GEOLOGICAL SOCIETY

QUATERNARY
NEOGENE
PALAEOGENE
CRETACEOUS

Special Report No. 15

JURASSIC

PART TWO

TRIASSIC
PERMIAN
CARBONIFEROUS
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PRECAMBRIAN

by

J. C. W. Cope
K. L. Duff
C. F. Parsons
H. S. Torrens
W. A. Wimbledon
J. K. Wright

A CORRELATION OF JURASSIC ROCKS IN THE BRITISH ISLES
PART TWO: MIDDLE AND UPPER JURASSIC

A correlation of Jurassic rocks in the British Isles Part Two: Middle and Upper Jurassic

JOHN CHRISTOPHER WOLVERSON COPE (Editor and Convener), KEITH LESLIE DUFF, COLIN FREDERICK PARSONS, HUGH SIMON TORRENS, WILLIAM ALBERT WIMBLEDON & JOHN KENNETH WRIGHT

CONTENTS

SUMMARY

The base of the Aalenian stage is taken as the base of the Middle Jurassic, and the base of the Oxfordian stage as the base of the Upper Jurassic.

The development of the Middle and Upper Jurassic rocks in the British Isles is illustrated in the correlation charts which are amplified by the text. The Aalenian and Bajocian Stages are treated on one chart, but there are separate charts for the Bathonian, Callovian, Oxfordian, Kimmeridgian and Portlandian Stages. The latter is preferred as a name for the terminal Jurassic Stage of the Boreal Province.

INTRODUCTION

For details of the stratigraphy of the Lower Jurassic of mainland Britain, the development of the whole of the Jurassic in offshore areas around Britain and for many general considerations of Jurassic stratigraphy the reader should refer to Part One of this report (Cope *et al.* 1980). The present part is concerned with the Middle and Upper Jurassic of onshore regions.

Geol. Soc. London, Special Report No. 15, 1980, 109 pp.

DEFINITION OF THE MIDDLE AND UPPER JURASSIC

H. S. Torrens

Leopold von Buch's (1839, pp. 17–22) division of the Jurassic in Germany into Lower, Middle and Upper divisions forms the basis for the currently accepted subdivisions of the Jurassic System. These were originally based on gross lithological divisions which von Buch (1839, p. 13) also called Black, Brown and White Jurassic respectively.

In 1946 Arkell sought to return as closely as possible to von Buch's usage of these boundaries, drawing them at the nearest appropriate stage boundary that was consistent; he chose the base of the Bajocian (*sensu anglico*, i.e. embracing the Aalenian) as the base of the Middle Jurassic and the base of the Oxfordian as the base of the Upper Jurassic. Agreement now seems to be general that the Upper Jurassic should commence with the Oxfordian (Maubeuge 1970; Callomon 1965; Hallam 1975). In this case the lithologically based White Jurassic of Southern Germany is a close but not exact approximation to the Upper Jurassic subsystem there, because the topmost Brown Jurassic is there of Lower Oxfordian age (Ziegler 1977).

Less agreement exists on the definition of the base of the Middle Jurassic. We have accepted it here at the base of the Aalenian Stage. This does not agree with the resolutions of the 1962 Luxembourg Colloquium (Maubeuge 1964, p. 78) where this limit was drawn at the base of the Bajocian (*sensu gallico*, i.e. excluding the Aalenian) above, from which resolution the British Mesozoic committee dissented (Ager 1964, p. 1059). In 1970 the Resolutions of the 2nd Luxembourg Colloquium were published and were contradictory in that they resolved to confirm the resolutions of 1962 and then showed voting figures contradicting this with a majority in favour of the Aalenian stage being placed in the Middle Jurassic (Maubeuge 1970, p. 38). This was the view of Arkell (1956) and is in agreement with recent German usage (Hahn & Schreiner 1971, p. 278; Schmidt-Kaler & Zeiss 1973, p. 160).

EXPLANATORY NOTES TO THE CORRELATION CHARTS

On the following charts the subzone has been taken as the basic unit and on the charts is represented by a vertical spacing of $\frac{1}{4}''$ (6.35 mm). A zone which is not divided up into subzones has been allotted $\frac{1}{2}''$ (12.7 mm) vertical spacing. Zonal boundaries are indicated between adjacent columns by dotted lines. On the charts, the presence of a zone (proved by ammonite fauna—though not necessarily the zonal index species) is indicated thus † and that of a subzone, similarly proved, thus *.

The absence of a horizon through non-sequence is denoted by vertical hatching. Absence through lack of exposure or modern erosion is indicated by diagonal hatching.

The text serves to amplify points not obvious, or too detailed to appear on the charts, and letters a, b, etc., are used to indicate specific reference points from chart to text. The following abbreviations are used in the text: BM: British Museum

(Natural History), BU: Bristol University, IGS: Institute of Geological Sciences, OUM: Oxford University Museum and SM: Sedgwick Museum.

AALENIAN AND BAJOCIAN CORRELATION CHART

C. F. Parsons

Following the decisions of successive International Jurassic Colloquia (Maubeuge 1964, 1970; Ager 1963) and current European practice, the Aalenian and Bajocian are here recognized as separate stages. Although the faunal division between these stages is relatively clear cut, in England beds of this age are closely associated in general lithology, making up the dominant parts of the Inferior Oolite and Ravenscar Groups. Because of this close association and the fact that the stages were long combined in an extended Bajocian Stage *sensu anglico* (cf. Arkell 1954a, 1956; Ager 1964; George *et al.* 1969; Morton 1974), their descriptions are here combined.

The deposition of the British Aalenian/Bajocian rocks, like much of the rest of the Jurassic, was controlled by deep-seated structural features, so that the thickest sequences were deposited in 'negative areas' or 'basins', whilst on the intervening 'positive areas' or 'swells', more attenuated or incomplete successions are preserved (see Fig. 1). The most well known and frequently used term spanning the Aalenian/Bajocian

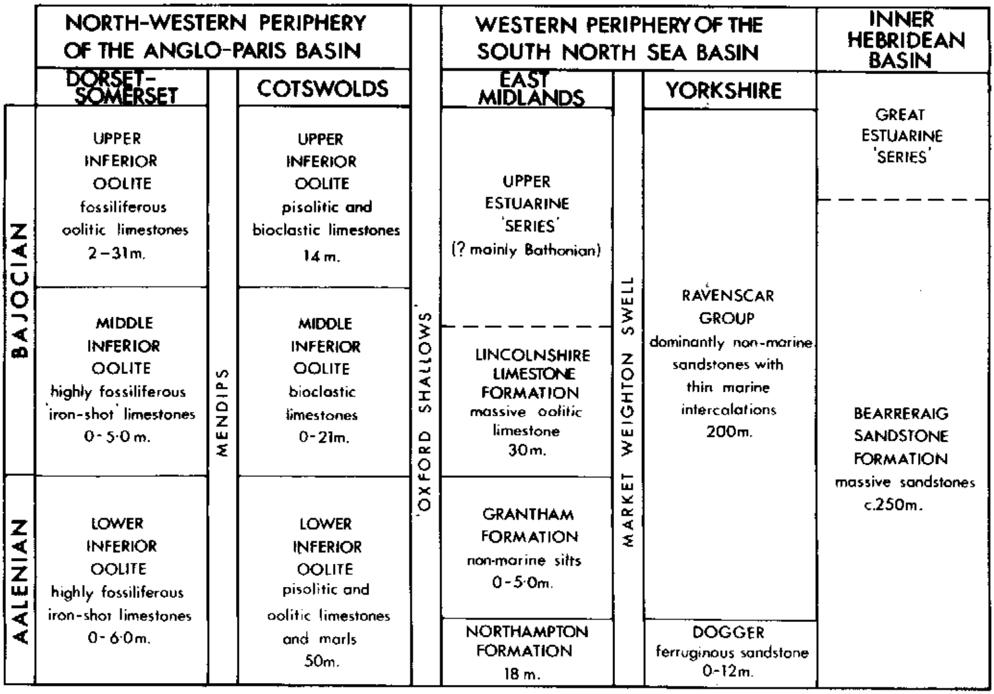


FIG. 1. The regional development of the Aalenian and Bajocian rocks of the British area.

is the Inferior Oolite Group or 'series'. As originally defined (Townsend 1813), the use of this name should be restricted to those rocks on the western periphery of the Hampshire/Weald basin.

The lithostratigraphical nomenclature used here for the Inferior Oolite Group is provisional, pending revision to bring it into line with current practice. Whilst it would be possible, when dealing with the thicker Cotswold Inferior Oolite, to apply a hierarchical classification of Formation and Member, considerable problems arise when one attempts to apply this method to the thin and lenticular Middle and Lower Inferior Oolite of Dorset and south Somerset. Herein an augmented modification of the existing informal nomenclature is used.

Zones

The present zonal scheme is relatively straightforward. That for the Upper Bajocian follows the suggestions of Pavia & Sturani (1968), as modified by Parsons (1976*a*, 1976*b*), the Lower Bajocian follows Parsons (1974*a*, 1976*b*), whilst the Aalenian essentially follows Contini *et al.* (1971).

Subzones

a. The subzones of the *parkinsoni* and *garantiana* Zones are to a certain extent provisional, as the stratigraphical distributions of their constituent ammonite faunas are still poorly known. This is particularly true of the *garantiana* Zone, where because of an extensive and widespread stratigraphical break, only the upper, *acris* Subzone has been well documented in Britain (Parsons 1976*a*, pp. 47–8), but it has now proved possible to recognize the *dichotoma*, *subgaranti* and *tetragona* subzones in north Dorset (Parsons *pers. obs.* 1977–78, see AB11 below). The use of *S.* (*Garantiana*) *subgaranti* (Wetzel) as a subzonal index was rejected by Pavia (1973), since he thought this taxon was exclusively *acris* Subzone in age; earlier records of it from lower horizons in the Basses-Alpes (Pavia & Sturani 1968) were based on misidentified specimens of *S.* (*G.*) *trauthi* (Bentz). However, *S.* (*G.*) *subgaranti* has an extended range through much of the *garantiana* Zone, including horizons now correlated with the *subgaranti* Subzone, in north Germany (Althoff 1928, pp. 7–8; Kumm 1952, pp. 390 & 430) and north Dorset, where it occurs together with *S.* (*G*). *trauthi* in the base of the 'Rubbly Beds', although ranging up into the *acris* Subzone. The latter in no way discredits its use as a subzonal index and the *subgaranti* Subzone (Pavia & Sturani 1968) has priority over the *trauthi* Subzone (Pavia 1973).

b. The recently erected *hebridica* Subzone of the *sauzei* Zone (Morton 1976) is not used here, as there are some doubts as to its validity. It may be the direct equivalent to the *sauzei* Zone *sensu stricto*, as defined in south Germany and Normandy (Parsons 1974*a*, pp. 158–9). The *sauzei* Zone has been recognized in Skye, north-west Scotland (the type area for the *hebridica* Subzone), almost exclusively on the basis of the presence of certain species of *Sonninia* (S.) and *S.* (*Papilliceras*) (Morton 1965, p. 198; 1975, p. 42; 1976, p. 28). Unfortunately sonniniid ammonites are notoriously unreliable as stratigraphical indices as they exhibit a high degree of morphological variation, extended stratigraphical ranges, and also suffer from a degree of 'facies control' (cf. Westermann 1954). It was because of these factors that the ammonite fauna used to define this zone was largely restricted to members of the Stephanoceratacea in a recent discussion and formal redefinition of the *sauzei* Zone (Parsons 1974*a*, p. 159). Since virtually no members of this characteristic fauna have been recorded from Skye, it is almost impossible to objectively define the limits of the *sauzei* Zone. In these circumstances it would seem to be an unsatisfactory region for formally defining new subzones of the *sauzei* Zone.

c. The use of the terms *formosum* and *gigantea* 'horizons' is a compromise; the faunas from these horizons are locally well defined, but there are doubts over their wider recognition, which at present prevents their acceptance as full subzones.

d. The use of *L.* (*L.*) *haugi* (Douvillé) as a subzonal index (Contini *et al.* 1971), may prove to be only an interim measure. Although the fauna from this horizon (=*Ancolioceras* hemera, Buckman 1910) is relatively well documented (Rieber 1963; Contini 1970), the interpretation and possible synonymy of many of its constituent taxa is still open to question. If the suggested synonymy (Contini 1969, pp. 27–8) of *Ancolioceras opalinoides* (Mayer) with various species of *Ancolioceras* described by Buckman is substantiated, then this taxon has priority as a replacement for *L.* (*L.*) *haugi* ('zone à *Harpoceras opalinoides*', Fabre 1894).

e. The *scissum* Subzone (Neumayr 1871) must have priority over the *comptum* and/or *bifidatum* Subzones (*contra* Contini *et al.* 1971). The fact that the genus *Tmetoceras* ranges beyond the *scissum* Subzone in no way rules out its use as a label for a subzonal fauna, of which it forms a common and highly characteristic element.

*AB*1. *Dorset*: *Burton Bradstock* (*SY* 483892) *and Stony Head cutting* (*SY* 496927)

Based on Gatrall *et al.* (1972), Parsons (1975*b*) and (Richardson (1928–30).

a. The Burton Limestone is a recent replacement (Parsons 1975*b*) for the 'Limestone beds' (Buckman 1910) or 'Top limestones' (Wilson *et al.* 1958).

b. The 'Red Conglomerate' is of *humphriesianum* Zone age at Stony Head, but at Burton Bradstock it has also yielded *subfurcatum* Zone ammonites (Gatrall *et al.* 1972).

c. The age of layer 'B' of the Red Beds is uncertain, as ammonites are rare at this horizon.

d. An impersistent conglomerate, the 'Yellow Conglomerate', is also locally found beneath the 'Snuff-box' bed, yielding derived fossils of *concavum* and *murchisonae* Zone age (Richardson 1928–30).

*AB*2. *Lyme Bay borehole*

This relatively thick offshore succession is based on a recent I.G.S. borehole (Penn *et al.* 1980).

*AB*3. *South Dorset*: *Chideock Quarry Hill* (*SY* 434931)

Based on Buckman (1910) and Richardson (1928–30).

a. There is no evidence of the Astarte Bed, and little or none for the presence of the Truellei Bed (Richardson 1928–30, p. 52).

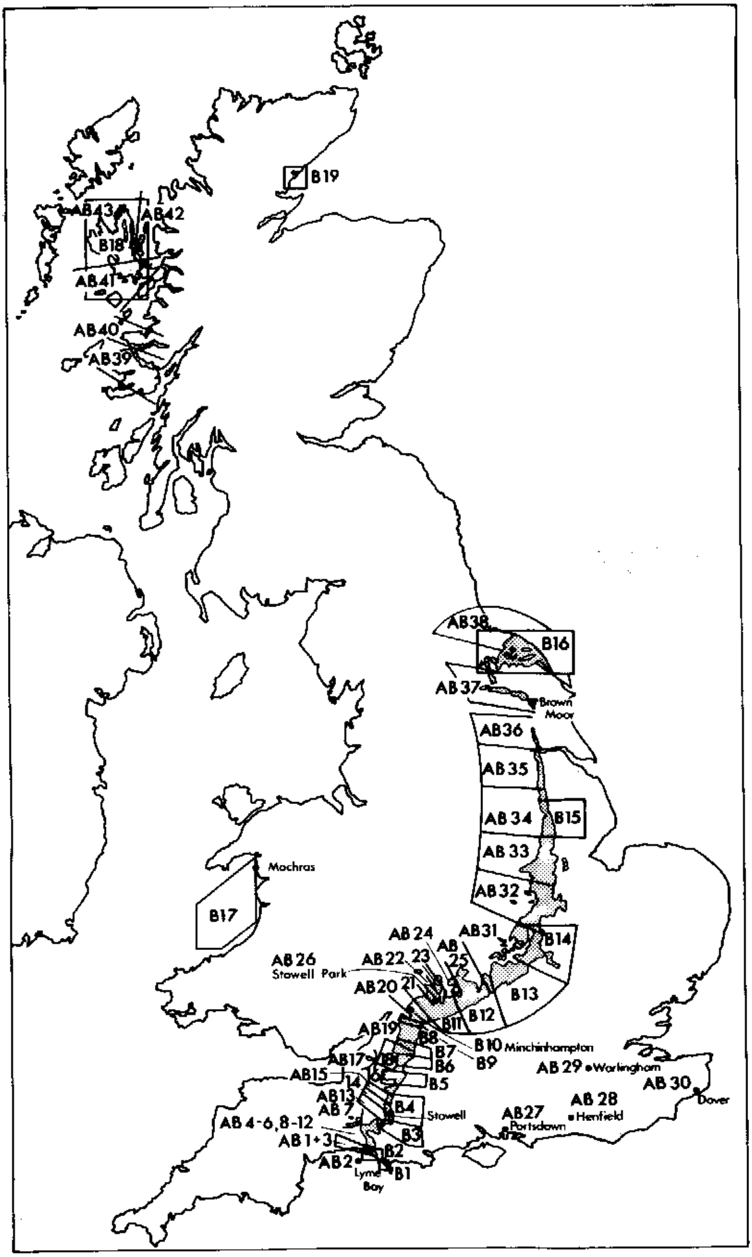


FIG. 2. Disposition of the columns on the Aalenian/Bajocian (AB) and Bathonian (B) correlation charts.

b. The term 'Wild Bed' was introduced by Buckman (1910, p. 60) for all the beds found between the base of the Red Beds and the top of the Scissum Beds.

*AB*4. *South Dorset*: *Waddon Hill* (*ST* 447015)

Based on Buckman (1910) Richardson (1928–30) and Parsons (unpublished).

a. The Building Stone is taken here to include the 'Waste' of Richardson (*op. cit.* p. 259). There is no evidence that any beds above this horizon are of *discites* Zone age; they are probably much younger.

b. The lower part of this succession is poorly dated owing to indifferent exposure.

*AB*5. *South Dorset*: *Horn Park Quarry* (*ST* 458022)

Based on Senior *et al.* (1970).

a. The **Horn Park Bed** is a new name for the richly fossiliferous 'iron-shot' beds (Senior *et al.* 1970, bed 5).

b. **Craterospongia Bed:** new name for the horizon rich in sponges (Senior *et al.* bed. 4).

c. The term Ancolioceras Bed originates from Richardson (1928–30, p. 41).

*AB*6. *South Somerset*: *Misterton*

Based on the Limeworks Quarry (ST 459074) and Ten-Acres-Field Quarry (ST 466074) described by Richardson (1919), whose names are used for the Lower Inferior Oolite. The correlation of the latter is uncertain, as few ammonites have been found. There is no real evidence for the thickness of the rocks of *scissum* and *opalinum* Subzone age. The Survey appear to have considered them absent (Wilson *et al.* 1958, p. 89), but this is contrary to Richardson's opinion (*op. cit.*). A similar thickness to that found in the nearby Crewkerne Railway-cutting (Richardson 1919, p. 159) is likely.

*AB*7. *South Somerset*: *Seavington St. Mary Quarry* (*ST* 898144)

Amended from Parsons & Torrens (*in* Torrens 1969*a*).

a. Bed 7 (Parsons & Torrens MS, 1969) has subsequently yielded a *humphriesianum* fauna, and is thus clearly the equivalent of the 'Irony Bed' to the east.

b. The term Bradford Abbas Bed derives from 'Bradford Abbas Fossil-Bed'—see below.

c. There is little evidence for the dating of the beds below the Bradford Abbas Bed.

*AB*8. *South Somerset*: *North Coker and Stoford*

Based on Richardson (1932, pp. 50–1 & 51–4) and Wilson *et al.* (1958, p. 93).

a. Crackment Limestones was White's (1923, p. 16) modification of Buckman's (1893, p. 486) term the 'Limestone Beds'.

b. The term Halfway-House Bed is a modification of 'Halfway-House Fossil-Bed' (Buckman 1893, p. 487).

c. Cirrus Bed is a reflection of the common gastropods found at this horizon

(Richardson 1932, p. 44). It is likely that the *murchisonae* Subzone beds rest directly on the *levesquei* Zone 'Dew Bed', as at Bradford Abbas, but there is some doubt as to the exact age of the Cirrus Bed, as ammonites are rare and the stratigraphical gap below may not be as great as at Bradford Abbas.

*AB*9. *South Somerset: Yeovil Railway cutting* (*ST* 575142)

Based on Parsons (unpublished) and Wilson *et al.* (1958). The Inferior Oolite is here extremely attenuated. The Halfway-House Bed may be present in close association with the Astarte Bed, but if so, it is represented by a more ferruginous facies than that to the east.

*AB*10. *North Dorset: Bradford Abbas Railway-cutting* (*ST* 594145)

Based on an unpublished section (Parsons MS & 1974*a*, pp. 169–71) and similar to that at the nearby East Hill Quarry (Buckman 1893, p. 485).

a. The Marl Bed is the name given to the result of the local deep weathering of the Astarte Bed (*loc. cit.*).

b. The Irony Bed (Buckman 1893) is a thin, highly condensed, ferruginous limestone found sporadically west of Sherborne. It has yielded ammonites of *discites* to *subfurcatum* Zones (Gatrall *et al.* 1972, p. 83), but here belongs predominantly to the *sauzei* Zone (cf. Buckman 1893, p. 485; 1909–30, pl. 557).

c. The Bradford Abbas Bed is here based on Buckman's use of Bradford Abbas 'Fossil-bed' (Buckman 1893, p. 485), for the highly fossiliferous 'iron-shot' limestone characteristic of this district.

d. The *bradfordensis* Subzone age is based on Buckman's ammonite records (1893).

e. The Paving Bed (Buckman 1893) is here extended so as to include all the very similar limestones between the Bradford Abbas Bed and the *moorei* Subzone, Dew Bed.

*AB*11. *North Dorset: Sandford Lane Quarry* (*ST* 628179)

Based on Buckman (1893) and Parsons (1974*a*, pp. 164–8).

a. Rubbly Beds and Sherborne Building Stone originate from Buckman (1893, pp. 497, 507). Recent collecting from the Rubbly Beds (*pers. obs.* 1977–8), has revealed the presence of extensive *garantiana* Zone ammonite faunas. Bed 1 (Richardson 1932, p. 74) has yielded *acris* and *tetragona* Subzone faunas, and bed 3 (*op. cit.*) a *subgaranti* fauna. Rare specimens of *S.* (*Pseudogarantiana*) *dichotoma* (Bentz) (e.g. BM C80969, ex.S.S.B.), from the 'Building-stone', suggest a correlation with the *dichotoma* Subzone.

b. The term Sandford Bed is derived from Buckman's (1893, p. 493) Sandford Lane 'Fossil-bed'.

c. A temporary exposure (1970) showed the presence of *murchisonae* Subzone beds in a similar sandy limestone facies to that of the *concavum* Zone. Unfortunately, due to lack of exposure, there is no evidence available to date the other beds found below the latter horizon.

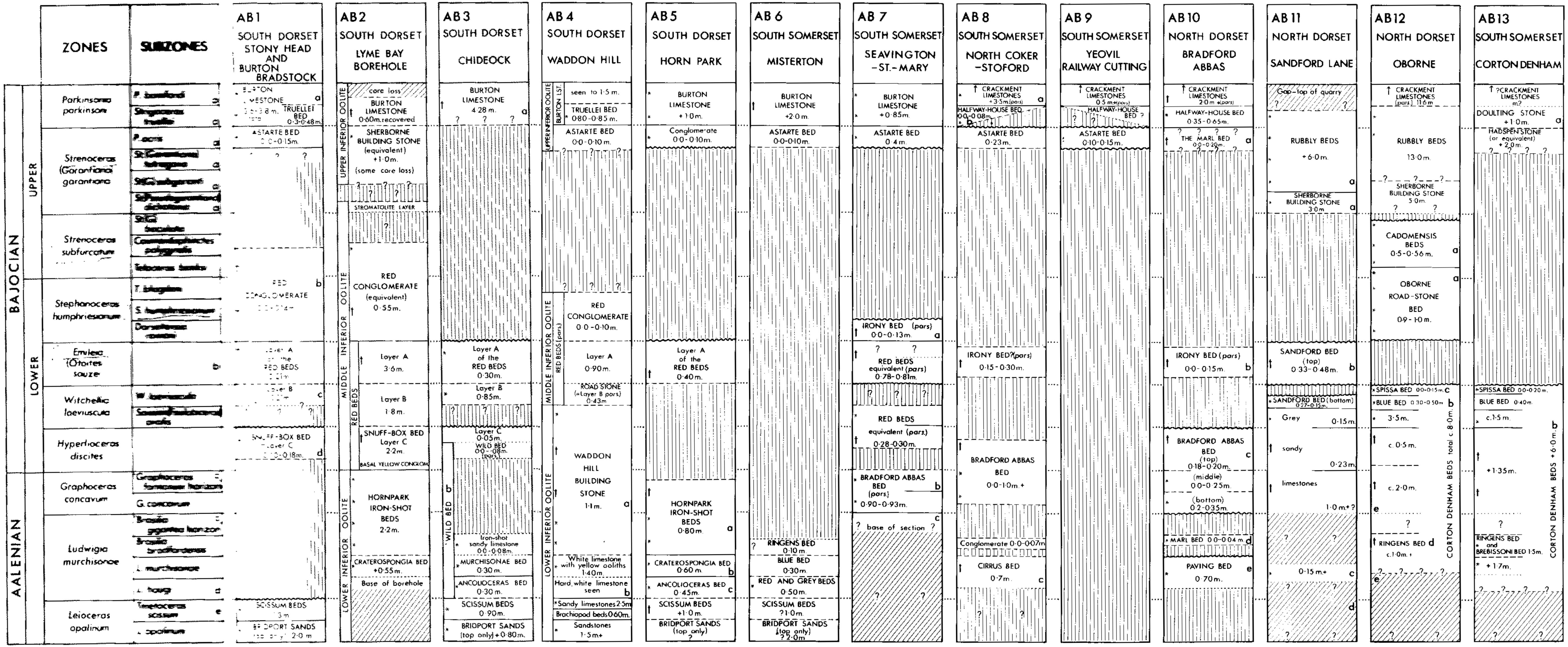
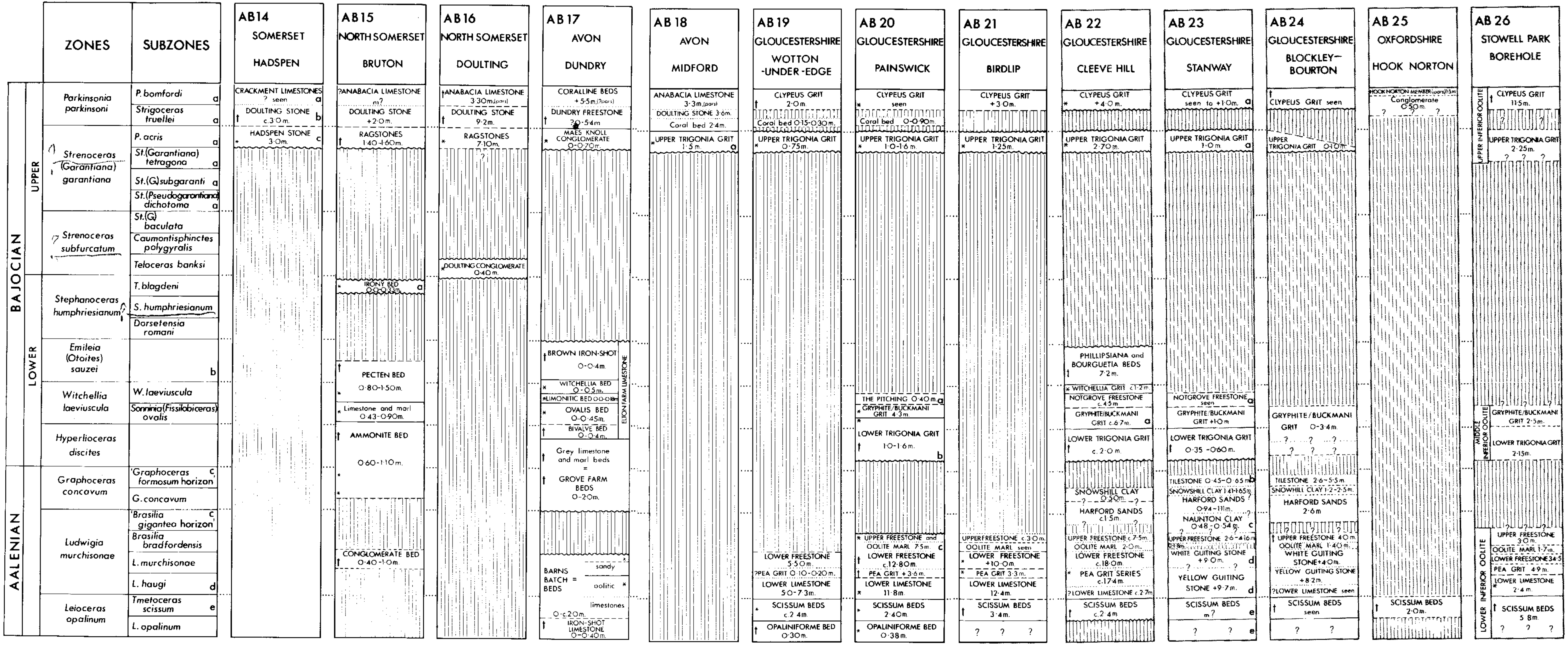


Fig. 3a. Correlation of Aalenian/Bajocian rocks. Columns AB1–AB13.



ZONES
SUBZONES
BAJOCIAN
AALENIAN
UPPER
LOWER
Parkinsonia parkinsoni
P. bomfordi
Strigoceras truellei
Strenoceras (Garantiana) garantiana
P. acris
St.(Garantiana) tetragona
St.(G.) subgaranti
St.(Pseudogarantiana) dichotoma
Strenoceras subfurcatum
St.(G.) baculata
Caumontisphinctes polygyralis
Teloceras banksi
Stephanoceras humphriesianum
T. blagdeni
S. humphriesianum
Dorsetensia romani
Emileia (Otoites) sauzei
Witchellia laeviuscula
W. laeviuscula
Sonninia (Fissilobiceras) ovalis
Hyperlioceras discites
Graphoceras concavum
'Graphoceras formosum horizon'
G. concavum
Ludwigia murchisonae
'Brasilia gigantea horizon'
Brasilia bradfordensis
L. murchisonae
L. haugi
Leioceras opalinum
Tmetoceras scissum
L. opalinum
AB 14 SOMERSET HADSPEN
CRACKMENT LIMESTONES ? seen
DOULTING STONE c.3·0m.
HADSPEN STONE 3·0m.
AB 15 NORTH SOMERSET BRUTON
?ANABACIA LIMESTONE m?
DOULTING STONE +2·0m.
RAGSTONES 1·40-1·60m.
IRONY BED 0·0-0·23m.
PECTEN BED 0·80-1·50m.
Limestone and marl 0·43-0·90m.
AMMONITE BED 0·60-1·10m.
CONGLOMERATE BED 0·40-1·0m.
AB 16 NORTH SOMERSET DOULTING
ANABACIA LIMESTONE 3·30m.(pars)
DOULTING STONE 9·2m.
RAGSTONES 7·10m.
DOULTING CONGLOMERATE 0·40m.
AB 17 AVON DUNDRY
CORALLINE BEDS +5·5m.(pars)
DUNDRY FREESTONE 2·0-5·4m.
MAES KNOLL CONGLOMERATE 0-0·70m.
BROWN IRON-SHOT 0-0·4m.
WITCHELLIA BED 0-0·5m.
LIMONITIC BED 0·0-0·18m.
OVALIS BED 0-0·45m.
BIVALVE BED 0-0·4m.
ELTON FARM LIMESTONE
Grey limestone and marl beds = GROVE FARM BEDS 0-2·0m.
BARNS BATCH = BEDS
sandy
oolitic
limestones
0-c.2·0m.
IRON-SHOT LIMESTONE 0-0·40m.
AB 18 AVON MIDFORD
ANABACIA LIMESTONE 3·3m.(pars)
DOULTING STONE 3·6m.
Coral bed 2·4m.
UPPER TRIGONIA GRIT 1·5m.
AB 19 GLOUCESTERSHIRE WOTTON-UNDER-EDGE
CLYPEUS GRIT 2·0m.
Coral bed 0·15-0·30m.
UPPER TRIGONIA GRIT 0·75m.
LOWER FREESTONE 5·50m.
?PEA GRIT 0·10-0·20m.
LOWER LIMESTONE 5·0-7·3m.
SCISSUM BEDS c.2·4m.
OPALINIFORME BED 0·30m.
AB 20 GLOUCESTERSHIRE PAINSWICK
CLYPEUS GRIT seen
Coral bed 0-0·90m.
UPPER TRIGONIA GRIT 1·0-1·6m.
THE PITCHING 0·40m.
GRYPHITE/BUCKMANI GRIT 4·3m.
LOWER TRIGONIA GRIT 1·0-1·6m.
UPPER FREESTONE and OOLITE MARL 7·5m.
LOWER FREESTONE c.12·80m.
PEA GRIT +3·6m.
LOWER LIMESTONE 11·8m.
SCISSUM BEDS 2·40m.
OPALINIFORME BED 0·38m.
AB 21 GLOUCESTERSHIRE BIRDLIP
CLYPEUS GRIT +3·0m.
UPPER TRIGONIA GRIT 1·25m.
UPPER FREESTONE c.3·0m.
OOLITE MARL seen
LOWER FREESTONE +10·0m.
PEA GRIT 3·3m.
LOWER LIMESTONE 12·4m.
SCISSUM BEDS 3·4m.
AB 22 GLOUCESTERSHIRE CLEEVE HILL
CLYPEUS GRIT +4·0m.
UPPER TRIGONIA GRIT 2·70m.
PHILLIPSIANA and BOURGUETIA BEDS 7·2m.
WITCHELLIA GRIT c.1·2m.
NOTGROVE FREESTONE c.4·5m.
GRYPHITE/BUCKMANI GRIT c.6·7m.
LOWER TRIGONIA GRIT c.2·0m.
SNOWSHILL CLAY 0·50m.
HARFORD SANDS c.1·5m.
UPPER FREESTONE c.7·5m.
OOLITE MARL 2·0m.
LOWER FREESTONE c.18·0m.
PEA GRIT SERIES c.17·4m.
?LOWER LIMESTONE c.2·7m.
SCISSUM BEDS c.2·4m.
AB 23 GLOUCESTERSHIRE STANWAY
CLYPEUS GRIT seen to +1·0m.
UPPER TRIGONIA GRIT 1·0m.
NOTGROVE FREESTONE seen
GRYPHITE/BUCKMANI GRIT +1·0m.
LOWER TRIGONIA GRIT 0·35-0·60m.
TILESTONE 0·45-0·65m.
SNOWSHILL CLAY 1·41-1·65m.
HARFORD SANDS 0·94-1·11m.
NAUNTON CLAY 0·48-0·54m.
UPPER FREESTONE 2·6-4·16m.
WHITE GUITING STONE +9·0m.
YELLOW GUITING STONE +9·7m.
SCISSUM BEDS m?
AB 24 GLOUCESTERSHIRE BLOCKLEY-BOURTON
CLYPEUS GRIT seen
UPPER TRIGONIA GRIT 0-1·0m.
GRYPHITE/BUCKMANI GRIT 0-3·4m.
TILESTONE 2·6-5·5m.
SNOWHILL CLAY 1·2-2·5m.
HARFORD SANDS 2·6m.
UPPER FREESTONE 4·0m.
OOLITE MARL 1·40m.
WHITE GUITING STONE +4·0m.
YELLOW GUITING STONE +8·2m.
?LOWER LIMESTONE seen
SCISSUM BEDS seen
AB 25 OXFORDSHIRE HOOK NORTON
HOOK NORTON MEMBER (pars)
Conglomerate 0·50m.
SCISSUM BEDS 2·0m.
AB 26 STOWELL PARK BOREHOLE
UPPER INFERIOR OOLITE
CLYPEUS GRIT 11·5m.
UPPER TRIGONIA GRIT 2·25m.
MIDDLE INFERIOR OOLITE
GRYPHITE/BUCKMANI GRIT 2·5m.
LOWER TRIGONIA GRIT 2·15m.
LOWER INFERIOR OOLITE
UPPER FREESTONE 3·0m.
OOLITE MARL 1·7m.
LOWER FREESTONE 34·5
PEA GRIT 4·9m.
LOWER LIMESTONE 2·4m.
SCISSUM BEDS 5·8m.

d. It is likely that the *haugi* and *scissum* Subzones are represented in this area, although not exposed, as they were recorded at the nearby now defunct Marston Road Quarry (ST 619182, Richardson 1932, pp. 70–1).

