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A formational framework for the Lower Jurassic of England and Wales (onshore area)

B M Cox, M G Sumbler and H C Ivimey-Cook

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British Geological Survey
Keyworth
Nottingham NG12 5GG
UK

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This report has been compiled on behalf of the BGS Stratigraphy Committee, and inevitably reflects a large degree of pragmatism and compromise. The final form of the formational framework is not necessarily the preferred version of the individual authors but, nevertheless, we are confident that it provides a workable scheme within which any new data and subdivision can be accommodated. If users of this document discover inconsistencies or factual errors in the specifications given for the various lithostratigraphical units, they are encouraged to notify M G Sumbler, British Geological Survey, Keyworth, Nottingham, NG12 5GG.

1 SUMMARY

This report, which has been prepared on behalf of the BGS Stratigraphy Committee, introduces a lithostratigraphical framework to formation level for the Early Jurassic, predominantly argillaceous, succession of England and Wales traditionally known as the Lias. It applies to the main English and Welsh outcrops, and the adjoining areas where the Lias is present at depth. The outcrop has been divided into four depositional areas - the Cleveland Basin, East Midlands Shelf, Worcester Basin (plus adjoining Bristol-Radstock Shelf) and Wessex Basin (including parts of Somerset and South Wales), and the approach adopted is one of unification, emphasising similarities between areas rather than differences, whilst retaining well established names where possible. Thus, within the Cleveland Basin, the five well established formations are retained — Redcar Mudstone, Staithes Sandstone, Cleveland Ironstone, Whitby Mudstone and Blea Wyke Sandstone. In the Wessex Basin, the well established Bridport Sand and Blue Lias formations are retained but between these, the succession is divided into the Charmouth Mudstone, Dyrham and Beacon Limestone formations. The Dyrham Formation is already established (in the Worcester Basin) but the Charmouth Mudstone and Beacon Limestone formations are newly defined. The successions in the Worcester Basin and East Midlands Shelf are sufficiently similar that they can largely share a common nomenclature which includes the Blue Lias, Charmouth Mudstone and Dyrham formations, the Marlstone Rock Formation (essentially restricted to these regions) and the Whitby Mudstone Formation (extended from the Cleveland Basin). Additionally, in the northern part of the East Midlands Shelf, the Blue Lias Formation is replaced by the Scunthorpe Mudstone Formation and, in the Worcester Basin, the Bridport Sand Formation of Wessex occurs above the Whitby Mudstone. Full specifications for these 12 formations, and of the Lias Group which they comprise, are presented. A full appraisal of component members is beyond the scope of this report, but members are listed where they are well established and considered to be satisfactory, and suggestions/proposals for new members are mentioned in some cases.

2 PREFACE

The Stratigraphy Committee of the BGS 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 results in a document suitable for publication.

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

The predominantly Lower Jurassic rocks of the Lias Group have been considered by the Jurassic Stratigraphical Framework Committee under the leadership of M G Sumbler and are the subject of this report.

The purpose of all the Stratigraphical Framework Committees is to establish a framework down to formation level that can be used as a central reference by geologists working in the region concerned. 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 though each is set against a chronostratigraphical reference column, the finer points of the chronostratigraphy of the succession are not the prime concern.

The lithostratigraphical conventions applied are those of the North American Commission on Stratigraphic Nomenclature (1983). It is expected that the framework documents will be refined and improved with time. Indeed, erecting them effectively poses a challenge to stratigraphers, which we hope will be taken up, to contribute to a better understanding of British stratigraphy. This report was reviewed for the Geological Society Stratigraphy Commission by Professor D T Donovan, Dr S P Hesselbo and Dr M J Oates, and is endorsed by the Commission.

P M Allen, BSc, PhD
Chairman
British Geological Survey Stratigraphy Committee

Professor P F Rawson
Chairman
Geological Society Stratigraphy Commission

3 INTRODUCTION

This report outlines a proposed lithostratigraphical framework and nomenclature down to formation level for the rocks, of mainly Early Jurassic age, traditionally known as the Lias. These strata are up to c.1300 m in thickness and represent c. 30 million years of Earth history. The predominant lithologies are grey, well-bedded, marine, more or less calcareous mudstones and silty mudstones but locally, and at certain levels, sediment types are more diverse.

The succession has been studied by many people over the years, and now includes numerous named units. In recent times, many of these units have been given formal status as members, formations etc. but, commonly, little consideration has been given to their explicit definition or boundaries, or to their lateral continuity and relationship to correlative units. Units recognised on the basis of down-hole geophysical logs often lack both adequate lithological definition and relevant exposure. Revised lithostratigraphies with properly defined formations have been proposed for Yorkshire (Powell, 1984; Knox, 1984; Howard, 1985), and for much of the succession in Lincolnshire (Brandon et al., 1990). In the other areas, existing stratigraphical nomenclature is inadequately defined, inconsistently applied and requires rationalisation, which may involve the introduction of some new formational names.

The traditional divisions Lower, Middle and Upper Lias have been used variously as litho-, bio- or chronostratigraphical units and, as a result, positioning of their boundaries by different workers has been inconsistent. Although these terms will no doubt continue

to be used informally, especially in conversation, their use in formal publications should be abandoned in favour of the formational nomenclature proposed herein.

In Britain, the Lias was deposited in a number of sedimentary basins, and their marginal and shelf areas (Figure 1a, b). For the main English and Welsh outcrops, and adjoining areas where the Lias is present at depth, these are (from north to south)

a Cleveland Basin

b East Midlands Shelf (Market Weighton to Vale of Moreton)

c Worcester Basin and adjoining Bristol-Radstock Shelf to west (Vale of Moreton to Mendips)

d Wessex Basin (including Central Somerset Basin and Bristol Channel Basin) with some adjoining, marginal areas (south of Mendips, plus South Wales)

In the initial attempt to rationalise the stratigraphical nomenclature (first draft discussion document prepared by B M Cox and H C Ivimey-Cook in consultation with M G Sumbler, November 1995), these areas were treated separately, and the East Midlands Shelf was subdivided into north and south. Emphasis was placed on differences between the successions in those five areas rather than similarities. However, after consultation with appropriate personnel within and outside the BGS (including D T Donovan, S P Hesselbo and K N Page), and discussion with the BGS Stratigraphy Committee (including P F Rawson), it became clear that the favoured approach for a formational scheme was a more unifying one that emphasised similarities rather than differences, with the latter being accommodated at member level. A second draft discussion document, which adopted this approach, was therefore prepared by B M Cox and M G Sumbler (April 1996). In this, the Cleveland Basin and Wessex Basin retained their separate nomenclatures which are mutually exclusive. The Lower Jurassic rocks in both basins are predominantly argillaceous, and were laid down in fully marine environments; synchronous sedimentary cyclicity can be recognised in the successions of both (Hesselbo and Jenkyns, 1995). However, the successions in the two basins differ in that the mudstones are generally more sandy in the north and more calcareous (marly) in the south (Hallam and Sellwood, 1976); sandy mudstones in Yorkshire commonly correspond to calcareous mudstones (marls) in Dorset, whereas silty mudstones in Yorkshire commonly correspond to organic-rich mudstones in Dorset (Hesselbo and Jenkyns, 1995). The lithological successions in the intermediate areas are considered to be sufficiently similar one to another that they can largely share a common nomenclature, with elements of both the Cleveland and Wessex nomenclatures featuring where appropriate (Figure 2). For this reason, in the notes that follow (4.2 to 4.5), the Cleveland and Wessex basins are considered before the other areas.

One group and 12 formations (two of which are new) are proposed. Specifications for these 13 items are appended. Inevitably, because of the emphasis on unifying and standardising nomenclature, some names are used outside their original and natural context. Component members are listed where they are well established and considered to be satisfactory, and suggestions/proposals for new members are mentioned in some cases. However, a full appraisal of members is beyond the scope of this review.

4 STRATIGRAPHICAL FRAMEWORK

4.1 Supraformational classification

The twelve formations here proposed are grouped into a single unit for which the name Lias Group is used (e.g. Powell, 1984). The term Lias has been used reasonably consistently in the UK and north-west Europe, as well as farther afield, for nearly 200 years. The hierarchical term group, rather than supergroup, is more in balance with the other major lithostratigraphical divisions of the Jurassic outcrop. Representative wireline logs through the Lias Group are shown in Figure 3; these reflect the lithological characteristics of the strata and have proved to be extremely useful for detailed correlation.

4.2 Cleveland Basin

A satisfactory formational scheme is already available for the Cleveland Basin based on Powell (1984). Five formations are recognised as shown in Table 1. Formal definitions were published by Powell (1984), Knox (1984) and Howard (1985). Members are also recognised and properly defined in these publications although those of the Redcar Mudstone Formation, until now considered to be informal, need to be formalised. More recently, some minor amendments to the scheme of members have been suggested (Buchem and McCave, 1989; Rawson and Wright, 1992; Hesselbo and Jenkyns, 1995), and these have been taken into consideration. Otherwise, no revision to existing nomenclature is required.

Table 1 Cleveland Basin: lithostratigraphical subdivision of the Lias Group.
* to be formalised

Formations	Members
Blea Wyke Sandstone	Yellow Sandstone Grey Sandstone
Whitby Mudstone	Fox Cliff Siltstone Peak Mudstone Alum Shale Mulgrave Shale Grey Shale
Cleveland Ironstone	Kettleness Penny Nab
Staithes Sandstone	
Redcar Mudstone	Ironstone Shale* Pyritous Shale* Siliceous Shale* Calcareous Shale*

4.3 Wessex Basin (including parts of Somerset and South Wales)

Stratal divisions of the Dorset coastal succession are well entrenched in the literature of many years. In the interests of historical precedence, national/international understanding and nomenclatural stability, these names should be retained as far as practicably possible, but they need to be incorporated in a proper formational scheme. Five

formations are proposed (Table 2). The Blue Lias and Bridport Sand are well established stratal units here given formation status. The Blue Lias Formation, at the base of the Lias Group, is widespread and is also present in the Worcester Basin and East Midlands Shelf areas. Between the Blue Lias and Bridport Sand formations, three formations are recognised, two of which are newly named. The Charmouth Mudstone Formation includes the predominantly argillaceous Shales-with-Beef, Black Ven Marls, Belemnite Marls and Green Ammonite Beds; the latter four divisions, with appropriately modified names, should be given member status (Table 2). The overlying sandy and silty beds (comprising the units traditionally known as the Eype Clay, Down Cliff Sands and Thorncombe Sands) are assigned to a single formation for which the name Dyrham Formation (type area in the Worcester Basin; see 4.4) is available. The latter three subdivisions, with slightly modified names, are herein given member status (Table 2).

Table 2 Wessex Basin (including Central Somerset Basin) and South Wales: lithostratigraphical subdivision of the Lias Group.

Formations	**Members** (Dorset coast)	**Members** (South Wales)
Bridport Sand	Down Cliff Clay	
Beacon Limestone	Eype Mouth Limestone Marlstone Rock	
Dyrham	Thorncombe Sand Down Cliff Sand Eype Clay	
Charmouth Mudstone	Green Ammonite Belemnite Marl Black Ven Marl Shales-with-Beef	
Blue Lias		Porthkerry Lavernock Shale St Mary's Well Bay

The final subdivision (the so-called Junction Bed) is the most difficult to deal with lithostratigraphically. Some rationalisation of nomenclature is clearly required because the term is at present used in two senses (sensu lato and sensu stricto) (e.g. Hesselbo and Jenkyns, 1995). The Junction Bed sensu lato, often only about 1 m thick, presents itself as a natural entity which is most appropriately given formation status; the new name Beacon Limestone Formation is here proposed. The upper and greater part of this formation (the Junction Bed sensu stricto) should be renamed the Eype Mouth Limestone Member. The latter is mainly a condensed, ammonite-rich 'Cephalopod Limestone' facies which also features at the base of the Whitby Mudstone Formation of the East Midlands Shelf, and at the top of the Bridport Sand Formation of the Worcester Basin. The consensus view is that 'Cephalopod Limestone' as the lithological component in a lithostratigraphical name is too cumbersome and that only 'Limestone' should be used. The latter usage also allows for the fact that ammonites are not always abundant; e.g. at the Eype Mouth Fault, on the east side of Eype Mouth, there is a local fissure facies of fine-grained, lithographic limestone. The lower part of the Junction Bed sensu lato has traditionally been called the Marlstone or Marlstone Rock, and is indeed the much reduced equivalent of that formation as developed in areas further north (see 4.4). This name can therefore be retained with member status; this is in accord with published guidelines for good practice in lithostratigraphical classification and nomenclature. Both members are limestone and have other lithological characters in common; on purely lithostratigraphical grounds, there is no justification for dividing them into or between more than one formation.

