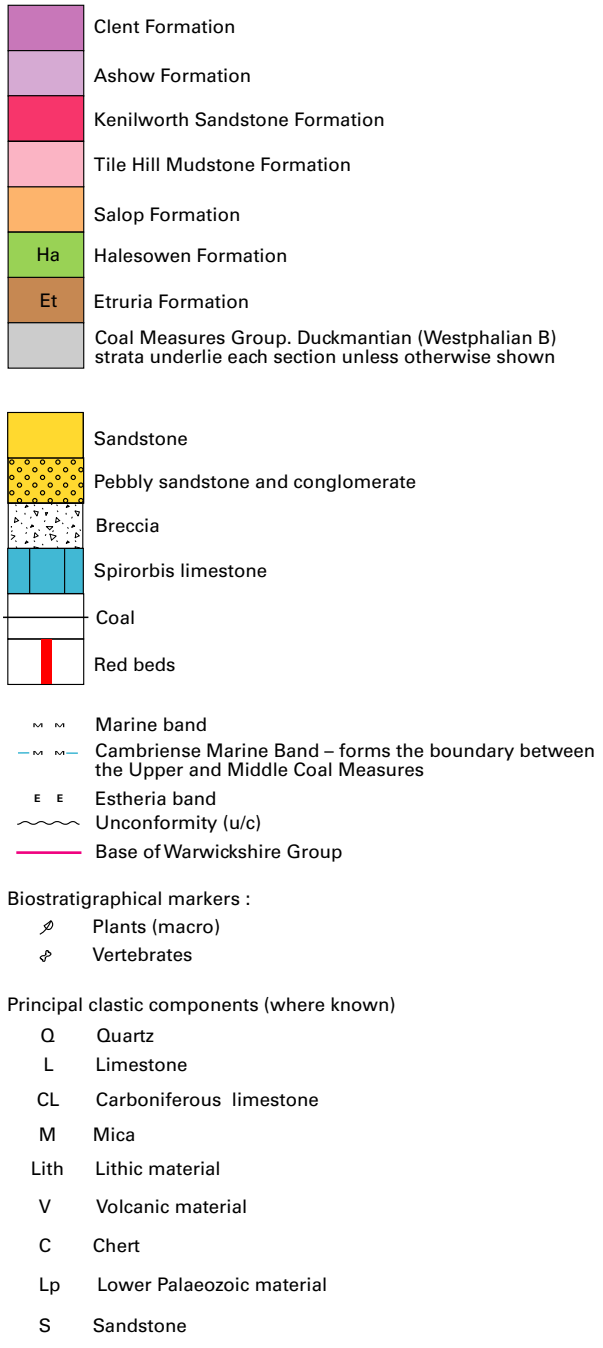

Figure 4 Key to Figures 2a, 2b and 3.