*AB*12. *North Dorset: Oborne*

Based on Frogden Quarry (ST 648183) (Buckman 1893, p. 500), Oborne Wood (ST 648188) (Parsons 1976*b*) and the Oborne Borehole (Wilson *et al.* 1958, pp. 96–7). The details of the succession down to the base of the *discites* Zone are taken from the surface exposures, below this from the borehole.

a. Oborne Road-stone is used here in a more restricted sense than by Buckman (1893, p. 507), since it excludes the Cadomensis Beds (Hudleston 1886, p. 193).

b. The **Corton Denham Beds** (type section: Holway Hill, ST 638211) are proposed herein for the 'grey-beds' of Richardson (1932, p. 81).

c. Spissa Bed is a modification of Richardson's (1916, p. 513) use of *Astarte spissa* bed for Buckman's (1893, p. 500, bed 9) 'green-grained marl'.

d. The Ringens Bed originates from Buckman (1893, p. 491).

e. There are two horizons which are difficult to correlate in the borehole. First it is impossible at present to determine the base of the *concavum* Zone and second it is impossible to date the base of the Corton Denham Beds, as there is a gap in the cores.

*AB*13. *South Somerset: Corton Denham*

Based on Richardson's (1916) Corton Down (ST 643228 & 647230) and Charlton Horethorne (ST 662237) sections.

a. The Upper Inferior Oolite is similar to that further north, since it is represented by Doulting Stone (Woodward 1894) and Hadspen Stone (Richardson 1916, pp. 486, 510). The Crackment Limestones are probably present, although unexposed, as they occur just to the north (see Hadspen section, AB14).

b. This is the type area for the Corton Denham Beds; good sections can be seen at ST 642215 and 639227. All Richardson's localities, bar Holway Hill, are now obscured. The Corton Denham Beds succession appears essentially similar to that recorded at Oborne (Wilson *et al.* 1958, p. 97). One extra horizon has been recognized; the Brebissoni Bed—a modification of Richardson's (1916, p. 480) *Pseudoglossothyris brebissoni* bed; but again there are doubts about the age of the basal Corton Denham Beds, this time due to lack of exposure.

*AB*14. *Somerset: Hadspen*

Based on Richardson (1916) (mainly Horsecombe Bottom Quarry, ST 656316) and Parsons (*pers. obs.* 1968–77).

a. The highest beds seen in the area at Grisway Quarry (ST 651310) could either be Anabacia Limestones or Crackment Limestones, although there is no ammonite evidence for their correlation (Richardson 1916, p. 506).

b. The Doulting Beds are over 1.5 m thick, and probably reach *c.* 3.0 m (cf. further south at Blackford, ST 661252: Richardson 1916, p. 510).

c. The Hadspen Stone section, which is complete (Richardson 1916, p. 505), has yielded a sparse *acris* Subzone ammonite fauna, but the rest of the succession has had to be pieced together from different sections.

*AB*15. *Somerset: Bruton*

Based on Richardson (1916)—Lusty Quarry (ST 679345, *op. cit.* p. 496), Lusty Railway-cutting (ST 682345) and Sunny-Hill Quarry (ST 672337; *op. cit.* pp. 497–8), with amended correlations based on new ammonite collections (Parsons 1979 & *pers. obs.*, 1968–73).

a. The hard ferruginous limestone, which has yielded *Teloceras* (Richardson 1916, p. 496), is extremely similar to the Irony Bed found to the south.

All other lithostratigraphical terms originate from Richardson (1916, p. 495).

*AB*16. *Somerset: Doulting Railway-cutting* (*ST* 646424)

Based on Richardson (1907, p. 390), with some changes in the correlations based on the work of Torrens (1969*b*) and Parsons (1975*a*).

*AB*17. *Avon: Dundry Hill*

Based on Buckman & Wilson (1896) and Parsons (1974*a*, 1979).

The section above the Brown Iron-shot is based on Towle's Quarry (ST 556668), between the Ovalis Bed and Brown Iron-shot Bed on the South Main-road Quarry (ST 567655), and below the Ovalis Bed on the Castle Farm exposure (ST 549670). Many of the lithostratigraphical terms, particularly for the Upper Inferior Oolite, originate from Buckman & Wilson (1896), including the Witchellia Bed, rather than the misleading 'Upper White Iron-shot'. Other informal beds within the Elton Farm Member (Parsons 1979) include the Limonitic Bed (= bed 8, Buckman & Wilson 1896, p. 681), Ovalis Bed (Parsons 1977*a* = 'Lower White Iron-shot'), and Bivalve Bed (=beds 3–4, Buckman & Wilson 1896, p. 689), whilst the 'Grey Limestone and marl beds' (*op. cit.* tab. iv), and the 'Hard, irony beds' (*loc. cit.*) have been redefined formally as the Grove Farm and Barns Batch Members respectively (Parsons 1979).

*AB*18. *Avon: Midford Road-cutting* (*ST* 759606)

Based on Richardson (1907, p. 407, tab. II).

a. Ammonites have been found only locally in the bed called the 'Upper Trigonia Grit' (Richardson 1910*a*), and correlation above this horizon is rather conjectural. Richardson (*op. cit.*) correlated the coral-rich horizon with the Upper Coral Bed of the mid Cotswolds (Witchell 1882), but there is no reliable biostratigraphical evidence for this, and it may be that the coral horizons around Midford are merely a local development of the Doulting Stone.

*AB*19. *Gloucestershire: Wotton-under-Edge*

Based on Richardson (1910*b*, pp. 103–5) in sections at Coombe Hill (ST 767943) and Wotton Hill (ST 753939 & 753937). Ammonites are known here from the Opaliniforme Bed, Upper Trigonia Grit and 'Upper Coral Bed'. Unfortunately the

Lissoceras psilodiscum recorded from the latter (Reading University, Geological collections, J523; Richardson 1910*b*, p. 86) is not as stratigraphically diagnostic as Richardson and Buckman believed, as this species is not restricted to the *truellei* Subzone. Apart from the Opaliniforme Bed (Richardson 1910*b*, p. 81), the other lithostratigraphical units are based on horizons recognized in the mid- and north-Cotswolds. The origins of these and other relevant horizons are given in the Cleeve Hill section (AB22).

*AB*20. *Gloucestershire: Painswick*

Based on Buckman (1895)—Swifts Hill Quarry (SO 878067) and Frith Quarry (SO 868083) with additional details from Kimsbury Castle; Richardson & Thacker (1920)—Worgan's quarry (SO 869076); Richardson (1904)—Haresfield Beacon (SO 820088).

a. The term 'Pitching' for the highly bored equivalent of the Notgrove Freestone originates from Buckman (1893, p. 512).

b. The Lower Trigonia Grit of the Painswick area has yielded an extensive, although poorly localized, *discites* Zone ammonite fauna, particularly from the Frith Quarry (Buckman 1895, p. 392). The precise horizon of this fauna has been confirmed by the location of a specimen of *Hyperlioceras* cf *rudidiscites* Buckman from bed 8, Frith Quarry (*op. cit.* p. 399). However, the topmost part of the Lower Trigonia Grit has locally yielded a basal *ovalis* Subzone fauna, including *Sonninia* (*Fissilobiceras*) aff. *fissilobata* (Waagen) from Frith Quarry (*loc. cit.*, bed 7) and *S.* (*Euhoploceras*) *acanthera* (Buckman) from Frampton Mansell railway-cutting.

c. Existing evidence for the presence of the *bradfordensis* Subzone in the Cotswolds consists primarily of poorly localized ammonites from the Frith Quarry (Buckman 1895, p. 392; Richardson 1904, pp. 230–1) and is largely unconvincing. Some confirmation has been provided by the recent rediscovery of *Brasilia* cf. *bradfordensis* and *B.* aff. *baylii* (Buckman) from bed 20, Frith Quarry (Buckman 1895, p. 400). It should be stressed that these specimens are not identical to those from the typical *bradfordensis* Subzone faunas of Dorset (e.g. Horn Park, AB5), and that they do not necessarily support a precise correlation with these beds.

*AB*21. *Gloucestershire: Birdlip*

Based particularly on the exposure near the Royal George Hotel (SO 926145) (Ager 1956). because of poor exposure thicknesses of beds below the Lower Freestone are taken from the nearest complete section (Crickley Hill, SO 931160; Ager, p. B41, *in* Torrens 1969*a*).

*AB*22. *Gloucestershire: Cleeve Hill*

Based on Richardson's (1929, p. 46) composite record of exposures around Rolling Bank Quarry (SO 987267). This area has the thickest and most complete Inferior Oolite sequence in the Cotswolds and thus the origins of the various lithostratigraphical terms are given here; the relative abundance of ammonites in each unit is a good measure of the reliability of its correlation (see Table 1).

TABLE 1. Lithostratigraphical units and relative frequency of ammonites in the Inferior Oolite of the Cotswold Hills.

Lithostratigraphical unit	Author	*Ammonite frequency	Recent reference to ammonite fauna
Clypeus Grit	Hull 1857	numerous	Parsons 1976*a*
Upper Trigonia Grit	Wright 1860	common	Parsons 1976*a*
Phillipsiana Beds & Bourguetia Beds	Buckman 1895 Buckman 1897	common	
Witchelia Grit	Buckman 1895	numerous	
Notgrove Freestone	Buckman 1888	extremely rare	
Gryphite Grit	Murchison 1834	occasional	Parsons 1976*a*
Buckmani Grit	Buckman 1895	occasional	Parsons 1976*a*
Lower Trigonia Grit	Wright 1860	common	Parsons 1976*a*
Snowshill Clay	Buckman 1897	none known	
Harford Sands	Buckman 1888	none known	
Upper Freestone	Hull 1857	rare	Baker 1974
Oolite Marl	J. Buckman 1842	very rare	
Lower Freestone	Hull 1857	rare	
Pea Grit	Murchison 1834	occasional	Mudge 1978
Lower Limestone	Witchell 1886	very rare	Green & Melville 1956
Scissum Beds	Richardson 1904	fairly common	Mudge 1978

* All ammonites are rare in the Cotswolds' Inferior Oolite and the frequencies listed here are relative to each other.

Mudge (1978) has introduced new lithostratigraphical units in a stratigraphic work on the Cotswold Lower Inferior Oolite, but much of his terminology contravenes the recommendations of the Geological Society of London (Holland *et al.* 1978, pp. 11–2), relating to the maintenance of long-established stratigraphical nomenclature. Thus his Devil's Chimney Oolite is largely a re-definition of the Lower Freestone, the Leckhampton Limestone is the equivalent of the Scissum Beds and the Frocester Hill Oolite is synonymous with the Lower Limestone *sensu stricto.* Another problem relates to the Crickley Limestone–Cleeve Hill Oolite sequence, which is exactly equivalent to the Pea Grit 'series' at Cleeve Hill (Richardson 1929); Mudge's terminology confuses the essential lithological homogeneity of these beds, evident in much of the Cotswolds. His Jackdaw Quarry Oolite and Crickley Oncolite are respectively the equivalents of the Guiting Stone (Richardson 1929) and the Pea Grit *sensu stricto.* A solution to these problems may be to re-define the Pea Grit 'series' as a formal Member, and where necessary utilize Mudge's units as formal beds. The Scottsquar Hill Limestone is the single most useful element of his terminology. This is the equivalent of the Oolite Marl 'series', as defined by Buckman (1893), where the Oolite Marl and Upper Freestone cannot be separated.

a. The Gryphite Grit and Buckmani Grit have yielded enough ammonites elsewhere to show that they are dominantly *ovalis* Subzone, *laeviuscula* Zone in age, although in the north Cotswolds the basal part of these beds has yielded *discites* Zone forms (Parsons 1976*a*).

*AB*23. *Gloucestershire: Stanway Hill*

Based on Jackdaw Quarry (Parsons 1976*a*; SP 078310).

a. The records of the Clypeus Grit, Upper Trigonia Grit, and Notgrove Freestone are based on Richardson's (1929, p. 61) section at Oat Hill (SP 096335).

b. The Tilestone (Buckman 1901) is relatively unfossiliferous, but it has yielded one ammonite from Harford cutting (SP 134218; Parsons 1976*a*).

c. The Naunton Clay (Richardson 1929) has produced no ammonites.

d. The White and Yellow Guiting Stones are local facies of the Lower Freestone and Pea Grit/Lower Limestone respectively (Richardson 1929).

e. Due to lack of exposure the thickness of the beds below the Yellow Guiting Stone is not known.

*AB*24. *Gloucestershire: Blockley and Bourton*

This is a composite succession based on Blockley Road Quarry (SP 138354; Richardson 1929, p. 66) for the Clypeus to Gryphite Grits; the Road-stone Quarry, Bourton-on-the-Hill (SP 1632; *op. cit.*, p. 69), Clypeus Grit to Harford Sands; Five-mile-drive Quarry (SP 134357; *op cit.*, p. 67), White and Yellow Guiting Stones; and Bourton Hill House (SP 152325; *op. cit.*, p. 70), ?Lower Limestone and Scissum Beds. The correlation of the beds included by Richardson (1929, p. 67) in the Buckmani Grit is doubtful. The Lower Trigonia Grit thickens in the north Cotswolds, and the bulk of it becomes indistinguishable from the beds above (e.g. Jackdaw Quarry).

*AB*25. *Oxfordshire: Hook Norton railway-cutting* (*SP* 360321)

Based on Richardson (1911*a*, p. 213) and Horton (1977). Apart from the *scissum* beds, the only representatives of Aalenian/Bajocian rocks in this section are the conglomerate and coral bed (Richardson 1911*a*, bed 22), which are doubtfully to be correlated with the *bomfordi* Subzone. The very base of the overlying Hook Norton Member (Sellwood & McKerrow 1974, p. 191) is possibly also of this age (Arkell 1951–8, p. 162).

*AB*26. *Gloucestershire: Stowell Park borehole* (*SP* 084118)

Based on Green, *in* Green & Melville (1956, pp. 36–8). Ammonites were recovered from the Clypeus Grit, Scissum Beds and Lower Limestone, whilst the other correlations are based on the brachiopod faunas and lithological comparisons with the nearby surface outcrops.

*AB*27. *Hampshire: Portsdown borehole*

Based on Taitt & Kent (1958, p. 29). The correlation of the Upper Inferior Oolite is based on the brachiopod faunas, whilst the ammonites and brachiopods from the lower beds suggest that they span the *concavum* and *murchisonae* Zones, with probably no breaks. The Middle Inferior Oolite sequence is very difficult to date, although the presence of cherts towards the middle suggests a possible correlation with the Malière of Normandy, which is also chert bearing, and which spans the *sauzei*/*murchisonae* Zones.

*AB*28. *Sussex: Henfield borehole*

Based on Taitt & Kent (1958, p. 30). The correlation of the Upper Inferior Oolite (the only part cored) is based on the brachiopod faunas. The correlation of the rest of the sequence is thus open to a variety of interpretations. That suggested here is based on lithological comparisons with other boreholes, and the surface outcrops in the Cotswolds. In terms of relative stratigraphical position and lithology, it is possible that the 'ragstones' and white oolitic limestones are the equivalent of the Cotswold Bourguetia and Phillipsiana Beds and Notgrove Freestone respectively, whilst the ferruginous limestone is probably the equivalent of the Lower Trigonia Grit. In this case it is possible that there is a stratigraphical break between these two sets of beds, marking the absence of the Gryphite/Buckmani Grit. The oolitic marl and limestones are probably the equivalent of the Upper Freestone and Oolite Marl, whilst the subjacent sandy beds are at a similar horizon to the cross-bedded sands at Portsdown.

*AB*29. *Surrey: Warlingham borehole*

Based on Worssam & Ivimey-Cook (1971, pp. 45–7, 85–6). The correlations suggested by the latter authors are provisionally accepted here, although they are based almost entirely on the brachiopod faunas, together with lithological comparisons with the Cotswold Inferior Oolite.

*AB*30. *Kent: Dover, 'No.* 3 *shaft'* (*TR* 296394)

Based on Lamplugh & Kitchin (1911, p. 30); Lamplugh *et al.* (1923, p. 21). The correlation of these beds is very uncertain, since it is almost entirely based on the bivalve faunas.

*AB*31. *Northamptonshire: Duston*

Based on two sections in the old iron-stone workings at Duston (SP 725605; Richardson 1926, p. 149) and New Duston (SP 714627; *op. cit.*, p. 146).

a. The distinction between the Grantham Formation (Kent 1975, p. 306, =Lower 'Estuarine Series') and the Upper 'Estuarine Series' (Judd 1875) has been confused by the previous records of 'White sands' (Richardson 1926, p. 140). Sylvester-Bradley (*in* Sylvester-Bradley & Ford 1968, p. 217) suggested that these sands are local developments, which occur at several different horizons. Although they are probably mainly of Bajocian age in Oxfordshire (Horton 1977), the distinction between the various different sand horizons is often rather arbitrary, and in this case relatively unimportant as no ammonites have been found to date them.

b. The Variable Beds (Sharp 1870) have yielded rare ammonites (Richardson 1926, p. 148; Buckman 1909–30, pl. 787) which could indicate the *haugi* Subzone; this would suggest that they are younger than the bulk of the Northampton Ironstone (Wedd 1920), which has produced *scissum* Subzone faunas (Hollingsworth & Taylor 1951, p. 14).

*AB*32. *Northamptonshire: Geddington Iron-stone workings* (*SP* 867824)

Based on Barker & Torrens (1971) and Aslin (*in* Sylvester-Bradley & Ford 1968,

p. 259). The ammonite from the Lower Lincolnshire Limestone (Barker & Torrens 1971) is a strong indication for a correlation with the upper *concavum* or *discites* Zones.

*AB*33. *Lincolnshire: Castle Bytham/Greetham District* (SK 990180–933146)

Based on Ashton (1977 & *pers. comm.*, 1976), Hollingsworth & Taylor (1951) and Kent (1966, 1968 *in* Sylvester-Bradley & Ford). The lithostratigraphical terminology for the Lincolnshire Limestone is in the process of revision and, as an interim measure, the present account essentially follows Kent (1966).

a. The Great Ponton Beds (=Great Ponton Gastropod & Terebratula Beds, Kent 1966, p. 65) have brachiopod and gastropod faunas apparently of Upper Bajocian affinities (Richardson 1939*b*, p. 471; Kent 1941, p. 50; Kent 1966, p. 68). However, palynological data suggests that there is little evidence to support a post-*humphriesianum* Zone age for any part of the Lincolnshire Limestone (J. Fenton *pers. comm.* 1978).

b. Ammonites from the Lincolnshire Limestone here include *Euhoploceras* cf. *polyacantha* (Waagen) (Judd 1875; GSM IGS. 25604) from Little Bytham, which suggests that at least part of the Lower Lincolnshire Limestone is of *discites* Zone age; whilst specimens of *Sonninia* (*Fissilobiceras*) cf. *ovalis* (Buckman *ex*. Qu. from the Lower part of the Upper Lincolnshire Limestone at Castle Bytham (BM C39337, C48800–1) are *laeviuscula* Zone, *ovalis* Subzone in age (Parsons 1974*b*). Finally the ?*Hyperlioceras* sp. from *c*. 5 m above the *crossi*-beds at Castle Bytham (Kent 1966, p. 68) has proved to be *Shirbuirnia* cf. *fastigata* Buckman (BM. C47900), a sure indication of the *laeviuscula* Zone and Subzone.

c. The possible stratigraphical break above the Blue Beds marks the absence of the marl beds at Greetwell (=?Hydraulic Limestone, see below, p. 16), although it may only indicate a lateral facies change rather than a gap.

d. The Collyweston Slate (Ibbetson & Morris 1848) is here considered to represent a lateral facies variation within the Blue Beds (Sylvester-Bradley *in* Sylvester-Bradley & Ford 1968, p. 220).

e. The age of the Northampton Formation is confirmed by a specimen of *Lioceras* from Harlaxton (SK 895311; Kent 1975, p. 314).

*AB*34. *Lincolnshire: The Lincoln District*

This section is based on the Greetwell Hollow Quarry (TF 003720), which is essentially the same exposure described at the 'Bowling Green Quarry', Wragby road (Richardson 1940, p. 248), with a few additional details from the Greetwell railway cutting (TF 010716; Evans 1952, fig. 3). The lithostratigraphical nomenclature follows Richardson (*loc. cit.*).

a. Ammonites of *discites* Zone age have been recovered from the Silver Beds (Kent & Baker 1938) and from the lower part of the Kirton Cementstones (Kent 1966, p. 67). It is likely that as at Leadenham (SK 962523; Ashton 1977), the *discites*/*laeviuscula* Zonal boundary falls within the Kirton Cementstones. Correlation of much of the rest of the sequence is problematic.

b. Recent extensive gas-pipe trenches have revealed sections which suggest that the Hydraulic Limestone of Humberside (cf. Kirton, col. 35) may be equivalent to the marl beds found between the Blue and Silver Beds (Kent *pers. comm.* 1976) rather than to those below the Blue Beds, as has been previously suggested (Kent 1966, fig. 1).

AB35. Humberside: Kirton

Based on the Manton Stone Quarry (SE 940024) (Ashton 1975), Kirton Limeworks (SE 945015) (Richardson 1940) and Mount Pleasant (SE 936006) (Ussher 1890). The lithostratigraphical subdivisions of the Lincolnshire Limestone apart from Hibaldstow Beds (Ussher 1890), follow Ashton (1975)

a. A single specimen of *Hyperlioceras* from the 'Cement Works' (Scunthorpe Museum, 352) suggests that at least part of the Cementstones is of *discites* Zone age.

b. There is a possibility that the Raventhorpe Member marks an influx of clastic material which approximately coincides in stratigraphical position with the Sycarham Beds of the Yorkshire coast (AB38).

c. The record of a typical Dogger fauna, with strong Yorkshire affinities, from near Brigg (Kent 1968) would indicate that the Dogger/Northampton Formations were once a continuous deposit along the western part of the southern North Sea basin, which has subsequently been removed from the Market Weighton district by intra-Bajocian erosion (Kent 1968, p. 29).

AB36. Humberside: South Cave

Based on Bate (1967*a*, pp. 124–5) and de Boer *et al.* (1958).

a. Detailed correlation is almost impossible, as only one ammonite has been recorded from these beds (Senior & Earland-Bennet 1973, p. 324). Unfortunately this specimen, from the Cave Oolite of Eastfield Quarry (SE 915325), is too badly preserved to allow anything more than a confirmation of the general correlation of the latter deposit with the Lincolnshire Limestone (Parsons 1974*b*, p. 115). Because of this lack of diagnostic faunas, much of the correlation of this and the succeeding two columns is based purely on inference and lithological comparisons between adjacent exposures. Thus the Cave Oolite (Phillips 1835) is probably the lateral equivalent of the Whitwell Oolite (Hudleston 1874) of the Derwent Valley, which in turn is the equivalent of the Millepore Beds (Wright 1860) of the Yorkshire coast (=Lebberston Member, Hemingway & Knox 1973, Cayton Bay Formation herein).

b. The shaly, so-called Basement Beds (de Boer *et al.* 1958, p. 165) mark a clastic influx which probably coincides in stratigraphical position with the Raventhorpe Beds to the south and the Sycarham Member to the north.

c. The Hydraulic Limestone (Hudleston 1874) is the probable equivalent of the Blowgill Beds to the north (Knox 1974).

d. The Dogger and Hayburn Formation (='Lower Deltaic Series') have been recorded from nearby exposures in Ellerker Beck (de Boer *et al.* 1958, p. 163), although the results of recent I.G.S. boreholes in the north Humberside/south

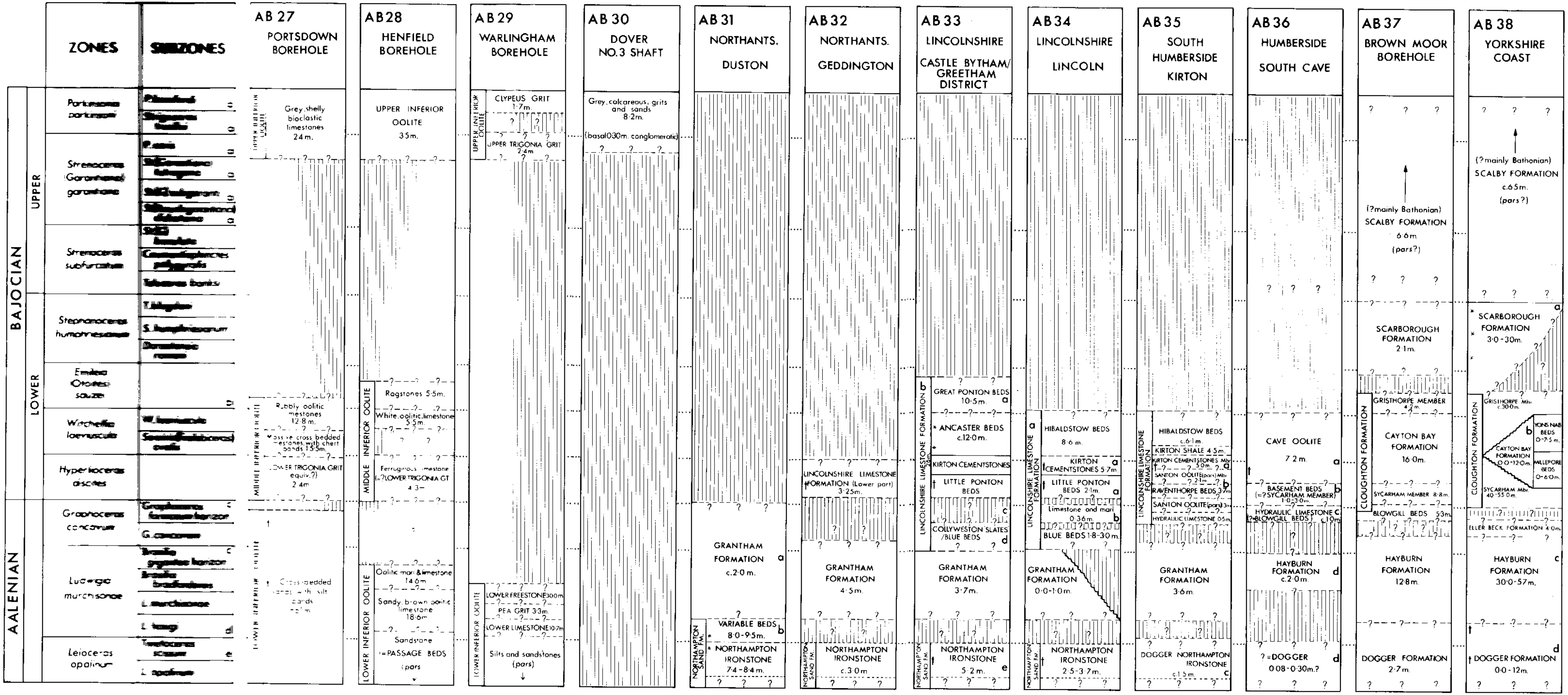


FIG. 4a. Correlation of Aalenian/Bajocian rocks. Columns AB27–AB38.

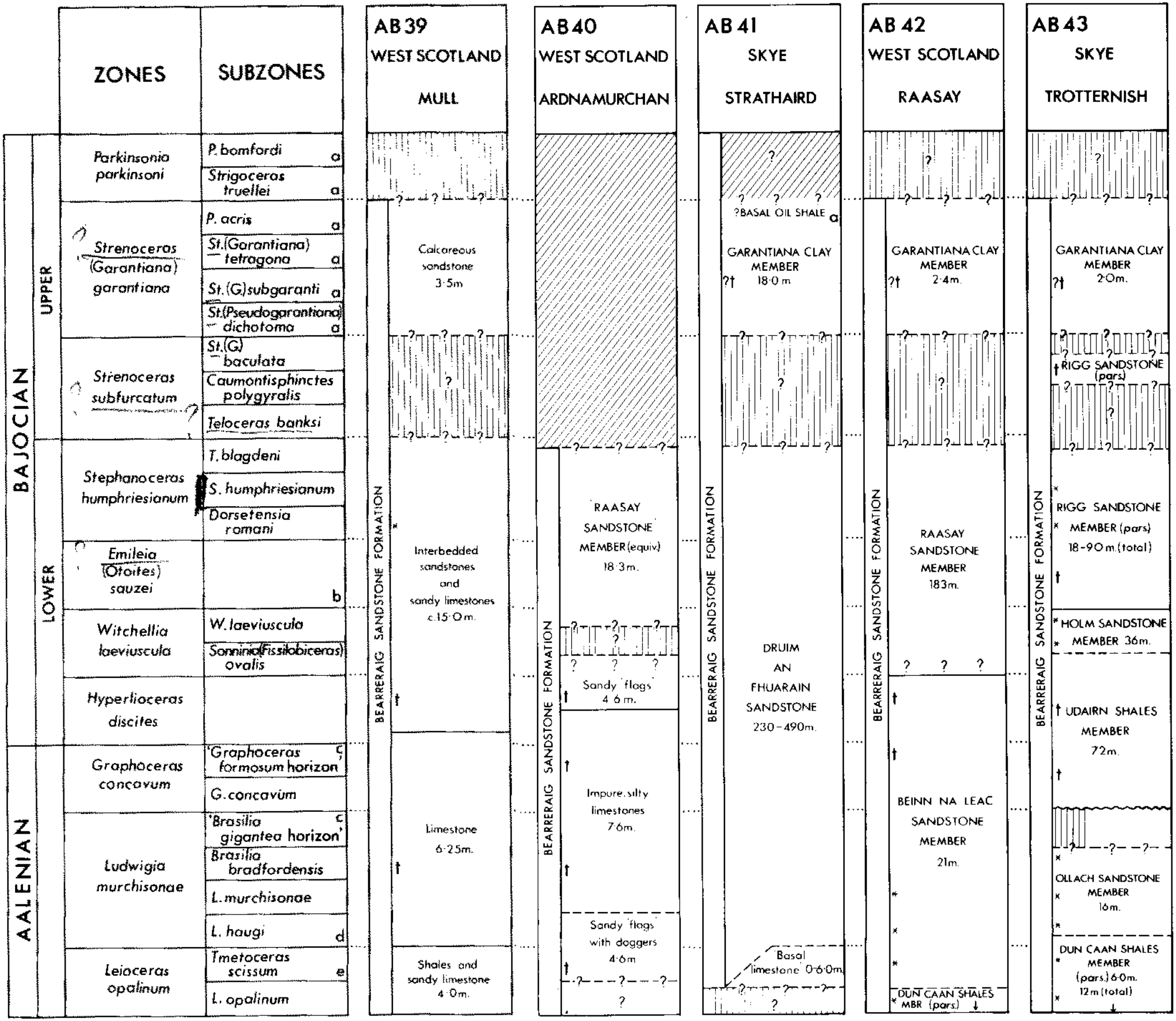


FIG. 4b. Correlation of Aalenian/Bajocian rocks. Columns AB39–AB43.

Yorkshire district suggest that these deposits are usually missing, due to intra-Bajocian erosion (I. Penn *pers. comm.* 1976).

AB37. Yorkshire: Acklam area, Brown Moor borehole (SE 812620)

Based on *Rept. Inst. geol. Sci. Lond.* 75/7, pp. 17–9 (see also Gaunt *et al.* 1980). The ostracod faunas from the Scarborough Formation give one of the few reliable correlations with their lateral equivalents on the coast.

AB38. Yorkshire coast

Based on Bate (1959), Hemingway (1974), Knox (1974), Parsons (1977*b*), Rastall & Hemingway (1940) and Richardson (1912).

The lithostratigraphical subdivisions of the Ravenscar Group (Hayburn-Scalby Formations) used here are largely those suggested by Hemingway & Knox (1973), with some modifications based on prior usage. Notably the Hayburn Formation replaces the 'Saltwick' Formation, whilst the terms Millepore and Yons Nab Beds are used as subdivisions of the Cayton Bay Formation, itself a replacement for the 'Lebberston Member' (*op. cit.*).

a. The considerable lateral variation of lithofacies found in the Scarborough Formation cannot be shown in column AB38. Hence a separate diagram showing the correlation of this formation, both inland and on the coast, is given here (Fig. 5). The ammonite records come from Parsons (1977*b*), with some subsequent additions (*pers. obs.* 1977–8). The sections are based on exposures at Gristhorpe Bay (TA 084841; *pers. obs.* 1972; Parsons 1977*b*, pp. 213–4), White Nab, Scarborough (TA 060865; *op. cit.*, pp. 220–1), Hundale Point, Cloughton (TA 026948; *op. cit.*, pp. 218–20), Spaunton Moor (SE 716928; *pers. obs.* 1978; Richardson 1912, p. 197), Harland Moor (SE 684914; Bate 1965, p. 90) and Helmsley Moor (SE 608905; *op. cit.*, pp. 90–1; *pers. obs.* 1978). Further south in the Howardian Hills, the Scarborough Formation is dominated by sandstone facies (e.g. Yearsley Moor, SE 579754; Bate 1965, p. 91; Stonecliff Wood; SE 744676; *op. cit.*, pp. 91–2), but there is no evidence to facilitate anything other than the most general correlation with the coastal exposures. Thus the position of the Brandsby Roadstone (Phillips 1829, p. 152) is unknown, although it is probably to be correlated with the siliceous limestone found at the base of the Scarborough Formation at Hemsley Moor (Bate 1965, p. 91, bed 1).

b. The Millepore Bed (Wright 1860) and Yons Nab Beds (Sylvester-Bradley 1953) have extensive coastal exposures (Yons Nab, TA 085843; Osgodby Point TA 065854; Cloughton Wyke TA 021955), but die out towards the north and are apparently absent at many inland exposures between Whitby and Kirby Knowle (Hemingway 1949, fig. 1). If a joint name is required for all the closely associated beds found on the coast, then the term 'Cayton Bay Beds' (Richardson 1912), which included both the Millepore Bed and the then un-named Yons Nab Beds, is available. The subsequently introduced, and totally synonymous, 'Lebberston Member' (Hemingway & Knox 1973) is thus redundant. However, there are doubts as to the absolute and relative rank of these beds within the lithostratigraphical

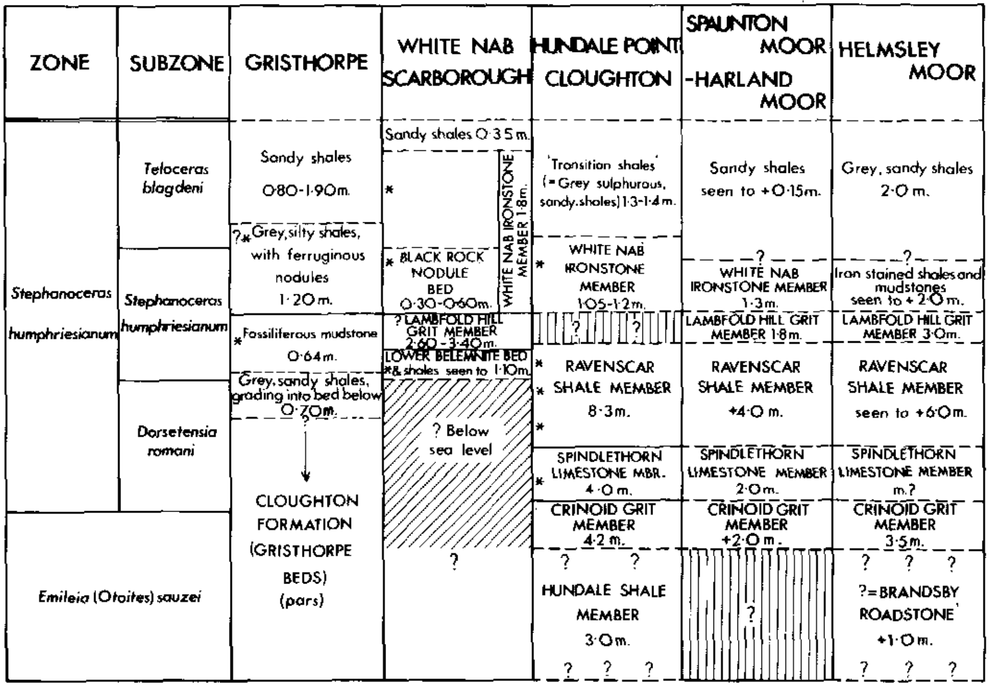


FIG. 5. A correlation of the Scarborough Formation (Lower Bajocian) in north-east Yorkshire.

framework. Hemingway & Knox (1973) suggested their inclusion as a member within the Cloughton Formation, a conclusion which is rejected here. From its first inception the Cloughton Formation was an un-workable and unnatural unit made up of two groups of unrelated beds; the non-marine Gristhorpe and Sycarham Beds and the marine Blowgill and Lebberston Beds. Apart from obvious lithological differences these two groups have very different origins, depositional histories and patterns of preservation. The non-marine sandstones were the products of delta fronts, mainly prograding from the north, whilst the marine beds were the products of shallow seas encroaching from the south and south-east. The resultant interfingering of different sediments produced a heterogeneous group of rocks, which could never fulfil the requirements of a Formation, in that they lacked a 'degree of internal lithological homogeneity, or distinctive lithological features that constitute a form of unity by comparison with adjacent strata' (Holland *et al.* 1978, p. 8). By comparison with the other marine horizons within the Ravenscar Group, it is evident that the Cayton Bay Beds should be accredited the status of Formation, and the Cloughton Formation restricted to the non-marine sandstones, with Gristhorpe and Sycarham Member 'tongues'.