Inland from the Dorset coast, data (particularly cored boreholes) are limited. The degree of lateral persistence of the members of the coastal sections is not entirely clear, whilst other members have been recognised (e.g. those proposed by Bristow and Westhead, 1993). Further work is required before division into members can be rationalised or finalised, but the priority is to have in place a formational framework into which any new data and subdivision can be fitted.

In the two other areas of exposure (the north Somerset and South Wales coasts), only the Blue Lias and a relatively small thickness of overlying mudstone are present. In recent BGS memoirs covering the South Wales outcrops (Waters and Lawrence, 1987; Wilson et al., 1990), the Blue Lias has been used as a facies term, without lithostratigraphical status, within the 'Lower Lias', but has, nonetheless, been divided into three formations. Although these are equivalent to the three members of the Blue Lias Formation developed in the Worcester Basin and East Midlands Shelf, the unique nomenclature for South Wales is retained, albeit with the three 'formations' redefined as members.

Data on the concealed Lias succession in the eastern part of the Wessex Basin (Sussex and Kent) is limited. It appears that the formations of the Dorset outcrop are recognisable, albeit with some minor variations in character. The best data come from the Warlingham Borehole, Surrey (Worssam and Ivimey-Cook, 1971) on the northern margin of the basin, where marginal facies associated with the London Platform are present.

Table 3 Worcester Basin: lithostatigraphical subdivision of the Lias Group. In the south, adjoining the Mendips and Bristol-Radstock Shelf, the Marlstone Rock Formation becomes the Marlstone Rock Member, forming the lower part of the Beacon Limestone Formation (see Table 2) at the latter's northern limit.

Formations	**Members**
Bridport Sand	pending
Whitby Mudstone	pending
Marlstone Rock	none
Dyrham	pending
Charmouth Mudstone	pending
Blue Lias	Rugby Saltford Shale Wilmcote

4.4 Worcester Basin and adjoining Bristol-Radstock Shelf area

Several of the formations recognised within the Wessex Basin (see above) are also present in the Worcester Basin (Figure 2; Table 3). In the lower part of the succession, marked local facies and thickness variations occur to the south and west of the basin as the Bristol-Radstock Shelf and Mendip High are approached. These condensed, marginal facies can be accommodated at member and bed level within the Blue Lias and Charmouth Mudstone formations, the boundary between the two being drawn at the base of the Turneri Clay. The overlying Dyrham Formation is well-established in the Worcester Basin, and a type section in this area is proposed. A lithological epithet is not included in this formation's name as the formation comprises predominantly silty mudstones with thin, fine-grained, locally cemented sandstones, and no single lithological descriptor is appropriate.

Above the Dyrham Formation, the Marlstone Rock Formation is a substantial ferruginous limestone unit throughout most of the Worcester Basin, but in the south-west, adjoining the Mendips and Bristol-Radstock Shelf, it forms the lower part (Marlstone Rock Member) of the unit formerly referred to as the Junction Bed, for which the name Beacon Limestone Formation is herein proposed, as in the Wessex Basin. For the overlying arenaceous strata, the Bridport Sand Formation of the Wessex Basin is extended to encompass the Cotswold and Midford Sands, long known to be part of the same diachronous sand body (Buckman, 1889). Northwards, these sands are progressively replaced (from the base upwards) by mudstones for which the term Whitby Mudstone Formation is used, as it is in all areas between here and its type area in the Cleveland Basin. Although the usage of this term is thereby extended well away from its type area, this is justified by the similarities of the successions across the whole region; it also avoids the necessity of creating a new name for this mudstone formation.

Table 4 East Midlands Shelf: lithostratigraphical subdivision of the Lias Group. A. South (Moreton in Marsh to Leicester area). B. North (Leicester area to Market Weighton).

A. South		B. North	
Formations	**Members**	**Formations**	**Members**
Whitby Mudstone	pending	Whitby Mudstone	pending
Marlstone Rock	none	Marlstone Rock	none
Dyrham	pending	Charmouth Mudstone	Pecten Ironstone
Charmouth Mudstone	pending		
		Scunthorpe Mudstone	Frodingham Ironstone Foston Beckingham Granby Barnby Barnstone
Blue Lias	Rugby Saltford Shale		

4.5 East Midlands Shelf

Compared with the Worcester Basin to the south, the main differences between the two areas are the gradual northwards disappearance of the silty/sandy Dyrham Formation and, in the northern part, replacement of the Blue Lias Formation by the Scunthorpe Mudstone Formation (Figure 2; Table 4). There, typical Blue Lias facies occurs only in the lowest part of the succession (Barnstone Member of Brandon et al., 1990). The limestone beds in the upper and greater part of the Scunthorpe Mudstone Formation are shell-fragmental, high energy deposits, resembling those of the Calcareous Shale 'Member' of the Cleveland Basin, as distinct from those of the Blue Lias Formation which are low energy calcilutites. In particular, the sandy limestones and ironstone facies occurring in the uppermost part of the Scunthorpe Mudstone Formation (within the Frodingham Ironstone and Foston members) are comparable with lithologies in the Siliceous Shale 'Member' of the Cleveland Basin. The members of the Scunthorpe Mudstone Formation proposed by Brandon et al. (1990) in the Melton Mowbray-Grantham region remain valid, though it is as yet uncertain how far north they extend. Provisional examination of wireline logs suggests that they are present at least as far north as the Scunthorpe region, where the Frodingham Ironstone Member (e.g. Gaunt et al., 1992) is developed, replacing the upper part of the Foston Member.

The Charmouth Mudstone Formation occurs throughout the East Midlands Shelf, and shows a high degree of lithological uniformity throughout this region. In the north, because of the development of the Scunthorpe Mudstone below, only the younger part of the Charmouth Mudstone is represented. These strata correspond with the Brant Mudstone Formation of Brandon et al. (1990), which, however, had no type section. The Pecten Ironstone has been separated as a member in this area (Gaunt et al., 1992), and sandy and silty beds in the lower part of the Charmouth Mudstone Formation (the Brandon Sandstone of Brandon et al. (1990), or 'Sandrock' of some authors) may warrant separation as a new member.

4.6 Other areas

The lower part of the Lias Group is preserved in north-west England, within the Cheshire and Solway Firth (Carlisle) basins, around Prees, Cheshire, and also near Carlisle (Figure 1a). The successions are poorly exposed and the best information comes from boreholes. In the Carlisle Basin (Ivimey-Cook et al., 1995), only the oldest part of the Lias Group is preserved beneath drift deposits. There are no well-defined limestones within the mudstone succession and it is not appropriate to classify these beds as Blue Lias Formation. In the Cheshire Basin (Pocock and Wray, 1925; Poole and Whiteman, 1966; Warrington, 1997), the Hettangian to Sinemurian succession is dominated by mudstones, with some thin limestones, but the distinctive lithofacies typical of the Blue Lias Formation elsewhere are not strongly developed. Within the Pliensbachian, sandy and micaceous shales and 'marlstone' are described, and it seems likely that extension of the terms Dyrham Formation and Marlstone Rock Formation to this area may be appropriate.

In west Wales, the Mochras Farm Borehole on Mochras Island near Llanbedr (Figure 1a), proved the presence of Lower Jurassic at depth on the margin of the fault-bounded Cardigan Bay Basin. It penetrated some 1300 m of Lower Jurassic, the thickest such succession yet proved in the UK

(Woodland, 1971). Detailed treatment of this succession, which relates to the offshore Cardigan Bay Basin, is beyond the scope of this report. It is sufficient to say that as virtually the whole of the succession is in mudstone facies, the term Lias Group remains appropriate, and it seems likely that a formational scheme analogous to that established for other onshore areas could be applied.

5 SPECIFICATIONS FOR THE LIAS GROUP AND ITS COMPONENT FORMATIONS

In the following pages, definitions and specifications for the Lias Group and its twelve component formations are given. These form the basis for the entries in the British Geological Survey Lexicon of Named Rock Units which, when complete, will provide definitions for all the lithostratigraphical terms found on current, published BGS maps. The BGS Lexicon can be searched via the BGS internet pages (http://www.bgs.ac.uk).

5.1 Lias Group

Previous nomenclature:
Lyas (Wm Smith *in* Townsend, 1813)
Lias (Buckland *in* Phillips, 1818)

Derivation of name:
'Leac': ancient gaelic meaning flat stone (Buckman, 1910; Arkell, 1933).

Reference sections:
Dorset coastal sections (Callomon and Cope, 1995; Hesselbo and Jenkyns, 1995).

North Yorkshire and Cleveland coastal sections (Powell, 1984; Rawson and Wright, 1995; Hesselbo and Jenkyns, 1995).

South and Mid-Glamorgan coastal sections (Waters and Lawrence, 1987; Wilson et al., 1990; Warrington and Ivimey-Cook, 1995).

BGS Llanbedr (Mochras Farm) Borehole, Mochras, Gwynedd (Reg. No. SH 52 NE/00) [SH 5533 2594] 601.83 m to 1906.78 m depth (Woodland, 1971).

BGS Stowell Park Borehole, Gloucestershire (Reg. No. SP 01 SE/1) [SP 0835 1176] 122.28 m to 618.29 m depth (Green and Melville, 1956; Melville, 1956; Spath, 1956; Ivimey-Cook, 1993; Sumbler and Barron, 1995; Sumbler et al., in press).

Extant exposures/sections:
See above and entries for constituent formations.

Lithology:
Predominantly grey, well bedded, marine calcareous mudstone and silty mudstone; thin tabular or nodular beds of argillaceous limestone ('cementstone'), particularly in the lower part; thicker units of siltstone and sandstone, particularly in the upper part, and ironstone, particularly in the middle part. Marginal and littoral limestone facies also occur.

Geographical extent:
Onshore and offshore UK (see Cope et al., 1980).

Lower boundary:
In most areas, markedly non-sequential on Penarth Group or older strata; at the base of the Blue Lias Formation (q.v.), Scunthorpe Mudstone Formation (q.v) or, in the Cleveland Basin, the Redcar Mudstone Formation (q.v.).

Upper boundary:
Commonly an eroded surface at the base of the lowest limestone or sandstone of the Inferior Oolite, or (in the Cleveland Basin) of the Ravenscar Group or Dogger Formation.

Thickness:
Up to c. 1300 m

Chronostratigraphy:
Uppermost Triassic to Middle Jurassic (lower Aalenian).

Subdivisions:
- Beacon Limestone Formation*
- Blea Wyke Sandstone Formation
- Blue Lias Formation
- Bridport Sand Formation
- Charmouth Mudstone Formation*
- Cleveland Ironstone Formation
- Dyrham Formation
- Marlstone Rock Formation
- Redcar Mudstone Formation
- Scunthorpe Mudstone Formation
- Staithes Sandstone Formation
- Whitby Mudstone Formation

*proposed herein

References:
Arkell (1933), Buckman (1910), Callomon and Cope (1995), Cope et al. (1980), Hesselbo and Jenkyns (1995), Phillips (1818), Powell (1984), Rawson and Wright (1995), Sumbler and Barron (1995), Sumbler et al. (in press), Townsend (1813), Warrington and Ivimey-Cook (1995), Waters and Lawrence (1987), Wilson et al. (1990), Woodland (1971).

5.2 Beacon Limestone Formation (new name)

Previous nomenclature:
Junction Bed and Marlstone [Rock Bed]
Junction Bed *sensu lato*
Watton Bed (Buckman 1922)

Name of next higher ranking unit:
Lias Group

Derivation of name:
Thorncombe Beacon, Dorset

Type area:
Dorset and east Somerset

Type section:
Cliff exposure beneath Thorncombe Beacon [SY 4354 9148] (accessible from the cliff top in gullies on the east side; House, 1989) (Callomon and Cope, 1995; Hesselbo and Jenkyns, 1995).