The Cayton Bay Beds fulfil all the criteria of a Formation. They are mappable on the coast and inland between Kirby Knowle and Malton, traceable at the subsurface (e.g. the Fordon No. 1 borehole, Falcon & Kent 1960, p. 27), and form a homogeneous lithological unit in comparison with the adjacent non-marine sandstones. Additionally these beds show contiguity across the Yorkshire basin; the 'Upper Limestones' and Whitwell Oolite (Hudleston 1874, pp. 324, 327) to the west (in the Howardian Hills) are equivalent to the Yons Nab and Millepore Beds on the coast, and all these conjointly are the equivalent of the Cave Oolite, and thence the Lincolnshire Limestone to the south. The Cayton Bay Formation is the most important of the marine intercalations in the Ravenscar Group. The Scarborough Formation, although often thicker, was deposited in a restricted basin opening to the east (Bate 1965, p. 96), and has no recognizable lateral equivalent across the Market Weighton structure in south Yorkshire and Lincolnshire. On the other hand the Cayton Bay Formation is undoubtedly the lateral equivalent of the Cave Oolite. The faunal similarity between these two is reinforced by their probable original connection across the Market Weighton structure, as they are both still of an appreciable thickness when they disappear beneath the Cretaceous unconformity (de Boer *et al.* 1958, p. 165; Hudleston 1874, p. 327). The Cave Oolite is unquestionably a continuation of the bulk of the Lincolnshire Limestone. The faunal correlation between the Cayton Bay Formation and the Lincolnshire Limestone, allowing for the lack of ammonites from the former, is strong, even down to the occurrence of a similar group of nerineid gastropods, *Ptygmatis* (Hudleston 1887–96, p. 211; 1884, p. 112). Taking their contiguity into account, the Cayton Bay, Cave Oolite and Lincolnshire Limestone Formations together form perhaps the most extensive marine Middle Jurassic incursion in Eastern England. The Cayton Bay Beds are thus here formally designated as a formation within the Ravenscar Group, with a type section at Yons Nab, where they are approximately 12 m thick (Bate 1959, pp. 158–9, beds 1–9). The Blowgill Beds (Hemingway & Knox 1973) probably warrant the same status, although formal designation must await the publication of Knox's work on the southern outcrop of these beds.

c. The term Hayburn (Beds) Formation (Sylvester-Bradley 1949*a*) must have priority over the Saltwick Formation (Hemingway & Knox 1973, p. 531), since both are exactly equivalent to the 'Lower Deltaic Series' *sensu* Hemingway 1949). The reason given for the rejection of the name Hayburn Beds was the lack of exposure of the basal part of this unit at its type locality, Hayburn Wyke (Hemingway & Knox 1973, p. 531). The original description of the Hayburn Beds designated no type locality, but merely stated 'The two new terms proposed (Scalby Beds and Hayburn Beds) are named *after* two famous localities for plants in the respective strata' (Sylvester-Bradley 1949*a*, p. 263) – the italics are mine. The unfortunate type locality for the Hayburn Beds is the result of a subsequent designation (Hemingway *in* Donovan & Hemingway 1963, p. 164), since the preceding cannot be considered as a choice of type section. However, this selection of a type locality does not preclude the use of the term Hayburn Formation, since a stratigraphical unit can have more than one type section (Holland *et al.* 1978, p. 8). The first section to be designated (Hayburn Wyke, TA 010951) may be thought of as showing this unit's typical lithological characteristics, whilst the second, or 'hypostratotype', here designated as

Saltwick Bay (NZ 917108), will define its base. Since the Hayburn Formation, thus defined, is exactly synonymous with the Saltwick Formation the former, which has 25 years seniority, must have priority.

d. The interpretation of the complex pattern of lithofacies in the Dogger Formation (cf. Hemingway 1974, fig. 48) is confused by a poor biostratigraphical framework. All of the ammonites recorded in the earlier literature appear to have been lost; thus, for example, the specimens cited by Black (1934*b*) cannot be traced in the Sedgwick Museum (J. E. Hemingway *pers. comm.* 1978). Hence it is impossible to confirm the earlier identifications. More recently collected specimens include: *Leioceras* (*L.*) aff. *opaliniforme* (Buckman) (BM C78909), of *opalinum* Zone age, from the middle of the Dogger at Ravenscar; and specimens of *Ludwigia s. lato* (including *L.* (*L.*) cf. *crassa* (Horn), *L.* (*L.*) cf. *tuberata* (Buckman), *L.* (*L.*) aff. *obtusiformis* (Buckman), *L.* (*Ludwigina*) cf. *umbilicata* (Buckman) from an ironstone facies beneath the disconformity at the base of the Danby Member at Cotcliffe Lodge (SE 420913). The latter specimens, together with the stratigraphical details, were kindly forwarded to me by Professor Hemingway (pers. comm. 1978). A specimen of *L.* (*L.*) aff *tuberata* (BM C72174), in a similar matrix to the above, has come from Cold Moor (NZ 549034). These are all of *murchisonae* Zone and *murchisonae* or, more probably, *haugi* Subzone age. This suggests that the various elements of the Dogger span a considerable time period, and that further evidence is required to ensure the correct correlation of the various lithofacies (*contra* Hemingway 1974, fig. 48).

*AB*39. *Mull*

Based on Lee (1925*a*, pp. 98–112). Exposures at Port nam Marbh, Port Donain and Ardnadrochet Glen are highly faulted and disturbed, and as with Ardnamurchan, the ammonite faunal succession is in urgent need of a detailed modern revision.

*AB*40. *Ardnamurchan*

Based on Lee & Bailey (1930, pp. 44–9); Richey (1933, p. 25); Richey & Thomas (1930). The exposures on the coast on either side of Sron Bheag Point are highly disturbed and the faunas are in need of revision.

*AB*41. *Skye, Strathaird*

Based on the shore adjacent to Faoilean (NG 567203) (Morton 1965, p. 209); lithostratigraphical nomenclature follows Morton (1976).

a. See B18, note f.

*AB*42. *Raasay*

Largely based on Beinn na Leac (NG 597379) (Morton 1965, p. 205; *pers. comm.* 1967; Morton *in* Hudson & Morton 1969, p. 15); lithostratigraphical subdivisions follow Morton (1976).

*AB*43. *Skye, Trotternish*

Based on the area of Bearreraig Bay (NG 518526) (Morton 1965, 1975, 1976 & *pers. comm.* 1977). Lithostratigraphical nomenclature follows Morton (1976). The only major deviation from the correlations suggested in the latter work relate to the base of the Rigg sandstones and the Holm Sandstone. I suspect the former is to be correlated with the *sauzei Zone sensu stricto* (rather than the '*hebridica* Subzone') whilst much, if not all, of the Holm Sandstones is of upper *laeviuscula* Zone age.

BATHONIAN CORRELATION CHART

H.S. Torrens

with a contribution by J. D. Hudson

The Bathonian rocks of England have been referred to frequently as the Great Oolite 'Series'. This term was first proposed by Judd (1875, p. 186) to include horizons from the Upper Estuarine 'Series' up to and including the Cornbrash in Rutland. Subsequent use of the term by Woodward (1894, p. 228) and Arkell (1947*b*, p. 35) included rocks from the base of the Fullers Earth to the top of the Cornbrash further south. More recently, Cave (1977, p. 131) defined the Great Oolite 'Series' as comprising the Fullers Earth, Great Oolite, Forest Marble and the Cornbrash.

The extreme rarity, or absence, of ammonites from many British Bathonian horizons presents problems in establishing a scheme of Standard Zones but more especially in correlating with this standard. Documentation and preservation of each Bathonian ammonite is thus of paramount importance, and much useful information has been lost by the failure to properly curate and document all those ammonites collected.

Zones

The standard used is largely that discussed previously (Torrens 1974*a*, written 1966) although two major changes have proved necessary.

a. The index tentatively used by Torrens (1974*a*), *Prohecticoceras retrocostatum* (de Grossouvre), has been criticized (e.g. Hahn 1968, p. 21; Elmi 1967, p. 602; Mangold 1970*a*, p. 298, etc.) although it has now come into general use for faunas in part of the same age in France (Mouterde *et al.* 1971). The grounds for its abandonment are both its complete absence from Britain and other areas of northern Europe and its known range into the *aspidoides* Zone above. Neither of these, however, entirely prohibit its use, but in view of its different usage in France and the fact that it now appears to be more common in the *aspidoides* Zone as understood here it seems best to replace it. For a scheme based predominantly on England, Normandy and south-west Germany an index of known stratigraphical horizon in these areas has clear advantages.

Of the possible indices *Procerites wattonensis* Arkell is ruled out because it has been placed in synonymy with a species whose type horizon is still unclear (Mangold 1970*b*, p. 27). *Procerites hodsoni* Arkell, first described from the lower Rugitela Beds of Whatley (Arkell 1951–59, p. 191) (Column B5), has been chosen as index for this basal Upper Bathonian zone for the following reasons: (a) the holotype comes from a known lithostratigraphical horizon; (b) the foreign occurrences of this form in north Germany (Hahn MSS, pp. 14–15), south Germany (Hahn 1969, pp. 62–4), the French Jura (Mangold 1970*b*, pp. 30–1), and the Vendée (Gabilly 1964, pp. 69–71) are all *in situ* at the same stratigraphical level. One of the specimens cited by Mangold came from a horizon 12.4 m above a well proven *morrisi* Zone (1970*a*, pp. 136–7); (c) the only other records of this form from known stratigraphical levels are those described by Arkell (1951–59, p. 191) from Lansdown near Bath, which may in fact come from the top of this Zone (see Column B6), and a single unfigured record from the *aspidoides* Zone also near Bath (Melville 1956, p. 30); (d) it seems to be a distinct form (Hahn MS, 1969; Mangold 1970*b*, p. 26). This is of considerable importance amongst the proceritids where contemporary variation in morphology is often as considerable as variation over time.

b. The earlier suggestion that Middle Bathonian ammonites of the genera *Tulites* and *Morrisiceras* (now including *Lycetticeras*) might be facies-bound and thus less reliable as zonal indicators (Torrens 1967, p. 83) now seems very much less likely for two separate reasons. Firstly Hahn (1971, pp. 62–64) was able to show that the relevant ammonite family—the Tulitidae (see Thierry (1976, p. 298)—was much less, if at all, connected with particular lithofacies than was at first thought. Secondly, he demonstrated that in south Germany the zonal faunas occurred in exactly the same order as in southern England. This has been further confirmed by Mangold (1970*a*, pp. 300–1) in the French Jura although there is not yet agreement about the grouping of these faunas into zones and subzones. Recent discoveries in the Cotswolds (see Columns B11 and B12) also support this faunal sequence.

One area crucial to the future development of a Standard Bathonian Zonation is south-west Poland. Here good faunas of the *tenuiplicatus*, *subcontractus* and *morrisi* Zones have been recorded (Torrens 1974*a*, pp. 586–9) but the *progracilis* Zone is as yet undemonstrated. Work in the Czestochowa region here (Potocki 1972), based on new faunas collected *in situ*, has demonstrated the presence of *tenuiplicatus* and *morrisi* Zones only.

c. The problem of the relationship of the *tenuiplicatus* and *progracilis* Zones is as yet unresolved; it is possible that they are in part at least time-equivalents. However, in the Swabian sections large *Procerites* including *P. imitator* (Buckman) are found directly overlying the *tenuiplicatus* Zone suggesting the two are not equivalent (Hahn 1968, p. 18). In the large new collections made from beds of *progracilis* Zone age in Southern England (Column B4, p. 26) large numbers of perisphinctids (*Wagnericeras & Procerites*, etc.) and not a single morphoceratid lead to the same conclusion. French authors (e.g. Mouterde *et al.* 1971) have summarily advocated the abandonment of the *progracilis* Zone, but more work on the relevant faunas is needed first and especially the lithostratigraphical position of the type horizon of this zone in Oxfordshire (see Column B12) urgently needs to be established.

d. Previously the possibility of two separate faunas within the *yeovilensis* Subzone of the *zigzag* Zone was raised (Torrens 1974*a*). Subsequent work by Hahn (1968, pp.

16–7) confirmed this, and two formal subzones were suggested, a lower *yeovilensis* Subzone *sensu stricto* and an upper *tenuiplicatus* Subzone (index *Asphinctites tenuiplicatus* (Brauns). Later work by Sturani (in progress at the time of his tragic death), based on many sections in the Basses-Alpes of south-east France, suggests that the faunas of the latter subzone are best accorded full zonal status as in the chart. However only one ammonite characteristic of this zone has ever been found in Britain—the holotype of *Asphinctites recinctus* S. Buckman which is from an unknown stratigraphical horizon (see notes to Column B6, p. 30). This again highlights the major problem of correlation using Bathonian ammonities.

The alternative zonation of the Boreal Middle Jurassic, faunas of which are recorded by Callomon from the northern North Sea (1975, 1979), must be noted. Correlations between these two schemes remain wholly conjectural.

*B*1. *Dorset: Weymouth Anticline*

Based on Arkell (1947*a*), Douglas & Arkell (1928), House (1957, 1961) and Torrens (1968*a*).

Despite its coastal outcrop the detailed sequence in the Bathonian rocks is not well known.

a. In the Langton Herring region two marker horizons have been demonstrated: the Boueti Bed which defines the base of the formation, and the Digona Bed *c.* 18 m higher. *Clydoniceras hollandi* (S. Buckman) (SM J47110: J. D. Hudson colln), identified by W. J. Arkell, was found loose beneath the outcrop of the Digona Bed at Herbury (SY 613807) and *Clydoniceras* (*Delecticeras*) cf. *ptychophorum* (Neumayr) (SM J19884) has been figured from Langton Herring (Arkell 1951–59) and is from the Boueti Bed. The latter does not allow precise correlation with the standard, but similar forms have been figured from north-west Germany as *C.* (*D.*) *crassum* Westermann (1958), from a horizon reinterpreted by Hahn (MS, p. 32) as belonging to the *aspidoides* Zone.

b. The Fuller's Earth in the Weymouth area is recorded in boreholes as reaching 297 m (Lulworth Banks borehole no. 1, Green & Donovan 1969, pp. 27–8). In the Weymouth Anticline borehole records have been disputed and the total thickness of the Fuller's Earth is uncertain (Martin 1967, p. 478). The surface outcrop exposes a total of only up to 34 m (House 1957). The only horizon to yield ammonites is the Wattonensis Beds equivalent (Stinton & Torrens 1968, p. 247), from which common *Procerites* cf. *quercinus* (Terquem & Jourdy) and *Procerites mirabilis* Arkell are recorded (Arkell 1951–59, pp. 196, 201). These are placed in the *hodsoni* Zone. The Wattonensis Beds seem somewhat condensed by comparison with the sequence known at the type locality in west Dorset. The age of the unexposed Fuller's Earth Clay below the Wattonensis Beds is not known but it presumably includes representatives of the complete sequence down to the base of the formation.

c. Use of the 'Elongata Beds' follows Arkell (1933, p. 252).

*B*2. *Dorset: Bridport area*

Based on Douglas & Arkell (1928), Torrens (1969*a*) and Wilson *et al.* (1958).

a. No diagnostic ammonites are known from the Forest Marble of west Dorset, making any detailed correlation with the standard impossible. The section at Watton Cliff must be nearly complete as Cornbrash was formerly exposed on the cliff-top. It is possible that the Digona Bed equivalent here is the 2.1 m thick 'Massive shelly current-bedded limestone' (Bed 5) (Torrens 1969*a*, pp. A 37–8) which has recently yielded mammal and therapsid teeth (Freeman 1976; Ensom 1977).

b. *Clydoniceras* (*Delecticeras*) aff. *legayi* (Rigaux and Sauvage) occurs in the topmost 10 m of the Upper Fuller's Earth Clay of Watton Cliff (e.g. BM C73341–2. 38313 and the specimen recorded by Arkell 1951–9, p. 44, now apparently lost). These records all suggest a level above the *hodsoni* Zone.

c. Use of 'Elongata Beds' follows Arkell (1933, p. 252).

d. The Wattonensis Beds (Buckman 1922; Muir-Wood 1936; Torrens 1969*a*; Wilson *et al.* 1958) are very rich in fossils, especially brachiopods, and have yielded ammonites including *Procerites wattonensis* Arkell (1951–9, holotype), *Choffatia* (*Subgrossouvria*) sp. (H.S.T. coll.) and *Procerites* spp. (H.S.T. coll.) all indicating the *hodsoni* Zone.

e. The Lower Fuller's Earth Clay must include time equivalents of the Fuller's Earth Rock of the area to the north (Column B3). An unknown thickness is cut out by faulting, but recent I.G.S. boreholes will shed considerable light on the detailed sequence.

f. The basal part of the Lower Fuller's Earth Clay and its contact with the Inferior Oolite below was well exposed at Stony Head (SY 496927) near Bridport during road widening (Parsons 1975*b*). 4 m of clay (Bed 18) contained in its lowest 0.6 m numerous specimens of *Sphaeroidothyris lenthayensis* (Richardson & Walker) (H.S.T. colln), not hitherto recorded this far south and inviting comparison with the Lenthay Bed of the Sherborne area (Column B3). The Knorri Beds, which have been recorded a little to the north just above the horizon with *S. lenthayensis* (Wilson *et al.* 1958, p. 101), were completely absent at the Stony Head cutting.

g. The Zigzag Bed, at the top of the Inferior Oolite, and the Scroff above are highly condensed representatives of the majority of the *zigzag* Zone and diagnostic faunas of all three subzones of it are recorded from this Bed (Arkell 1951–59, pp. 7–8; Torrens 1974*a*). Sections of the Zigzag Bed in this area were described by Richardson (1928–1930), Torrens (1969*a*, pp. A21–3) and Parsons (1975*b*).

*B*3. *North Dorset: Sherborne area*

Based on Douglas & Arkell (1928), Fowler (1957) and Torrens (1964, 1966, 1969*b*, 1974*a*).

a. Details for the Lower Cornbrash are based on the Holwell section (Douglas & Arkell 1928, p. 148). The *discus* Subzone is proven throughout the area and a large collection of ammonites has been recorded from Yetminster by Torrens (1969*b*, pp. 312–3).

b. The Forest Marble is not well known and many former sections in the limestone units are now infilled. Woodward's (1894, pp. 346–7) section at West Hill, south of Sherborne, is used here; a total thickness of *c.* 40 m was recorded. The development

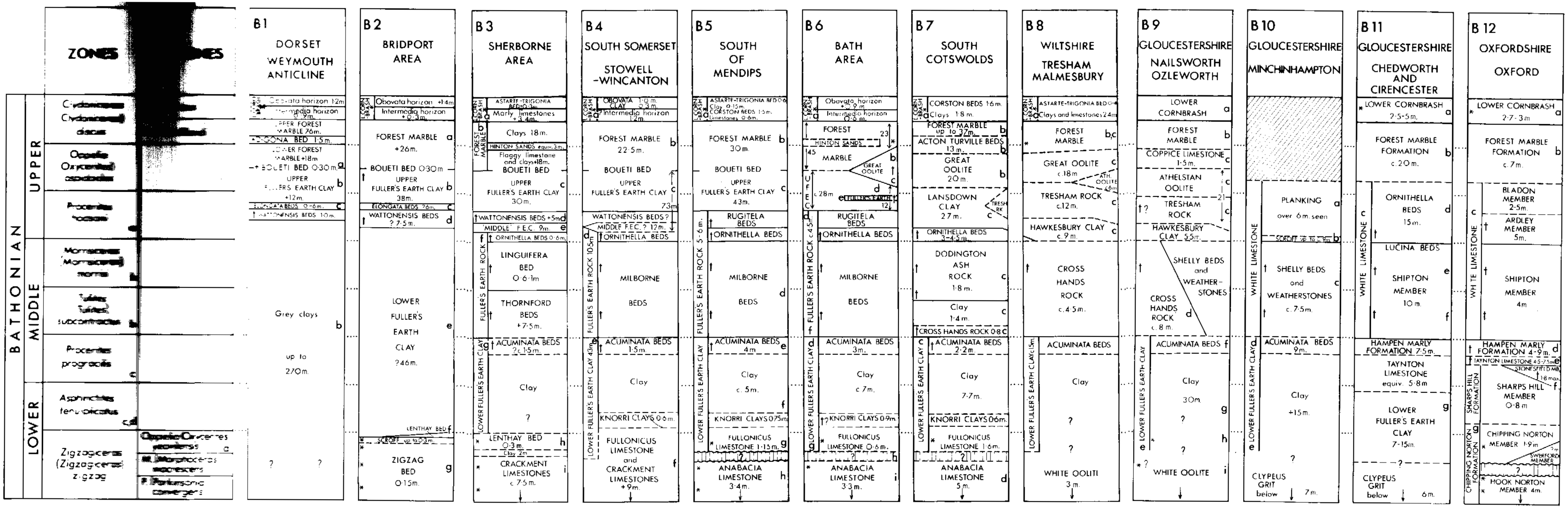


FIG. 6a. Correlation of Bathonian rocks. Columns B1–B12.

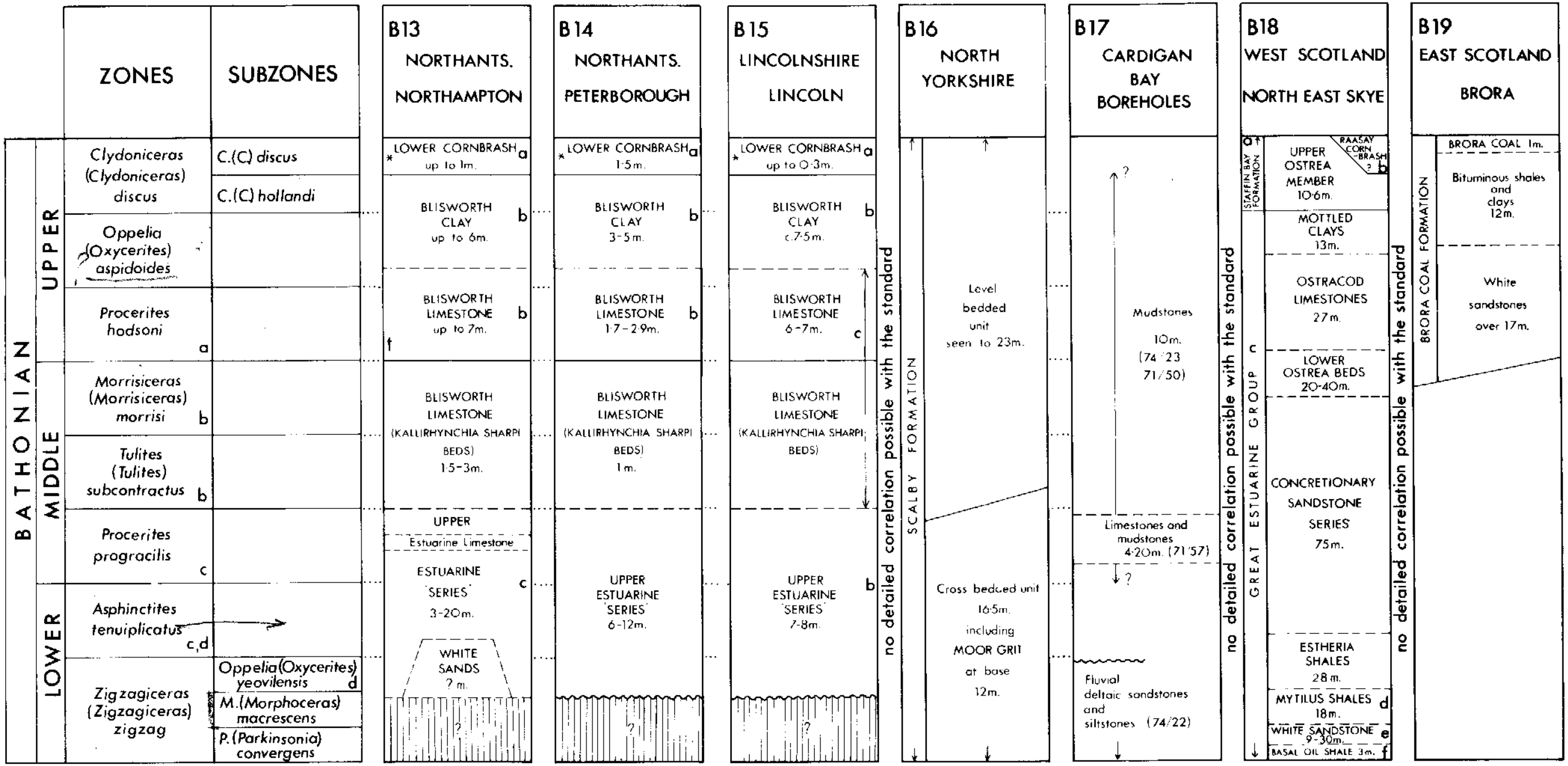


FIG. 6b. Correlation of Bathonian rocks. Columns B13–B19.

of a sandy facies in the central part of the sequence, reminiscent of the Hinton Sands to the north, is recorded by Woodward (1894) and Fowler (1957, p. 56). The Boueti Bed is well developed (Fowler 1957; Torrens 1969*b*), *Clydoniceras* (*Delecticeras*) sp. was recorded from Honeycomb Wood (Arkell 1951–9, p. 244).

c. The sequence within the Upper Fuller's Earth Clay needs investigation.

d. The Wattonensis Beds (Kellaway & Wilson 1941, p. 160) have now yielded a considerable number of ammonites including *Procerites quercinus* (Terquem & Jourdy) from Lake Farm, Thornford (SM J 20328-9, J 46917 and H.S.T. colln) (Arkell 1951–59, p. 196); *Choffatia* (*Homeoplanulites*) *homeomorpha* S. Buckman from the same locality (H.S.T. colln) and from near Whitevine Farm, Halstock, ST 501078 (IGS BW 1426); and *Prohecticoceras costatum* (J. Roemer) from Beer Hackett (Arkell 1951–59, p. 73). These records are all of *hodsoni* Zone age.

e. The 'Middle Fuller's Earth Clay' has yielded no ammonites. It needs to be formally named.

f. The Fuller's Earth Rock is well developed in the Sherborne area. The famous section at Troll Quarry (ST 594127), near Thornford (described by Torrens 1974*a*, p. 588), has been used to define typologically the base of the Standard Subcontractus Zone—the faunas of which are very common here. The *morrisi* Zone is also well represented in the Linguifera Bed (Torrens 1964, p. 39; 1966, pp. c36–8). The Ornithella Beds of the topmost part of the Fuller's Earth Rock have yielded diagnostic ammonites (*Choffatia*, *Procerites* etc.) only in the east of the area (Goathill Quarry) where they are of basal *hodsoni* Zone age as to the north.

g. The Lower Fuller's Earth Clay is as badly known as the majority of the Upper Fuller's Earth Clay above. The Acuminata Beds were exposed in an unpublished section in Lovers Lane (ST 643160), south of Sherborne (Torrens MS). Here 5 m of white, largely unfossiliferous marls separate the basal bed of the Fuller's Earth Rock from the top of the beds rich in *Liostrea acuminata*—the latter are 1.70 m thick and well developed. *Wagnericeras* (*Suspensites*) *suspensum* (S. Buckman) (SM J 34792), a species known from the Acuminata Beds to the north, has been recorded from this section and comes from the Acuminata Beds and not the Fuller's Earth Rock (as wrongly stated by Arkell 1951–59, p. 210).

Despite good sections exposed during gas-pipe-laying operations near Sherborne in the last 10 years little is known of the Lower Fuller's Earth Clay below the Acuminata Beds.

h. The Lenthay Bed with abundant *Sphaeroidothyris lenthayensis* (Richardson & Walker) was well exposed in 1967 in a section showing its relationship to the underlying Crackment Limestones (Torrens 1968*a*, p. 42). The Lenthay Bed has yielded the holotypes of *Procerites fowleri* Arkell (SM J 20330) and *Siemiradzkia lenthayensis* (Arkell) of the *yeovilensis* Subzone.

i. The Crackment Limestones have yielded good faunas of both the *convergens* and *macrescens* Subzones (see Arkell 1951–9, p. 10; Torrens 1969*b*, pp. 314–5, 318, 321–2). The basal beds of the Crackment Limestones west of Sherborne have yielded ammonites now placed in the Upper Bajocian, *parkinsoni* Zone (Torrens 1974*a*, p. 584) and here thus straddle the Bajocian–Bathonian boundary.

B4. South Somerset: Stowell and Wincanton

Based on Douglas & Arkell (1928), Edwards & Pringle (1926–Wincanton Borehole), Phelps (1909–Stowell Borehole), Pringle (1909–Stowell Borehole) and Torrens (1966).

a. The local variation of sections in the Lower Cornbrash of the area is remarkable (Douglas & Arkell 1928).

b. The Forest Marble has not been described but F. H. A. Engleheart measured sections west-north-west of Stalbridge in the 1920's (Oxford University Museum Archives). The basal bed of the Forest Marble is well documented by faunas collected in Wincanton Borehole (Edwards & Pringle 1926, p. 185) which proved a total of 22.5 m of Forest Marble. Good faunas of the Boueti Bed have been discovered recently at Jack White's Gibbet, west of Wincanton (ST 677292).

c. The Upper Fuller's Earth was penetrated only in part in the Stowell Borehole which showed only 6.7 m of this formation. Records of highly fossiliferous beds in the well above at a depth of 21–24 m below surface are probably the Wattonensis Beds of the Sherborne area (Column B3) and to the north (Column B5). The total thickness of Upper Fuller's Earth Clay here must be well over 37 m. The Wincanton Borehole penetrated 73 m of undivided Middle and Upper Fuller's Earth Clay.

d. The Fuller's Earth Rock, of which 10.7 m were recorded in both the Wincanton and Stowell boreholes, has yielded good faunas of the *hodsoni, morrisi* and *subcontractus* Zones. Sections are described in the Laycock railway cutting (ST 678213) south-west of Stowell (Woodward 1894, p. 236; Torrens 1966, pp. C78–C85) where the *morrisi* and *subcontractus* Zones only are now represented, and the more complete section at Maperton Road cutting (ST 667253—Richardson 1909, p. 212; Torrens 1966, pp. C92–C101). This section ranges from the *subcontractus* Zone to the basal *hodsoni* Zone. The sequence and faunas of the Fuller's Earth Rock in the Stowell borehole have also been discussed by Torrens (1966, pp. C90–C91).

The Milborne Beds of the Fuller's Earth Rock were 7.3 m thick at Stowell. It was thought that the Acuminata Beds were faulted out below the escarpment at Maperton. However, this may need revision if the bed with *Meleagrinella* sp. recorded by Richardson (1909) within the Lower Fuller's Earth Clay here is the same as that recognized by Wyatt & Penn (1975, p. 19) as occurring between the Fuller's Earth Rock and the main Acuminata Bed to the north near Frome.

e. The Lower Fuller's Earth Clay was 43 m thick in the Stowell Borehole. The Acuminata Beds at the top were 1.5 m thick and the Knorri Clays (recognized subsequently from the I.G.S. colln at between 91.4 and 92.0 m depth) are 0.6 m thick at the base of the formation.

f. The Upper beds of the Inferior Oolite were in part placed in the record of the Lower Fuller's Earth Clay in the log of the borehole. They are almost unknown at surface outcrop in this area, but are developed in a facies similar to the development at Sherborne (Crackment Limestone).

A temporary section on the A303 west of Dancing Cross (ST 6626) in 1972 exposed the upper part of the Lower Fuller's Earth Clay and the Fuller's Earth Rock. Large faunas of *Procerites* and *Wagnericeras* indicative of the *progracilis* Zone were found in the Acuminata Beds. No specimens of *Asphinctites* or any other morphoceratids were seen in these excavations which exposed over 15 m of Lower Fuller's Earth Clay, supporting the idea that the *tenuiplicatus* and *progracilis* Zones are successive and not wholly or in part overlapping.

B5. Somerset: Southern margin of the Mendip Hills

a. Douglas & Arkell (1928, p. 145) described the Lower Cornbrash formerly visible at Cards Farm, South Brewham, whence the zonal index was figured by Arkell (1951–59, p. 33, text fig. 6, pl. 2, fig. 7).

b. Published information about the Forest Marble is scanty. The Geological Survey (1″ Frome Sheet 281) record 21–40 m and the Westbury Borehole (Pringle 1922, p. 150) gave *c.* 28 m although the base was not fixed with any certainty. The Boueti Bed has been recorded between Upton Noble and Batcombe (ST 707394) (S. Holloway *pers. comm.* 1979). Farther north, near the Goole, West Cranmore (ST 682417), characteristic brachiopods of the Boueti Bed were also found (BM BB 45401-4, Green & Donovan 1969, p. 26), demonstrating its occurrence this far north.

c. The Fuller's Earth sequence is claimed as *c.* 48 m thick at Bonnyleigh Hill near Frome (Ponsford 1969) and 54 m at Batcombe (Woodward 1894, p. 238). Sylvester-Bradley & Hodson (1957) described the sequence in the Whatley area and divided the Fuller's Earth Rock into an upper Rugitela Beds, and a lower Ornithella Beds unit, the whole totalling some 6 m. Ammonites from the Rugitela Beds were described by Arkell (1957*b*) as a 'highly anomalous assemblage', but increased knowledge of English Bathonian ammonites has now resolved many of the anomalies (Torrens 1974*a*, p. 591).

In 1970 a new railway into Merehead Quarry, West Cranmore (ST 694436) exposed the complete Fuller's Earth Rock sequence (Beds 1–4):

Rugitela Beds	6. Clay interbedded with nodular limestone	over 0.6 m
	5. Clay (and unexposed portion)	*c.* 0.9–1.5 m
	4. Rubbly detrital limestone rich in brachiopods (*Rugitela, Tubithyris* etc.)	*c.* 1.8 m
	3. Marly limestone and clay. *Catinula, Pholadomya, Rhynchonelloidella* all very common	0.9–1.2 m
2. Ornithella Beds 1. Milborne Beds		*c.* 3.7 m
(Acuminata Beds below)		

Beds 5–6 are best regarded lithologically as part of the Upper Fuller's Earth Clay but can be equally grouped on palaeontological grounds with the Rugitela Beds. Beds 3 and 4 yielded the same faunas as those described by Sylvester-Bradley &

Hodson (1957). Bed 6 yielded a large number of ammonites (which will be described elsewhere), together with all the typical benthic elements of the Wattonensis Beds of the Sherborne area (e.g. *Trigonia elongata, Lopha marshii, Amberleya fowleri, Rugitela bullata, Acanthothiris powerstockensis, Nucula waltoni, Risseloidea biarmata,* etc). The upper part of the Wattonensis Beds of Sherborne is clearly equivalent in time to Bed 6 here, and the lower part of the Wattonensis Beds of Sherborne equivalent to Beds 3–4. The diverse ammonite faunas of the Rugitela Beds are identical to those of the Wattonensis Beds and they can all be placed in the *hodsoni* Zone.

d. The *morrisi* and *subcontractus* Zones are well represented within the Milborne Beds (here thinner than to the south).

e. The Acuminata Beds have yielded *Procerites imitator* (S. Buckman) from near Leighton (ST 696435) (H.S.T. colln) and *Wagnericeras* (*Suspensites*) *suspensum* (S. Buckman) west of Higher Alham Farm, Somerset (SM J 28994) (wrongly recorded as from Fuller's Earth Rock by Arkell 1951–59, p. 209). These are placed in the *progracilis* Zone.

f. The Lower Fuller's Earth Clay is not well known in this area. The Knorri Clays are well developed but have yielded no ammonites.

g. The junction with the Inferior Oolite is based on the fine section in the Doulting Railway-cutting (ST 651424) described by Torrens (1969*a*, pp. B18-B20). Major problems have arisen with the interpretation of this section because of errors by previous workers. Richardson (1907) described some brown 'oolitic' limestones with '*Anabacia*' as a separate unit from the Anabacia Limestones below. He designated these the 'Rubbly Beds', but clearly found it difficult to separate them lithologically from the underlying unit (1907, pp. 388, 393; 1908, p. 511). He recorded one ammonite *in situ* from his Rubbly Beds at Doulting Bridge Quarry (Reading Univ. No. 3095) identified by Buckman as *Perisphinctes evolutoides* Siemiradzki. This unique ammonite appears to be the earliest representative of the Bathonian '*Bigotites*' described by Sturani (1967, p. 40) from south-east France, and the matrix confirms Richardson's Rubbly Beds as being fine-grained pelmicrite lithologically similar to the Anabacia Limestones below. Use of his term is thus here discontinued as the beds are not clearly separable from the rest of the Anabacia Limestones. Arkell (1951–59, p. 11) misidentified higher beds, yielding *zigzag* Zone ammonites, at nearby Brambleditch Quarry (ST 647423, 0.8 km south of Doulting) with Richardson's Rubbly Beds. To these higher yellow limestone beds, which commonly yield *Procerites laeviplex* (olim *Parkinsonites fullonicus*), the name **Fullonicus Limestone** is given. This new unit (the lowermost unit of the Lower Fuller's Earth Clay) is defined by beds 3a–i of the section described at the type locality, Doulting Railway-cutting (Torrens 1969*a*). It is distinguished from the beds below (the Anabacia Limestones—which now include the Rubbly Beds of Richardson—of the Inferior Oolite Formation) by a total lack of ooliths and a micritic matrix, and is readily distinguished from the soft remaining Lower Fuller's Earth Clay above. The basal boundary is sharp, and erosion at this point is indicated by pebbles of Inferior Oolite in its basal bed. The upper boundary is gradational into the Lower Fuller's Earth

Clay. The ammonite faunas of the Fullonicus Limestone are entirely of *yeovilensis* Subzone age (Torrens 1974*a*, p. 585; Hahn 1969, p. 48).

h. The Anabacia Limestones have yielded ammonite faunas demonstrating the presence of the *macrescens* and *convergens* Subzones (Torrens 1969*a*, pp. B18–9) in the topmost part.

*B*6. *Avon: Bath area*

The Bath area has historical significance from the pioneer work of William Smith (Eyles 1969), which led to the Bathonian Stage being named after Bath (Donovan & Hemingway 1963, p. 38). When attempts were first made to define a stratotype for the Bathonian stage the Bath area was preferred for this reason (Sylvester-Bradley 1964; Cox 1964) but the difficulty of finding any permanent sections which could serve as a stratotype for the whole stage quickly became apparent. The view now prevalent amongst Jurassic workers in this country, that we should seek a typological definition for the base of each Standard Zone (see Cope *et al.* 1980, p. 4), means that the significance of the Bath area as a stratotype for the definition of the Stage has gone; it was not in any case suitable (Torrens 1974*a*, p. 581). The definition of the basal boundary of the basal Bathonian Standard Zone in the Bath area is also not yet possible, and it has been recommended that a section in the south-east of France be designated to define this particular boundary (Morton 1974).

a. Based on the section at Corsham, east of Bath (Douglas & Arkell 1928, p. 142).

b. Details for the Forest Marble and the Great Oolite derive largely from Green & Donovan (1969). Problems of correlation with a standard are considerable due to rarity or absence of ammonites.

The Bradford Clay of Bradford-on-Avon, recently described by Palmer & Fürsich (1974), has yielded rare ammonites (Arkell 1951–59, p. 42; Stinton & Torrens 1968, p. 247) which allow it to be assigned to the *hollandi* Subzone of the *discus* Zone. The use of the Bradford Clay as a marker horizon away from the type area, where it is now included within the Forest Marble, is militated against because of its impersistence (Green & Donovan 1969, pp. 24, 43) and because its characteristic fauna is a facies fauna known to appear at a number of horizons when the right conditions of deposition prevailed (Cave 1977, p. 150).

c. The Great Oolite has yielded ammonites in abundance only from the Twinhoe Ironshot (Torrens 1974*a*, p. 593; Hahn 1968); this is the only ammonite fauna of *aspidoides* Zone age known from Britain. A specimen of *Clydoniceras* cf. *schlippei* S. S. Buckman (IGS Zr 1842–3) from the overlying Winsley Facies of the Twinhoe Beds (Green & Donovan 1969, p. 15) is of uncertain zonal position. From the Freshford Facies specimens of *Wagnericeras arbustigerum* (d'Orbigny), also indicating the *aspidoides* Zone, are known (Arkell 1951–9, pp. 207–8). The two *Procerites hodsoni* Arkell from the Combe Down Oolite of Lansdown (Arkell 1951–59, p. 191) may indicate that the basal beds of the Great Oolite there belong to the top of the *hodsoni* Zone rather than to the position assigned in the chart.

d. The stratigraphy of the Fuller's Earth (Green & Donovan 1969, p. 5) at outcrop is confused by landslipping and cambering which is widespread in the area (Kellaway

& Taylor 1968; Chandler *et al.* 1976) and is known to be oversimplified (*Ann. Rep. Inst. Geol. Sci.* for 1973 (1974), p. 24). When the stratigraphy of the I.G.S. boreholes through the Fuller's Earth in this area is published our knowledge will considerably improve. (See Penn, Merriman & Wyatt 1980, published too late for consideration in this Report).

e. The commercial Fuller's Earth seam of Combe Hay near Bath, 11 m below the top of the Upper Fuller's Earth Clay (=Lansdown Clay of Arkell & Donovan 1952; =Frome Clay of Bourne 1846), has yielded *Choffatia homeomorpha* (S. S. Buckman), *Wagnericeras bathonicum* Arkell, *W. detortus* (de Grossouvre) and *Procerites* sp.; an assemblage here placed in the upper part of the *hodsoni* Zone. The origin and age of the Bath commercial Fuller's Earth is discussed by Jeans *et al.* (1977).

f. The Fuller's Earth Rock totals only *c.* 3–4.5 m; it has yielded ammonites of the *morrisi* and *subcontractus* Zones. Anomalies in the distribution of these faunas can all be explained by mixing or inversion due to land-slipping. Bate (1978, p. 218) wrongly assigns the entire thickness of the Fuller's Earth Rock at Bath to the *hodsoni* Zone; only the Ornithella Beds, well represented here, can be thus assigned. The Rugitela Beds are apparently also represented in the Fuller's Earth Rock but the characteristic brachiopod fauna is scarce and no ammonites have been reported. There is no support either for Bate's view (1978, p. 222) that the Middle Bathonian ammonite zones are here condensed (i.e. mixed), although they are somewhat thinner than the development to the south.

g. The Lower Fuller's Earth Clay is similar to its development both to the north and south, with the Acuminata Beds and Knorri Clays clearly recognizable (see Donovan 1948; Richardson 1907, 1910*c*). The Fullonicus Limestone (p. 28) is also present and represented both by the beds wrongly called by Richardson (1907, Table opp. p. 408) the Rubbly Beds (which are *not* the same as his Rubbly Beds at Doulting), and by some part of the beds above which have yielded the characteristic ammonite fauna of *yeovilensis* Subzone age (Arkell 1951–59, p. 190). It is from this area that the only known ammonite diagnostic of the *tenuiplicatus* Zone has been recorded from England, i.e. *Asphinctites recinctus* S. Buckman; the holotype (BM C41724) was purchased by J. W. Tutcher and recorded simply as being from the Fuller's Earth of Midford, Somerset. From its matrix it seems probable the type horizon is either the Fullonicus Limestone or more likely the Knorri Clays. The latter is the basis for the zonal symbol at this level in the chart, but it needs confirmation.

h. The non-sequential junction between the Fuller's Earth and Inferior Oolite at Midford is seen in the Midford Railway-cutting (Richardson 1907, p. 408) between Beds I and II, and the extent of the non-sequence is presumed to be the same as in the column to the south.

i. Faunas from the Anabacia Limestones of the Bath area are not well known. *Ebrayiceras pseudoanceps* (Ebray) (BU M 3482) from Pipley Bottom Nursery Quarry indicates a *zigzag* Zone age for the Anabacia Limestones at Bitton. More diagnostic faunas come from excavations at Kingswood school (Arkell 1951–59, p. 11) where *Zigzagiceras pseudoprocerus* (SM J 28983) and *Morphoceras densicostatum*

(SM J 24664) were collected amongst faunas which included a landslipped mixture of all beds from the Fuller's Earth Rock down to the Inferior Oolite (Arkell 1951–59, p. 11).

B7. South Cotswolds

Based on Cave (1977), Curtis (1978), Douglas & Arkell (1928), Reynolds & Vaughan (1902), Richardson (1935) and Torrens (1968*b*).

a. Douglas & Arkell (1928, p. 141) and Cave (1977, p. 213) described the section at Lower Stanton St. Quinton whence ammonites are recorded. Oppel's *Clydoniceras discus hochstetteri* came from the *discus* Subzone of Chippenham (Arkell 1951–59, p. 36, pl. 1, fig. 4).

b. Knowledge of the Forest Marble, Acton Turville Beds and the Great Oolite largely derives from Reynolds and Vaughan's (1902) descriptions of the railway sections between Filton and Wootton Bassett; more recently these rocks were discussed by Cave (1977). No correlation with the standard is possible through lack of diagnostic fossils.

c. The complete sequence of Fuller's Earth in the area is now clear despite lateral facies change and the somewhat erroneous reconstruction of the sequence in the Sodbury tunnel (ST 7581–7981) (see Arkell & Donovan 1952, p. 234). New sections through the Fuller's Earth have been described on the M4 motorway near Dodington Ash (ST 757782) (Torrens 1968*b*) and near Dyrham Park (ST 743760–758763) (Curtis 1978). The latter section was more complete, and a total of 45 m of Fuller's Earth was seen. At Dodington Ash the Tresham Rock was exposed but yielded no ammonites. Reynolds & Vaughan (1902, p. 741) recorded *Procerites* (now lost) from their passage beds in the Upper Fuller's Earth of the Sodbury tunnel. *Procerites* sp. were found in the Ornithella Beds and overlying clays of the basal *hodsoni* Zone by Curtis (1978, Beds 13–9) and Torrens (1968*b*, Beds 12–3).

The *morrisi* Zone age of the topmost part of the Dodington Ash Rock was proven in both sections. The age of the base of the rock was also proved to be *subcontractus* Zone by *Tulites modiolaris* (W. Smith) recorded by Curtis (1978, p. 26), and found *in situ* near the base of Bed 11 (Bristol City Museum Cb 4729–4730). The *Tulites* (*Rugiferites*) sp. from Bed 9 of the Cross Hands Rock below (Cb 4727—not *in situ*) demonstrated that this subgenus is here characteristic of the lower part of the *subcontractus* Zone as in the Fuller's Earth Rock of south Somerset. The Acuminata Beds in the M4 Motorway section yielded ammonites which are best assigned to the *progracilis* Zone. Nearby at the type locality of the Cross Hands Rock (Richardson 1935) the Acuminata Beds have yielded *in situ* a specimen of *Wagnericeras fortecostatum* (de Groussouvre) which seems characteristic of this level. The section at Cross Hands described by Richardson has been re-interpreted by Torrens (1968*b*). Arkell & Donovan (1952, p. 238) and Cave (1977, p. 158) show that the loose and anomalous ornithellid brachiopods recorded from the Cross Hands Rock here were misidentified. The brachiopod fauna found is one wholly characteristic of the Acuminata Beds below.

The Knorri Clays were demonstrated in both sections. Beneath this level the

Fullonicus Limestone (=Rubbly beds of Curtis 1978 *non* Arkell, see column B5) yielded *Procerites laeviplex* (Quenstedt) of the *yeovilensis* Subzone (recorded by Curtis as *P. fullonicus*).

d. No ammonites are known from the Anabacia Limestones, thus it is not known whether the lower subzones of the *zigzag* Zone are represented in the uppermost part of the Inferior Oolite. The erosion surface on the top of the Anabacia Limestone (as to the south) was noticeable in the Dyrham gas pipe trenches.

B8. Tresham–Malmesbury

Based on Arkell & Donovan (1952), Cave (1977), Douglas & Arkell (1928) and Torrens (1969*c*).

a. The chart is based on Foxley Road Quarry (Douglas & Arkell 1928, p. 139) where the characteristic brachiopod fauna of the Lower Cornbrash is well represented. Some ammonites are known, e.g. from Lower Stanton St. Quintin (*op. cit.*, p. 141).

b. The *hollandi* Subzone provided the holotype of the subzonal index collected long ago from the 'Bradford Clay' of Tetbury Road Station (Arkell 1951–59, p. 42; Woodward 1894, p. 363). This is a level placed by Cave (1977, p. 150) in the lowest part of the Forest Marble.

c. The rapid and confusing facies changes below the Cornbrash are reflected only in part in the lithostratigraphical nomenclature of this column and that of the two adjacent columns. (See details in Arkell & Donovan 1952 and Cave 1977). Ammonite control is largely unavailable and when present is often ambiguous. As an example, the loose specimen of *Morrisiceras comma* (S. S. Buckman) (BU 13462) from Kilcott, near Hawkesbury, has been assigned to the Fuller's Earth Rock, the Dodington Ash Rock (Torrens 1969*c*, p. 70) and the Cross Hands Rock (Cave 1977, p. 142). It at least proves the *morrisi* Zone is present.

For the remainder of the sequence ammonite control is largely lacking. There is also lack of information about the lithostratigraphy at the junction of the Inferior Oolite and Lower Fuller's Earth in this area.

B9. Ozleworth–Nailsworth area

a. The Cornbrash of the area down-dip from Nailsworth is badly known. Douglas & Arkell (1928) did not describe any sections between Shorncote (SV 0296) and Charlton (ST 9689) in detail, but recorded Lower Cornbrash at Pool Keynes.

b. The area includes the type area of the Kemble Beds of the Forest Marble (Woodward 1894, p. 248) but the realization that the Bradford Clay fauna is a facies fauna (Palmer & Fürsich 1974) and thus likely to recur when conditions are repetitive (Cave 1977, p. 150) has led to the separate terms Wychwood and Kemble Beds being largely abandoned.

c. The complexities of Fuller's Earth facies changes are well demonstrated by Cave (1977, fig. 13), who introduced the Coppice Limestone and Athelstan Oolite as new lithostratigraphical units. The only Upper Bathonian ammonites known are *Bullatimorphites bullatimorphus* S. Buckman (e.g. IGS. GSM25620) from Tiltups

End, south of Nailsworth. Arkell & Donovan (1952, p. 241) stated they came from the Tresham Rock of a quarry described by Witchell (1886*b*) which showed 1.2 m of Tresham Rock overlain by 2.75 m of Forest Marble (Kemble Beds). Cave (1977, pp. 143, 175, 196) re-interpreted the section as showing Coppice Limestone (0.3 m now seen) overlain by Forest Marble; as he did not find any of the species found by Witchell it is not clear if the fossils recorded by the latter all come from the Coppice Limestone. The balance of evidence suggests that the ammonites did come from the Tresham Rock as shown on the chart—they suggest the *hodsoni* Zone. Further research is needed on the Tiltups End material.

d. Beds mapped as 'Cross Hands Rock' in this area by Arkell & Donovan (1952) and Cave (1977) include representatives of the Cross Hands Rock and the overlying Dodington Ash Rock further to the south, as the fine *morrisi* Zone fauna from Woodchester Park Farm described by Arkell & Donovan (1952, p. 240) and Cave (1977, p. 162) proves. To the four ammonites recorded by Torrens (1969*c*, p. 70) can be added *Morrisiceras comma* (S. Buckman) (OUM J29899) and a *Morrisiceras* sp. indet. nucleus both *in situ* in Bed 5 (of Arkell & Donovan 1952). This is a uniquely *morrisi* Zone fauna.

e. The Lower Fuller's Earth Clay of this area is poorly known because of the lack of outcrop.

f. The Acuminata Beds are well represented near Binley Farm (Arkell & Donovan 1952, p. 239) and elsewhere (Cave 1977).

g. The Knorri clays seem to be on the point of disappearing. Richardson (1910, p. 79) recorded the index oyster north of the Slad valley near Stroud, but the unlocalized material he also mentioned from Coopers Hill near Gloucester has not been confirmed by Channon's (1950, p. 262) redescription of the sections here. Channon's (1951) section near Chalford to the north-east of Minchinhampton (col. B10) confirms the absence of the Knorri Beds in that area. Specimens of *Catinula knorri* (Voltz) are recorded no farther north than from boreholes at Sheriton (ST 8485) and near Malmesbury (ST 9487) in the Lower Fuller's Earth Clay (Cave 1977, pp. 280, 291).

h. *Procerites laeviplex* (Quenstedt) (IGS. GSM52180), a species characteristic of the Fullonicus Limestone to the south and which indicates the *yeovilensis* Subzone, was recorded from the basal Fuller's Earth at Kingscote (Cave 1977, p. 112).

i. The White Oolite at the top of the Inferior Oolite is apparently a lateral equivalent of the Anabacia Limestones to the south, and has yielded *Chomatoseris* (=olim *Anabacia*) (Cave 1977, p. 280). That the Bajocian-Bathonian boundary falls within the White Oolite is suggested by *Procerozigzag crassizagsag* (BM C 10063) from Stroud Hill (Cave, 1977, p. 112), a form restricted to the *macrescens* Subzone. Some authors have considered the White Oolite of this area as part of the Clypeus Grit 'Series' (see Arkell 1933, p. 230; Cave 1977, p. 109; see also Column AB 19).

B10. Minchinhampton

This column refers only to the immediate vicinity of Minchinhampton (SO 8600) and the Golden Valley to the east of Stroud. The Minchinhampton plateau exposes rocks made famous by the works of Morris & Lycett (1851–1855) and Lycett (1863), which were systematically revised by Cox & Arkell (1948–1950).

a. The highest beds exposed in the old Minchinhampton quarries seem to have been the higher beds of the White Limestone called the 'Planking', of which over 6 m have been recorded here with the Scroff at the base (up to 1 m).

b. The record by Channon (1950, p. 251) of a large ammonite (probably *Procerites*) *in situ* in 'The Scroff Bed' only suggests a correlation with the beds immediately overlying the last *Morrisiceras* in the south of England, i.e. basal *hodsoni* zone. Confirmation from gastropod evidence that the *hodsoni* Zone is well represented in the Minchinhampton faunas comes from the work of Barker (1976, pp. 1.54–1.67). He showed that the gastropods here are in part a facies fauna unique in the British Bathonian with common *Purpuroidea* and nine species of patellids—indicative of a high energy facies. However, forms like *Fibuloptyxis witchelli* and *Bactroptyxis implicata* are characteristic of the *hodsoni* Zone elsewhere in the Cotswolds. It is also possible that *Aphanoptyxis bladonensis* occurs at Minchinhampton—another form of the same age.

c. The Shelly Beds and Weatherstones are probably the source of the many stratigraphically unlocalized ammonites. Minchinhampton has yielded only one accurately localized specimen, the holotype of *Morrisiceras morrisi*, recorded from 'the base of the Great Oolite'. Cave (1977, pp. 140, 163) stated that the beds at Pinfarthing, from which this specimen came, could pass laterally into the Minchinhampton Shelly Beds and Weatherstones. The underlying *subcontractus* Zone fauna, also well represented, would thus occur in its normal place at the base of the White Limestone (above the Acuminata Beds). Arkell & Donovan (1952) suggested that the ammonites all came from beds equivalent to the Scroff and the Planking, an interpretation which postulates both unnecessary downfaulting and extraordinarily thick local developments of both the *subcontractus* and *morrisi* Zones.

The correlation of these faunas was reviewed by Torrens (1969*c*, pp. 70–1). Rapid lateral and vertical facies variation makes it very difficult to resolve the problems of ammonite biostratigraphy, whilst the amount of cambering precludes much detailed mapping.

d. The thickness of the Lower Fuller's Earth Clay is recorded as 21 m at Stroud Hill (Witchell 1882, p. 69), probably similar to its development at Minchinhampton.

e. The base of the Fuller's Earth was recorded at Cowcombe Hill, east of Minchinhampton (Channon 1951), where the White Oolite facies of the topmost Inferior Oolite is no longer present. Instead there is typical Clypeus Grit of which Channon recorded nearly 7 m. Klein (1965, p. 187) misidentified this section as lying within the White Limestone. That it is Clypeus Grit is confirmed by the parkinsoniid ammonites found *in situ*.

*B*11. *Chedworth and Cirencester*

a. The Lower Cornbrash is well represented in the neighbourhood of Cirencester (Douglas & Arkell 1928; Richardson 1933) and ammonites are recorded from Shorncote, south of Cirencester and Fairford to the east.

b. The Forest Marble sequence at Cirencester is based on a borehole record (Richardson 1933, p. 75 with references). No correlation here with the standard is yet possible.

c. The White Limestone and lower beds of the Bathonian are known from the descriptions of the old railway cuttings between Chedworth and Cirencester and nearby sections described by Richardson (1911*b*, 1930, 1933), Arkell & Donovan (1952, p. 246 and map 5) and Callomon & Torrens (1969, pp. 12–3). The correlation of the White Limestone Formation, Beds 5–28 of Richardson 1933, p. 61, has considerably improved thanks to a number of ammonites discovered *in situ* over the years.

d. Correlation of the White Limestone above Bed 18 in the cuttings with the *hodsoni* Zone is confirmed by a large *Procerites quercinus* (Terquem & Jourdy) found *in situ* by Mr D. J. Iles, the quarry owner, at Dagham Downs Quarry (Iles colln). This is at the top of Bed 3 of the section, described by Torrens (1967, p. 87). M. J. Barker (1976, fig. 1.6) showed this is at a level 4.8 m above the top of the underlying Excavata Bed which marks the top of the Shipton Member and which is exposed in the floor of this quarry.

e. The presence of the *morrisi* Zone was previously suggested by a loose specimen of *Morrisiceras morrisi* thought to have come from Bed 18 of Stony Furlong cutting (IGS. GSM52177). A further specimen of *Morrisiceras* sp. indet. (OUM J30179) from the Foss Cross Quarry (SP 056091) by Aldgrove cutting, where the Lucina Beds (Beds 18–19) of Richardson (1911, p. 111) are the lowest exposed, supported this. Confirmation that the Lucina Beds are of *morrisi* Zone age was provided by a largely complete specimen of *Morrisiceras comma* (S. S. Buckman) (OUM J29900) *in situ* 0.30 m below the top of Bed 2 of the section here (Callomon & Torrens 1969, p. 13). The topmost 0.3 m of the same bed has now yielded abundant *Aphanoptyxis excavata* Barker MS (1976, fig. 1–7), a species characteristic of the top of the Shipton Member in Oxfordshire (column B12).

f. A specimen of *Tulites mustela* Arkell (1951–59, p. 103) (IGS. GSM48482) a metre or so above the top of the Hampen Marly Beds in a small quarry 0.8 km west-north-west of Salperton Church (SP 0720), 8 km north of Chedworth (Richardson 1929, p. 119), demonstrates that the base of the White Limestone Formation is of the same age between Ardley and Salperton. However, Palmer (1979, p. 191) suggested that some Hampen Marly Formation is replaced laterally to the south of this by beds of the White Limestone Formation.

In the area between Foss Cross, Salperton and Dagham Downs we thus have limited evidence of a sequence of ammonite faunas through the *subcontractus* to basal *hodsoni* Zones identical to that demonstrated in the Fuller's Earth Rock (columns B3–B7).

g. The sequence of strata below the White Limestone down into the Bajocian was exposed in part in the Chedworth cuttings but no detailed correlation of them with the standard is possible.

*B*12. *Oxford area*

The Bathonian rocks of the Oxford area have received an enormous amount of attention, summarized by Arkell (1947*b*), McKerrow & Kennedy (1973), Sellwood & McKerrow (1974) and Palmer (1979), but problems of correlation with the standard are still manifold because of the rarity of biostratigraphically significant macro- or micro-fossils, although the situation is continually improving.

a. As throughout England the only Bathonian formation which can be continuously correlated is the Lower Cornbrash (Arkell 1947*b*, p. 47, with references).

b. The Forest Marble remains difficult to correlate, although improvements are likely when lithostratigraphical units are defined by marked beds in designated localities. McKerrow *et al.* (1969) attempted a definition based largely on the occurrence of oysters and took the basal bed of the Forest Marble to be the base of an oyster-*Epithyris* marl at Kirtlington, Oxfordshire. This view was challenged by Palmer (1974, p. 61) and M. J. Barker (1976) and is also rejected here. It seems better to take the base of the clay overlying the Coral-*Epithyris* bed or of the bed above at Kirtlington as the base of the Forest Marble in this part of Oxfordshire. Where developed, the laminated micrite interpreted as indicating a supratidal environment by Palmer & Jenkyns (1975) (the Bladonensis Bed of Barker 1976, pp. 1:48–1:52) is the most reliable indicator of the topmost bed of the White Limestone Formation.

As used here the Forest Marble Formation appears on the basis only of the correlation of beds above and below to be largely *aspidoides* and basal *discus* Zones in age. The so-called Bradford Fossil Bed of Oxfordshire has been claimed to have a significant correlative value (McKerrow 1955, p. 353), but its fauna is largely facies-controlled and unlikely to occur at a single synchronous horizon (Palmer & Fürsich 1974; Barker 1976). Consequently, its use to separate the Forest Marble into Wychwood and Kemble Beds as formerly advocated is not accepted here.

The age of the Kirtlington Mammal Bed (Freeman 1979) in the basal bed of the Forest Marble (Palmer 1974, 1979), or at the top of the White Limestone (Barker 1976, fig. 1, 17 and p. 1.50) is not known with certainty. It seems likely to be of *aspidoides* Zone age.

c. The White Limestone can be correlated in part with the standard thanks to the few but significant ammonites that have been found. Specimens of *Tulites glabretus* (of which IGS. GSM31364 survives) were found between Bucknell and Ardley Wood, Oxfordshire, and very probably came from the basal bed of the White Limestone there (Torrens 1969*c*, p. 69). A further specimen of this species was found at Eton College Quarry near Witney (OUM J863) and was wrongly recorded from a level *c.* 5 m from the top of the White Limestone by Torrens (1969*c*). Worssam & Bisson (1961, p. 95) have shown that Arkell miscorrelated horizons within the White Limestone exposed here, and M. J. Barker (1976, p. 1:41) has shown that he wrongly identified both gastropod beds at this locality. He misidentified the *Aphanoptyxis excavata* Barker MS of Beds 9–10 as *A. ardleyensis* and *A.* cf. *langruensis* as *A. bladonensis* (Barker 1976, p. 1:41). Worssam & Bisson (1961, p. 95) showed the true level of *A. bladonensis* is considerably higher in the sequence

(Bed 22) and thus the *Tulites glabretus* was almost certainly from Bed 1 of the section here (Arkell 1931, pp. 607–8) and can be re-assigned to a level very near, if not at, the base of the White Limestone Formation, in line with the other specimens known (Column B11).

Arkell divided the White Limestone of the Oxford area into two on the basis of the gastropod faunas; the Ardley Beds with type locality the Ardley Railway-cutting making up the lower two-thirds of the formation and 'defined upwards by a limestone near the top crowded with the gastropod *Aphanoptyxis ardleyensis* Arkell' (1947*b*, p. 42). The succeeding Bladon beds (type locality Bladon) yielded the gastropod *Aphanoptyxis bladonensis* Arkell. Palmer's work on the lithostratigraphy and conditions of deposition of the White Limestone Formation (1974, 1979) and M. J. Barker's (1976) on the gastropod faunas have independently shown the need for a tripartite division, which must be achieved by dividing Arkell's Ardley Beds into two. Both Palmer and Barker came to this conclusion but using rather different criteria. Palmer has now named a lower part of the Ardley Beds the Shipton Member, with the remaining Ardley Beds as the Ardley Member. The type locality is the Shipton Cement Works (SP 4717) and a distinctive feature of the Shipton Member was the higher proportion of clastic material. Barker on the other hand separated off almost exactly the same beds as Palmer, but on palaeontological grounds, since he found the uppermost part of the Shipton Member was characterized by a new species of *Aphanoptyxis, A. excavata* Barker MS, which he found to occur continuously between Foss Cross Quarry (see B11) and Ardley Fields Quarry (SP 543264).

Barker's work has shown that the three subdivisions of White Limestone here separated from below into Shipton, Ardley and Bladon members are characterized by different species of the gastropod *Aphanoptyxis* which are respectively *A. excavata* MS, *A, ardleyensis* and *A. bladonensis.* That the Shipton member with *A. excavata* ranges over both the *subcontractus* and *morrisi* Zones in the Oxford area as at Chedworth (B11) is now confirmed by the discovery of *Morrisiceras* cf. *morrisi* (Oppel) (OUM J29901) *in situ* at Sturt Farm Quarry (SP 271109) (the quarry described by Worssam & Bisson (1961, p. 94) as White Hill Quarry), 2.5 km south-east of Burford which is less than 3 km west of Eton College Quarry. It is the most northerly indication of this zone in England. Worssam and Bisson were unable to identify the horizons in the White Limestone then exposed here but the quarry has been considerably enlarged and Barker (1976, Fig. 1.10) showed that the ammonite bearing bed (4) is 1.2–1.4 m below the top of the Shipton Member, here identified by its top bed (5) replete with *A. excavata.* It is thus convenient to take the Shipton Member, apparently 5.6 m thick in this area, as equivalent to the *morrisi* and *subcontractus* Zones, although the exact boundaries of the zones may be slightly modified by future discoveries.

Evidence for the Upper Bathonian age of the Ardley and Bladon members of the White Limestone in the Oxford area is not compelling. Several Upper Bathonian ammonites have been collected but they have either not survived, or have survived without accurate stratigraphical information. An example of the former is

Buckman's (1921, p. 52) record of an ammonite 250–300 mm in diameter found at Ardley but still untraced; an example of the latter is the Upper Bathonian *Procerites* recently located in the S. S. Buckman collection no. 4809 (BM C79345) from 'Enslow Bridge, Oxon. Great Oolite Bottom Hard about half way down in quarry purchased from quarryman 1928'. The description of Allorge & Bayzand (1911, pl. II opp. p. 5) suggests that the specimen is likely to come from the Ardley Member. A similar undocumented (and also probably lost) specimen from Enslow Bridge was recorded by Whiteaves (1861, p. 106) as *Tulites subcontractus*, and thus indicates the *subcontractus* Zone. Whiteaves' collection is now in Canada but Professor Hans Frebold has kindly reported (*in lit.* 1.11.77) that a search has failed to locate it.

The best ammonite evidence for the Upper Bathonian age of some of the White Limestone Formation probably comes from the quarry at Croughton (SP 563336), described by Palmer (1974, p. A13) and M. J. Barker (1976, fig. 1.19). From here have come three different macroconch ammonites, *Procerites* sp. indet (nucleus) (OUM J29896), *Procerites* sp. transitional to *Choffatia* (OUM J29905) and a body-chamber fragment of a large *Procerites* (OUM J29166). All are thought to have come from Palmer's bed 12 of the Ardley Member at Croughton according to the testimony of quarrymen and the comparison of matrices. This is equated by Palmer with the base of the Ardley Member here, whereas Barker, by reference to other gastropod beds with the Ardley Member here, places the base of Bed 12 0.5 m above the top of the Shipton Member.

d. The Hampen Marly Formation has yielded one ammonite from near its base in the Fritwell cutting, the holotype of *Procerites imitator* (S. Buckman (IGS. GSM30328; Arkell 1951–59, p. 192–3)—a species known from the Acuminata Beds in Somerset as well as a number of higher horizons.

e. Beds probably belonging to the Taynton Formation have now yielded two *Procerites* sp. indet (OUM J30180–1) from Snowshill Hill Quarry (SP 131322) (Torrens 1969*a*, p. 16). From Slade Quarry, Salperton (SP 070215), the Taynton Stone has yielded a *Procerites mirabilis* Arkell (Bristol Univ. Geology Dept. collection), a *progracilis* Zone form typical of the Stonesfield Slates below (Torrens 1969*c*, p. 73).

f. Stonesfield Slates provide a further problem in the Oxford district. They are the type horizon for the Standard Progracilis Zone (Torrens 1974*a*); the ammonite faunas have been described by Arkell (1951–59, p. 240). References to the many other macrofossil groups found in the slates are given in Arkell (1947*b*). *Procerites progracilis* and *P. mirabilis* are the two most characteristic ammonite species, with rarer forms of long-ranging genera like *Micromphalites* and *Clydoniceras*. Arkell (1951–59, p. 100) also reported a single specimen of ?*Tulites pravus* S. Buckman (OUM J862), supposedly from the Stonesfield Slates of Stonesfield. It is the only specimen of *Tulites* recorded, at least in England, from outside the *subcontractus* Zone and has even been used to argue the Middle Bathonian affinities of the *progracilis* Zone. Its registration number shows it is from an old collection and the collector is unknown. The specimen is certainly a *Tulites* but preserved in the typical lithology of the Fuller's Earth Rock of Somerset in which *subcontractus* Zone *Tulites* are frequent. The preservation is quite wrong for the Stonesfield Slate and it is certain that the locality and stratigraphical horizon given by Arkell are wrong (see Hahn 1971, p. 69).