Primary reference section:
BGS Winterborne Kingston Borehole, Winterborne Kingston, Dorset (Reg. No. SY 89 NW/1) [SY 8470 9796]

1114.60 m to 1117.89 m depth (Ivimey-Cook, 1982; Rhys et al., 1982).

Other reference sections:
Ridge (Down) Cliff, Dorset [SY 42 91] (Wilson et al., 1958; Howarth, 1992).

Cliff below Doghouse Hill, Dorset [SY 43 91] (Wilson et al., 1958; Howarth, 1992).

Watton (or West) Cliff, Dorset [SY 45 90] (Wilson et al., 1958; Howarth, 1992).

BGS Hill Lane Borehole, Brent Knoll, Somerset (Reg. No. ST 35 SW/2) [ST 3346 5156] 14.96 m to 15.44 m depth (Whittaker and Green, 1983).

Extant exposures/sections:
See above
Maes Down, near Shepton Mallet, Somerset [ST 647 406] (K N Page, personal communication).

Lithology:
Limestone, ferruginous-ooidal in the lower part, nodular in the upper part; conglomeratic in parts; variably grey, pink, reddish-brown and brown in colour.

Geographical extent:
Wessex Basin (including Central Somerset Basin) and Bristol-Radstock Shelf area, i.e. Dorset coast to approximately Chipping Sodbury, Gloucestershire.

Lower boundary:
Non-sequential; at the downward change from ferruginous, conglomeratic limestone to argillaceous, silty or sandy beds of the Dyrham Formation (q.v.) or (locally, in parts of the Bristol-Radstock Shelf area) on the Charmouth Mudstone Formation.

Upper boundary:
Non-sequential; at the base of the sands or mudstones of the Bridport Sand Formation (q.v.).

Thickness:
Up to 5 m; typically less than 1.5 m

Chronostratigraphy:
Lower Jurassic, Upper Pliensbachian (Spinatum Zone) to Upper Toarcian (Thouarsense Zone) (Howarth, 1992).

Subdivisions (to be rationalised):
Marlstone/Marlstone Rock Bed [=Marlstone Rock Member*]
Eype Mouth Limestone Member*
Barrington [Member] (Bristow and Westhead, 1993)

*proposed herein

Additional references:
Arkell (1933), Hallam (1967), Howarth (1957, 1980a, b), Jackson (1922, 1926).

5.3 Blea Wyke Sandstone Formation

Previous nomenclature:
Blue Wick Sands (Tate and Blake, 1876)
Blea Wyke Beds (Davies, 1929)
Blea Wyke Series (Fox-Strangways and Barrow, 1915)
Blea Wyke Sands (Hemingway, 1974)
Upper Lias (part)

Name of next higher ranking unit:
Lias Group

Derivation of name:
Blea Wyke Point [NZ 991 015], North Yorkshire

Type area:
Known only in the immediate vicinity of the type section (see below).

Type section:
Coastal section at Blea Wyke Point [NZ 991 015] (Knox, 1984; Hesselbo and Jenkyns, 1995).

Reference sections:
None

Extant exposures/sections:
Type section only (see above)

Lithology:
Micaceous, fine-grained sandstones; grey-weathering and argillaceous in the lower part, yellow-weathering and silty in the upper part (Knox, 1984).

Geographical extent:
Ravenscar coastal area, North Yorkshire (Cleveland Basin).

Lower boundary:
Gradational; taken at the level of relatively rapid downward decrease in coarse silt and sand content which coincides with the downward change from relatively pale, burrow-mottled sediments to the grey and dark grey mudstone and siltstone of the Whitby Mudstone Formation; also coincides approximately with the downward appearance of dense smooth carbonate concretions that characterise the latter formation; in the field, most easily positioned where sediments change in appearance from ‘sandy’ above to ‘muddy’ below.

Upper boundary:
Unconformable base of the ferruginous, pebbly sandstone of the Dogger Formation (Middle Jurassic).

Thickness:
Up to c. 18 m

Chronostratigraphy:
Lower Jurassic, Upper Toarcian (Levesquei Zone).

Subdivisions:
Grey Sandstone Member (Knox, 1984)
Yellow Sandstone Member (Knox, 1984)

Additional references:
Arkell (1933), Howarth (1980b).

5.4 Blue Lias Formation

Previous nomenclature:
Blue Lias (Wm Smith, 1799 MS)
Lyme Regis Beds (Woodward and Ussher, 1911)

N.B. Blue Lias sensu Williams and Whittaker (1974), Edmonds and Wilson (1965), Old et al. (1987) and Worssam et al. (1989) excluded the mainly mudstone unit of the Saltford Shale (Old et al., 1991).

Name of next higher ranking unit:
Lias Group

Derivation of name:
'Blue'-coloured 'leac' (ancient Gaelic meaning flat stone).

Type area:
Around Bath and Bristol, Somerset (Torrens and Getty, 1980).

Type section:
Saltford railway cutting [ST 685 671 to ST 681 676], near Keynsham, Somerset (Bristow et al., 1873, col.9; Donovan, 1956; Torrens and Getty, 1980; Donovan and Kellaway, 1984).

Primary reference section:
Cliff sections between Pinhay Bay and Lyme Regis, Dorset [SY 320 908 to SY 333 914] (Lang, 1924; Hallam, 1960; Hesselbo and Jenkyns, 1995; Callomon and Cope, 1995).

Other reference sections:
Cliff and foreshore exposures east of Watchet, Somerset (SSSI) [ST 080 436 to ST 220 470] (Palmer, 1972; Whittaker and Green, 1983; Warrington and Ivimey-Cook, 1995).

Coastal exposures west and south of Penarth Head, west of Lavernock Point, between Barry, Nash Point and Southerndown, South and Mid Glamorgan (SSSI) (Waters and Lawrence, 1987; Wilson et al., 1990; Warrington and Ivimey-Cook, 1995).

BGS Burton Row Borehole, Brent Knoll, Somerset (Reg. No. ST 35 SW/3) [ST 3356 5208] 271.95 m to 409.97 m depth (Whittaker and Green, 1983).

BGS Elton Farm Borehole, near Dundry, Somerset (Reg. No. ST 56 NE/3) [ST 5636 6589] 150.12 m to 187.03 m depth (Ivimey-Cook, 1978).

BGS Stowell Park Borehole, Gloucestershire (Reg. No. SP 01 SE/1) [SP 0835 1176] 560.48 m to 618.29 m depth (Green and Melville, 1956; Melville, 1956; Spath, 1956; Ivimey-Cook, 1993; Sumbler and Barron, 1995; Sumbler et al., in press).

BGS Twyning Borehole, near Tewkesbury, Gloucestershire (Reg. No. SO 83 NE/5) [SO 8943 3664] 24.24 m to 121.70 m depth (Worssam et al., 1989; Old et al. 1991; Ivimey-Cook MS).

Rugby Quarry, Rugby, Warwickshire [SP 493 759] (Clements, 1977; Hallam, 1968; Old, Sumbler and Ambrose, 1987).

NCB Hollowell Borehole, Hollowell, Northamptonshire (Reg. No. SP 67 SE/24) [SP 4683 7183] 271.81 m to 283.16 m depth (Allsop et al., 1987).

BGS Thorpe by Water Borehole, Thorpe by Water, Leicestershire (Reg. No. SP 89 NE/1) [SP 8857 9648] 190.01 m to 221.46 m depth (Horton, 1973; Brandon et al., 1990).

Extant exposures/sections:
Dorset, Somerset and Glamorgan coastal sections (see above).

Banks of the River Severn at Hock Cliff, Fretherne, Gloucestershire [SO 730 089] (Richardson, 1908; Henderson, 1934; Ager, 1969).

Other quarries in Warwickshire (Long Itchington [SP 421 640], Harbury [SP 385 589], Stockton [SP 440 640]) (Old et al., 1987).

SSSIs in Somerset:
Bowldish Quarry [ST 668 558]
Kilmersdon Road Quarry [ST 689 542]
Huish Colliery Quarry [ST 695 542]
Leighton Road Cutting [ST 702 437]
Viaduct Quarry [ST 621 443]

Lithology:
More or less argillaceous calcilutite limestone (laminated, nodular, or massive and persistent) interbedded with calcareous mudstone or siltstone (sometimes laminated, bituminous 'paper-shale'). Individual limestones are typically 0.10 m to 0.30 m thick, and intervening mudstones, which may contain limestone nodules, are typically less than 1 m thick, though more substantial units of mudstone with relatively few limestone beds may also occur in some areas. It also includes the marginal/littoral limestone facies of the Bristol-Radstock Shelf and South Wales.

Geographical extent:
Wessex Basin, Central Somerset Basin, Worcester Basin and adjoining marginal areas (Bristol-Radstock Shelf and South Wales), and the southern part of the East Midlands Shelf, i.e. Dorset coast to approximately Leicester.

Lower boundary:
The base coincides with the base of the Lias Group which, in most areas of UK, is markedly non-sequential. At the base of grey limestone or mudstone (sometimes 'paper-shale') sharply overlying the eroded, commonly bored surface of pale porcellanous limestone of the Langport Member (Lilstock Formation, Penarth Group) or the irregular surface of pale grey or bluish and greenish-grey or, less commonly, reddish-brown calcareous mudstone of the Cotham Member (Lilstock Formation). In the type section, it is taken at the top of the Sun Bed (limestone up to 0.46 m thick) with vertical U-shaped burrows at the top of the Langport Member (Lilstock Formation). The top of Sun Bed also provides an appropriate boundary marker in the Dorset and Somerset coastal sections.

Upper boundary:
This is taken at the base of the Charmouth Mudstone Formation (q.v.). In any one section, it coincides with a marked upward decrease in abundance of limestone beds, sometimes associated with a marked decrease in their individual thickness and lateral persistence. In many cases, the horizon to be taken is obvious. Where there is doubt, the thickness and vertical frequency of limestone beds should be considered, and the following guidelines used: at the top of a more or less persistent, thick (> 0.10 m) limestone above which the overlying mudstone (beneath any subsequent

similar limestone) is at least twice the thickness typical of the underlying limestone - mudstone interbedded unit and above which there is no return, within the Lias Group, to limestone - mudstone spacing on that previous scale.

In the type section, the top has previously been taken at the top of the Scipionianum Bed (a condensed or remanié horizon with phosphatised ammonites on its upper surface) but the characteristic interbedded limestone/mudstone sequence continues above that bed (e.g. in the BGS Elton Farm Borehole; see above); the upper boundary in the type area should therefore be drawn at a higher stratigraphical level.

In the Dorset coastal sections, the top is at the top of the Grey Ledge (Bed 49 of Lang, 1924); in the Somerset coastal sections, the top is at the top of Bed 238 of Whittaker and Green (1983).

Thickness:
Up to c. 140 m

Chronostratigraphy:
Uppermost Triassic (Rhaetian) to Lower Jurassic, Sinemurian; upper boundary markedly diachronous (Bucklandi, Semicostatum, Turneri, Obtusum or Oxynotum zones).

Subdivisions (to be rationalised):
South Midlands and Worcester Basin:
Wilmcote (Limestone) Member (Old et al., 1991)
Saltford Shale Member (Old et al., 1991)
Rugby (Limestone) Member (Old et al., 1991)

South Wales:
St Mary's Well Bay Member (Waters and Lawrence, 1987)
Lavernock Shale Member (Waters and Lawrence, 1987)
Porthkerry Member (Waters and Lawrence, 1987)
(originally proposed as formations)

Bristol-Radstock Shelf and South Wales, marginal/littoral facies:
Southerndown Beds
Sutton Stone
Brockley Down Limestone
Downside Stone

Other units of uncertain status include:
Calcaria Bed (Donovan, 1948)
Saurian Beds (Murchison, 1845)
Plagiostoma/Lima Beds (Murchison, 1845; Wright, 1860)
Aldergrove Beds (Palmer, 1972)
St Audrie's Shales (Palmer, 1972)
Kilve Shales (Palmer, 1972)
Quantocks Beds (Palmer, 1972)

Additional references:
Arkell (1933), Getty (1980), Hallam (1964), Weedon (1986; 1987).

5.5 Bridport Sand Formation

Previous nomenclature:
Cotteswold Sands (Lycett, 1857)
Midford Sand(s) (Phillips, 1871)
Yeovil Sands (Hudleston *in* Buckman, 1879)
Bridport Sands (Woodward, 1888)
Upper Lias Sands
Cotswold Sands (Arkell, 1933)
Bridport and Yeovil Sands (Wilson et al., 1958)

Name of next higher ranking unit:
Lias Group

Derivation of name:
Bridport [SY 46 93], Dorset

Type area:
Broadwindsor [ST 437 026] to Burton Bradstock [SY 488 895], Dorset (Wilson et al., 1958).

Type section:
Coastal cliff exposures (East Cliff and Burton Cliff) between West Bay [SY 465 905] and Burton Bradstock [SY 48 89], Dorset (Callomon and Cope, 1995; Hesselbo and Jenkyns, 1995).

Primary reference section:
BGS Winterborne Kingston Borehole, Winterborne Kingston, Dorset (Reg. No. SY 89 NW/1) [SY 8470 9796] 927.89 m to 1114.60 m depth (Ivimey-Cook, 1982; Knox et al., 1982; Rhys et al., 1982).

Other reference sections:
Cliff sections below Thorncombe Beacon [SY 4354 9148] and the adjoining Doghouse Hill [SY 430 915], Dorset (Callomon and Cope, 1995).

Wotton Hill, Wotton-under-Edge, Gloucestershire [SSSI] [ST 754 939] (upper beds only) (see Doyle, 1990).

Extant exposures/sections:
See above

Quarries in Ham Hill Country Park, Ham Hill, Somerset (Prudden, 1995).

Around the village of Dursley [ST 75 98], Gloucestershire, numerous small sections are available on the narrow ridge connecting Stinchcombe Hill [ST 741 985] with the main Cotswold escarpment (Cave, 1977).

SSSIs (K N Page, personal communication):
Halfway House cutting and quarry [ST 601 164] between Yeovil and Sherborne (Torrens, 1969; Whicher, 1969; Callomon and Cope, 1995)
Babylon Hill, Yeovil, Somerset [ST 578 155]
Cliff Hill Road, Burton Bradstock, Dorset [SY 478 895]
Nibley Knoll, Gloucestershire [ST 744 956]
Haresfield Hill, Gloucestershire [SO 819 088]
Coaley Wood, Gloucestershire [ST 788 996]

Lithology:
Grey, weathering yellow or brown, micaceous silt and fine-grained sand, locally with calcite-cemented beds, doggers or lenticular masses ('sand-burrs') and sporadic more argillaceous beds; commonly includes a unit of variably sandy mudstone at the base (including the Down Cliff Clay of the type area) (Knox, Morton and Lott, 1982; Hesselbo and Jenkyns, 1995, and references therein) and, in the Worcester Basin area, ironshot marl and limestone ('Cotswold Cephalopod Bed') at the top.

Geographical extent:
Wessex Basin, Worcester Basin, i.e. Dorset coast to central Cotswolds (Cheltenham area).

Lower boundary:
Base of sand/silt or mudstone as described above, resting non-sequentially on limestone of the Beacon Limestone Formation or, north of the Chipping Sodbury area in the Worcester Basin, the gradational boundary with mudstone of the Whitby Mudstone Formation (q.v.).

Upper boundary:
Base of the lowest limestone of the Inferior Oolite (= base of the Scissum or Bottom Bed (Bed 6a of Callomon and Cope, 1995) in the type section (Richardson, 1928) and the base of the Dew Bed (Buckman, 1893) in Somerset), resting on sand/silt or (locally) ironshot marl as described above.

Thickness:
Up to c. 120 m

Chronostratigraphy:
Lower and Middle Jurassic, Toarcian to Aalenian. In the type section, Upper Toarcian (Levesquei Zone) to Aalenian (Opalinum Zone). In the Worcester Basin (central and south Cotswolds), there is a thick middle Toarcian development (Bifrons to Variabilis zones) and a relatively thin upper Toarcian development (Thouarsense to Levesquei zones); further south, towards the Mendips, the situation is reversed, with a relatively thick upper Toarcian (Levesquei Zone) and relatively thin middle Toarcian (Falciferum to Thouarsense zones).

Subdivisions (to be rationalised):
Down Cliff Clay [Member] (Buckman, 1922) occurs at the base of the Bridport Sand Formation in the type area; thinner mudstone units at the base of the formation elsewhere in the Wessex area may also be included in this unit. Analogous thin mudstones in the southern part of the Worcester Basin, represent the feather-edge of the Whitby Mudstone Formation (q.v.), but are best regarded as part of the Bridport Sand Formation.

Ham Hill Stone (Woodward, 1887) (Yeovil area, Somerset)

Cephalopod Bed or Cotswold Cephalopod Bed (Arkell, 1933) (occurs at the top of the Bridport Sand Formation in the southern part of the Worcester Basin, as far north as Stroud). Aalensis Bed (a part of the Cotswold Cephalopod Bed)

Additional references:
Arkell (1933), Boswell (1924), Buckman (1889), Howarth (1980b), Lycett (1860, 1865), Parsons (1980), Witchell (1865), Woodward (1893).

5.6 Charmouth Mudstone Formation (new name)

Previous nomenclature:
Blue Marl (Wm Smith, 1817)
Lower Lias Clay(s)
Lower Lias
Brant Mudstone Formation (Brandon et al., 1990)
Obtusum-Oxynotum Clays (upper part), Sandrock and Upper Clays plus Middle Lias mudstones and siltstones (Swinnerton and Kent, 1949; 1976).
Coleby Mudstone Formation (part) (Gaunt et al., 1992)

Name of next higher ranking unit:
Lias Group

Derivation of name:
Charmouth [SY 36 93], Dorset

Type area:
Lyme Regis to Charmouth coastal area, Dorset, where the formation is well exposed in the cliffs and on the foreshore (Hesselbo and Jenkyns, 1995 and references therein).

Type section:
Cliff and foreshore exposures between Seven Rock Point [SY 327 909] and Golden Cap [SY 407 922], Dorset.

Primary reference section:
BGS Stowell Park Borehole, Gloucestershire (Reg. No. SP 01 SE/1) [SP 0835 1176] 276.51 m to 560.48 m depth (Green and Melville, 1956; Melville, 1956; Spath, 1956; Ivimey-Cook, 1993; Sumbler and Barron, 1995; Sumbler et al., in press).

Other reference sections:
BGS Burton Row Borehole, Brent Knoll, Somerset (Reg. No. ST 35 SW/3) [ST 3356 5208] c. 37.20 m to 271.95 m depth (Whittaker and Green, 1983).

Blockley Brickworks, Blockley, Gloucestershire [SSSI] [SP 182 369] (Channon, 1950; Callomon *in* Hallam, 1968; Callomon *in* Callomon and Torrens, 1969).

BGS Elton Farm Borehole, near Dundry, Somerset (Reg. No. ST 56 NE/3) [ST 5636 6589] 45.42 m to 150.12 m depth (Ivimey-Cook, 1978).

BGS Upton Borehole, Burford, Oxfordshire (Reg. No. SP 21 SW/1) [SP 2315 1313] 36.04 m to 156.62 m depth (Melville, 1963; Worssam, 1963; Sumbler, 1994).

BGS Apley Barn Borehole, Witney, Oxfordshire (Reg. No. SP 31 SW/3) [SP 3438 1066] 61.11 m to 162.31 m depth (Poole, 1969).

BGS Steeple Aston Borehole, Oxfordshire (Reg. No. SP 42 NE/12) [SP 4687 2586] 50.90 m to 164.40 m depth (Poole, 1977).

BGS Withycombe Farm Borehole, Banbury, Oxfordshire (Reg. No. SP 44 SW/9) [SP 4319 4017] 24.99 m to 164.47 m depth (Poole, 1978).

BGS Barby Borehole, near Daventry, Northamptonshire (Reg. No. SP 56 NW/5) [SP 5416 6957] 9.6 m to 120.0 m depth (base not proved) (Ambrose and Ivimey-Cook, 1982).

NCB Hollowell Borehole, Hollowell, Northamptonshire (Reg. No. SP 67 SE/24) [SP 4683 7183] c. 104 m to 271.81 m depth (partial core plus geophysical logs) (Allsop, Ambrose and Elson, 1987).

BGS Thorpe by Water Borehole, Thorpe by Water, Leicestershire (Reg. No. SP 89 NE/1) [SP 8857 9648] 29.00 m to 190.01 m depth (Horton, 1973 and MS; Brandon et al., 1990). N.B. The designation of this Borehole as reference section for the Brant Mudstone Formation in Brandon et al. (1990) needs amendment. As the Scunthorpe Mudstone Formation is absent, and the Dyrham Formation is present, East Midlands Shelf (south) nomenclature is more appropriate.

BGS Copper Hill Borehole, Ancaster, Lincolnshire (Reg. No. SK 94 SE/56) [SK 9787 4265] 67.30 m to 182.60 m depth (Berridge et al., in press).

Borehole F/B5, Fulbeck, Lincolnshire (Reg. No. SK 95 SW/17) [SK 9062 5076] 1.12 m to 4.58 m depth (basal beds only) (Brandon et al., 1990).

Extant exposures:
See above

SSSIs in the Radstock area:
Bowldish Quarry, Somerset [ST 668 558]
Kilmersdon Road Quarry, Somerset [ST 689 542]
Huish Colliery Quarry, Somerset [ST 695 542]

Lithology:
Dark grey laminated shales, and dark to pale grey and bluish grey mudstones; occasional concretionary and tabular beds of argillaceous limestone; abundant argillaceous limestone, phosphatic or sideritic nodules in some areas; organic-rich 'paper shales' at some levels; silty and finely sandy beds particularly in the upper part and also (East Midlands Shelf north) in the lower part. Also included is the littoral limestone facies of the Bristol-Radstock Shelf area.

Geographical extent:
Wessex Basin to East Midlands Shelf i.e. Dorset coast to Market Weighton, including Somerset and South Wales

Lower boundary:
Generally at the top of the Blue Lias Formation (q.v.). In any one section, the top of the Blue Lias coincides with a marked upward decrease in abundance of limestone beds, sometimes associated with a marked decrease in their individual thickness and lateral persistence. In many cases, the horizon to be taken is obvious. Where there is doubt, the thickness and vertical frequency of limestone beds should be considered, and the following guidelines used: at the top of a more or less persistent, thick (> 0.10 m) limestone above which the overlying mudstone (beneath any subsequent similar limestone) is at least twice the thickness typical of the underlying limestone - mudstone interbedded unit and above which there is no return, within the Lias Group, to limestone - mudstone spacing on that previous scale. In the type section, at the top of the Grey Ledge (Bed 49 of Lang, 1924). Where littoral facies are developed in the Bristol-Radstock Shelf area, the base is taken at the base of the Turneri Clay. In the East Midlands Shelf (north), where the Blue Lias is absent, the base is taken at the top of the Scunthorpe Mudstone Formation (q.v.), i.e. in north Lincolnshire, at the top of the Frodingham Ironstone, or elsewhere at the base of a thin pebbly ferruginous oolite (Glebe Farm Bed) which rests erosively and non-sequentially on the Scunthorpe Mudstone Formation.

Upper boundary:
Generally at the marked or gradational upward change to coarser siliciclastic deposits of the Dyrham Formation (q.v.). In the type section, this is at the base of the Three Tiers, a unit of fine sandstone with three cemented beds (Hesselbo and Jenkyns, 1995). In boreholes, it is taken at the upward change to markedly silty/sandy lithologies which coincides with a leftward (low) shift in the gamma ray log. Where the Dyrham Formation is absent (East Midlands Shelf north), it is taken at the base of the Marlstone Rock Formation (q.v.) or locally, in the Bristol-Radstock Shelf area, at the base of the Beacon Limestone Formation.

Thickness:
Up to c. 335 m

Chronostratigraphy:
Lower Jurassic, Sinemurian to Pliensbachian. Both top and base may be diachronous; the base is within the Bucklandi, Semicostatum, Turneri or Obtusum zones; the top is within the Davoei or Margaritatus zones.