The Stonesfield Slate occurs only round the village of Stonesfield (Arkell 1947*c*, p. 139) and this has resulted in much discussion about the stratigraphical horizon of the slates. The British Association Reports (Walford 1895–7) concluded, on uncertain evidence, that the Stonesfield Slate lay at the top of the Taynton Formation. Arkell (1947*b*, 1947c) suggested that the true position was below the Taynton Formation, as shown in this chart, and further argued that it was a lateral equivalent of the Upper Sharp's Hill Beds (Sylvester-Bradley & Ford 1968, p. 231). Ammonite evidence adds nothing in support of this as the Sharps Hill Beds are devoid of ammonites. More recently Sellwood & McKerrow (1974, p. 192) have argued, on not very compelling grounds, that the Stonesfield Slates are instead developed at a third level, below the Lower Sharp's Hill Beds. Until the exact lithostratigraphical position of the Stonesfield Slates is determined, the interpretation of the *progracilis* Zone will be difficult and its typological definition by a base in a recorded section quite impossible. A borehole is urgently needed to resolve the problem. Aston (1974) described in detail both the history of the industry and the location of the known workings; these will be of much assistance in choosing a site.

g. Correlation of the Chipping Norton Formation has not improved since discussion by Torrens (1969*c*, pp. 74–5). The majority of ammonites from the lower Hook Norton Member belong to the *convergens* subzone of the *zigzag* Zone. One form confined to the *macrescens* Subzone above is *Zigzagiceras* (*Procerozigzag*) *pseudoprocerus* (Sturani 1967, p. 50), which is also recorded from the Hook Norton Member.

*B*13. *Northampton*

Between Oxford and Northampton many of the Bathonian rocks undergo a rapid and major change which is reflected in the changes in lithostratigraphical names in the relevant columns.

a. The only stratigraphical unit to maintain its lithological continuity is the transgressive Lower Cornbrash. *Clydoniceras* was recorded from the Lower Cornbrash at Stowe Nine Churches, 13 km west of Northampton, by Douglas & Arkell (1932, p. 129). A recent discussion of the Cornbrash can be found in Sylvester-Bradley & Ford (1968, pp. 246–52) although an important correction needs now to be made. In the Bedford area P. J. Smart (1959, pp. 22–4; 1961*a*, pp. 19–21; 1961*b*) referred the Oakley Junction Quarry (TL 027521) to the Cornbrash. Re-examination of the 'Cornbrash' fossils after their presentation to Northampton Natural History Society indicates that the fauna of epithyrids and digonellids is from the Blisworth Limestone. Douglas & Arkell's (1932, p. 128) note that *Cererithyris intermedia* was notable by its total absence in any exposures near Bedford is thus vindicated. The Oakley Junction pit is an old one and almost identical stratigraphical and structural features were already recorded in this area by Woodward (1904) who correctly identified the rock as the Blisworth Limestone.

b. Details of the Blisworth Clay and Blisworth Limestone can be found in

Sylvester-Bradley & Ford (1968) and Torrens (1967) and for the area around Milton Keynes in Horton *et al.* (1974). The only horizon which has yielded ammonites is the Blisworth Limestone and these biostratigraphically significant specimens from the basal few metres above the Kallirhynchia sharpi Beds are discussed by Torrens (1967, pp. 81, 83). The specimen recorded by Thompson (1927, pp. 31, 84) as cf. *Perisphinctes bakeriae* (Sow.) has been located in Northampton Central Museum but is an indeterminate juvenile perisphinctid and thus of no stratigraphical significance.

Two ammonites found since 1968 confirm that the age of the Blisworth Limestone above the Kallirhynchia sharpi Beds is Upper Bathonian (*hodsoni* Zone). The first is a specimen rediscovered in Northampton Museum, labelled 'Banks Pit, Kingsthorpe Great Oolite, [Thomas] Jesson collection'. The exact location of this quarry has not been determined, but it must be one of the Kingsthorpe quarries in the Blisworth Limestone described by Sharp (1870, pp. 357, 360). Beeby Thompson (*in lit.*) to S. S. Buckman, Nov. 11 1921, said of this ammonite it 'is highly probable that it came from Bed 11' of Sharp's description. This is within 0.4 m above the top of the Kallirhynchia sharpi Beds. The ammonite is a very large macroconch *Choffatia* (*Subgrossouvria*) sp. (325 mm diameter) with only a fraction of body-chamber. One other *Choffatia* from the Blisworth Limestone was recorded by Arkell (1951–59, pp. 219–22) (BM. C32424). The exact horizon of this specimen is also now known from a letter from Beeby Thompson to S. S. Buckman dated Aug. 15 1928 and preserved in Northampton Reference Library. 'It was from Bed 5 "Paving" of the Moulton Park House Pit near Kingsthorpe' (see Thompson 1927, p. 40). This is *c.* 2.8 m from the top of the Kallirhynchia sharpi Beds. The two confirm the Upper Bathonian age of the majority of the Blisworth Limestone. In South Germany *Choffatia* appears in the Upper Bathonian (Hahn 1969, pp. 70, 81) as it does in France (Mangold 1970*b*, p. 136). In England it is only common in the base of the *hodsoni* Zone and only a single specimen (of this same subgenus of *Choffatia*) is known *in situ* from the *morrisi* Zone of Shepton Montague Railway-cutting, HT 2101 (Torrens 1966, pp. C.186–7).

A further new ammonite from the Blisworth Limestone is one collected *in situ* at the junction of Beds 5–6 of the former Stewarts and Lloyds Twywell Ironstone Pit (SP 943776) in the section described here by Taylor (1963, p. 96). This is at the top of the 'very rubbly white oyster limestone with *Liostrea* cf. *undosa* Phillips 1 ft'. which corresponds with bed 4 of Pittham's redescription (1970, p. 63). It is only 0.3 m above the highest recorded occurrence of *Kallirhynchia sharpi* Muir-Wood here, and thus very close to the horizon of all other Blisworth Limestone ammonites found *in situ*. It is a specimen of *Procerites quercinus* (Terquem & Jourdy), closely comparable to many specimens from the topmost Fuller's Earth Rock of Somerset of basal *hodsoni* Zone age.

This correlation of the Blisworth Limestone above the Kallirhynchia sharpi Beds with the *hodsoni* Zone (and thus with an upper part of the White Limestone of Oxfordshire) receives support both from the digonellid brachiopods (Torrens 1967, pp. 85–8) and both from the nerineid gastropods. Barker (1976) recorded *Eunerinea arduennensis* (Buvignier), *Nerinella* cf. *acicula* (d'Archaic) and *Bactroptyxis implicata* (d'Orbigny) from the Nerinea Beds at Blisworth Quarry (Bed 10 of Torrens 1968, p. 68) and Roade Railway-cutting (Bed 4 *op. cit.* p. 70). Of these the first is uncommon in the *morrisi* and *subcontractus* Zones but abundant in the *hodsoni* Zone, whilst the other two are restricted in the English Bathonian to the Upper Bathonian. However, *B. implicata* is common in the *parkinsoni* Zone Clypeus Grit of the Bajocian, so is a long-ranging fossil of much less significance. Further evidence of the Upper Bathonian age of the upper Blisworth Limestone is provided by *Aphanoptyxis bladonensis* Arkell (in M. J. Barker (ex. Pittham) collection) from the now-infilled Stewarts and Lloyds No. 6 Ironstone Pit, Wellingborough (SP 915707), recorded by Pittham (1970, pp. 52–3). The exact horizon of the specimens is not known but they probably came from Bed 4, just above the Kallirhynchia sharpi Beds.

c. The Upper Estuarine 'Series' has received a considerable amount of attention from Thompson (1930), Aslin (1968), Bate (1967*b*) and Ferguson (1970, 1972). It is currently being studied by M. J. Bradshaw whose new names for the Upper Estuarine 'Series' and constituent limestone await publication. Thompson used a central upper Estuarine Limestone unit to separate beds above and below, but Aslin demonstrated that the limestones were not all at the same horizon. However there is one main limestone development within the Upper Estuarine 'Series' (Kent 1971, p. iv) which allows some comparison between sections. Another method of comparison is to use the sequence of sedimentary rhythms. More recently Bradshaw (1975) showed that montmorillonite was of common occurrence at certain horizons which, if of volcanic origin, may become a tool in correlating over wider areas and a wider range of facies, such as the numerous quasi-marine and brackish episodes in the English and Scottish Bathonian which have defied attempts using orthodox palaeontological methods.

The correlation of the Upper Estuarine 'Series' with the standard or with the more marine sequence to the south has not advanced significantly since the work of Buckman (1918). He pointed out that the brachiopod *Burmirhynchia* (now including *B. concinna* (Sowerby)) occurred in both the Hampen Marly Beds and the Upper Estuarine Limestone and allowed them to be correlated. Horton *et al.* (1974, p. 14), on the basis of mapping evidence, have instead equated the Upper Estuarine Limestone with the Taynton Formation. More significantly, Bradshaw (*pers. comm.* 1978) has traced the topmost rhythms of the Upper Estuarine 'Series' of this area into the upper part of the Hampen Marly Formation farther south. By extrapolation and in view of the lack of any evidence for a non-sequence in Northamptonshire above this level it seems best to place the Kallirhynchia sharpi Beds, which straddle the boundary between the Great Oolite Limestone and Upper Estuarine 'Series', in the *morrisi* and *subcontractus* Zones as shown in the chart. But there is no ammonite evidence in the area for the age of any of these beds, from the Kallirhynchia sharpi Beds downwards to the base of the Stage.

B 14. *Peterborough*

Based on Horton *et al.* (1974).

a. The only horizon here allowing a correlation with the standard is the Lower

Cornbrash, from which a characteristic fauna has been collected (Douglas & Arkell 1932, p. 133; Horton *et al.* 1974, p. 28), including the subzonal index *C.* (*Clydoniceras*) *discus* (J. Sowerby) near Ailsworth (TL 1199) (Judd 1875, p. 224). This formation was formerly well exposed in numerous quarries, but now is hardly seen except in small natural exposures and boreholes (Callomon *in* Sylvester-Bradley & Ford 1968, p. 280).

b. Nothing can be added from this area to substantiate the correlation of the Blisworth Limestone above the Kallirhynchia sharpi Beds with the standard. However, the outcrop is continuous and there is no evidence to suggest the formation is diachronous or varies in age from that well established in the south (Column B13). The Kallirhynchia sharpi marker beds at or near the base of the formation are still present here. The few Blisworth Limestone ammonites from this area are all old records, none of which have apparently survived (Torrens 1967, pp. 79–80).

*B*15. *Lincoln*

Based on Douglas & Arkell (1932), Evans (1952), Sylvester-Bradley & Ford (1968) and Swinnerton & Kent (1976).

a. The only horizon firmly dated by ammonites is the Lower Cornbrash. From Sudbroke (TF 0276), north-east of Lincoln, Arkell (1951–59, pp. 40, 44, 222) recorded *Clydoniceras discus* and its microconch *C.* (*Delecticeras*) *legayi* (Rigaux & Sauvage) which constitute the most northerly records of this genus in Britain. Also from Sudbrooke *Choffatia* (*Subgrossouvria*) *cerealis* Arkell is recorded although this species is by no means subzonally diagnostic. The Lower Cornbrash of this area has thinned considerably (Douglas & Arkell 1932, p. 136) from the south.

b. As in the area to the south (column B14) no biostratigraphically significant macrofossils are yet known from the Blisworth Clay or Upper Estuarine Series.

c. The Blisworth Limestone is a fully marine horizon from which rare ammonites have been found to the south. The most northerly is an old and unconfirmed record of *Ammonites macrocephalus* Schlotheim from Uffington (SK 0607) (see Torrens 1967, p. 79). The Kallirhynchia sharpi marker beds at the base of the formation occur at Lincoln (Torrens 1967, p. 81) and persist as far north as Spital (SK 9690) (Kent 1971, p. v).

*B*16. *North Yorkshire*

Based on Black (1929).

No detailed correlation with the standard is possible for the Bathonian rocks of North Yorkshire. The White Nab Ironstone Member of the Scarborough Formation has yielded *blagdeni* Subzone faunas from its upper part (Parsons 1977*b*, p. 214) but the Transition Shales at the top of the Scarborough Formation and the entire Scalby Formation above have yielded no faunas allowing any correlation with the standard.

The classic view is that the Scalby Formation records continuous deposition through the Upper Bajocian, entire Bathonian and a small part of the Callovian, although its total thickness is only up to 65 m, and that the environment of deposition was deltaic (Hemingway 1974). Accepting the figures for the average duration of complete ammonite zones (Cope *et al.* 1980, p. 17) and that the Scalby

Formation is the result of uninterrupted sedimentation, gives a figure of only 0.0076 m of sediment per thousand years over this long period. Recent work has suggested the Scalby Formation is instead a wholly alluvial and non-deltaic deposit (Leeder & Nami 1979). In this model, the basal Moor Grit Member rests erosively on the Scarborough Formation which is separated by a very considerable time gap from the Scalby Formation. Leeder and Nami argue for relatively high depositional rates quite at variance with the continuous rates noted above. They suggest the whole Scalby Formation may have been the result of less than one million years of deposition and thus that the greater proportion of Bathonian time is quite unrepresented by any sediment in the North Yorkshire area.

In the absence of any convincing palaeontological evidence the earlier view is followed here merely for convenience.

B17. *Cardigan Bay*

Based on Penn & Evans (1976).

The Middle Jurassic here is known only from boreholes. As a result, correlation is very uncertain and is based on lithofacies and very limited biostratigraphical control in most cases. Sandstones and siltstones of uncertain age found in IGS borehole 74/22 were comparable with parts of the Yorkshire Scalby Formation. Mudstones cored in boreholes 74/23 and 71/50 seem likely to be of Middle to Upper Bathonian age, as noted by Penn & Evans, and the limestones and mudstones in 71/57 compare with the Hampen Marly Beds (*progracilis* Zone) on macrofaunal grounds.

The 6 m of fine-grained limestone with nerineid gastropods and brachiopods recorded in borehole 72/38 is compared with the White Limestone of Middle and Upper Bathonian age. However, *Bactroptyxis bacillus* (d'Orb) and *Stiphrothyris*? sp. could equally indicate a correlation with the Upper Bajocian Clypeus Grit (Barker 1976, pp. 2:66–8, Channon 1951). These two lithologies have been often confused even at surface outcrop.

B18. *West Scotland (by J. D. Hudson)*

The Great Estuarine 'Series' of Judd (1878) can be correlated in detail neither with the successions in England nor with the standard. However, the succession can be divided into well-characterized formations (*sensu lato*) on lithological and faunal grounds, as shown in column B18. These can be traced throughout the area of Trotternish (North Skye), Raasay, Strathaird (South Skye), Eigg, and Muck (Hudson 1962). The succession is most complete in Trotternish on which the chart is largely based. Thicknesses of some formations are approximate owing to incomplete exposure and all are given to the nearest metre. Tan & Hudson (1974, with earlier references) give a summary. The revision of the lithostratigraphy of the Great Estuarine Group by Harris & Hudson (1980) appeared too late for inclusion in this Report.

a. The present unsatisfactory situation concerning the top of the Bathonian is discussed by Hudson (1962) and Sykes (1975, pp. 67–8). The Staffin Bay Formation of Trotternish is partly Callovian; whether the lower part of it is Bathonian is unknown.

b. The record of marine Lower Cornbrash (Upper Bathonian) in Raasay seems anomalous in the regional picture, and needs to be confirmed. See also note c, column C17.

c. When considering whether the Great Estuarine 'Series' should be regarded as a formation or as a group, one seeks comparable units. Obvious comparisons are with the contemporaneous Great Oolite Series (now Group: Sellwood & McKerrow 1974), or the underlying Bearreraig Sandstone Series (now Formation: Morton 1976). Consistency with both is impossible. In 1962 (p. 143) and 1974 (Tan & Hudson p. 93) I stated that I regarded the Great Estuarine 'Series' as a group in terms of modern stratigraphical nomenclature and that is still my preferred solution. The subdivisions (then formations) are at least as thick, continuously mappable and distinctive as the traditional formations of the English Middle Jurassic. Originally the term 'series' was also used for the Concretionary Sandstone Series within the Great Estuarine Group: recently I have called this unit simply Concretionary Sandstones (Tan & Hudson 1974). In various other respects the formations are not named in accordance with the Geological Society code, but it seems quite pointless to change them.

Most of the distinctive bivalve species of the Great Estuarine Group have long ranges both within the local area and within the Great Oolite Group of England (Hudson 1963; cf. Cox & Arkell 1948–50). However, few of them apparently occur in the known Bajocian of either area, and this may be an argument for regarding the fossiliferous parts of the Great Estuarine Group, from Mytilus Shales upwards, as entirely Bathonian. However it may simply reflect the absence of suitable facies within the Bajocian. *Praeexogyra hebridica*, despite earlier statements, is apparently confined to the Lower Ostrea Beds within the Great Estuarine Group, although it also occurs in the Upper Ostrea Member of the Staffin Bay Formation above. Its range according to Cox & Arkell (1948–50) is 'throughout the Great Oolite from Chipping Norton Limestone and Sharps Hill Beds onwards'. *P. acuminata*, which occurs with *P. hebridica* in the Sharp's Hill Beds of Oxfordshire does not occur in the Hebrides. This might suggest a closer comparison with higher horizons from the Hampen Marly Formation to the Forest Marble Formation, which contain typical *P. hebridica* only (Hudson & Palmer 1976). However, the Acuminata Beds of southern England are, according to the present chart, approximately correlative with the Hampen Marly Formation, so facies control seems more important than time in separating the occurrence of the two species.

Ostracods may give promise of more refined correlation in the future but many, if not all, of the Scottish species are endemic (Anderson, Boyd & Bate, separate *pers. comm.*).

d. The Mytilus Shales were recognized previously only in Eigg and Strathaird, but recent work has shown that they occur also in Trotternish, and are indeed well exposed in several places along the coast between Rudha nam Brathairean and Inver Tote (Hudson MS). The distinctive algal bed at the top is lithologically identical to the Eigg development (Hudson 1970). The Mytilus Shales thus deserve cognate rank with the other formations rather than to be regarded as a Member of the Estheria

Shales, as they maintain their distinctive character over an equally wide area. The Mytilus Shales and all the higher formations have a bivalve and gastropod fauna of Bathonian aspect (see note c).

e. The only ammonite that might have come from the Great Estuarine Group is a *Procerites* sp. described and figured by Morton (1975, p. 88 & pl. 17 figs 1 & 2) as possibly derived from the White Sandstone which is otherwise virtually unfossiliferous. It was found in a loose block. [Dr. J. H. Callomon (*pers. comm.* 1979), who collected the supposed *Procerites* sp. mentioned above, considers it is probably only the very crushed body-chamber whorl of a large macroconch *Emileia* (*Emileia*) from the Lower Bajocian and this seems certain. Its original stratigraphical horizon is thus the upper Massive Sandstones. H.S.T.]

f. In that it apparently conformably overlies the Garantiana Clay the Basal Oil Shale may be Upper Bajocian; but there is no evidence of any disconformity above it, either, so the position of the lower boundary of the Bathonian is indeterminate. It is perhaps more likely to occur within the shale than within the probably rapidly-deposited White Sandstone above.

B 19. *East Scotland: Brora*

Based on Lee (1925*b*) and Neves & Selley (1975).

The Brora Coal Formation is here regarded as of entirely Bathonian age although no detailed correlation with the standard is possible. It is overlain by the Brora Argillaceous Formation whose basal bed has yielded faunas of the *calloviense* Zone, *koenigi* Subzone (Sykes 1975, p. 54). The remaining Callovian *macrocephalus* Zone is normally regarded as cut out by erosion but it is conceivable that an upper part of the Brora Coal Formation is of basal Callovian age. The basal part of the Brora Coal Formation is faulted out.

It should be noted that Neves & Selley (1975) inexplicably assign the Brora Roof Bed to both the Brora Coal Formation and to the Brora Argillaceous Formation. It is here excluded from the Brora Coal Formation following Sykes (1975, p. 53).

CALLOVIAN CORRELATION CHART

K. L. Duff
with a contribution on the subzones of the stage
by J. H. Callomon & R. M. Sykes

THE BASE OF THE STAGE

The base of the Stage is placed by international agreement at the base of the *macrocephalus* Zone (Callomon 1964, p. 274), where ammonites of the genus *Macrocephalites* replace *Clydoniceras*. In England, the *macrocephalus* Zone has been shown to begin at the base of the Upper Cornbrash (Callomon 1964, p. 272), the Cornbrash itself being strictly divisible, on the basis of lithology and fauna, into an Upper (Callovian) and Lower (Bathonian) part (Douglas & Arkell 1928, 1932, 1935).

ZONES

The standard zonal scheme for the Callovian, established by Callomon (1964). is adopted here and, in addition, subzones for the *athleta* and *lamberti* Zones are formalized.

Subzones of the Callovian Stage (*by J. H. Callomon & R. M. Sykes*)

Two subzones are erected within the *lamberti* Zone, and three within the *athleta* Zone.

Athleta Zone.
Phaeinum Subzone.
Author: Callomon & Sykes, herein.
Index: *Kosmoceras* (*Lobokosmokeras*) *phaeinum* (S. Buckman).

The characteristic fauna is mainly kosmoceratids, dominantly forms with bundled ribbing, such as the index species, in which the secondary ribs unite on the ventrolateral shoulder. Other characteristic (although often much longer-ranging) species are *Kosmoceras* (*Spinikosmokeras*) *acutistriatum* S. Buckman, *K.* (*S.*) *aculeatum* (Eichwald), *K.* (*S.*) *ornatum* (Reinecke), *Binatisphinctes comptoni* (Pratt), *B. fluctuosus* (Pratt) (all common near the base), *K.* (*Gulielmiceras*) *rimosum* (Quenstedt) and *K.* (*G.*) *gemmatum* (Phillips).

Type-locality: Calvert brickpit, Buckinghamshire (Callomon 1968, p. 285; base, Bed 10).

Reference section: the shore sections in the Brora Brick Clay Member and the Fascally Siltstone Member south of Brora, Sutherland (Sykes 1975, p. 56).
Remarks: Equivalent to the Lower *athleta* Zone of Callomon (1968, p. 274).

Proniae Subzone.
Author: Callomon & Sykes, herein.
Index: *Kosmoceras* (*Lobokosmokeras*) *proniae* Teisseyre.

In the East Midlands the fauna is typically pyritized, and comprises mainly kosmoceratids with bundled ribbing, such as the index species, *K.* (*L.*) *rowlstonense* (Young & Bird), *K.* (*K*). *bigoti* (Douvillé), *K*, (*G.*) *rimosum* (Quenstedt), *K. duncani* (J. Sowerby) and *K.* (*S.*) aff. *spinosum*, together with large peltoceratids such as *Peltoceras athleta* (Phillips) and *Peltoceras* spp., and occasional *Longaeviceras placenta* (Leckenby) and *Longaeviceras* spp. (The latter occur especially in Scotland and East Greenland).

Type-locality: Calvert brickpit, Buckinghamshire (Callomon 1968, p. 285; base, bed 13).

Reference section: the shore sections in the Fascally Siltstone Member, south of Brora, Sutherland (Sykes 1975, p. 56).

Remarks: Equivalent to the Middle *athleta* Zone of Callomon (1968, p. 275).

Spinosum Subzone.
Author: Callomon & Sykes, herein.
Index: *Kosmoceras* (*Kosmoceras*) *spinosum* (J. de C. Sowerby).

The kosmoceratid fauna is dominated by *K.* (*K.*) *spinosum* (J. de C. Sowerby), *K.* (*K.*) *tidmoorense* Arkell, and *K.* (*Lobokosmokeras*) *kuklikum* (S. Buckman), and is accompanied by a more diverse fauna including *Distichoceras, Horioceras, Hecticoceras, Grossouvria* and other perisphinctids. The fauna is characteristically pyritized in the East Midlands pits.

Type-locality: Woodham brickpit, Buckinghamshire (Arkell 1939*a*, beds E–D; Callomon 1968, p. 287).

Reference section: the shore section in the Fascally Siltstone Member south of Brora, Sutherland (Sykes 1975, p. 56).

Remarks: Equivalent to the Upper *athleta* Zone of Callomon (1968, p. 276).

Lamberti Zone.

Henrici Subzone.

Author: Callomon & Sykes, herein.

Index: *Quenstedtoceras* (*Eboraciceras*) *henrici* (R. Douvillé).

The fauna is dominated by *Quenstedtoceras* of the arch-whorled *Eboraciceras* type, rather than the sharp-ventered *Lamberticeras* of the succeeding subzone, together with kosmoceratids such as *K.* (*K.*) *compressum* (Quenstedt) Arkell (= *Ammonites compressus* Quenstedt non auctt.), *K.* (*K.*) *spinosum* (J. de C. Sowerby) and *K.* (*K.*) *tidmoorense* Arkell. The kosmoceratids are usually in approximately equal numbers with the *Quenstedtoceras.*

Type-locality: The clays below the Lamberti Limestone at Woodham brickpit, Buckinghamshire (Arkell 1939*a*; Callomon 1968, p. 287, bed D2).

Reference section: the River Brora section in the lower part of the Fascally Sandstone Member and the top of the Fascally Siltstone Member (Sykes 1975, p. 57).

Lamberti Subzone.

Author: Callomon & Sykes, herein.

Index: *Quenstedtoceras* (*Lamberticeras*) *lamberti* (J. Sowerby).

The fauna is characterized by (i) the appearance of *Lamberticeras* alongside *Eboraciceras,* and (ii) the numerical dominance of *Quenstedtoceras* over *Kosmoceras.* At Brora, the commonest species are *Q.* (*L.*) *lamberti, Q.* (*Q.*) *leachi* (J. Sowerby), *Q.* (*E.*) *sutherlandiae* (J. Sowerby), *Q.* (*L.*) *intermissum* (S. Buckman), *K.* (*K.*) *compressum* (Quenstedt) Arkell and *Aspidoceras* (*Euaspidoceras*) *clynelishense* Arkell; whilst at Woodham the abundant and diverse fauna includes *Q.* (*L.*) *lamberti, Q.* (*L.*) spp., *Q.* (*Q.*) spp. and many distinctive inflated forms of *Q.* (*Eboraciceras*) spp., together with *Kosmoceras* spp. s.s., *Pachyceras* sp., *Hecticoceras* spp. (abundant), *Distichoceras* sp., *Grossouvria* spp. (abundant), *Perisphinctes* spp., *Peltoceras* (*Peltomorphites* and *Parawedekindia*) spp., *Aspidoceras* (*Euaspidoceras*) spp. (abundant—the subzone marks the sudden appearance in quantity of this genus), and the last *Reineckeia* (*Collotia*) spp. (relatively rare). These faunas reflect the differences between the Boreal Province in Scotland, and the Sub-Boreal (or even Sub-Mediterranean) Province in southern England.

Type-locality: Woodham brickpit, Buckinghamshire (Arkell 1939*a*) bed C; Callomon 1968, p. 287).

Reference section: the River Brora section in the upper part of the Fascally Sandstone Member, and the Clynelish Quarry Sandstone Member at Clynelish Quarry (Sykes 1975, p. 57 and 1976 *pers. comm.*).

*C*1. *Dorset Coast*

Based on Arkell (1947*a*), Douglas & Arkell (1928), Smith (1969) and Torrens (1969*a*).

a. Smith (1969, p. A41) recorded over 8 m of clays with septarian concretions from the Middle and Upper *athleta* Zone (*proniae* and perhaps *spinosum* Subzones) of Crook Hill brickpit, near Weymouth, but the total thickness of the Middle Oxford Clay in this area is unknown. The *lamberti* Zone is seen in the Fleet shore at Tidmoor Point, and in a small upfaulted block east of Ham Cliff between Redcliff and Shortlake, but the exposures are very poor, and thicknesses cannot be accurately measured.

b. The exact level of the Lower Oxford Clay–Kellaways Rock junction is uncertain, but is placed at about the top of the *calloviense* Subzone as suggested by Callomon (1955, p. 254). The shaly clays and bituminous shales of the Lower Oxford Clay are lithologically distinct from the more plastic clays of the Middle Oxford Clay, as noted by Smith (1969, p. A41). The overall thickness of the Lower Oxford Clay in this area is estimated to be *c*. 19 m (Smith 1969, pp. A40–1). From the same source, the *phaeinum* Subzone may be calculated to be *c*. 7 m thick, the *grossouvrei* Subzone *c*. 7.5 m, and the *obductum* Subzone *c*. 3.8 m.

c. Arkell (1947*a*, p. 27) recorded 18″ (0.45 m) of sandy clay and sands with cementstone concretions above the Kellaways Clay at Putton Lane, referred to the Kellaways Rock. The 12″ (0.3 m) of large septarian concretions above this are of more doubtful age, but are united with the Kellaways Rock on lithological grounds.

d. Arkell (1947*a*, p. 27) recorded over 8 feet (2.4 m) of blue clay with *Proplanulites* and *Cadoceras* from Putton Lane brickyard, near Weymouth, and this is here assigned to the Kellaways Clay. However, the total thickness is almost certainly much greater, encompassing a lower (pyritic-phosphatic) Kellaways Clay of *kamptus* Subzone age, and an upper, silty, Kellaways 'Clay' of *koenigi* Subzone age (Callomon 1955, p. 246). The transition to Kellaways Rock above is gradational, the 'Rock' being only quite locally indurated.

e. Douglas & Arkell (1928, p. 153) recorded a thickness of *c*. 4.5 m for the Upper Cornbrash at Abbotsbury. House (1958) recorded *Macrocephalites* from the Fleet area.

*C*2. *North Dorset–Wiltshire*

Based mainly on Cave & Cox (1975) and Douglas & Arkell (1928).

a. The poor exposure and lack of borehole evidence precludes the division of Lower and Middle Oxford Clay in this area, and even the total thickness of the Oxford Clay is unknown, although Callomon (1968, p. 264) quoted the combined

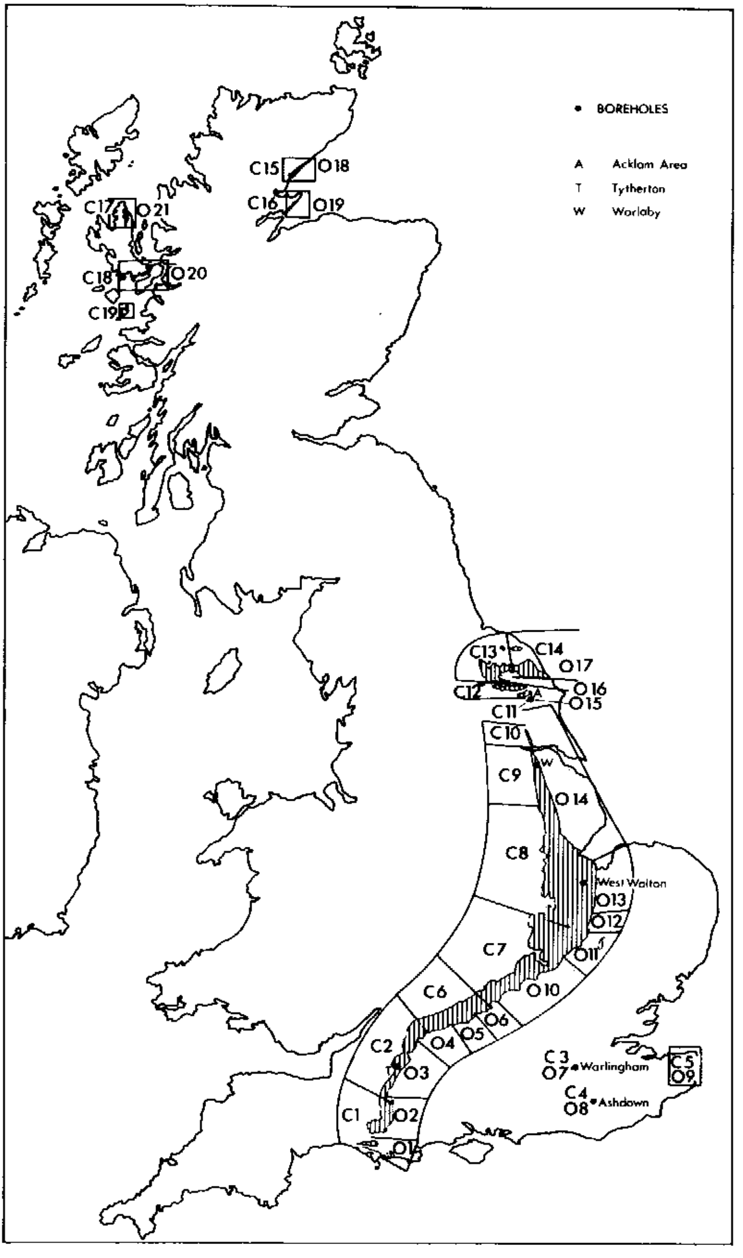


FIG. 7. Disposition of the columns on the Callovian (C) and Oxfordian (O) correlation charts.

thickness of Oxford Clay and Kellaways Beds, given by Woodward (1895, p. 28), as 600 feet (*c.* 190 m). However, from the observations of Cave & Cox (1975, pp. 55–60) on the rocks of the Tytherton No. 2 borehole, it is possible to estimate the *enodatum* Subzone as *c.* 1.3 m, the *medea* Subzone *c.* 2.9 m, the *jason* Subzone *c.* 4.3 m and the *obductum* Subzone as *c.* 10.7 m thick. The *lamberti* Zone was exposed in a railway cutting near Brinkworth (Callomon 1976, *pers. comm.*).

b. Both Cave & Cox (1975, p. 52) and Callomon (1955, p. 254) placed the Kellaways Beds–Oxford Clay junction at the base of the *enodatum* Subzone.

c. Thickness range from Cave & Cox (*op cit.*). Cope & Cox (1970, p. 122) have recorded the earliest known British specimen of *Reineckeia* from this horizon near Corscombe, Dorset.

Callomon (1955, p. 246) divided the Kellaways Clay into two units, characterized by both lithological and faunal features. He recognized an upper pyritic, silty facies, in which the rich and diverse ammonite fauna (*Kepplerites, Torricelliceras, Proplanulites, Choffatia, Grossouvria, Cadoceras, Pseudocadoceras, Chamoussetia, Macrocephalites* and *Pleurocephalites*) is preserved in pyritic mudstone with a white covering; and a lower, shaly phosphatic facies, in which the ammonite body-chambers (*Macrocephalites* and *Kamptokephalites*) are preserved in buff marl rich in calcium phosphate. This same occurrence has been recognized in the Tytherton No. 2 borehole, near Chippenham (Cave & Cox 1975, p. 44).

The thickness of the Kellaways Clay appears to be rather variable in this area, and is further complicated by the transitional change from the Kellaways Clay to the Kellaways Rock/Sand. Cave & Cox (1975) gave the thickness range in the Chippenham-Malmesbury area as 15.8–21.5 m, but recorded a maximum of 28.6 m at Oaksey, 6.5 km south of Kemble. Part of this is thought to be due to the Kellaways Rock/Sand being variably developed at the top of the Kellaways Clay; this view is supported by the local occurrence, south of Chippenham and north-east of Malmesbury, of Oxford Clay resting directly on Kellaways Clay (Cave & Cox 1975). In a recent exposure for a road cutting at Wincanton, no boundary could be drawn between Kellaways 'Clay' and 'Rock', some 12 m being seen, with perhaps another 10 m proved by borings. However, the *calloviense* Subzone extended over only the top 2 m (Callomon 1976, *pers. comm.*).

d. Douglas & Arkell (1928, p. 148) recorded a thickness of *c.* 4.7 m for the Upper Cornbrash at Holwell Quarry, south-west of Bishop Caundle. The formation thins rapidly northwards, to *c.* 2.5 m at Stalbridge and *c.* 1.2 m at South Brewham, near Wincanton (Douglas & Arkell 1928, pp. 145, 147) although further west, at Sutton Bingham near Yeovil, Arkell (1954*b*, p. 115) recorded the greatest thickness known, in what was subsequently designated as the type-section of the *macrocephalus* Zone and Subzone by Callomon (1964, p. 275). Northwards, between Malmesbury and Frome, the thinning becomes extreme, and the formation is represented solely by a thin seam of brown marl (Douglas & Arkell 1928, p. 139). The variability of the Cornbrash is shown by Cave & Cox's record (1975, p. 66) of 4.39 m of Cornbrash (undivided) from the Tytherton No. 3 borehole, but only 2.81 m of Cornbrash (undivided) from Tytherton No. 2 (Cave & Cox 1975, p. 63). Besides thickness, the

Upper Cornbrash also varies rapidly in both facies and fauna, so that there seems little doubt that it should be regarded as a condensed deposit, consisting of lenticles of sediment, differing in age from place to place, separated by innumerable non-sequences, and representing but a fraction of the time-intervals involved (Callomon 1976, *pers. comm.*). A detailed correlation, based on (for example) ammonites, remains to be made, but is likely to prove difficult through lack of material.

C3. Warlingham borehole

Based on Callomon & Cope (1971) and Worssam & Ivimey-Cook (1971).

a. From the evidence available, it is difficult to separate the *athleta* and *lamberti* Zones, but from the data of Callomon (*in* Callomon & Cope 1971, p. 166), the author calculates a thickness for the *athleta* Zone of *c*, 17 m and *c*. 12 m for the *lamberti* Zone. Callomon stated that faunas representing all the subzones of the *athleta* Zone may be recognized, but are too sparse to allow subzonal thicknesses to be calculated.

b. Callomon (*in* Callomon & Cope 1971, table 5) gave the following subzonal thicknesses for the bituminous shales of the Lower Oxford Clay: *medea* Subzone *c*. 0.8 m, *jason* Subzone *c*. 1.2 m, *obductum* Subzone *c*. 2.1 m, and *grossouvrei* Subzone *c*. 8.5 m.

c. No Kellaways Clay is developed here, the whole of the Kellaways Beds consisting of fine clean sandstone, resembling the Kellaways Rock of Dorset and Wiltshire (Callomon & Cope 1971, p. 163).

d. The Cornbrash cannot be clearly divided from the underlying Forest Marble, although a tentative lithological separation may be made on the basis of information given by Worssam & Ivimey-Cook (1971, p. 42). The reason for the separation is the change from detrital-shelly limestones above (here placed in the Cornbrash) to fine-grained oolitic limestones below (here placed in the Forest Marble); this suggests a thickness of *c*. 6.5 m for the whole of the Cornbrash. Faunal evidence is insufficient to subdivide the unit, and to separate the Cornbrash from the Forest Marble.

C4. Ashdown boreholes

Based on Ivimey-Cook *in* Bristow & Bazley (1972).

a. The Oxford Clay was only partially cored in the Ashdown boreholes, and details of zonal thicknesses are incomplete; the overall thickness is recorded as 96.7 m in No. 1, and 92.6 m in No. 2. From the data given by Ivimey-Cook (1972, pp. 20–1), it is possible to calculate an approximate thickness of at least 5.3 m for the *coronatum* Zone, *c*. 3.5 m for the *jason* Subzone, and *c*. 0.3 m for the *medea* Subzone, but no lithological division into Lower and Middle Oxford Clay may be made. Ammonite evidence indicates that the Oxford Clay—Kellaways Beds junction occurs at about the base of the *medea* Subzone.

b. In both Ashdown No. 1 and No. 2 boreholes, the Kellaways Beds are represented by 9.1 m of grey muddy sandstones; as in the Warlingham borehole, no Kellaways Clay is developed.

c. Ivimey-Cook (*loc. cit.* p. 21) recorded *c.* 3.4 m of grey mudstones and silty limestones beneath the Kellaways Beds in the Ashdown No. 1 borehole; the age of these beds is difficult to determine, but they have been assigned to the Cornbrash. It is not possible to divide the Cornbrash into Upper and Lower.

C5. *Kent*

Based on Callomon (1955) and Smart *et al.* (1966), the latter authors having summarized much of the data of Lamplugh & Kitchin (1911), Lamplugh *et al.* (1923) and Pringle (1928).

a. The total thickness of the Oxford Clay varies from *c.* 27 m at Dover to *c.* 53 m at Brabourne (Lamplugh *et al.* 1923, p. 15); however, it is difficult to assign thicknesses to subdivisions of the Oxford Clay here, as the faunas are too imperfectly known. Lamplugh & Kitchin (1911, p. 135) recorded *c.* 4 m of 'Ornatus Beds' at Dover, whilst at Brabourne (1911, p. 166) this unit has thickened to *c.* 17.8 m; the 'Ornatus Beds' are broadly equivalent to the Lower Oxford Clay of central England, appearing to occupy the *jason* Zone, *coronatum* Zone, and the lower part of the *athleta* Zone. Callomon (1955, p. 248) recorded *K. jason* (Reinecke) from the base of the Oxford Clay at Guilford and Tilmanstone, and the fauna higher up included *K.* (*G.*) *gulielmi* (J. Sowerby), *K.* (*Spinikosmokeras*) *castor* (Reinecke), *K.* (*S.*) *pollux* (Reinecke) and *K. duncani* (J. Sowerby). Lamplugh *et al.* (1923, p. 209) recorded fragments of *Erymnoceras* from both Chilham and Fredville, which indicate the presence of the *coronatum* Zone. There is no direct evidence for the *athleta* Zone, but good evidence for the *lamberti* Zone, which is indicated by a rich fauna of *Quenstedtoceras*, including *Q. lamberti* (J. Sowerby), *Q. leachi* (J. Sowerby), *Q. macrum* (Quenstedt) and *Q. goliathus* (d'Orbigny); these occur in the 'Renggeri Beds' of Lamplugh & Kitchin, which occupy *c.* 27 m at Brabourne and *c.* 14 m at Dover (Lamplugh *et al.* 1923 pp. 134, 164). It seems likely that the 'Renggeri Beds' belong at least in part to the *mariae* Zone, and perhaps also to the *athleta* Zone in part.

b. The Kellaways Rock is very variable in thickness in Kent ranging from *c.* 6.5 m at Brabourne and Harmansole to *c.* 13.2 m at Fredville. In addition, there is a marked lithological variation, the impure marly sandstones with ferruginous beds of the southern and eastern area (i.e. Dover) being replaced northwards by ferruginous marlstones which locally have the composition of very glauconitic 'millet-seed' ironstones (i.e. Fredville). Ammonites are very rare, the only records being those of *Sigaloceras calloviense* (J. Sowerby) from Tilmanstone (Lamplugh & Kitchin 1911, p. 137), and *K. medea* Callomon from near the top of the unit at Guilford, and also at Dover (Callomon 1955, p. 248). Callomon believed that the '*S. calloviense*' may be a specimen of *K. medea.* The only other ammonite known is a fragment that may be part of a *Proplanulites* (Callomon 1955, p. 249).

c. Following the usage of Arkell (1933, p. 375), the sandy clays above the limestones of the Cornbrash are assigned to the Kellaways Clay. This particular horizon is widespread, and ranges from about 1 m at Oxney, 1.5 m at Harmansole, to 2 m at Guilford and Bobbing (thicknesses after Lamplugh *et al.* 1923). It has

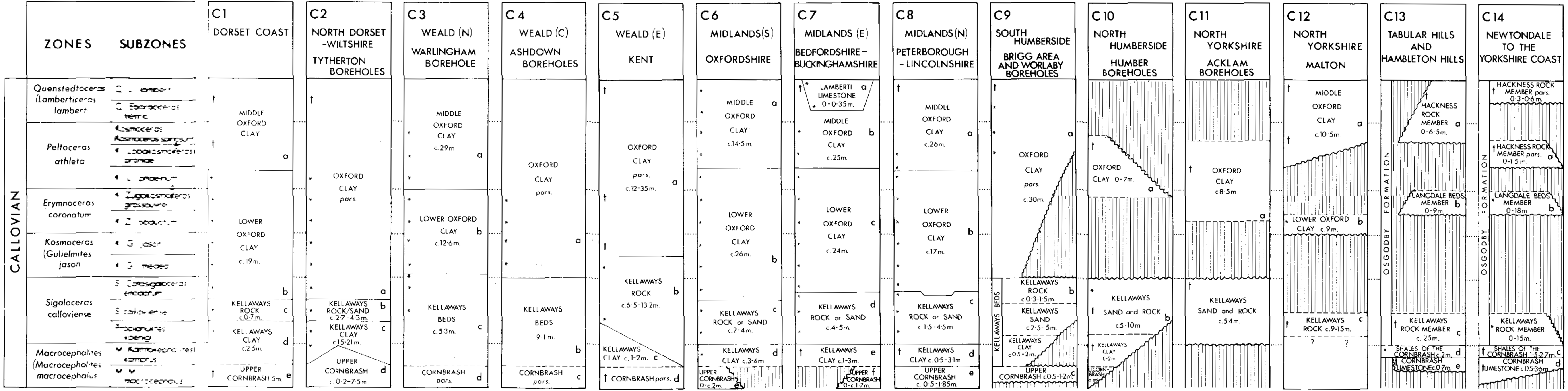


FIG. 8. Correlation of Callovian rocks. Columns C1–C14.

yielded no ammonites, although *Macrocephalites* has been recorded from the limestones immediately below the clay at Bobbing (Lamplugh *et al.* 1923, p. 204).

d. The Cornbrash of east Kent was stated by Lamplugh *et al.* (1923, p. 204) to consist generally of a variable impure limestone with a rich bivalve, brachiopod and echinoid fauna, below, and a thin argillaceous band with bivalves and very few brachiopods, above. However, Arkell (1933, p. 375) preferred to group these sandy clays with the Kellaways Beds, and this practice is followed here.

Variation in both thickness and lithology is widespread, with the Cornbrash being locally absent (Stodmarsh and Littlebourne—Smart *et al.* 1966, p. 37), although thicknesses of up to about 6.5 m have been recorded at Fredville (Lamplugh *et al.* 1923, p. 91). Smart *et al.* (1966, pp. 31, 36, 37) gave details of this variability. Callomon (1955, p. 249) quoted a thickness of *c.* 8 m for the Cornbrash at Tilmanstone, and suggested that it is possible to separate the Lower and Upper Cornbrash; the Upper Cornbrash is assigned a thickness of *c.* 6.6 m.

C6. Oxfordshire

Based on Callomon (1955, 1968) and Douglas & Arkell (1928, 1932, 1935).

a. Callomon (1968) recorded a thickness for the upper part of the *athleta* Zone in excess of 11.5 m at Calvert, and believed (1968, p. 276) that the full thickness is probably not less than 13 m. The lower part of the *athleta* Zone, approximating to the *phaeinum* Subzone, is *c.* 9.7 m thick. The *lamberti* Zone crops out in Oxford, where it is represented by at least 1.5 m of clay (Callomon 1955, p. 277). Two old borings in the Oxford area, at Wytham and St. Clements, began in the *lamberti* Zone (Callomon 1976, *pers. comm.*), and gave a total thickness for the Oxford Clay and Kellaways Beds of *c.* 80 m (Woodward 1895, p. 42). The *henrici* Subzone is frequently exposed in foundations for buildings in Oxford.

b. The Lower Oxford Clay is not permanently exposed in Oxfordshire, and the division into Lower and Middle Oxford Clay is based on an extrapolation of information collected from Calvert (Buckinghamshire) by Callomon (1968, p. 285). Likewise, the subzonal thicknesses given are those recorded from Calvert by Callomon: *c.* 3 m for the *enodatum* and *medea* Subzones combined, *c.* 5.5 m for the *jason* Subzone, *c.* 4 m for the *obductum* Subzone, and *c.* 4 m for the *grossouvrei* Subzone. Cuttings for the Witney bypass recently exposed Lower Oxford Clay, and confirmed that the *jason* Subzone there is at least 5 m thick (Callomon 1977, *pers. comm.*).

c. About 2 m of Kellaways Rock occur at Kidlington (Callomon 1955, p. 219), although Callomon later (1976, *pers. comm.*) stated that the formation varies from 2 to 4 m within the area, locally persisting into the *enodatum* Subzone.

d. Callomon (1955, p. 219) recorded *c.* 3.7 m of Kellaways Clay at Kidlington, and believes (1976, *pers. comm.*) it to be 3–4 m thick in the Oxfordshire area.

e. For a considerable distance between Oxford and Bedford, there is no evidence of the existence of the Upper Cornbrash (Douglas & Arkell 1932, p. 123; Torrens 1968*c*, pp. 246–52). North and west of Oxford it is thin, ranging from *c.* 0.3 m at Long Hanborough (Doublas & Arkell 1928, p. 129), to *c.* 0.5 m at Enslow Bridge

(Douglas & Arkell 1935, p. 319), and *c.* 1.2 m in the Woodstock railway cuttings (Callomon 1955, p. 243).

C7. Bedfordshire–Buckinghamshire

Based on Arkell (1939*a*), Callomon (1968), Douglas & Arkell (1932), Duff (1974).

a. The Lamberti Limestone is 0.3–0.5 m thick at Woodham, and there is evidence to suggest that it contains a range of faunas, which elsewhere allow the *lamberti* Zone to be divided into subzones. Further east, the *lamberti* Zone is represented only by a thin layer of rolled and bored pebbles or oysters, 0.05 m thick, with occasional ammonites, which was exposed in temporary cuttings for a car-testing track north of Ampthill. It is not known whether both subzones of the *lamberti* Zone are represented. (Data from Callomon 1976, *pers. comm.*).

b. As there is no complete section through the Middle Oxford Clay in this area, the estimated thickness given is a composite one, based on Callomon's records of over 13.7 m of Middle *athleta* Zone (=*proniae* Subzone) at Stewartby (1968, p. 281), and over 10.8 m of Upper *athleta* Zone (=*spinosum* Subzone) at Woodham (1968, p. 276). In addition, he also recorded *c.* 0.95 m of clay containing a *henrici* Subzone fauna at Woodham (1968, p. 288).

c. At both Bletchley (Buckinghamshire) and Stewartby (Bedfordshire), the silts and silty clays of the Kellaways Rock or Sand continue up into the *enodatum* Subzone (Duff 1974). The subzonal thicknesses measured by Callomon (1968, pp. 281–2) at Stewartby are: *enodatum* Subzone *c.* 0.5 m, *medea* Subzone *c.* 0.8 m, *jason* Subzone *c.* 3 m, *obductum* Subzone *c.* 2.7 m, *grossouvrei* Subzone *c.* 7.5 m and *phaeinum* Subzone *c.* 9.3 m.

d. Callomon (1968, p. 282) recorded *c.* 4.7 m at Stewartby, and gave the general thickness in the area as 3–5 m (1976, *pers. comm.*).

e. Callomon (1968, p. 282) recorded just under 1 m of Kellaways Clay at Stewartby, although Woodward (1895, p. 51) recorded *c.* 3 m at Bedford. Pipe-trenches at Loughton, north of Bletchley, exposed 1 m of Kellaways Clay and others in the Milton Keynes area yielded the characteristic *Kamptokephalites* of the *kamptus* group (Callomon 1976, *pers. comm.*).

f. The Upper Cornbrash is absent over most of Buckinghamshire, Douglas & Arkell (1932, p. 137) recording Kellaways Clay resting directly on Lower Cornbrash at Akeley, near Buckingham. Into Bedfordshire, it reappears and thickens north-eastwards, with a record of Upper Cornbrash at Bedford (Douglas & Arkell 1932, p. 128), *c.* 0.85 m at Bletsoe (Woodward 1894, p. 451), and *c.* 1.7 m at Thrapston, Northamptonshire (Douglas & Arkell 1932, p. 130).

C8. Peterborough–Lincolnshire

Based on Callomon (1968), Callomon & Cope (1971), Douglas & Arkell (1932) and Horton *et al.* (1974).

a. Callomon & Cope (1971) gave the following thicknesses (based on the Geological Survey borehole at Warboys, Cambridgeshire) for the zones of the Middle

Oxford Clay: *athleta* Zone (Middle Oxford Clay portion) *c.* 22 m, *lamberti* Zone *c.* 3.8 m.

b. At Peterborough, the Kellaways Beds–Oxford Clay junction is placed at the base of the *enodatum* Subzone (Callomon 1968, p. 280), although here, as elsewhere, the transition is gradual, silts persisting upwards in alternation with clays. The lithological change from Lower to Middle Oxford Clay probably occurs within the *phaeinum* Subzone (Callomon 1968, p. 278).

Callomon & Cope (1971, table 5) recorded the following subzonal thicknesses at Peterborough: *enodatum* Subzone *c.* 0.2 m, *medea* Subzone *c.* 0.35 m, *jason* Subzone *c.* 0.8 m, *obductum* Subzone *c.* 4.3 m, *grossouvrei* Subzone *c.* 5.4 m and the Lower Oxford Clay part of the *athleta* Zone *c.* 5.7 m.

c. Callomon's record (1968, p. 280) of *c.* 3.5 m at Yaxley is complemented by that of Horton *et al.* (1974, p. 30), who recorded between 1.5 and 4.5 m in the Peterborough area.

d. Callomon (1968, p. 280) recorded *c.* 2.2 m of Kellaways Clay at Yaxley; however, Horton *et al.* (1974, p. 30) noted a thickness variation for the Peterborough area of 0.5–3.1 m.

e. Callomon (1968, p. 280) recorded *c.* 1.55 m of Upper Cornbrash from Yaxley, Peterborough, whilst the formation thickens to *c.* 1.85 m at Hacconby quarry, near Bourne, Lincolnshire (Douglas & Arkell 1932, p. 135). The minimum recorded thickness is *c.* 0.95 m at Sudbrooke Park, north-east of Lincoln (Douglas & Arkell 1932, p. 136), although Callomon (1976, *pers. comm.*) believes that it may be as thin as *c.* 0.50 m locally.

C9. South Humberside

The general sequence for this column is compiled from data supplied by G. W. Green (1976, *pers. comm.*), based on unpublished I.G.S. survey work on the Brigg (89) sheet, whilst details of particular parts of the sequence are drawn from Richardson (1979).

a. Richardson (1979, p. 8) recorded 28 m of Oxford Clay from the Worlaby E Borehole, 19.5 m of which are assigned to the Callovian. The *lamberti* Zone is 3.35 m thick and the presence of the *henrici* Subzone is confirmed by the occurrence of the index species; no evidence of the *lamberti* Subzone is present. Ammonite evidence has confirmed the presence of the *spinosum* (16.16 m) and *phaeinum* (2.44 m) Subzones of the *athleta* Zone in the Worlaby E Borehole, but the absence of any sediments yielding faunas from lower in the Oxford Clay indicates that the lower zones have been cut out by a disconformity.

b. Richardson (*op. cit.*, p. 8) recorded 6.43 m of undifferentiated Kellaway Beds from Worlaby, all represented in sandy facies. The occurrence at the base of the Kellaways Beds of an argillaceous calcareous sandstone containing pebbles of grey limestone probably derived from the Cornbrash, together with the absence of clays, is taken to indicate the presence of a disconformity which has cut out the lower part of the Kellaways Beds. No diagnostic ammonites were recorded.

c. 1.19 m of Upper Cornbrash are recorded from Worlaby E by Richardson (*op.*

cit., p. 8), resting unconformably on Blisworth Clay. No fauna characteristic of the Cornbrash was found.

*C*10. *North Humberside, Humber boreholes*

Details supplied by G. W. Green (1976, *pers. comm.*), based on the I.G.S. Humber boreholes (Gaunt *et al.* 1980) and on Brasier & Brasier (1978).

a. Arkell (1933, p. 358) recorded the junction of the Oxford Clay and the Kellaways Rock in a railway cutting at Drewton, north of South Cave, and referred the former to the *jason* Zone because of the occurrence of *K. elizabethae*) (Pratt) and *K. comptoni* (Pratt). However, modern interpretations would place these species as being characteristic of the *coronatum* Zone. Green (1976, *pers. comm.*) recorded 0.3 m of Kellaways Sand and Rock at the base of the Oxford Clay, separated from the main bulk of the Kellaways Sand and Rock by a non-sequence. This lithology has yielded a fauna characteristic of the *coronatum–athleta* zonal boundary (Cox 1977, *pers. comm.*). I believe the *coronatum* to *athleta* Zone Kellaways Beds to be a remanié deposit of reworked material, constituting the basal bed of the Oxford Clay, with which it is here united.

b. At South Cave Quarries (2.5 km from South Cave, at Drewton), the Kellaways Sand and Rock rests on white sands referred to the 'Upper Deltaic Series' (Walker 1972, p. 110), and there may be a non-sequence between the two units. Brasier & Brasier (1978) have given a detailed description of the section.

*C*11. *North Yorkshire, Acklam boreholes*

Details supplied by G. W. Green (1976, *pers. comm.*), based on the I.G.S. boreholes (Gaunt *et al.* 1980).

a. As in column C10 (note a), Green has recorded a thin band of Kellaways Sand and Rock, here 0.04 m thick, at the base of the Oxford Clay. This consists mainly of silty clays which have also yielded a *coronatum* to *athleta* Zone fauna (Cox 1977, *pers. comm.*), and in which it seems likely that more of the *coronatum* Zone is represented. It is interpreted as a remanié deposit, and is here united with the Oxford Clay.

*C*12. *North Yorkshire, Malton*

Compiled from the data of Wright (1968*b*—based on the sequence at Peckondale Hill, Malton—and 1977).

a. Wright (1968*b*, fig. 2) recorded the *athleta* Zone as being *c.* 4.5 m thick. The overlying *lamberti* Zone, recorded as *c.* 6 m thick by Wright, is represented in the pit solely by a remanié deposit of limonitic ammonites washed down from the field above. However, Arkell (1945, p. 345) recorded *c.* 4.5 m of *lamberti* Zone clays from the High Hutton road cutting close by.

b. *Coronatum* Zone—the *grossouvrei* Subzone is absent, but a good *obductum* Subzone fauna is present (Wright 1968*b*, p. 94). No evidence was found for the *jason* Zone, there being apparently a non-sequence between the Lower Oxford Clay and the underlying Kellaways Rock. As in southern England, the Callovian Oxford Clay may be divided, on lithological grounds, into Lower and Middle units.

c. Although Wright (*op. cit.*, fig. 2) recorded an approximate thickness of *c.* 9 m of Kellaways Rock at Peckondale Hill, later work (Wright 1978) revealed a thickness of at least 15 m in the region of Burythorpe, south of Malton. At this locality, the Kellaways Rock has yielded two species of *Kepplerites, Proplanulites* sp. and *Chamoussetia* sp.

The base of the Kellaways Rock was not seen at Peckondale Hill or Burythorpe, but comparisons with the Acklam boreholes suggest that there is a non-sequence between the Kellaways Rock and the underlying Ravenscar Group.

*C*13. *Western Tabular Hills and Hambleton Hills*

Based on Wright (1968*a*, 1977, 1978*a*).

a. In the Hambleton Hills, the Hackness Rock consists of 6.5 m of marls of definite *lamberti* Zone age, and may extend down into the *athleta* Zone. In the southern part of the Hambleton Hills, the Hackness Rock is overstepped by the Lower Calcareous Grit (Wright 1978*a*).

b. The Langdale Beds occur in the Tabular Hills, but are absent in the Hambleton Hills due to overstep by the Hackness Rock (Wright 1978*a*).

c. Early authors, particularly S. Buckman (1913), but also Phillips (1829), Leckenby (1859) and Hudleston (1876), used the name "Kelloway Rock' as a group term for the formations now known separately as the Kellaways Rock, Langdale Beds and Hackness Rock, thus causing confusion when the 'Kelloway Rock' was compared with the Kellaways Rock of southern England. The term Osgodby Formation has now replaced 'Kelloway Rock' (Wright 1978*a*), the Kellaways Rock, Langdale Beds and Hackness Rock now being regarded as members of the Osgodby Formation.

The upper subzonal limit of the Kellaways Rock is difficult to determine, as *Sigaloceras* does not occur (Wright 1968*a*, pp. 377–8). The abundant ammonite fauna is that of the Wiltshire Kellaways Clay (*koenigi* Subzone) not the Wiltshire Kellaways Rock (*calloviense* Subzone). Thus it seems unlikely that the *calloviense* Subzone is represented (Callomon 1978, *pers. comm.*). There is certainly no indication of the *enodatum* Subzone.

d. Wright (1977) has formalized the term 'Shales of the Cornbrash', demonstrating that the rocks have a shaly, rather than a clayey, nature. Previously, most authors have used this name, although Douglas & Arkell (1932, p. 139) preferred to assign the rocks to the Kellaways Clay, as developed in southern England.

e. The term 'Cornbrash Limestone', as originally used by Smith, has been formalized by Wright (1977) and is retained here. Douglas & Arkell (1932, p. 138) showed that the whole of the Yorkshire Cornbrash is of Callovian age, with the Lower Cornbrash (Bathonian) not being represented in marine facies. No Cornbrash Limestone is known in the Hambleton Hills; Senior (1975) recorded only fossiliferous clay (?Shales of the Cornbrash) beneath the Kellaways Rock.

*C*14. *Newtondale to the Yorkshire coast*

Based on Wright (1968*a*, 1977, 1978*a*).

a. The non-sequence within the Hackness Rock of the Yorkshire coast is deduced from the absence of typical *spinosum* and *henrici* Subzone faunas. The highest proven *athleta* Zone fauna is dominated by *K. proniae* Teisseyre and *K. rimosum* (Quenstedt), although the local abundance of *Hecticoceras* and *Grossouvria* may indicate the presence of at least part of the *spinosum* Subzone. The succeeding fauna is that of the *lamberti* Subzone (Wright 1976, *pers. comm.*). Wright also believes that the 'Clynelishense Horizon' of Sykes (see Column 15, note a) is almost certainly present in Bed 5 (Wright 1968*a*, p. 384) of the Hackness Rock at Gristhorpe.

b. The age of the top of the Langdale Beds is uncertain, as no recognizable ammonites occur in the highest 10–15 m (Wright 1976, *pers. comm.*).

c. The ammonite fauna is that of the *kamptus* Subzone, and closely resembles that of the lower part of the Kellaways Clay of central and southern England (Callomon *in* Wright 1968*a*, p. 370). (See C1, note d; C2, note d.)

d. It is not clear whether the Scalby Beds, which underlie the Cornbrash Limestone, are of Callovian or Bathonian age. On the coast, the junction between the two is sharp, but at Newtondale, the Scalby Beds gradually become more marine upwards, and pass into the Cornbrash Limestone more transitionally (Wright 1977). For convenience, the Scalby Beds are here taken as being of Bathonian age. The Cornbrash Limestone varies greatly in thickness, with a maximum of 4.4 m at Newtondale, thinning south-eastwards to only 0.57 m at Cunstone Nab (Wright 1979, *pers. comm.*).

*C*15. *Brora*

Based on Sykes (1975).

a. The Clynelish Quarry Sandstone Member, whilst being characterized by *lamberti* Subzone ammonites as a whole (Sykes 1975, p. 57), also contains a further fauna at the top of the *lamberti* Zone: *Quenstedtoceras* (*Eboraciceras*) *sutherlandiae* (J. Sowerby), *Q.* (*E.*) *ordinarium* (Leckenby), *Q.* (*Lamberticeras*) sp., *Q.* (*Q.*) *macrum* (Quenstedt), *Hecticoceras* sp. and *Aspidoceras* (*Euaspidoceras*) *clynelishense* (Arkell). No kosmoceratids occur. Sykes (1976, *pers. comm.*) believes that this fauna, known as the 'Clynelishense Horizon', represents the topmost fauna of the *lamberti* Zone. This fauna may occur in Yorkshire (see C14, note a), perhaps at Woodham (where it may be condensed within the Lamberti Limestone) (see C7, note a), but is unknown elsewhere in Britain; it can, however, be recognized in Normandy.

b. Sykes (1976, *pers. comm.*) has extended the top of the Glauconitic Sandstone Member upwards, to be included partially within the *grossouvrei* Subzone.

c. The Brora Roof Bed forms the basal unit of the Brora Shale Member, and lies wholly within the *koenigi* Subzone.

d. The age of the Brora Coal Formation is uncertain, but in view of the proven *koenigi* Subzone age of the overlying Brora Roof Bed, it is possible that it may be of basal Callovian age.

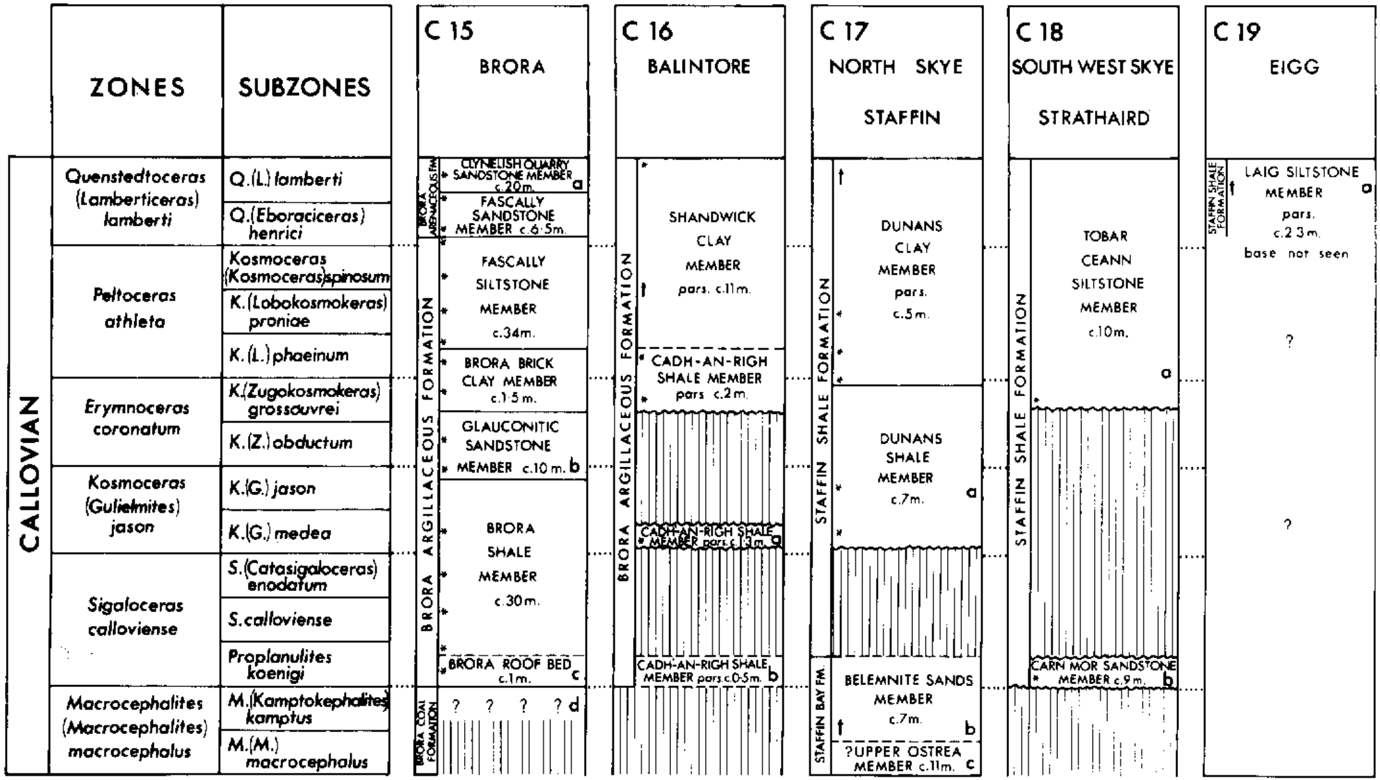


FIG. 9. Correlation of Callovian rocks. Columns C15–C19.

*C*16. *Balintore*

Based on Sykes (1975).

a. The *medea* Subzone, proved by the occurrence of *K.* (*G.*) *medea* Callomon, is capped by a nodular limestone, marking a non-sequence (Sykes 1975, p. 60).

b. The lowest part of the Cadh'-an-Righ Shale Member is represented by the Brora Roof Bed, here only 0.5 m thick. The age of the Roof Bed here is unknown, as no ammonites occur, but Sykes (1976, *pers. comm.*) believes that it is almost certainly of the same age as the Roof Bed at Brora. As at Brora, the Roof Bed overlies the Brora Coal Formation.

*C*17. *North Skye, Staffin*

Based on Hudson (1962, 1963) and Sykes (1975).

a. Although both *K.* (*G.*) *medea* Callomon and *K.* (*G.*) *jason* (Reinecke) have been recorded from the lower part of this member, the upper 6 m have not yielded any ammonites (Sykes 1975, p. 64); the presence of the *obductum* and *grossouvrei* Subzones is inferred from Sykes (1976, *pers. comm.*), who states that there is no unconformity between the Dunans Shale and the Dunans Clay, and that deposition was probably continuous.

b. The only ammonite known from this member at Staffin is *Kepplerites* (*Kepplerites*) cf. *keppleri* (Oppel), identified by Callomon (Hudson 1962, p. 146), and suggestive of the *macrocephalus* Zone. Murchison's record (1829, p. 311) of *Ammonites koenigi* J. Sowerby from a temporary exposure near Uig seems improbable on stratigraphical grounds (Sykes 1976, *pers. comm.*).

c. The Upper Ostrea Member is of uncertain age, with a fauna dominated by brackish-water bivalves (Hudson 1963); it is possible that it is of early Callovian age (Sykes 1976, *pers. comm.*). See also notes for Column B18.

*C*18. *South West Skye, Strathaird*

Based on Sykes (1975).

a. The only diagnostic ammonites are *K.* (*Z.*) *grossouvrei* R. Douvillé, which occurs just above the base, and *Quenstedtoceras* (*Lamberticeras*) sp. of the *lamberti* Zone (Sykes 1975, p. 68). In the lack of obvious non-sequences, the remainder of the *athleta* and *lamberti* Zones is presumed to be represented also.

b. Dated to *koenigi* Subzone age by the occurrence of *Proplanulites koenigi* (J. Sowerby) and *Kepplerites* (*Gowericeras*) *gowerianus* (J. de C. Sowerby) (Sykes 1975, p. 68).

*C*19. *Eigg*

Based on Sykes (1975).

a. The presence of *Quenstedtoceras* (*Lamberticeras*) cf. *lamberti* (J. Sowerby) and *Q.* (*L.*) *intermissum* (S. Buckman) indicates the existence of the *lamberti* Zone within the Laig Siltstone Member (Sykes 1975, p. 71).