Subdivisions (to be rationalised):
Well-established units in Dorset which it is appropriate to formalise as members (Table 2):
Green Ammonite Beds
Belemnite Marls
Black Ven Marls
Shales-with-Beef

East Midlands Shelf (north):
Glebe Farm Bed (Brandon et al., 1990)
Sand Beck Nodule Bed (Brandon et al., 1990)
Brandon Sandstone (Brandon et al., 1990)
Loveden Gryphaea Bed (Brandon et al., 1990)
Jericho Gryphaea Bed (Berridge et al., in press)
Pecten Ironstone [Member] (Gaunt et al., 1992)

'70', '85' and '100' markers (Horton and Poole, 1977). These are units of limestone and calcareous mudstone first recognised on the basis of wireline geophysical logs, and recognisable throughout the Worcester Basin and East Midlands Shelf.

Bristol-Radstock Shelf area, marginal/littoral facies:
Valdani Limestone (Tutcher and Trueman, 1925)
Jamesoni Limestone (Tutcher and Trueman, 1925)
Armatum(s) Bed (Tutcher and Trueman, 1925)
Raricostatum Clay (Tutcher and Trueman, 1925)
Obtusum Nodules (Tutcher and Trueman, 1925)
Turneri Clay (Tutcher and Trueman, 1925)
Spiriferina Bed (Tutcher and Trueman, 1925)
Bucklandi Bed (Tutcher and Trueman, 1925)

Other named units of uncertain status:
Ditcheat Clay Member (Bristow and Westhead, 1993)
Pylle Clay Member (Bristow and Westhead, 1993)
Spargrove Limestone Member (Bristow and Westhead, 1993)
Helwell Marl [Member] (Palmer, 1972)
Marston Marble (Kellaway and Wilson, 1941; Wilson et al., 1958)
Gryphaea Bed
Coral Band
Hippopodium Bed (Murchison, 1845)
Wright's Ammonite Bed
Belemnite Bed (Buckman, 1843)
Murchison's Ammonite Bed (Murchison, 1845)
Banbury Marble (Beesley, 1872)

Additional references:
Arkell (1933), Callomon and Cope (1995), Getty (1980), Howarth (1980a), Lang (1914, 1936), Lang and Spath (1926), Lang et al. (1928), Lang et al. (1923), Palmer (1972), Wilson et al. (1958).

5.7 Cleveland Ironstone Formation

Previous nomenclature:
Kettleness Beds (Young and Bird, 1822) (for lower part only)
Ironstone Series (Phillips, 1829)
Cleveland Ironstone Series (Chowns, 1966)

Name of next higher ranking unit:
Lias Group

Derivation of name:
Cleveland Hills

Type area:
North Yorkshire coast

Type section:
Coastal exposures near Staithes, North Yorkshire (Penny Nab [NZ 788 189] to Brackenberry Wyke [NZ 794 183]) (Howarth, 1955; 1973; Hemingway *in* Hemingway et al., 1963; Hesselbo and Jenkyns, 1995).

Primary reference section:
Coastal exposures at Hawsker Bottoms, North Yorkshire (between Clockcase Nab [NZ 955 071] and Hawsker High Scar [NZ 952 075]) (Howarth, 1955; Hesselbo and Jenkyns, 1995).

Other reference sections:
Coastal exposures at Kettle Ness [NZ 832 161], North Yorkshire (upper part only).

BGS Felixkirk Borehole, Felixkirk, North Yorkshire (Reg. No. SE 48 NE/2) [SE 4835 8576] 61.0 m to 70.01 m depth (Ivimey-Cook and Powell, 1991).

Extant exposures/sections:
Numerous poor quality exposures inland in North Yorkshire and Cleveland, e.g. at Eston Moor, Botton Head, Osmotherly and Grosmont (Howard, 1985).

Lithology:
Mudstone, argillaceous siltstone and silty sandstone with interbedded thin seams of sideritic and berthierine-ooidal ironstone which occur typically at the tops of small-scale sedimentary rhythms (Chowns, 1968).

Geographical extent:
Cleveland Basin

Lower boundary:
Downward transition from shaly mudstone with scattered sideritic nodules to siltstone or sandstone of the Staithes Sandstone Formation. In the type section, it is taken at the base of a bed of argillaceous concretions (Bed 24 of Howarth,1955); at Hawsker Bottoms, at the base of Bed 17 (of Howarth,1955) where shale passes down into hard ferruginous and calcareous sandstone.

Upper boundary:
At the top of the highest ooidal ironstone or at the top of a bed of hard sideritic nodules, succeeded by grey mudstone of the Whitby Mudstone Formation. In the type section, this is at the top of Bed 56 of Howarth (1955); at Hawsker Bottoms, at the top of Bed 42 of Howarth (1955); at Kettleness, at the top of Bed 24 of Howarth (1955). Elsewhere at the top of the Main Seam or at the top of the Top Main Dogger.

Thickness:
Up to c. 25 m

Chronostratigraphy:
Lower Jurassic, Upper Pliensbachian (Margaritatus to Spinatum zones).

Subdivisions:
Penny Nab Member (Howard, 1985)
Kettleness Member (Howard, 1985)

Additional references:
Arkell (1933), Howarth (1980a), Knox (1984), Powell (1984).

5.8 Dyrham Formation

Previous nomenclature:
Dyrham Silt(s) (Kellaway, 1960; Stubblefield, 1963; Cave, 1977; Donovan and Kellaway, 1984)
Middle Lias Sandy Beds (Richardson, 1929, 1933; Richardson, Arkell and Dines, 1946)
Middle Lias Clays (Worssam and Bisson, 1961)
Middle Lias Silts (Whittaker, 1972)
Middle Lias Silts and Clays (Edmonds and Wilson, 1965)
Middle Lias
Pennard Sands (Kellaway and Wilson, 1941)

Name of next higher ranking unit:
Lias Group

Derivation of name:
Dyrham [ST 741 758], Gloucestershire

Type area:
Bath, Malmesbury and Gloucester districts

Type section:
Tuffley Brickworks, Robin's Wood Hill, near Gloucester, Gloucestershire (SSSI) [SO 836 149] (Ager, 1956, 1969; Palmer, 1971; Murray and Hancock, 1977; Simms, 1990).

Primary reference section:
Cliff and foreshore exposures between Seatown [SY 420 918] and Eype Mouth [SY 447 910], Dorset.

Other reference sections:
BGS Elton Farm Borehole, near Dundry, Somerset (Reg. No. ST 56 NE/3) [ST 5636 6589] 36.36 m to 45.42 m depth (Ivimey-Cook, 1978).

Stonehouse Brick and Tile Co. and Jeffries pits, Stonehouse, near Stroud, Gloucestershire [SO 810 053] (Ager, 1956, 1969; Ackermann and Cave, 1967; Palmer, 1971; Murray and Hancock, 1977; Simms, 1990).

BGS Bredon Hill No. 1 (Lalu Barn) Borehole, Worcestershire (Reg. No. SO 93 NE/1) [SO 9577 3996] 152.58 m to 187.76 m depth (Whittaker, 1972).

BGS Stowell Park Borehole, Gloucestershire (Reg. No. SP 01 SE/1) [SP 0835 1176] 222.28 m to 276.51 m depth (Green and Melville, 1956; Melville, 1956; Spath, 1956; Ivimey-Cook, 1993; Sumbler and Barron, 1995; Sumbler et al., in press).

BGS Upton Borehole, Burford, Oxfordshire (Reg. No. SP 21 SW/1) [SP 2315 1313] 16.18 m to 36.04 m depth (Melville, 1963; Worssam, 1963; Sumbler, 1994).

BGS Apley Barn Borehole, Witney, Oxfordshire (Reg. No. SP 31 SW/3) [SP 3438 1066] 52.35 m to 68.40 m depth (Poole, 1969).

BGS Steeple Aston Borehole, Oxfordshire (Reg. No. SP 42 NE/12) [SP 4687 2586] 38.25 to 50.90 m depth (Poole, 1977).

Napton-on-the-Hill Brickpit, Napton, Warwickshire [SP 456 613] (SSSI) (Callomon *in* Hallam, 1968; Old et al., 1987).

BGS Thorpe by Water Borehole, Thorpe by Water, Leicestershire (Reg No. SP 89 NE/1) [SP 8857 9648] 5.60 m to 29.00 m depth (Horton, 1973 and MS; Brandon et al., 1990).

Extant exposures/sections:
See above

Former brickworks at Aston Magna, Gloucestershire [SP 198 354] (Arkell, 1947; Callomon *in* Hallam, 1968).

Lithology:
Pale to dark grey and greenish grey, silty and sandy mudstone, with interbeds of silt or very fine sand (in some cases muddy or silty), weathering brown or yellow. Variably micaceous. Impersistent beds or doggers of ferruginous limestone (some ooidal) and sandstone which may be very fine or laminated, and show sedimentary structures or bioturbation; these occur at the tops of sedimentary rhythms and include the so-called Sandrock, commonly regarded (and mapped) as part of the Marlstone Rock Formation (e.g. Hallam, 1968). Occasional large argillaceous, silty or sandy limestone nodules.

Geographical extent:
Wessex Basin, Worcester Basin and East Midlands Shelf (south), i.e. Dorset coast to approximately Grantham.

Lower boundary:
Marked or gradational downward change from silty or finely sandy sediments to the smoother mudstones of the Charmouth Mudstone Formation; generally coincides with a negative change of slope and/or line of seepage which may correspond with a sandy bed, e.g. the Capricornus Sandstone in the Cotswolds (Sumbler et al., in press) or the Three Tiers (Bed 6 of Howarth, 1957) on the Dorset coast (Hesselbo and Jenkyns, 1995).

Upper boundary:
At the base of the ferruginous limestone or ironstone of the Marlstone Rock Formation or the Marlstone Rock Member of the Beacon Limestone Formation.

Thickness:
Up to c. 125 m

Chronostratigraphy:
Lower Jurassic, Upper Pliensbachian, Davoei Zone to Margaritatus Zone. Base diachronous.

Subdivisions (to be rationalised):
Well established units on the Dorset coast which it is appropriate to formalize as members (Table 2).
Thorncombe Sands
Down Cliff Sands
Eype Clay

Worcester Basin:
Capricornus Sandstone [Bed] (Simms, 1990)
Subnodosus Sandstone [Bed] (Simms, 1990)

Additional references:
Arkell (1933), Callomon and Cope (1995), Howarth (1980a), Wilson et al. (1958).

5.9 Marlstone Rock Formation

Previous nomenclature:
Marlstone (Wm Smith, 1817)
Marlstone Rock
Marlstone Rock Bed
Marlstone Rock Member (Gaunt et al., 1992)

Name of next higher ranking unit:
Lias Group

Derivation of name:
Old lithological term

Type area:
English Midlands (Warwickshire to south Lincolnshire) where it 'forms an almost continuous band, giving rise from Edge Hill north-eastward to a broken escarpment overlooking the Midland Plain and the Vale of Belvoir' (Arkell, 1933).

Type section:
Tilton Railway Cutting, Tilton, Leicestershire [SK 762 055] (SSSI) (Hallam, 1955, 1968; Howarth, 1980c, 1992).

Primary reference section:
Stanley's Quarry, Edge Hill, Warwickshire [SP 373 471].

Other reference sections:
BGS Bredon Hill No. 1 (Lalu Barn) Borehole, Worcestershire (Reg. No. SO 93 NE/1) [SO 9577 3996] 146.56 m to 152.58 m depth (Whittaker, 1972).

BGS Stowell Park Borehole, Gloucestershire (Reg. No. SP 01 SE/1)[SP 0835 1176] 220.50 m to 222.28 m depth (Green and Melville, 1956; Melville, 1956; Spath, 1956; Ivimey-Cook, 1993; Sumbler and Barron, 1995; Sumbler et al., in press).

BGS Apley Barn Borehole, Witney, Oxfordshire (Reg. No. SP 31 SW/3) [SP 3438 1066] 51.84 m to 52.35 m depth (Poole, 1969).

BGS Steeple Aston Borehole, Oxfordshire (Reg. No. SP 42 NE/12) [SP 4687 2586] 34.75 m to 38.25 m depth (Poole, 1977).

Neithrop Fields railway cutting, near Banbury, Oxfordshire [SP 439 419] (SSSI) (Edmonds and Wilson, 1965).