OXFORDIAN CORRELATION CHART

J. K. Wright
with a contribution by J. H. Callomon

Substages

The subdivision into Lower, Middle and Upper Oxfordian follows Sykes & Callomon (1979). In the present work, the term 'Upper Oxfordian' will be used as defined in the Boreal zonal scheme, i.e. by the first appearance of *Amoeboceras.*

Zones and Subzones

The subdivision of the Lower Oxfordian follows Arkell (1941*a*), as discussed by Callomon (1964). More recently, Marchand (1979) has introduced a *paucicostatum* horizon at the base of the *scarburgense* Subzone. During the Middle and Upper Oxfordian, ammonite provincialism became so extreme that three separate zonal schemes have to be used in Europe for the Boreal, north-west European and Submediterranean Provinces. Britain occupied a position astride the north-west European and Boreal Provinces, and thus two zonal schemes have been used side by side in recent publications. However, only one zonal scheme can be used in the chart as the number of subzones determines the vertical spacing. Thus, the Boreal zonal scheme of Sykes & Callomon (1979) has been chosen as standard for the Middle and Upper Oxfordian. In southern England, Boreal ammonites are almost unknown from a number of horizons, and the north-west European zonal scheme has to be employed. The correlation of the Boreal, north-west European and Submediterranean zonal schemes, as far as it is known, is given in Fig. 10. This is based almost entirely on Sykes & Callomon (1979, fig. 2) with the exception of the subzones of the *pseudocordata* Zone. Recent work in Staffin (J. H. Callomon *pers. comm.*) has shown that the *pseudocordata* Subzone comes above the *pseudoyo* Subzone. *Ringsteadia caledonica* Sykes & Callomon (*vide* the *caledonica* horizon of the *regulare* Zone: Sykes & Callomon 1979), occurs beneath *R. pseudoyo.*

O1. *South Dorset*

Based on Arkell (1947*a*), Blake & Hudleston (1877), Brookfield (1978), Cope & Torrens (1969), Talbot (1973), J. H. Callomon and R. M. Sykes (*pers. comms*) and the writer (*pers. obs.*).

a. Blake (1875) introduced the term 'Kimmeridge Passage Beds' for the variable series of argillaceous, calcareous and arenaceous beds which lies immediately above and below the Oxfordian/Kimmeridgian junction. This usage has been continued as the Passage Beds Formation by Brookfield (1978), who gave detailed descriptions of the beds.

b. The thickness of the Sandsfoot Grit at Sandsfoot Castle was underestimated by Arkell (1947*a*) and Brookfield (1978). Carefully measured sections show that the 10.3 m at Sandsfoot is reduced to 6.8 m at Black Head, with removal of the highest 3.5 m by erosion beneath the Ringstead Clay. Recent ammonite finds have enabled

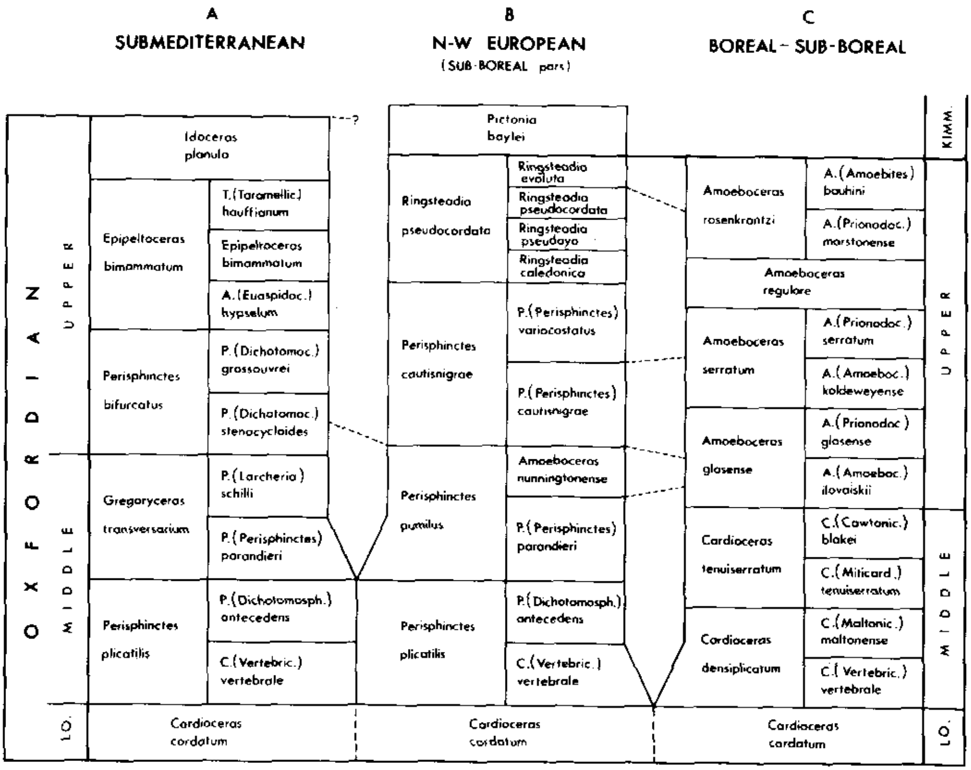


FIG. 10. Correlation of the Submediterranean, north-west European and Boreal zonal schemes for the Middle and Upper Oxfordian. (Modified after Sykes & Callomon 1979, fig. 2).

the zonal range of the Sandsfoot Grit to be established. *Ringsteadia* sp. and *Perisphinctes* spp. occur in the lowest 1.2 m suggesting the very base of the *pseudocordata* Zone. *Amoeboceras rosenkrantzi* found higher up indicates the middle of the *pseudocordata* Zone (Sykes, *pers. comm.*)

c. The Sandsfoot Clay was estimated at 12 m at Sandsfoot by Blake & Hudleston (1877). It is reduced to 3.7 m at Black Head by erosion beneath the Sandsfoot Grit. A sharp erosive junction of Sandsfoot Grit on Sandsfoot Clay is visible even at Sandsfoot.

d. The extent of the break beneath the Trigonia clavellata Beds is uncertain as the junction of the Osmington Oolite and Sandy Block is hard to define, and there are almost no ammonites. There could be a continuous, condensed sequence.

e. Cope & Torrens (1969) summarize all records of ammonites from the Osmington Oolite. To these must be added *Perisphinctes parandieri* de Loriol. Thus, four named species are now known. The top of the formation is certainly of *parandieri* Subzone age, and it probably extends well down into the *antecedens* Subzone. The use of the term Osmington Oolite 'Group' by Talbot (1973), Fürsich (1977) and Brookfield (1978) is to be deplored. A group is of necessity divisible into two or more clearly defined formations, and it is difficult to divide the Osmington Oolite at Osmington into distinct members, let alone formations.

f. At Osmington, the Oolite rests with a sharp, bored junction on Bencliff Grit, a shallow water, probably lagoonal sandstone, which has not yielded any ammonites.

g. The lowest 5.5 m of the Nothe Clay contains, west of Redcliff, frequent beds of oolite and oolitic marl. Many *vertebrale* Subzone ammonites recorded as 'Preston Grit' have probably come from these beds.

h. The Preston Grit is a medium- to coarse-grained, shelly, sparsely oolitic sandstone (the Trigonia hudlestoni Bed of Arkell). It rests with a sharp but not erosive junction on Nothe Grit on the coast. According to Blake & Hudleston, the Nothe Grit thins almost to nothing inland from Osmington, possibly at the expense of the Preston Grit.

O2. North Dorset

Based on Arkell (1927, 1933), Blake & Hudleston (1877), Gutman (1970), Mottram (1956), White (1923), J. H. Callomon (*pers. comm.*) and the author (*in prep.*).

No mapping of the southern part of this area has been carried out subsequent to the original one inch survey in 1850–76. In order to produce a reasonable correlation for these charts, reconnaissance mapping on a 1:25000 scale was carried out by J.K.W.

a. Characteristic Ringstead Clay and Sandsfoot Grit are seen in road cuttings near Sturminster (ST 787133). Sandsfoot Clay was seen here by Blake & Hudleston. Elsewhere, these uppermost Oxfordian beds are frequently overstepped by Kimmeridge Clay (i.e. the Gillingham district—Geological Survey Sheet 297).

b. The Trigonia clavellata Beds are well developed right across the area as shelly, very fine oolite and *Rhaxella* biomicrite. Mottram (1936) recorded several *cautisnigrae* Subzone ammonites.

c. The Coral Rag has only one probable representative in the area, 3 m of rubbly, very fossiliferous limestone containing *Plegiocidaris florigemma* (Phillips), resting with an erosive junction on oolite. These beds were formerly seen in the Sturminster Newton railway cutting (Blake & Hudleston 1877). There is no Coral Rag at Todber, where Trigonia clavellata Beds rest with a sharp junction on oolite.

d. The Osmington Oolite Formation is divisible into three members. At the base is the **Newton Oolite** (new name): 3 m of rubbly, creamy oolite described by Blake & Hudleston (1877) in a road cutting at Newton (ST 782135) and still visible. The Newton Oolite rests on clay, but not Oxford Clay as Blake & Hudleston thought. The unit is traceable southwards to Cockcrow Copse (ST 762093), where it contains bands of white marl and clay, and is sandy at the base. Northwards, it is overstepped by the Sturminster Pisolite.

e. The **Sturminster Pisolite** (new name): used informally by White (1923) for the 1.3 m of pisolitic marl seen in the road cutting between Newton and Sturminster

(ST 783135). This remarkable member, consisting of up to 4.5 m of marl and oolite with abundant 1–2 cm pisoliths, is traceable right across the area from Lyons Gate (ST 656063) to Cucklington Quarry (ST 756276). In the south it is always poorly cemented, but northwards it becomes a pisolitic limestone, containing clasts of the underlying sandy oolite. Almost certainly the pisolite 3 m up in the Osmington Oolite of Osmington is of the same age.

f. The third member of the Osmington Oolite Formation is the Todber Freestone (the Marnhull and Todber Freestone of Arkell 1933). Strongly cross-bedded oolite is still well seen in Todber Quarry (ST 796198). In the north, this member appears to pass into oomicrite at Langham (ST 770260). Southwards, nothing is seen south-west of evenly-bedded oolite at Cockcrow Copse Quarry (ST 76250925).

g. Beneath the Newton Oolite at Newton, Fifehead Neville (ST 768109) and Cockcrow Copse (ST 762093) is seen up to 6 m of clay, thought to be Oxford Clay by Blake & Hudleston (1877), but which almost certainly correlates with the Nothe Clay.

h. **Cucklington Oolite** (new name): proposed informally as '?Limestone at Langham and Cucklington' by Arkell (1927, p. 159). Arkell's section at Cucklington (ST 756276) is less complete than it once was, but a 2 m section is visible in a nearby quarry at Stoke Tryster (ST 745297). The Cucklington Oolite comprises between 4.5 and 11 m of sandy, often distinctively brown-coloured oolite. It is traceable across from Lyons Gate (ST 656063) to Cucklington. At Humber Wood (ST 727078), in the south, it is pisolitic and shelly. At Fifehead Neville (ST 765108) it contains beds of calcareous sandstone. A good section is visible in a road cutting near Todber (ST 795204 and 794208). Though it yields few diagnostic ammonites, the Cucklington Oolite correlates quite satisfactorily with the Preston Grit and oolite of the Nothe Clay in south Dorset.

i. In temporary sections near Fifehead Neville and East Stour, the Cucklington Oolite was seen to rest on 2–4 m of clay.

j. The Oxford Clay is poorly seen in ditches near Lyons Gate (ST 659062). It contains red sideritic nodules suggesting the Red Nodule Beds. A temporary section in a road cutting for the Wincanton Bypass (1976) showed the usual transitional nature from the Oxford Clay, *costicardia* Subzone, to the silts and sands of the Lower Calcareous Grit (J. H. Callomon, *pers. comm.*).

O3. North-west Wiltshire

Based on Arkell (1934, 1935–48, 1951), Blake & Hudleston (1877), White (1925) and the writer (*pers. obs.*). As for north Dorset (Column O2), much of the published work is out of date and not always reliable. However, the northern part of the area was mapped by Arkell (1951), and the succession in the south appears fairly straightforward.

a. The Westbury Ironstone is a localized deposit found only in the area to the north-west of Westbury. Elsewhere, beds of this age are absent, probably due to erosion beneath the Kimmeridge Clay. The Ironstone has yielded many *Ringsteadia*

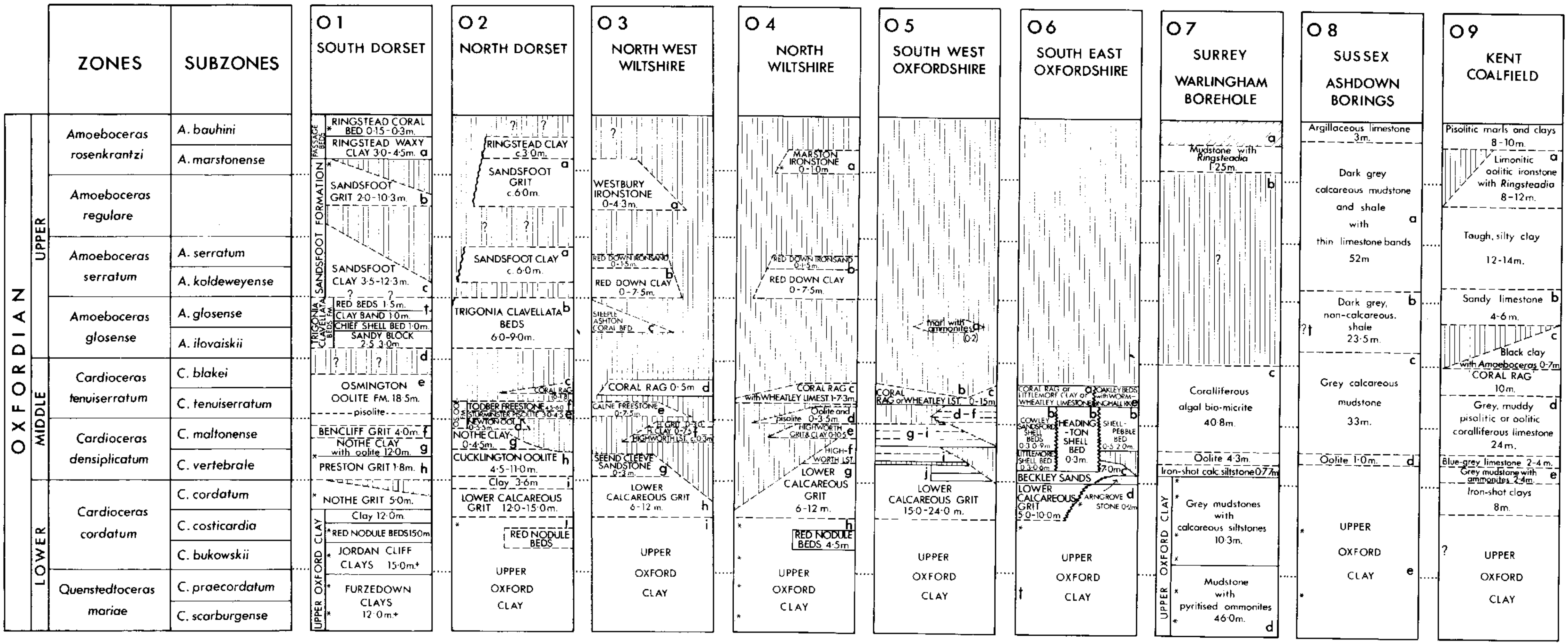


FIG. 11a. Correlation of Oxfordian rocks. Columns O1–O9.

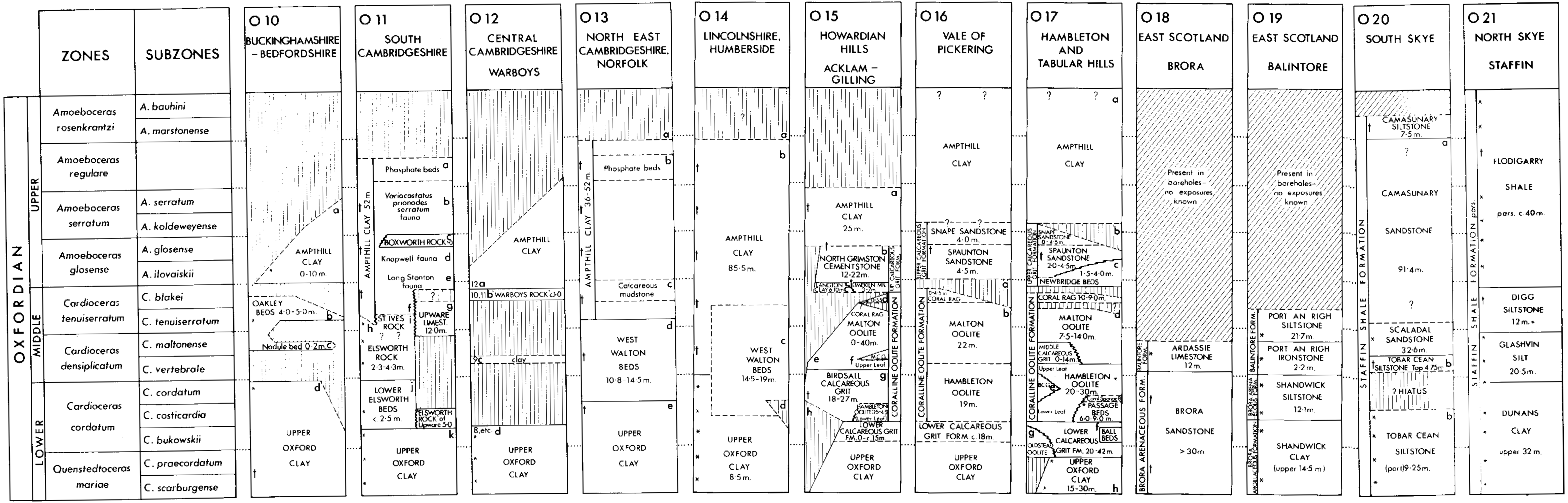


FIG. 11b. Correlation of Oxfordian rocks. Columns O10–O21.

(including the holotype of *R. pseudocordata*), but also *Perisphinctes*, suggesting that it ranges from the base to the middle of the *pseudocordata* Zone.

b. The Red Down Ironsand and the Red Down Clay were mapped in the area around Lyneham by Arkell (1951). They are absent in the south of the area.

c. The Steeple Ashton Coral Bed has yielded *Amoeboceras damoni* Spath (Sykes, *pers. comm.*), and correlates with the Trigonia clavellata Beds. Negus & Beauvais (1979) note that the outcrop of the Coral Bed is more extensive than was thought by Blake & Hudleston (1877). The latter authors and Arkell (1933) note that it passes laterally into a shell bed with *Myophorella clavellata* (Parkinson) 1 km to the south.

d. The Coral Rag is not present in the Westbury district, but is well developed between Calne and Wootton Bassett. The Calne Freestone was regarded as the local equivalent of the Coral Rag by Blake & Hudleston (1877) and by White (1925). However, in exposures in the new housing estate at Quemerford (SU 006701) Coral Rag in typical coralliferous micrite facies is present above the Calne Freestone; the two are distinct.

e. The Coral Rag normally rests on the coarse oolite and pisolite of the Calne Freestone, but near Lyneham rests with a 0.3 m pebble bed on calcareous grit (Arkell 1951). The Calne Freestone almost certainly correlates with the Osmington Oolite Formation.

f. These three units can be grouped together as the Highworth Formation. The Highworth Grit and Clay were mapped by Arkell (1951) around Lyneham; they also occur at Westbury (Arkell 1934). In between, they are missing (White 1925), Calne Freestone resting on Lower Calcareous Grit. Beneath the Highworth Clay at Spirt Hill is a 0.3 m bed of limestone correlated by Arkell (1951) with the Highworth Limestone of north Wiltshire. This thin limestone rests with a pebble bed on Lower Calcareous Grit. A remarkably similar section was seen in the Westbury railway cutting (Arkell 1934). Clay and marl rested on a 0.3 m bed of pebbly, shelly limestone, and that on 'Lower Calcareous Grit'.

g. **Seend Cleeve Sandstone** (new name). Arkell (1935–48) noted that the 'highest bed of shelly gritstone' in the Lower Calcareous Grit of Seend Cleeve appeared to have yielded *vertebrale* Subzone ammonites, and probably also correlated with the Highworth Limestone. 3 m of these beds are still visible at ST 934609. They consist of medium- to coarse-grained, shelly calcareous sandstone and sandy limestone containing occasional ooliths, and with a distinctive, brown-weathering matrix. The lithological similarity to the Cucklington Oolite (which becomes sandy northwards) is striking, and correlation with this member seems certain. However, correlation of the Seend Cleeve Sandstone north-eastwards with the Highworth Limestone appears doubtful. The Westbury cutting showed what Arkell considered to be Highworth Limestone resting on 1 m of 'yellow, blue-hearted gritstone containing a large *Perisphinctes*.' The latter is surely Seend Cleeve Sandstone, separated from Highworth Limestone by an erosion surface.

h. The main part of the Lower Calcareous Grit of Seend and Calne (unfortunately no longer exposed) is the type area of the *cordatum* Subzone.

i. The Upper Oxford Clay is poorly known. From *cordatum* Zone Oxford Clay at

Vastern, near Wootton Bassett, probably came the holotype of *Cardioceras* (*Plasmatoceras*) *plastum* S. Buckman (Arkell 1935–48, p. lxxvii).

O4. North Wiltshire

Based on Arkell (1933, 1935–48, 1937*a*, 1941*b*, 1951), Callomon (1960), Talbot (1973), J. H. Callomon (*pers. comm.*) and R. Sykes (*pers. comm.*). The column is an attempt to summarize the complicated geology of the area around Highworth, mapped in great detail by Arkell (1941*b*). Arkell made no attempt to interpret his map stratigraphically; thus the column is my interpretation based on Arkell's work.

a. The Marston Ironstone was formerly exposed in the railway cutting at Marston. It yielded *Ringsteadia* spp. and also the holotype of *Amoeboceras marstonense* Spath. Middle *pseudocordata* Zone is indicated (Sykes, *pers. comn.*).

b. The terms Red Down Ironsand and Red Down Clay were introduced by Arkell (1951). The Ironsand has yielded *Amoeboceras prionodes* S. Buckman (= *A. serratum* (Sowerby)), indicating the *serratum* Zone. It thus correlates not with the Sandsfoot Grit and Westbury and Marston Ironstones, but possibly with sandy beds formerly visible in the Sandsfoot Clay of Sandsfoot, noted by Blake & Hudleston (1877).

c. A period of erosion beneath the Coral Rag is indicated by the fact that west of Highworth, the Rag rests on very attenuated oolite and pisolite. At Badbury Hill Quarry east of Highworth, it contains pebbles of oolite at its base (Arkell 1941*b*).

d. The oolite and pisolite (Osmington Oolite) rest directly on Lower Calcareous Grit in the Coleshill-Fresden area east of Highworth, having apparently cut across Highworth Grit and Clay.

e. No sign of erosion has been seen beneath the Highworth Clay, but I believe that overstep of the Clay, or intra-formational erosion within the Highworth Limestone, is the only explanation for the thinning of the Highworth Limestone in all directions from Highworth. Arkell repeatedly said that it had become 'too thin to map', and there is no mention of the transitional facies of sandy oolite and argillaceous oolite so common in the facies transitions from oolite into sandstone in Yorkshire. Thus, the geology of the Highworth district is seen as a structural basin centred on Highworth, surrounded by areas repeatedly affected by erosion.

f. In age, the Highworth Limestone apparently covers the uppermost *vertebrale* Subzone and the lowermost *antecedens* Subzone (Callomon 1960). An excellent 'Coral Rag' is developed south of Highworth, called the Lower Coral Rag by Arkell. A development of 'Urchin Marl' between Highworth Limestone and Highworth Clay was included in the correlation table of Callomon (1960). The term Urchin Marl is reserved in the chart for marls occurring above the Third Trigonia Bed in Column O5. The marl occurring below the Highworth Clay was included within the original definition of the Highworth Limestone by Arkell (1941*b*). The Highworth Limestone, Grit and Clay can conveniently be grouped together as the Highworth Formation.

g. The Lower Calcareous Grit probably extends down into the *cordatum* Subzone. Exposures are poor.

h. The Oxford Clay was described as seen in the pit at Purton (Arkell 1941*a*). It is exposed there from the *cordatum* Zone, *costicardia* Subzone (Red Nodule Beds) down to the *mariae* Zone, *scarburgense* Subzone. The *lamberti* Zone was exposed in a railway cutting near Brinkworth, not far to the west, so the succession is probably complete (Callomon, *pers. comm.*).

O5. South-west Oxfordshire (formerly Berkshire)

Based on Arkell (1939*b*) and Callomon (1960 and *pers. comm.*). This area is the type district for the Berkshire Oolites, an outdated term employed by Arkell for *vertebrale* and lower *antecedens* Subzone oolites here incorporated in the Highworth Formation. The Middle Oxfordian as presented here is an interpretation by J.K.W. based upon the mapping of the area by Arkell (1939*b*) as revised by Callomon (1960). Up to date sections at Shellingford and Cothill are given by McKerrow & Kennedy (1973).

a. Substantial erosion beneath the Kimmeridge Clay has removed the Upper Oxfordian over almost all the outcrop, excepting small remanié deposits containing *glosense* Zone ammonites, which occur locally at Cumnor and Abingdon at the base of the Kimmeridge Clay (Morris 1968 and Callomon, *pers. comm.*).

b. In the area around Garford, Coral Rag with its associated Wheatley Limestone facies is missing. Kimmeridge Clay rests directly on oolite, or on very thin Coral Rag. It is suggested here that this is due at least in part to the erosion beneath the Kimmeridge Clay.

c. At Cothill and Shellingford Coral Rag with some oolite at its base rests on Urchin Marls. In the centre of the area, south of Buckland, Coral Rag rests on the Third Trigonia Bed.

d. The Urchin Marls consist of alternations of oolitic marl and oolite with abundant echinoids. In the past, the term has been applied to any echinoid-rich oolite regardless of age.

e. The Third Trigonia Bed was confused with the Upper Trigonia Bed by Arkell (1939*b*); the problem was discussed by Callomon (1960). There is a prominent erosion surface beneath the Urchin Marls/Third Trigonia Bed. At Stanford Pit, south of Buckland, the Third Trigonia Bed comprises 'a gravel of rolled pebbles and shells cutting down in channels into the underlying sands' (Highworth Grit) (Arkell 1939*b*). In the east at Marcham, Urchin Marls come to within 0.3 m of the Lower Calcareous Grit.

f. The term 'Faringdon facies' or 'Faringdon Oolite' has never been formalized and it is proposed here that it should be dropped. Arkell used it only as the 'Faringdon facies of the Berkshire/Osmington Oolite'. Shellingford Crossroads Quarry was included in Arkell's definition of the facies (1939*b*, p. 498). Thus the 'Faringdon Oolite' of later authors must be the equivalent of the pebble bed/Third Trigonia Bed/Urchin Marls oolitic succession (i.e. Osmington Oolite) described there by Callomon (*in* Callomon & Torrens 1969). However, Callomon equated the Faringdon Oolite with the Pusey Flags, this being apparently a reference to Blake & Hudleston's section at the Faringdon Workhouse Quarry (1877, pp. 301–3), wherein

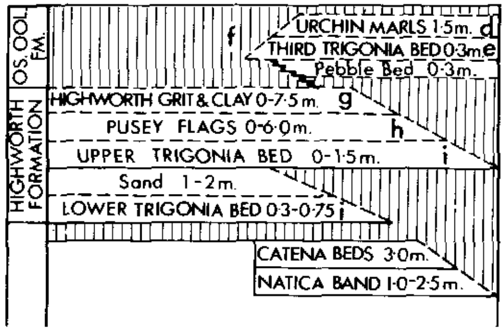


FIG. 12. Enlarged portion of the Oxfordian correlation chart for column O5.

1 m of oolite below the pebble bed was called the 'Faringdon building stone'. Arkell rightly correlated this with the Pusey Flags (1939*b*, p. 497).

g. The Highworth Grit and Clay comprise false-bedded sands, locally with clay developed at the base. At Hatford, the Highworth Grit has yielded *antecedens* Subzone ammonites (Callomon *pers. comm.*). It is unlikely that the clay at the base of the unit correlates exactly with the Highworth Clay of Wiltshire, as Arkell (1939*b*) described a transition downwards from Highworth Grit into Pusey Flags at several localities, no clay having been deposited.

h. The Pusey Flags, some 6 m of sandy oolite, are younger than the Highworth Limestone, and may occupy the timespan of the Highworth Clay, or of marls within the highest Highworth Limestone (Arkell 1941*b*).

i. The representatives of the Highworth Limestone in the south-west Oxfordshire area are almost certainly the Upper and Lower Trigonia Beds. The Upper Trigonia Bed has yielded numerous *antecedens* Subzone ammonites. At Marcham and north-east of Cumnor, it rests directly on Lower Calcareous Grit (Callomon 1960). The Lower Trigonia Bed has yielded many corals (cf. the 'Coral Rag' in the Highworth Limestone of north Wiltshire).

j. The Lower Calcareous Grit was described in detail by Arkell (1936), and this paper is the only source too for information on the Oxford Clay of the area.

O6. South-east Oxfordshire

Based on Arkell (1936, 1942, 1947*b*), Callomon (1960 and *pers. comm.*). and Sykes (*pers. comm.*).

The area comprises the Oxford district. Upper Oxfordian is again absent above Coral Rag.

a. The Coral Rag is present in a variety of facies as the reefs merge eastwards into the deeper-water sediments of the Ampthill Clay. Average thicknesses are: Coral Rag 6–9 m; Littlemore Clay Beds 5 m; Wheatley Limestone 15 m.

b. The *antecedens* and upper *vertebrale* Subzones are present as a series of probably lenticular shell-beds rarely totalling more than 2 m. These can only be depicted diagrammatically on the chart.

c. The Beckley Sands consist of even-bedded sands and calcareous sandstones thought by Arkell (1942) to be younger than the typical Lower Calcareous Grit of south-west Oxfordshire. This seems to be only partly true, the Beckley Sands probably correlating with the Natica Band and the Catena Beds, i.e. the top part of the Lower Calcareous Grit. The principle difference between them, the even-bedding of the Beckley Sands and the cross-bedding of the Lower Calcareous Grit, is probably of little significance.

d. The Lower Oxfordian Lower Calcareous Grit of Wiltshire and Dorset appears to have passed largely into clay facies. The *cordatum* Subzone is present as clay at Hinksey, west of Oxford, where a temporary section of 20 m of clay was seen yielding *cordatum* Subzone ammonites, underlain by *costicardia* Subzone Oxford Clay, and overlain by *vertebrale* Subzone calcareous grit (Sykes, *pers. comm.*).

e. 'East of Oxford, the predominantly arenaceous and calcareous facies of the Corallian Beds rapidly die out, and Upper Oxfordian reappears in clay facies above a greatly-reduced series of siltstones full of *Nanogyra* and Serpulae, of rapidly variable thicknesses and lithologies but remarkable persistence, called the Oakley Beds (Arkell 1942). A local calcareous siltstone in these beds, the Worminghall Rock, is securely dated as *tenuiserratum* Subzone as it yielded the holotype of *Cardioceras* (*Mitecardioceras*) *mite* S. Buckman, the macroconch companion of *Cardioceras tenuiserratum* (Oppel). It also yields *Perisphinctes gamelai* Arkell' (Callomon, *pers. comm.*).

O7. Warlingham borehole (Surrey)

Based on Callomon & Cope (1971) and Worssam & Ivimey-Cook (1971).

a. The highest Oxfordian beds are cut out by a fault.

b. The mudstone rests with no apparent break on coralliferous limestone but comparison with the Kent Coalfield succession suggests a substantial stratigraphical break here.

c. No ammonites were found in the coralliferous limestone, and the position of this unit can be shown only approximately.

d. The *scarburgense* Subzone has its thickest development in Britain in this borehole—37.5 m.

O8. Ashdown borings (Sussex)

Based on Bristow & Bazley (1972).

Though only four standard zones were proved in these borings, the sequence established is important from a stratigraphical point of view, almost the whole Oxfordian succession being represented by shales and mudstones. The Ashdown No. 2 Boring provided a better stratigraphy, as depicted in the column. The No. 1 Boring provided more ammonite information.

a. *Ringsteadia* occurs frequently in the lowest 15 m.

b. Only one ammonite was obtained from this unit: '*Amoeboceras* cf *serratum* Salfeld, of the *cautisnigrae* Subzone' (Bristow & Bazley 1972, p. 20).

c. No ammonites were found in this unit.

d. This bed may correlate with oolite seen in the Warlingham Borehole.

e. The coring of the Upper Oxford Clay ended in the *praecordatum* Subzone 16 m below the oolite.

Wilson (1968*a*,*b*) combined information from the Warlingham, Kent and Ashdown boreholes with a study of the outcrops to produce a synthesis of Corallian palaeogeography in southern England. Brookfield (1973*a*) summarized the Upper Oxfordian palaeogeography of Britain. These three papers require slight updating in the light of new information contained within this report.

O9. Kent

The information from the boreholes and mineshafts of the Kent Coalfield was collected by Lamplugh & Kitchin (1911) and Lamplugh *et al.* (1923). The Upper Oxfordian as presented here is a synthesis of this information taking into account possible correlations with Wiltshire and Dorset.

a. The oolitic iron ore has been correlated with the Westbury Ironstone by several authors, and undoubtedly is of closely similar age. It was not present in all sections, and thus a possible overstep of the overlying marls has been incorporated.

b. The sandy limestone was met in all sections, and may correlate with the Trigonia clavellata Beds of Dorset.

c. The black clay with *Amoeboceras* was met with in only a few borings. It seems to represent the basal Ampthill Clay (cf. the Langton Clay in Yorkshire, Column O15). The identification of *Amoeboceras* could possibly be in error for high *tenuiserratum* Zone *Cardioceras*, the two being difficult to distinguish with poor material.

d. No ammonites were recorded from the limestone unit, whose age can only be determined by that of the beds above and below.

e. A considerable number of *cordatum* Zone ammonites was obtained from this unit; however, the identifications given are out of date and unreliable.

O10. Buckinghamshire, Bedfordshire (by J. H. Callomon)

Once one of the least known areas of the British Oxfordian, sufficient information has become available in recent years to give a reasonably accurate picture of the stratigraphy of this area.

a. The succession in the Ampthill Cutting—the type locality of the Ampthill Clay—has never been measured adequately. The column is based on a section measured in a large temporary cutting at Milbrook (2 km west-north-west of the Ampthill Cutting) in 1968, combined with trial excavation in the cutting, which made it possible to establish the succession. Of the Ampthill Clay proper, at most 10 m are preserved below the Lower Greensand. The only ammonites found suggest the *ilovaiskii* Subzone of the *glosense* Zone. A few old museum specimens said to have come from here indicate higher beds of the *serratum* Zone, but it is always possible that they came from glacial boulder clay.

b. Below the Ampthill Clay and separated from it by a sharp junction with a bored surface are 4–5 m of silts and silty limestones, the Oakley Beds. They are slightly cross-bedded, highly variable and full of *Nanogyra* and Serpulae concentrated locally in lumachelles. Ammonites are fairly common throughout, and all indicate the *tenuiserratum* Subzone.

c. At the base, below another sharp junction, occurs a remanié bed of nodular limestone, 0.20 m thick, with rolled and bored pebbles of ammonites of the *plicatilis* Zone, *vertebrale* Subzone, and intensely bored *Gryphea*.

d. This nodule bed in turn rests with sharp junction on the top bed of Oxford Clay, a black, shaly clay packed with fossils of the *cordatum* Subzone. Though the Upper Oxford Clay succession is usually complete, at Sandy Oakley beds rest on *praecordatum* Subzone Oxford Clay (Edmonds & Dinham 1965).

O11. *South Cambridgeshire*

Based on Arkell (1929–37, 1935–48, 1937*a*,*b*), Edmonds & Dinham (1965), Gallois & Cox (1977), Hancock (1954), Torrens & Callomon (1968), Worssam & Taylor (1969) and Callomon (*pers. comm.*).