Napton-on-the-Hill Brickpit, Napton, Warwickshire [SP 456 613] (SSSI) (Callomon *in* Hallam, 1968; Old, Sumbler and Ambrose, 1987).

BGS Copper Hill Borehole, Ancaster, Lincolnshire (Reg. No. SK 94 SE/56) [SK 9787 4265] 63.70 m to 67.30 m depth (Berridge et al., in press).

Nettleton Bottom Borehole, Nettleton, Lincolnshire (Reg. No. TF 19 NW/54) [TF 1249 9820] 413.99 m to 420.99 m depth (Gaunt et al., 1992).

Tuffley Brickworks, Robin's Wood Hill, near Gloucester, Gloucestershire (SSSI) [SO 836 149] (Ager, 1956; 1969; Palmer, 1971; Murray and Hancock, 1977; Simms, 1990).

Stonehouse Brick and Tile Co. and Jeffries pits, Stonehouse, near Stroud, Gloucestershire [SO 810 053]

(Ager, 1956, 1969; Ackermann and Cave, 1967; Palmer, 1971; Murray and Hancock, 1977; Simms, 1990).

Extant exposures/sections:
See above

Browns Hill Quarry, Holwell, Leicestershire [SK 742 235] (Clements, 1989).

Lithology:
Sandy, shell-fragmental, ferruginous berthierine-ooidal limestone, weathering to limonitic ironstone, with ferruginous and calcareous sandstone; thin ferruginous mudstone partings; variably shelly but generally highly fossiliferous.

Geographical extent:
East Midlands Shelf and Worcester Basin

Lower boundary:
At the downward change to the grey or greenish grey silty mudstone/ siltstone of the Dyrham Formation (q.v.), or the grey mudstone of the Charmouth Mudstone Formation (q.v.); base typically erosive and conglomeratic. Locally, it may rest on a sandstone of the Dyrham Formation, which it may be impractical to separate from the Marlstone Rock.

Upper boundary:
Generally a non-sequential boundary with the mudstone (or locally, nodular limestone) of the Whitby Mudstone Formation (q.v.).

Thickness:
Up to c. 10 m

Chronostratigraphy:
Lower Jurassic, Upper Pliensbachian (Spinatum Zone) to Lower Toarcian (Tenuicostatum Zone)

Subdivisions:
Transition Bed (as described by Howarth (1978), this is the weathered upper part of the Marlstone Rock and is not a valid lithostratigraphical unit).
Sandrock (e.g. Hallam, 1968; this is strictly part of the Dyrham Formation but is commonly mapped with the Marlstone Rock).

Additional references:
Howarth (1980b), Whitehead et al. (1952).

5.10 Redcar Mudstone Formation

Previous nomenclature:
Lower Lias

Name of next higher ranking unit:
Lias Group

Derivation of name:
Redcar [NZ 6024], near Middlesborough, where Tate and Blake (1876) described the lowest exposed Lias of the Cleveland Basin (Powell, 1984).

Type area:
North Yorkshire and Cleveland coast

Type section:
Robin Hood's Bay [NZ 9505 to NZ 9702], North Yorkshire (most of the formation exposed including junction with the overlying Staithes Sandstone Formation) (Fox-Strangways and Barrow, 1915; Bairstow, 1969; Hesselbo and Jenkyns, 1995).

Primary reference section:
BGS Felixkirk Borehole, Felixkirk, North Yorkshire (Reg. No. SE 48 NE/2) [SE 4835 8576] 94.85 m to 288.87 m depth (Ivimey-Cook and Powell, 1991).

Other reference sections:
Foreshore exposures at Redcar, Cleveland (lower part only, but not base).

Extant exposures/sections:
Coastal exposures in North Yorkshire and Cleveland (localities listed above).

Lithology:
Grey, fossiliferous, fissile mudstones and siltstones with subordinate thin beds of shelly limestone below, and fine-grained carbonate-cemented sandstone above; argillaceous limestone concretions occur throughout.

Geographical extent:
Cleveland Basin

Lower boundary:
Where grey, silty mudstone with thin beds of limestone and calcareous sandstone rest with a sharp and irregular contact on grey-green soft mudstone with thin siltstone laminae (Penarth Group, Lilstock Formation, Cotham Member); this is at a depth of 288.87 m in the BGS Felixkirk Borehole.

Upper boundary:
Gradational contact with sandstone and siltstone of the overlying Staithes Sandstone Formation (q.v.), but taken for consistency at the base of the 'Oyster Bed', a fossiliferous calcareous and ferruginous sandstone packed with the bivalves *Gryphaea gigantea*, *Oxytoma inaequivalvis* and *Pseudopecten aequivalvis* (Fox-Strangways and Barrow, 1882, 1915; Fox-Strangways et al., 1885; Barrow, 1888; Fox-Strangways, 1892; Buckman, 1915; Howard, 1985); at Cowbar Nab, Staithes, it is Bed 14 of Tate and Blake (1876); at Castle Chamber, Hawsker Bottom, it is Bed 5 of Buckman (1915) and Bed 591 of Bairstow (1969).

Thickness:
Up to c. 283 m

Chronostratigraphy:
Lower Jurassic, Hettangian to Pliensbachian (Planorbis to Davoei zones). The presence of Pre-Planorbis Beds (Triassic) at the base of the Redcar Mudstone has not been proved.

Subdivisions:
Ironstone Shale Member
Pyritous Shale Member
Siliceous Shale Member
Calcareous Shale Member
These are formalised versions of widely used informal divisions based on Buckman (1915).

Additional references:
Arkell (1933), Getty (1980), Howarth (1980a).

5.11 Scunthorpe Mudstone Formation

Previous nomenclature:
Scunthorpe Mudstones
Scunthorpe Mudstones Formation (Gaunt et al., 1992)
Approximates to Hydraulic Limestones, Angulata Clays, Granby Limestones, Bucklandi Clays and Ferruginous Limestone Series/Frodingham Ironstone (Swinnerton and Kent, 1949, 1976).

Name of next higher ranking unit:
Lias Group

Derivation of name:
Scunthorpe [SE 8910], Humberside.

Type area:
North Lincolnshire and Humberside.

Type section:
BGS Blyborough Borehole, Blyborough, Lincolnshire (Reg. No. SK 99 SW/79) [SK 9206 9428] c. 51.57 m to 139.50 m depth (Gaunt et al., 1992).

Primary reference section:
Borehole F/B5, Fulbeck, Lincolnshire (Reg. No. SK 95 SW/17) [SK 9062 5076] 4.58 m to 117.65 m depth (Brandon et al., 1990).

Other reference sections:
Borehole F/B1, Fulbeck, Lincolnshire (Reg. No. SK 85 SE/25) [SK 8889 5053] 1.84 m to 100.92 m depth (all but the uppermost beds) (Berridge et al., in press).

BGS Copper Hill Borehole, Ancaster, Lincolnshire (Reg. No. SK 94 SE/56) [SK 9787 4265] 182.60 m to 202.11 m depth (upper part only) (Berridge et al., in press).

Extant exposures/sections:
Crosby Warren, near Scunthorpe, Humberside to uppermost part (Frodingham Ironstone) only (K N Page, personal communication).

Lithology:
Grey, variably calcareous and silty, blocky or fissile mudstone with thin beds of argillaceous limestone (bioclastic or micritic) and calcareous siltstone, particularly near the base and in the upper part which is ferruginous in the type area.

Geographical extent:
East Midlands Shelf (north), i.e. approximately Leicester to Market Weighton.

Lower boundary:
Where the lowest grey mudstone (may be laminated) of the Lias Group rests with a sharp contact on the bluish and greenish grey to (less commonly) reddish brown mudstone of the Cotham Member (Lilstock Formation, Penarth Group) or on the grey porcellanous limestone of the Langport Member (Lilstock Formation, Penarth Group) where locally present.

Upper boundary:
In the type area, at the top of the Frodingham Ironstone (Gaunt et al., 1992); elsewhere, at the erosive base of a thin pebbly ferruginous oolite (Glebe Farm Bed) which marks the base of the Charmouth Mudstone Formation (q.v.).

Thickness:
Up to 128 m

Chronostratigraphy:
Upper Triassic to Lower Jurassic, uppermost Rhaetian to Upper Sinemurian (Obtusum or Oxynotum Zone).

Subdivisions:
Frodingham Ironstone Member (Gaunt et al., 1992) (developed only in the formations's type area).
Foston Member
Beckingham Member
Granby Member
Barnby Member
Barnstone Member
These units were defined by Brandon et al. (1990) in the Grantham-Vale of Belvoir area of Leicestershire and Lincolnshire; they may well be applicable further north.

Additional references:
Arkell (1933), Getty (1980).

5.12 Staithes Sandstone Formation

Previous nomenclature:
Staithes Beds (Young and Bird, 1822)
Marlstone Series (Phillips, 1829)
Sandy and Micaceous Beds (Simpson, 1855)
Sandy Series (Fox-Strangways and Barrow, 1882)
Cleveland Sand Formation (Chowns, 1968)
Staithes Formation (Hemingway, 1974)

Name of next higher ranking unit:
Lias Group

Derivation of name:
Staithes [NZ 7818], North Yorkshire

Type area:
North Yorkshire coast

Type section:
Coastal exposures at Staithes harbour between Cowbar Nab [NZ 783 191] and Penny Nab [NZ 788 189] (Barrow, 1888, p.12; Howarth, 1955; Hesselbo and Jenkyns, 1995).

Primary reference section:
Coastal exposures between Robin Hood's Bay and Hawsker

Bottoms, North Yorkshire (between Ness Point [NZ 960 065] and Clockcase Nab [NZ 955 071], including Castle Chamber) (Fox-Strangways and Barrow, 1915, p.11; Buckman, 1915, p.69; Hesselbo and Jenkyns, 1995).

Other reference sections:
BGS Felixkirk Borehole, Felixkirk, North Yorkshire (Reg. No. SE 48 NE/2) [SE 4835 8576] 70.10 m to 94.85 m depth (Ivimey-Cook and Powell, 1991).

Extant exposures/sections:
Good inland sections at Cliff Ridge, Great Ayton and Tom Gill Scar, Busby Moor in North Yorkshire (Howard, 1985).

Lithology:
More or less argillaceous silty sandstone with 2 to 4 m thick sequences of cleaner fine-grained laminated sandstone in the middle and upper parts; typically intensely bioturbated and/or showing bedding structures of many types.

Geographical extent:
Cleveland Basin

Lower boundary:
Gradational with the underlying mudstones of the Redcar Mudstone Formation (q.v.); but taken for consistency at the base of the 'Oyster Bed', a fossiliferous calcareous and ferruginous sandstone packed with the bivalves *Gryphaea gigantea*, *Oxytoma inaequivalvis* and *Pseudopecten aequivalvis* (Fox-Strangways and Barrow, 1882, 1915; Fox-Strangways et al., 1885; Barrow, 1888; Fox-Strangways, 1892; Buckman, 1915) which apparently persists as a continuous horizon throughout the Cleveland Basin (Howard, 1985); at Cowbar Nab, Staithes, it is Bed 14 of Tate and Blake (1876); at Castle Chamber, Hawsker Bottom, it is Bed 5 of Buckman (1915) and Bed 591 of Bairstow (1969).

Upper boundary:
Upward transition from sandstone/siltstone to shaly mudstone with scattered sideritic nodules of the Cleveland Ironstone Formation (q.v.); at Staithes, this is at the base of Bed 24 of Howarth (1955); at Hawsker Bottoms, it is at the base of Bed 17 of Howarth (1955).

Thickness:
Up to c. 30 m

Chronostratigraphy:
Lower Jurassic, Pliensbachian (Davoei and Margaritatus zones)

Subdivisions:
None

Additional references:
Arkell (1933), Howarth (1980a).

5.13 Whitby Mudstone Formation

Previous nomenclature:
Upper Lias (part)

Name of next higher ranking unit:

Lias Group
Derivation of name:
Whitby [NZ 8911], North Yorkshire

Type area:
North Yorkshire coast

Type section:
Coastal exposures from Hawsker Bottoms [NZ 951 077] to Whitby Harbour [NZ 901 114] (Howarth 1962, 1973, 1992).

Primary reference section:
BGS Stowell Park Borehole, Gloucestershire (Reg. No. SP 01 SE/1) [SP 0835 1176] 122.28 m to 220.50 m depth (Green and Melville, 1956; Melville, 1956; Spath, 1956; Ivimey-Cook, 1993; Sumbler and Barron, 1995; Sumbler et al., in press).

Other reference sections:
For the lower part (up to Mulgrave Shale Member) — coastal exposures from Brackenberry Wyke [NZ 795 181] to Rosedale Wyke [NZ 801 174] (Howarth, 1962; 1973). For the upper part — coastal exposures north of Blea Wyke Point [NZ 986 018 to NZ 993 013] (Dean, 1954; Hemingway *in* Hemingway et al., 1963; Knox, 1984).

BGS Felixkirk Borehole, Felixkirk, North Yorkshire (Reg. No. SE 48 NE/2) [SE 4835 8576] 18.09 m to 61.0 m depth (lower beds only) (Ivimey-Cook and Powell, 1991).

BGS Brown Moor Borehole, Acklam, North Yorkshire (Reg. No. SE 86 SW/4) [SE 8126 6203] 156.18 m to 185.96 m depth (lower beds only) (Gaunt et al., 1980).

Nettleton Bottom Borehole, Nettleton, Lincolnshire (Reg. No. TF 19 NW/54) [TF 1249 9820] 391.70 m to 413.99 m depth (Gaunt et al., 1992).

BGS Copper Hill Borehole, Ancaster, Lincolnshire (Reg. No. SK 94 SE/56) [SK 9787 4265] 17.31 m to 63.70 m depth (Berridge et al., in press).

Site investigation boreholes, Empingham Dam, Leicestershire SD6 (Reg. No. SK 90 NW/24) [SK 9472 0737] 15.10 m to 69.90 m depth; DG9 (Reg. No. SK 90 NW/33) [SK 9448 0756] 5.95 m to 49.94 m depth; DG2 (Reg. No. SK 90 NW/25) [SK 9397 0825] 6.50 m to 56.52 m (Horton and Coleman, 1977).

BGS Heathencote Borehole (otherwise known as Towcester No. 3) (Reg. No. SP 74 NW/1) [SP 7048 4725] 30.48 m to 71.27 m depth.

BGS Lillingstone Lovell Borehole (otherwise known as Towcester No. 2) (Reg. No. SP 74 SW/1) [SP 7197 4197] 47.47 m to 67.06 m depth.

BGS Halse Grange Borehole (otherwise known as Towcester No. 4) (Reg. No. SP 54 SE/2) [SP 5670 4079] 22.30 m to 63.75 m depth.

BGS Steeple Aston Borehole, Oxfordshire (Reg. No. SP 42 NE/12) [SP 4687 2586] 15.40 m to 34.75 m depth (Poole, 1977).

BGS Apley Barn Borehole, Witney, Oxfordshire (Reg. No. SP 31 SW/3) [SP 3438 1066] 46.79 m to 51.84 m depth (Poole, 1969).
BGS Bredon Hill No. 1 (Lalu Barn) Borehole, Worcestershire (Reg. No. SO 93 NE/1) [SO 9577 3996] 36.04 m to 146.56 m depth (Whittaker, 1972).

BGS Elton Farm Borehole, near Dundry, Somerset (Reg. No. ST 56 NE/3) [ST 5636 6589] 11.05 m to 35.10 m depth (Ivimey-Cook, 1978).

Extant exposures/sections:
Coastal exposures in North Yorkshire (localities listed above, and also at Kettle Ness [NZ 832 161]).

There are no extensive working pits. The basal beds may still be visible in old workings of the Marlstone Rock Formation including the SSSI at Neithrop Fields Cutting [SP 439 419], Oxfordshire. The basal beds are exposed at Tilton Railway Cutting [SK 762 055] SSSI, and small sections in other railways cuttings, e.g. Great Oxendon, Northamptonshire (Poole et al., 1968), Nevill Holt, Leicestershire (Poole et al., 1968), and Hook Norton, Oxfordshire (Horton et al., 1987), may still be available.

Lithology:
Medium and dark grey fossiliferous mudstone and siltstone, laminated and bituminous in part, with thin siltstone or silty mudstone beds and rare fine-grained calcareous sandstone beds; dense, smooth argillaceous limestone nodules are very common at some horizons; phosphatic nodules at some levels. Nodular and fossiliferous limestones occur at the base in some areas.

Geographical extent:
Cleveland Basin, East Midlands Shelf and Worcester Basin, i.e. Yorkshire coast to approximately Chipping Sodbury, Gloucestershire.

Lower boundary:
In the Cleveland Basin, at the base of the mudstone resting upon the ooidal limestone or sideritic nodules (ironstone doggers) of the Cleveland Ironstone whichever is stratigraphically higher in any particular section. This is the top of Bed 56 of Howarth (1
955) at Staithes, the top of Bed 42 of Howarth (1955) at Hawsker Bottoms and the top of Bed 24 of Howarth (1955) at Kettleness; elsewhere, the top of the Main Seam or Top Main Dogger. N.B. This differs from the Powell (1984) and Knox (1984) definition, which places the boundary at the base of a grey micaceous mudstone resting on a bed of calcareous concretions at the top of a ferruginous sandy mudstone of the Cleveland Ironstone Formation (i.e. Bed 44 of Howarth (1955) at Hawsker Bottoms; Bed 28 of Howarth (1955) at Kettle Ness). In the East Midlands Shelf and Worcester Basin, it is at the base of the mudstone (or locally nodular limestones), non-sequentially overlying ferruginous limestone or ironstone of the Marlstone Rock Formation.

Upper boundary:
In most areas, a sharp, eroded boundary with limestones, sandstones or mudstones of the Ravenscar Group or Dogger Formation (Cleveland Basin), or of the Inferior Oolite Group (East Midlands Shelf to Worcester Basin). In the Ravenscar area, and southern parts of Worcester Basin, an arbitrary boundary in the transition to sandy sediments of, respectively, the Blea Wyke Formation or the Bridport Sand Formation (Lias Group).
Thickness:
Up to c. 130 m

The thickest sequences occur in the Worcester Basin. The Bredon Hill No.1 Borehole proved c. 110 m (Whittaker, 1972) but the thickness beneath the centre of the Bredon Hill outlier may be slightly greater. The Stowell Park Borehole proved 98.22 m but near Dundry, on the southern flanks of the basin, the Elton Farm Borehole proved only 24.05 m. On the East Midlands Shelf, the thickness is typically c. 40 m; with a maximum of c. 55 m in parts of Leicestershire. Northwards, there is thinning (due mainly to overstep) towards the Market Weighton High where the formation is absent. South of the type area, there is also thinning; thicknesses proved in Oxfordshire range between c. 5 m and c. 20 m. In the Cleveland Basin (including the type area), the thickness is up to c. 105 m.

Chronostratigraphy:
Lower Jurassic, Upper Pliensbachian (topmost Spinatum Zone) to Toarcian. On the East Midlands Shelf, Lower Toarcian only (Tenuicostatum, Falciferum and Bifrons zones). In the Worcester Basin, Lower Toarcian (Tenuicostatum, Falciferum and Bifrons zones) to Upper Toarcian (Levesquei Zone), although in the south, the zonal range is much reduced due to the development of the Bridport Sand Formation and Beacon Limestone Formation.

Subdivisions:
The following units are currently recognised only in the Cleveland Basin:
Fox Cliff Siltstone Member (Knox, 1984)
Peak Mudstone Member (Knox, 1984)
Alum Shale Member (Powell, 1984; Knox, 1984) with Hard Shales, Main Alum Shales and Cement Shales as informal subdivisions.
Mulgrave Shale Member (Rawson and Wright, 1992) with Jet Rock, Bituminous Shales and Ovatum Band as informal subdivisions.
Grey Shale Member (Powell, 1984)

In the south Midlands and northern parts of the Worcester Basin, condensed ‘cephalopod limestone’ facies belonging to the Tenuicostatum to Bifrons zones occur at the base of the Whitby Mudstone. These include:
Serpentinus Beds (Judd, 1875)
Cephalopod Limestones/Beds including Lower Cephalopod Limestone, Upper Cephalopod Limestone and Inconstant Cephalopod Limestone (Thompson, 1910)
Cephalopod Limestones Member (Horton et al., 1974)
Transition Bed (sensu Horton et al., 1987)
It would be appropriate to consider these units as a Member of the Whitby Mudstone, equivalent to the Eype Mouth Limestone Member of the Wessex Basin.

Other units of uncertain status include:
Leptaena Bed (Moore, 1867)
Fish Beds including Abnormal Fish Bed, Saurian and Fish Zone (Brodie, 1845)
Fish Beds Member (Horton et al., 1974)
Ammonite Nodule Bed (Horton and Coleman, 1977)
‘Smartie’ Nodule Bed (Horton and Coleman, 1977)
Pisolite Bed (Horton and Coleman, 1977)
Unfossiliferous Beds
Leda [= *Nuculana*] *ovum* Beds (Lower, Middle and Upper) (Judd, 1875; Woodward, 1893)
Dumbleton Beds (Judd, 1875)

Additional references:
Arkell (1933; 1947), Hallam (1968), Howarth (1978, 1980b, 1992), Howarth and Rawson (1965), Thompson (1884–88).

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APPENDIX 1

List of formations by name in alphabetical order with BGS Lexicon computer codes.

Beacon Limestone Formation	BNLS
Blea Wyke Sandstone Formation	BW
Blue Lias Formation	BLI
Bridport Sand Formation	BDS
Charmouth Mudstone Formation	CHAM
Cleveland Ironstone Formation	CDI
Dyrham Formation	DYS
Marlstone Rock Formation	MRB
Redcar Mudstone Formation	RMU
Scunthorpe Mudstone Formation	SMD
Staithes Sandstone Formation	STA
Whitby Mudstone Formation	WHM

APPENDIX 2

List of formations in alphabetical order with preferred BGS Map symbol:

Beacon Limestone Formation	BnL
Blea Wyke Sandstone Formation	BWS
Blue Lias Formation	BLi
Bridport Sand Formation	BdS
Charmouth Mudstone Formation	ChM
Cleveland Ironstone Formation	CdI
Dyrham Formation	DyS
Marlstone Rock Formation	MRB
Redcar Mudstone Formation	ReM
Scunthorpe Mudstone Formation	SMd
Staithes Sandstone Formation	Sta
Whitby Mudstone Formation	WhM

APPENDIX 3

List of redundant names and codes

Angulatum Clays	ANGC
Blea Wyke Beds (BW) (name redundant; code retained for Blea Wyke Sandstone Formation)	
Blue Lias (BLS) (obselete code, use BLI)	
Brant Mudstone Formation	BMN
Coleby Mudstones	CLM
Cotteswold Sands	CTS
Dyrham Siltstone Formation (name redundant; DYS code retained for Dyrham Formation)	
Gonerby Member	GO
Hougham Mudstones	HGHM
Hydraulic Limestones	HYDL
Jet Rock Beds	JRB
Junction Bed	JB
Lavernock Shales [Formation] (LVN) (name redundant; code to be retained for Lavernock Shale Member)	
Leadenham Mudstones	LDNM
Lower Lias	LLI
Lower Lias Clay Formation	LLIC
Lower Lias Clay and Limestone	LLCL
Lower Lias, marginal facies	MRGF
Middle Lias	MLI
Middle Lias Sands and Silts	MLS
Middle Lias Marls	MLM
Midford Sands	MS
Pennard Sands	PNS
Pennard Sand Member	PENS
Porthkerry Formation (PO) (name redundant; code to be retained for Porthkerry Member)	
St Mary’s Well Bay Formation (STM) (name redundant; code to be retained for St Mary’s Well Bay Member)	
Upper Lias	ULI
Upper Lias Clay Formation	ULC
Upper Lias Sand	ULIS
Yeovil Sands	YS

Figure 1a Generalised outcrop map of the Lias Group in England and Wales showing the structural elements that controlled deposition.

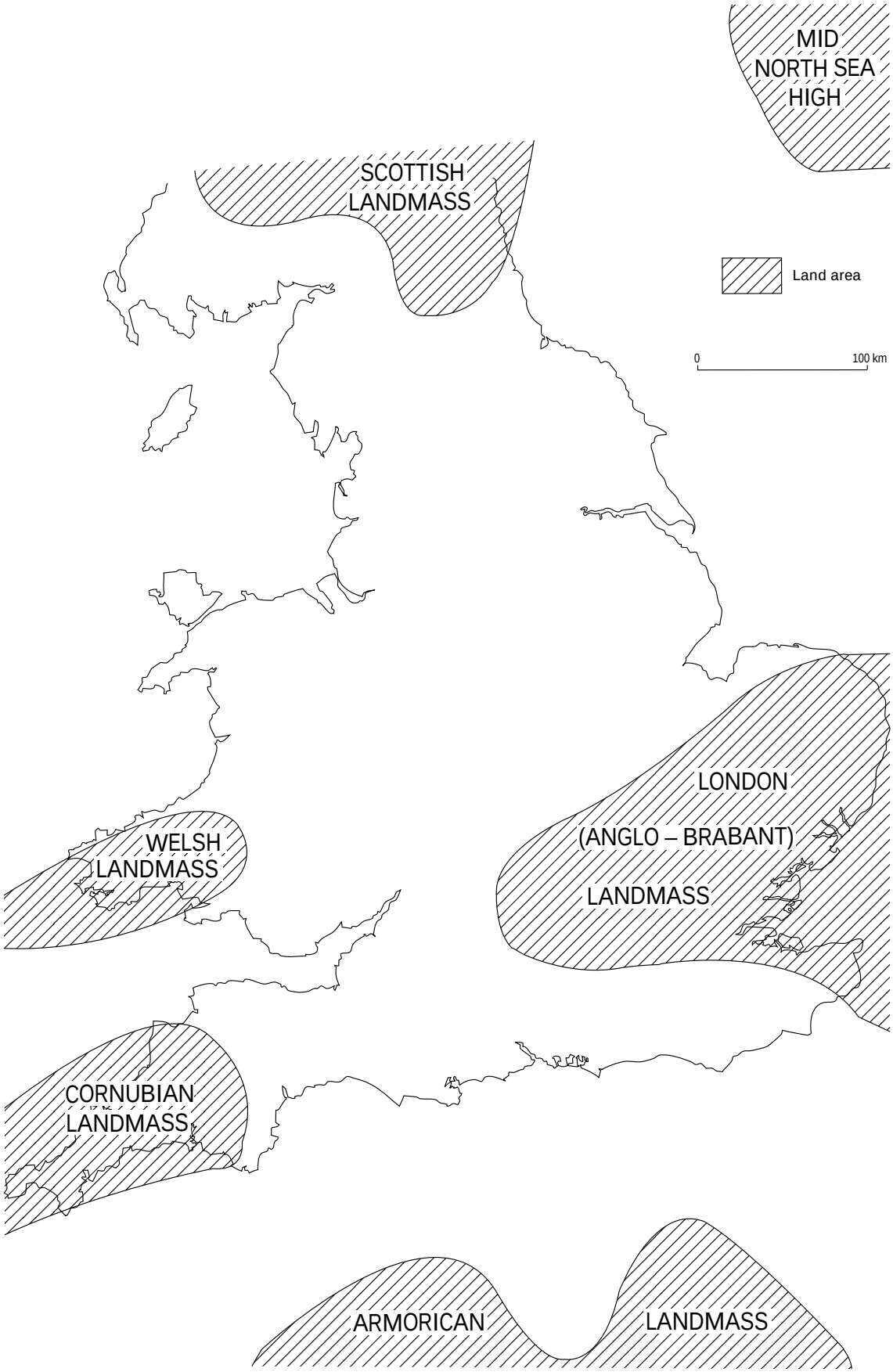

Figure 1b Inferred distribution of land and sea during deposition of the Lias Group based on Donovan and Howarth *in* Cope et al. (1992). In general, land areas gradually reduced through the Early Jurassic.

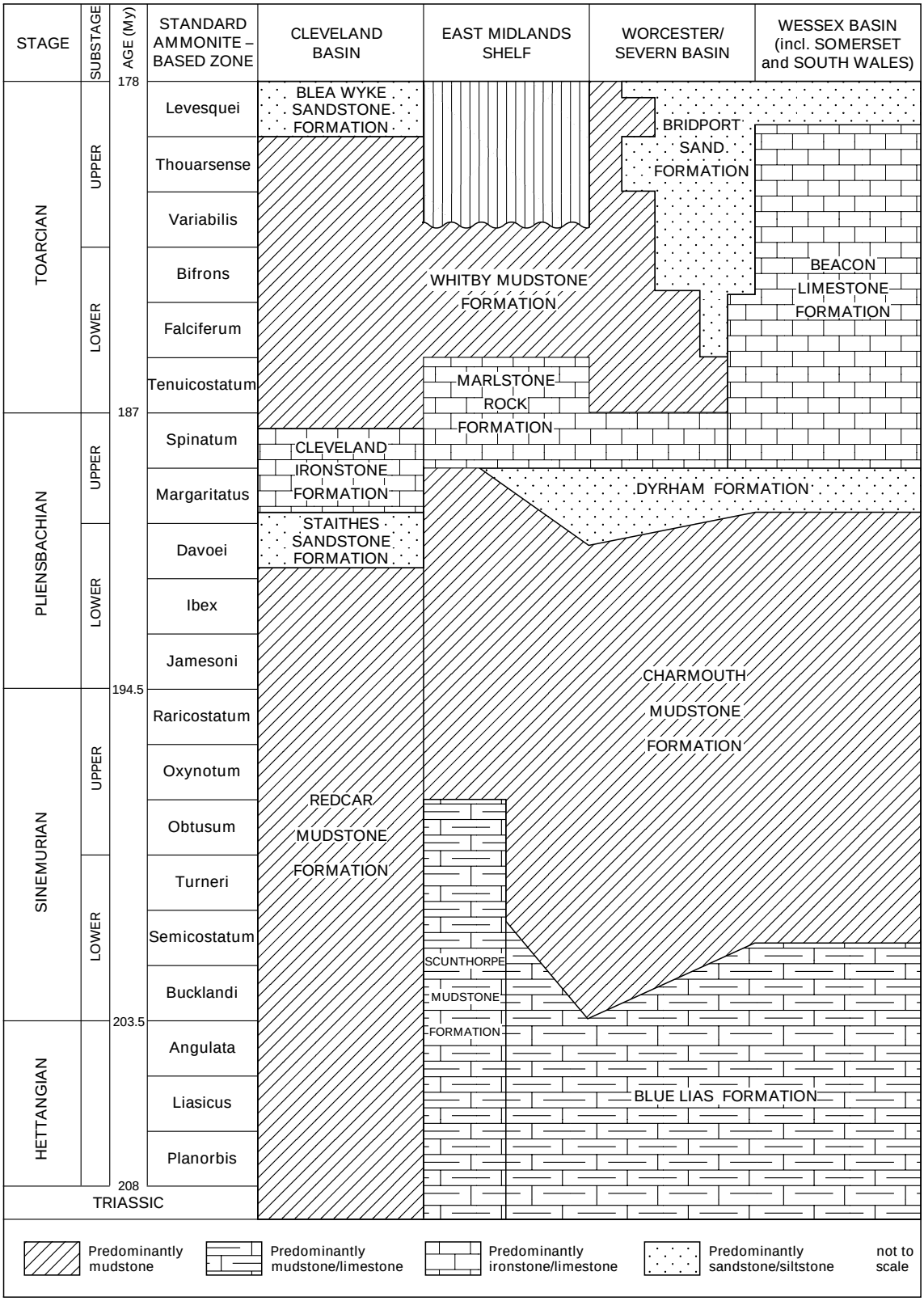

Figure 2 Proposed formational framework for the Lias Group. Vertical ruling indicates non-sequence; intraformational non-sequences not shown.

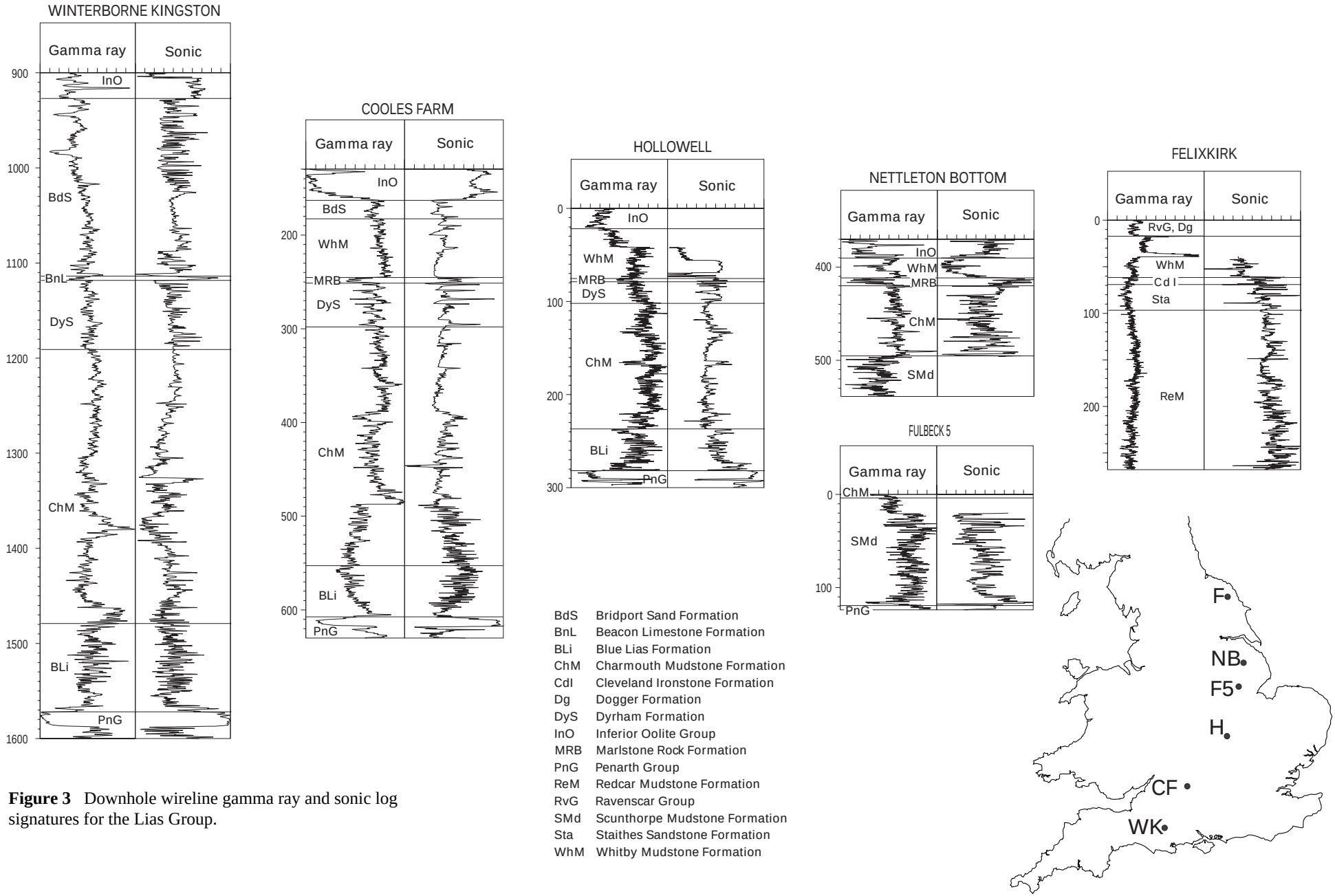

Figure 3 Downhole wireline gamma ray and sonic log signatures for the Lias Group.

BdS	Bridport Sand Formation
BnL	Beacon Limestone Formation
BLi	Blue Lias Formation
ChM	Charmouth Mudstone Formation
CdI	Cleveland Ironstone Formation
Dg	Dogger Formation
DyS	Dyrham Formation
InO	Inferior Oolite Group
MRB	Marlstone Rock Formation
PnG	Penarth Group
ReM	Redcar Mudstone Formation
RvG	Ravenscar Group
SMd	Scunthorpe Mudstone Formation
Sta	Staithes Sandstone Formation
WhM	Whitby Mudstone Formation