The column summarizes the geology of the country between Elsworth and Upware. Exposures in the area are few, and this, combined with the gentle, often deceptive dip, has led many people, including Arkell, to confuse the true order of the succession. It is only in recent years, with the help of work outside this area, that the faunas can be put in their true order.

a. The Phosphate Beds were placed in the Upper Ampthill Clay by Worssam & Taylor (1969), and in the Lower Kimmeridge Clay by Edmunds & Dinham (1965). Their age has now been established as late Oxfordian (see column O13 notes).

b. Arkell's fauna came almost entirely from the drift. It has now been found *in situ* in the area (Gallois & Cox 1977).

c. The Boxworth Rock has yielded *Amoeboceras glosense* (Bigot & Brasil), and is thus of *glosense* Zone age (Callomon, *pers. comm.*). The specimen in question was described as an *Amoeboceras* of the *serratum* group by Gallois & Cox 1977); however, Callomon's identification is accepted here.

d. Gallois & Cox (1977) correlated the beds containing the Knapwell fauna with high *tenuiserratum* Zone beds seen in the West Walton cored borehole (column O13). This revised correlation was based largely on lithological grounds. Hancock (1954) noted that Arkell had identified the Knapwell specimens, and had correlated the fauna with that of the *glosense* Zone Trigonia clavellata Beds in Dorset on the basis of his extensive knowledge of Oxfordian perisphinctids. Arkell's correlation is accepted here.

e. The Long Stanton fauna (Arkell 1937*a*) is placed towards the base of the *glosense* Zone following the discovery of elements of this fauna in the basal Upper Calcareous Grit in Yorkshire. This agrees with recent I.G.S. discoveries in the Wash boreholes (Gallois & Cox 1977).

f. The lowest Ampthill Clay contains *Cardioceras* spp. of the *tenuiserratum* Zone (Gallois & Cox 1978).

g. Ammonites from the Upware Limestone were recorded by Arkell (1937*b*), Torrens & Callomon (1968) and Gallois & Cox (1977). They indicate the *maltonense* and *tenuiserratum* Subzones, which makes at least part of the Upware Limestone of the same age as the Osmington Oolite and Coral Rag of Oxfordshire and north Wiltshire. Arkell (1933) argued that the unusually diverse bivalve fauna also includes elements that indicate a slightly younger age. However, many of these bivalves also occur in the Yorkshire Coral Rag, of *tenuiserratum* Subzone age. It is considered here that the Tethyan aspect of the Upware fauna (including the coral *Spongiomorpha*—Ali 1977) is due to a close connection of the area with Tethys via the London Platform shoal, rather than to any younger age of the Upware fauna. The lithologies present at Upware were described by Gallois & Cox (1977). The unit is not divided here into Coral Rag and Oolite, as the two facies interdigitate (Worssam & Taylor 1969: Gallois & Cox 1977). According to Worssam & Taylor, Ampthill Clay of indeterminate age rests on a clean cut surface of oolite, suggesting a non-sequence.

h. The zonal position of the Elsworth Rock has been dealt with comprehensively by Arkell (1937*b*), Callomon (1960) and Gallois & Cox (1977). 'It shows all the characters of a highly condensed deposit, and its age proven by ammonites varies from place to place, including one, several or all of the subzones between the *cordatum* and *tenuiserratum* Subzones, with probably concomitant non-sequences' (Callomon, *pers. comm.*).

In that the Elsworth Rock ranges from the *cordatum* to *tenuiserratum* Subzones, and the Upware Limestone from the *maltonense* to *tenuiserratum* Subzones, the two units must be co-eval in part. However, the Upware Limestone has yielded an abundant fauna of the *parandieri* Subzone (probably equivalent to the highest *tenuiserratum* and lowest *blakei* Subzones). The Elsworth Rock reaches only into the lower *tenuiserratum* Subzone (Gallois & Cox 1977). Thus, the upper part of the Upware Limestone is regarded here as younger than the Elsworth Rock, and may be represented by calcareous bands lying within the lower Ampthill Clay of areas adjoining Upware.

i. The St Ives Rock contains an abundant fauna of the *tenuiserratum* Subzone (Callomon, *pers. comm.*). Gallois & Cox (1977) also recorded ammonites of the *densiplicatum* Zone, and considered the Elsworth and St Ives Rocks to be entirely equivalent.

j. The Elsworth Rock and the Lower Elsworth Beds (Arkell 1937*b*) were included in the Elsworth Rock 'Group' of Edmunds & Dinham (1965). Gallois & Cox (1977) proposed 'West Walton Beds' as an alternative formation name. The 'Elsworth Rock' seen by Arkell (1937*b*) in an excavation beneath the Upware Limestone is equivalent to the Lower Elsworth Beds of Elsworth.

k. The *bukowskii*, *praecordatum* and *scarburgense* Subzones are well represented in the abundant museum collections of pyritic ammonites from the Huntingdon–St Ives region (Callomon, *pers. comm.*).

O12. *Central Cambridgeshire (formerly Huntingdonshire)*

Based on Callomon (1968 and *pers. comm.*) and Torrens & Callomon (1968). The column depicts the section at the well-known Warboys Pit, which is still accessible despite contrary reports.

a. Zonal range of Ampthill Clay after J. H. Callomon (*pers. comm.* 1978).

b. Beds 10 and 11, the 'Warboys Rock', have yielded a high *parandieri* Subzone fauna (Callomon, *pers. comm.*). Gallois & Cox (1977) placed these beds in the lower *tenuiserratum* Subzone, below the *parandieri* Subzone, but did not give any ammonite records to substantiate this.

c. Recent work has shown that Bed 9 is older than previously considered, and belongs to the *vertebrale* Subzone (Callomon, *pers. comm.*).

d. Bed 9 rests with a sharp, erosive contact on *bukowskii* Subzone Oxford Clay (Callomon, *pers. comm.*).

O13. *North-east Cambridgeshire, Norfolk*

Based on Gallois & Cox (1977).

This area was studied intensively by means of cored boreholes in connection with the proposed Wash Barrage.

a. The Ampthill Clay succession is almost complete except for the *rosenkrantzi* Zone at the top; this is almost certainly absent due to erosion beneath the Kimmeridge Clay.

b. The Phosphate Beds, a sequence of clays with bands of phosphatic nodules occurring over a wide area in the East Midlands, have been dated for the first time by the occurrence of *regulare* Zone *Amoeboceras.*

c. In the lower part of the Ampthill Clay, there are beds of calcareous mudstone of upper *tenuiserratum* Zone age. I consider that these probably correlate with the 'Warboys Rock' and the highest Upware Limestone.

d. 'West Walton Beds' is a new term introduced by Gallois & Cox for silts and calcareous mudstones which would formerly have been allocated to the Elsworth Rock 'Group' of Edmunds & Dinham (1965). The West Walton Beds range from the uppermost *costicardia* Subzone into the lower part of the *tenuiserratum* Subzone.

e. Drilling was stopped at the top of the Oxford Clay.

O14. *Lincolnshire, Humberside*

Based on Gray (1955), Richardson (1979) and Smart & Wood (1976).

An almost complete succession is present, almost entirely in clay facies, through Upper Oxford Clay and Ampthill Clays.

a. The *rosenkrantzi* Zone is again probably absent.

b. In South Humberside, *Ringsteadia* is common in the highest Ampthill Clay seen (Smart & Wood 1976; Richardson 1979).

c. Calcareous silty mudstones and siltstones in the Osgodby (Lincolnshire) and Worlaby (South Humberside) boreholes appear to correspond with the West Walton Beds of Cambridgeshire, but are not separable by mapping from the Ampthill Clay.

d. In boreholes in North Humberside, West Walton Beds of *cordatum* Subzone age rested on Oxford Clay of probable *mariae* Zone age (Gray 1955).

O15. *Howardian Hills*

Based on Gaunt *et al.* (1980), C. D. Wright (1976) and J. K. Wright (1972).

The area covered comprises the Howardian Hills proper, and their continuation on the south side of the Derwent as far as Acklam. The column attempts to bring out the effects of repeated uplift and erosion towards the Market Weighton Swell.

a. The Institute of Geological Sciences (1974, in *Annu. Rep. Inst. geol. Sci.* for 1973, p. 36) reported that they had recognized the Ampthill Clay Formation overlying Corallian Beds in Yorkshire. Previously, this clay had been identified as Kimmeridge Clay (Wright 1972). *Glosense* and *serratum* Zone ammonites were found in the Acklam area boreholes.

b. The North Grimston Cementstone has yielded *glosense* Zone ammonites, while from the basal beds of the formation were collected *Cardioceras* spp. of the *tenuiserratum* Zone (Wright 1976). At Acklam, Ampthill Clay oversteps the North Grimston Cementstone completely (see below).

c. C. D. Wright (1976) reported the discovery of 'Ampthill Clay' beneath the North Grimston Cementstone south of Malton. Obviously, it is inadvisable to have two Ampthill Clays in Yorkshire, one above and one below the North Grimston Cementstone. Such marginal interdigitations of formations always present problems, but it seems best to accept the I.G.S. definition of Ampthill Clay because it has priority and it is the most widespread Middle/Upper Oxfordian clay formation in Yorkshire. C. D. Wright's clay is here named the **Langton Clay** (type section, Langton Beck, SE 805668). Northwards, towards Malton, the Langton Clay passes into a more arenaceous facies, the Limekiln Member. As was noted above, *Cardioceras* spp. were discovered by C. D. Wright in beds immediately overlying the Langton Clay, which is thus of middle Oxfordian age, correlating with the lowest Ampthill Clay of Cambridgeshire. Wright's map (1976) shows Langton Clay continuing to Acklam; however, it is considered here that the clay at Acklam is true Ampthill Clay which has overstepped the North Grimston Cementstone and the Langton Clay.

d. Over a large area south of Langton, Coral Rag is missing together with much of the Malton Oolite, there being a marked period of erosion beneath the Langton Clay in this area (Wright 1976). The unconformity between the Coral Rag and Malton Oolite in the Hovingham area was described by Twombley (1965).

e. In the Acklam area boreholes, only 4 m of Malton Oolite were present beneath the overstepping 'North Grimston Cementstone' (the Langton Clay was not distinguished from the Cementstone in the boring log). At Acklam itself, in a further overstep, *glosense* Zone Ampthill Clay with *Decipia decipiens* (J. Sowerby) rests on Birdsall Calcareous Grit (Wright 1976).

f. M.C.G. = Middle Calcareous Grit. In my previous work on this area (Wright 1972), it was considered that the Middle Calcareous Grit was absent from the whole of this area, and that the Malton Oolite had to be carried down to encompass beds equivalent in age to the Upper Leaf of the Hambleton Oolite of Column O17. However, a thin, transitional representative of the Middle Calcareous Grit, 1.5 m thick, was exposed in 1977 during excavations for the Malton Bypass (Wright 1978*b*). It is thus possible to distinguish at least 6 m of Hambleton Oolite in the Malton area.

g. The Birdsall Calcareous Grit is a distinctive series of buff sandstones and sandy limestones of *costicardia* and *cordatum* Subzone ages. There is no type section available at present, the type area being the Birdsall District (Wright 1972). In the Hovingham area, the lowest beds of the Birdsall Calcareous Grit pass into impure oolite, the Lower Leaf of the Hambleton Oolite (Wright 1972).

h. In the Acklam area boreholes, the Lower Calcareous Grit was absent, Birdsall Calcareous Grit resting directly on eroded Middle Oxford Clay. It is clear that the southerly source of sand postulated for the Birdsall Calcareous Grit by Wright (1972) did in fact exist, that it was due to uplift of the Market Weighton swell, and that the source rocks were the Lower Calcareous Grit, and possibly the Kellaways Rock and the Ravenscar Group.

O16. *Vale of Pickering*

Based on Reeves *et al.* (1978) and Wright (1972).

a. At Ness, the Newbridge Beds (see Column O17) are absent, and Spaunton Sandstone rests directly on Malton Oolite, possibly due to a combination of overstep and overlap rather than to a facies transition of Coral Rag into oolite as postulated previously (Wright 1972).

b. Though this entirely calcareous Coralline Oolite succession is exposed over only a small area at Ness, it is considered likely by the author that much of the Vale of Pickering is underlian by a similar succession, with the proviso that in the centre of the Vale, Middle Calcareous Grit extends south to Malton (see notes to Column O15).

O17. *Tabular and Hambleton Hills*

Based on Arkell (1945), Fox-Strangways (1892), Hemingway & Twombley (1964), Pyrah (1977) and Wright (1972).

a. The discovery of Ampthill Clay in the area was reported by the I.G.S. (1974, in *Annu. Rep. Inst. geol. Sci.* for 1973). Until then, it has been assumed that Kimmeridge Clay rested directly on the Corallian Beds (Wright 1972). Pyrah (1977) recorded *Ringsteadia* sp. from Ampthill Clay exposed near Kirkby Moorside. It is probable that the *serratum*, *regulare* and *rosenkrantzi* Zones are all present in clay facies in this area.

b. In a revised interpretation to that published in Wright (1972), it is now considered that at Spaunton, Snape Sandstone has been removed by erosion beneath the Ampthill Clay.

c. The Newbridge Beds, best described as a sandy shale, variably calcareous, are probably equivalent to the Langton Clay of Column O15. They rest on a beautiful bored erosion surface cut in Coral Rag at Wrelton Quarry (SE 760867). At Spaunton, the Newbridge Beds have yielded *Decipia* ('*Pomerania*') aff *dewari* Arkell (J.K.W. colln), indicating the uppermost *tenuiserratum* Zone.

d. Near Scarborough, the highest Malton Oolite is of *antecedens* Subzone age, whereas at Malton and Pickering, younger *parandieri* Subzone ammonites are present in oolitic facies (Arkell 1935–49). The Coral Rag may have begun forming earlier in the east than elsewhere (Wright 1972), or it may cut down somewhat eastwards to rest on *antecedens* Subzone oolite; the precise evidence is lacking.

e. B.C.G. = Birdsall Calcareous Grit, separating the Hambleton Oolite of the south Hambleton Hills into Upper and Lower 'Leafs'. The column does not show the attenuated lower Coralline Oolite succession at Filey, where the Hambleton Oolite is 3.7 to 4.3 m thick, and the Passage Beds only 1.8 m.

f. The zones of the Lower Calcareous Grit were dealt with by Arkell (1945). The Ball Beds consist of localized developments of large cannonball concretions, sometimes highly fossiliferous. They are best seen on the coast, and inland at Gundale (Hemingway & Twombley 1964).

g. In the south Hambleton Hills, the lower part of the Lower Calcareous Grit passes into oolite (Fox-Strangways 1892). This oolite is named here the **Oldstead Oolite** (type section, Ravens Gill (SE 529819)).

h. On the coast, the *scarburgense* Subzone is condensed and only 0.5 m thick. A detailed section was given by Wright (1969, fig. C4). The fauna of Bed 10 indicates early *scarburgense* Subzone, possibly even the *paucicostatum* Horizon of Marchand (1979).

O18. *East Scotland* (*Brora*)
Based on Sykes (1975).

O19. *East Scotland* (*Balintore*)
Based on Sykes (1975).

O20. *South Skye*
Based on Sykes (1975).

a. The Camasunary Sandstone has yielded almost no ammonites, and can be shown only very tentatively.

b. The total thickness of the Tobar Cean Siltstone is 19 m. The lowest 5 m are Callovian. The next 9.25 m are early Oxfordian in age, but with the *cordatum* Subzone apparently missing. The highest 4.75 m of the Tobar Cean Siltstone, of *vertebrale* Subzone age, must thus rest with a non-sequence on the lower beds.

On the Isle of Eigg, some 25 km to the south-south-west of Skye, 30 m of Lower Oxfordian silts range in age from *scarburgense* to *cordatum* Subzones. They are known as the Laig Siltstones.

O21. *North-west Skye, Staffin*
Based on Sykes (1975).

KIMMERIDGIAN CORRELATION CHART

J. C. W. Cope
with contributions by J. H. Callomon

The first use of Kimmeridge in a geological sense appears to have been by Thomas Webster who published a geological map of the Isle of Wight and Purbeck in 1816.

The lowest horizons he represented thereon were 'Kimmeridge Strata', now the Kimmeridge Clay Formation. The Kimmeridge Clay has not attracted a great deal of attention in the past; the fact that virtually all the fossils are crushed has no doubt contributed to this, and until recently many of the ammonite faunas were poorly known.

There has been considerable confusion over the spelling of 'Kimmeridgian', which stems from W. J. Arkell's insistence on spelling Kimmeridge with only one 'm'—a practice which agrees neither with the present spelling of the village nor with its first geological use. There is now general agreement on the spelling 'Kimmeridgian' (see Morton 1974, p. 89).

The base of the Kimmeridgian is defined by the base of the *Pictonia baylei* Zone; the type locality for the base of the Zone has been proposed at Ringstead Bay, Dorset, some 15 km to the west of Kimmeridge (Morton 1974). At the locality of Kimmeridge there is a magnificent succession, virtually unbroken from the *eudoxus* Zone upwards to the top of the Jurassic. A large part of the thickness here exposed is of Kimmeridge Clay, a formation equated by d'Orbigny with his Kimmeridgian stage. However, amongst the ammonite species d'Orbigny cited as typifying his Portlandian stage were species now included in the genus *Gravesia*. This has led to two meanings of the word Kimmeridgian. In Britain it is customary to equate 'Kimmeridgian' with the Kimmeridge Clay and 'Portlandian' with the Portland Beds (and higher Jurassic rocks). On the European continent, however, the Kimmeridgian–Portlandian boundary is taken at the base of the *Gravesia* beds, so that the British Upper Kimmeridgian (*elegans* Zone upwards) is already Portlandian in France.

The subdivisions of the Kimmeridgian stage have not hitherto been satisfactorily defined. Arkell (1947*a*, p. 67) divided the Kimmeridge Clay into Upper and Lower parts, equating the Lower Kimmeridge Clay with the continental meaning of 'Kimmeridgian' and the Upper Kimmeridge Clay with Blake's term 'Bolononian' and the 'Portlandian inférieur' of continental authors. Later (1947*b*) he introduced the term 'Middle Kimeridge' [sic]. This seemingly was because the upper part of the Kimmeridgian in the Oxford area is present in a largely sandy facies, the 'Sandy Upper Kimeridge' of Arkell (1947*b*, p. 105). The clay facies below this included equivalents of beds he had earlier included in the Upper Kimmeridge Clay in Dorset, and his Middle Kimmeridge was thus introduced initially to distinguish different parts of the succession in the Oxford area. Subsequently (Arkell 1956, p. 21), these divisions were elevated to formalized subdivisions of the Kimmeridgian stage: Lower, Middle and Upper. However, the Middle Kimmeridgian is not a useful term, and a two-fold division into Lower and Upper Kimmeridgian is much more satisfactory from a faunal point of view. The line of division is drawn at the boundary between the Lower and Upper Kimmeridge Clay, that is, in Dorset, at Blake's Bed 42, at the base of the *elegans* Zone (see Cope 1967). The line is an important faunal boundary, marking the upward limit of *Aulacostephanus* and the first appearance of true *Pectinatites*, though fore-runners (*Propectinatites*) of the latter occur at least as low as the *eudoxus* Zone (Cope 1968).

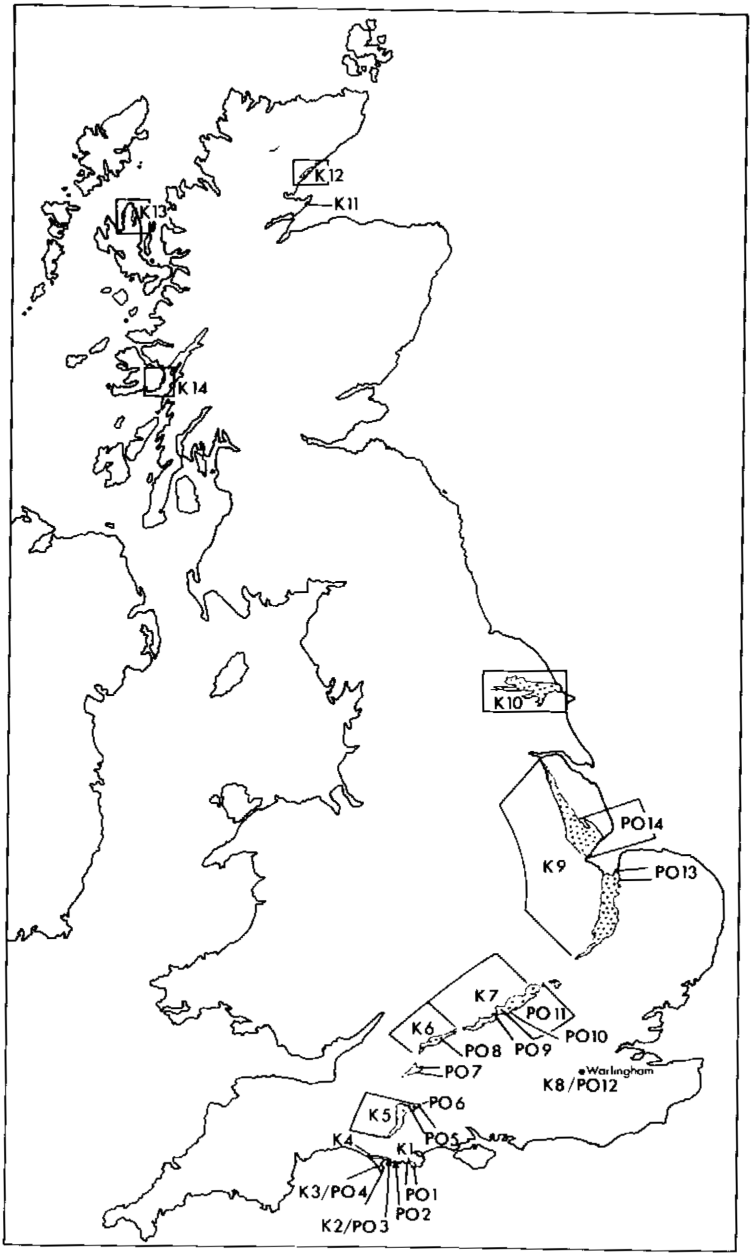


FIG. 13. Disposition of the columns on the Kimmeridgian (K) and Portlandian (PO) correlation charts.

Zonal Scheme

Based on Casey (1967), Cope (1967, 1978), Salfeld (1913) and Ziegler (1962).

a. Cope (1978) proposed a new zone based on a new genus and species.

b. The respective order of the zones is after Casey (1967) which has been confirmed by work in Dorset (Cope 1978). The previous confusion stemmed from Neaverson's (1924, p. 149) assertion that ammonites similar to *P. pallasioides* occurred in the uppermost beds of the Kimmeridge Clay in Dorset. Casey (1967) demonstrated that the position of the *pallasioides* Zone was below that of the *rotunda* Zone in the south Midlands (see section K7, note b). In Dorset *P. pallasioides* has now been found beneath *P. rotunda* and the beds above have yielded a completely new fauna (see a above) (Cope 1978).

c. These zones follow the scheme set up by Cope (1967). The equation of the British pectinatitids with the Tithonian genera *Subplanites* and *Lithacoceras* by Spath (1936) was not disproved until 1967. Species of *Gravesia* were also abandoned as a zonal indices in Britain at that time. It seems unlikely that *Gravesia* occurs north of Dorset (or the Warlingham Borehole). Older records of *Gravesia* from areas including Swindon (Chatwin & Pringle 1922, p. 165) and north-east Scotland (Arkell 1933, p. 474, footnote) have subsequently proved to be obliquely crushed pectinatitids.

d. These zones were revised by Ziegler (1962) in a monograph of *Aulacostephanus. A. yo,* quoted as a zonal index by Salfeld (1913), apparently does not occur in Britain.

e. These zones follow Salfeld (1913) and are the only part of his zonal scheme for the Kimmeridgian which it has not been found necessary to revise in the light of recent work.

Subzonal Scheme

a. Subzones after Cope (1974*b*).

b. Birkelund *et al.* (1978*b*) recognized four subdivisions of the *cymodoce* Zone which were listed as horizons:

Horizon IV	*Rasenia (Semirasenia) askepta* and *R. (Rasenioides) lepidula*
Horizon III	*R. (Zonovia) evoluta*
Horizon II	*R. (Rasenia) involuta* and *R. (Eurasenia)* spp.
Horizon I	*R.* cf. *cymodoce* and *R. (Prorasenia) triplicata.*

No formalized subzones were proposed pending further work on the faunas and stratigraphy of the *cymodoce* Zone.

c. The *baylei* Zone is divisible into at least two subzones (J. H. Callomon, *pers. comm.* 1979) but these are not formalized at present.

K1. Dorset (Purbeck)

Based on Arkell (1947*a*), Blake (1875) and Cope (1967, 1978).

a. Bed numbers follow the scheme used by Blake (1875). Although Blake numbered his beds from the top downwards, his beds are by and large readily recognizable, and have been used in subsequent work (Arkell 1947*a*; Cope 1967, 1978).

b. Thicknesses here upwards are from Cope (1978) and differ somewhat from previously published figures.

c. Bed thicknesses for the *Pectinatites* zones are from Cope (1967).

d. At Kimmeridge the beds below the top of the *eudoxus* Zone are not exposed and the thickness recorded here is from boreholes (see Arkell 1947*a*, pp. 73–4).

*K*2. *Dorset* (*Ringstead*/*Osmington*)

Based on Arkell (1947*a*) and Cope (1978).

a. The *fittoni* Zone has not yet been proved here, though a succession of shales and clays (recorded Arkell 1947*a*, p. 82) above the Rotunda Nodule Bed is almost certainly of this age. Only some 8 km to the east, at Dungy Head, the zonal index has been found in silts below the *albani* fauna in the Portland Sand (Cope 1978).

b. Details here to the base are largely from Arkell (1947*a*).

c. Brookfield (1978) has revised the stratigraphy of these beds.

*K*3. *Dorset* (*Wyke Regis*/*Portland*)

Based on Arkell (1933), Cope (1978), House (1958) and Salfeld (1914).

a. The Lower Black Nore Beds yield the zonal index, which was recorded by House (1958) as *Zaraiskites* sp. (Cope 1978, p. 517). This confirms the suggested correlation of the Lower Black Nore Beds with the Hounstout Marl of Purbeck made by Arkell (1933, p. 497).

b. Individual zones have not been proven in this area where exposures are very poor, but in view of the thickness of the Kimmeridge Clay in the region, the succession is presumed to include representatives of all zones. The lower parts of the succession floor Portland Harbour.

c. Nodules from the floor of the harbour are washed ashore around Wyke Regis and have yielded ammonites of these zones (Salfeld 1914, p. 203).

d. See Arkell (1947*a*, p. 88) and Birkelund *et al.* (1978*b*, p. 35).

e. Arkell (1947*a*).

*K*4. *Dorset* (*Portesham*/*Abbotsbury*)

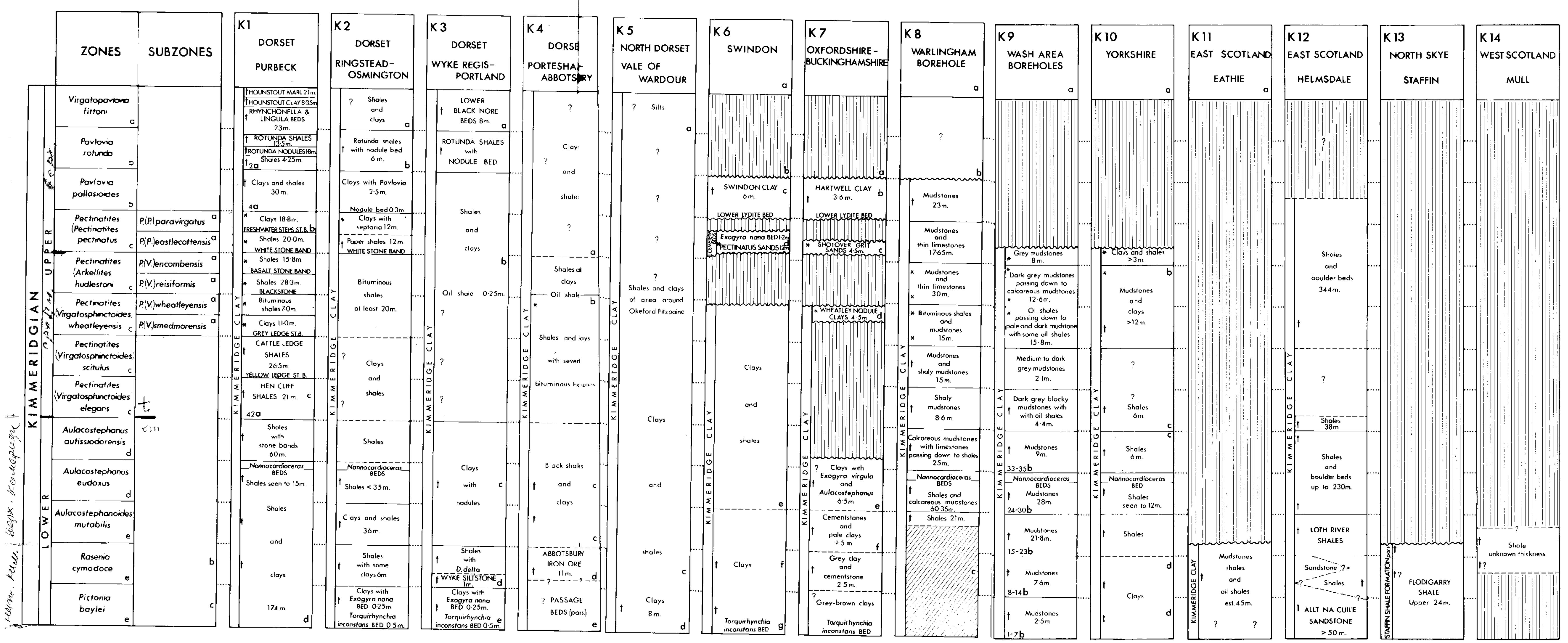
Based on Blake (1875), Cope (1971 & MS) and Wilson *et al.* (1958).

a. Individual zones are not proven in this area although the thickness of the Kimmeridge Clay Formation in the area suggests that there are no major breaks.

b. The *wheatleyensis* Subzone is proved by specimens (including the holotype) of *P.* (*V.*) *grandis* (Neaverson 1925, p. 52) but other zones (or subzones) have not been identified (but see a. above).

c. These zones have been proved in temporary sections (Cope MS.).

d. The precise age of the Abbotsbury Iron Ore within the *cymodoce* Zone remains to be determined. Extensive new exposures in 1966 made possible a redescription of the lithostratigraphy (Brookfield 1973*b*) and yielded abundant ammonites, now in Oxford University Museum. These constitute a distinctive fauna, differing from


KIMMERIDGIAN
UPPER
LOWER
ZONES
SUBZONES
Virgatopavlovia fittoni
Pavlovia rotunda
Pavlovia pallasioides
Pectinatites (Pectinatites) pectinatus
Pectinatites (Arkellites) hudlestoni
Pectinatites (Virgatosphinctoides) wheatleyensis
Pectinatites (Virgatosphinctoides) scitulus
Pectinatites (Virgatosphinctoides) elegans
Aulacostephanus autissiodorensis
Aulacostephanus eudoxus
Aulacostephanoides mutabilis
Rasenia cymodoce
Pictonia baylei
P.(P.) paravirgatus
P.(P.) eastlecottensis
P.(V.) encombensis
P.(V.) reisiformis
P.(V.) wheatleyensis
P.(V.) smedmorensis
K1 DORSET PURBECK
HOUNSTOUT MARL 21m.
HOUNSTOUT CLAY 8·35m.
RHYNCHONELLA & LINGULA BEDS 23m.
ROTUNDA SHALES 13·5m.
ROTUNDA NODULES 18m.
Shales 4·25m.
Clays and shales 30m.
Clays 18·8m.
FRESHWATER STEPS ST. B.
Shales 20·0m.
WHITE STONE BAND
Shales 15·8m.
BASALT STONE BAND
Shales 28·3m.
BLACKSTONE
Bituminous shales 7·0m.
Clays 11·0m.
GREY LEDGE ST. B.
CATTLE LEDGE SHALES 26·5m.
YELLOW LEDGE ST. B.
HEN CLIFF SHALES 21m.
Shales with stone bands 60m.
Nannocardioceras BEDS
Shales seen to 15m.
Shales and clays 174m.
K2 DORSET RINGSTEAD-OSMINGTON
Shales and clays
Rotunda shales with nodule bed 6m.
Clays with Pavlovia 2·5m.
Nodule bed 0·3m.
Clays with septaria 12m.
Paper shales 12m.
WHITE STONE BAND
Bituminous shales at least 20m.
Clays and shales
Shales
Nannocardioceras BEDS
Shales < 35m.
Clays and shales 36m.
Shales with some clays 6m.
Clays with Exogyra nana BED 0·25m.
Torquirhynchia inconstans BED 0·5m.
K3 DORSET WYKE REGIS-PORTLAND
LOWER BLACK NORE BEDS 8m.
ROTUNDA SHALES with NODULE BED
Shales and clays
Oil shale 0·25m.
Clays with nodules
Shales with D. delta 1m.
WYKE SILTSTONE
Clays with Exogyra nana BED 0·25m.
Torquirhynchia inconstans BED 0·5m.
K4 DORSET PORTESHAM-ABBOTSBURY
Clays and shales
Shales and clays
Oil shale
Shales and clays with several bituminous horizons
Black shales and clays
ABBOTSBURY IRON ORE 11m.
PASSAGE BEDS (pars)
K5 NORTH DORSET VALE OF WARDOUR
Silts
Shales and clays of area around Okeford Fitzpaine
Clays and shales
Clays 8m.
K6 SWINDON
SWINDON CLAY 6m.
LOWER LYDITE BED
Exogyra nana BED 1·2m.
PECTINATUS SANDS 12m.
Clays and shales
Clays
Torquirhynchia inconstans BED
K7 OXFORDSHIRE-BUCKINGHAMSHIRE
HARTWELL CLAY 3·6m.
LOWER LYDITE BED
SHOTOVER GRIT SANDS 4·5m.
WHEATLEY NODULE CLAYS 4·5m.
Clays with Exogyra virgula and Aulacostephanus 6·5m.
Cementstones and pale clays 1·5m.
Grey clay and cementstone 2·5m.
Grey-brown clays
Torquirhynchia inconstans BED
K8 WARLINGHAM BOREHOLE
Mudstones 23m.
Mudstones and thin limestones 17·65m.
Mudstones and thin limestones 30m.
Bituminous shales and mudstones 15m.
Mudstones and shaly mudstones 15m.
Shaly mudstones 8·6m.
Calcareous mudstones with limestones passing down to shales 25m.
Nannocardioceras BEDS
Shales and calcareous mudstones 60·35m.
Shales 21m.
K9 WASH AREA BOREHOLES
Grey mudstones 8m.
Dark grey mudstones passing down to calcareous mudstones 12·6m.
Oil shales passing down to pale and dark mudstone with some oil shales 15·8m.
Medium to dark grey mudstones 2·1m.
Dark grey blocky mudstones with with oil shales 4·4m.
Mudstones 9m.
33-35b
Nannocardioceras BEDS
Mudstones 28m.
24-30b
Mudstones 21·8m.
15-23b
Mudstones 7·6m.
8-14b
Mudstones 2·5m.
1-7b
K10 YORKSHIRE
Clays and shales >3m.
Mudstones and clays >12m.
Shales 6m.
Shales 6m.
Nannocardioceras BED
Shales seen to 12m.
Shales
Clays
K11 EAST SCOTLAND EATHIE
Mudstones shales and oil shales est. 45m.
K12 EAST SCOTLAND HELMSDALE
Shales and boulder beds 344m.
Shales 38m.
Shales and boulder beds up to 230m.
LOTH RIVER SHALES
Sandstone
Shales
ALLT NA CUILE SANDSTONE > 50m.
K13 NORTH SKYE STAFFIN
STAFFIN SHALE FORMATION pars
FLODIGARRY SHALE Upper 24m.
K14 WEST SCOTLAND MULL
Shale unknown thickness
KIMMERIDGE CLAY

those of Horizons I–IV quoted above (p. 79), but very close to, and possibly identical with, one long known from the 'Marnes à Pterocères' at Villerville in Normandy, which yielded the types of *Rasenia erinus* (d'Orbigny) and *R. berryeri* (Dollfus) (J.H.C.).

Typical Abbotsbury Iron Ore also occurs some 6 km to the north-west of Abbotsbury in the Litton Cheney syncline (Cope 1971).

e. Blake (1875, p. 213) introduced the term 'Passage Beds' to include the uppermost Oxfordian and lowermost Kimmeridgian Beds. This term was revived by Wilson *et al.* (1958) for a ferruginous formation spanning the interval between the Sandsfoot Beds (Upper Oxfordian) and the Abbotsbury Iron Ore. This formation probably therefore includes the *baylei* Zone, though no ammonite faunas are known.

K5. North Dorset/Vale of Wardour

Based on White (1923) and Wimbledon (1976).

a. These beds were penetrated by a borehole (Wimbledon 1976) but no ammonite fauna was obtained. They may belong to the *albani* Zone, or may be even as old as the *pectinatus* Zone. In this latter event the small pebbles recorded higher in the borehole (Wimbledon 1976) would represent the Upper Lydite Bed, and the silts would be the lateral equivalent of the Pectinatus Sands of the Swindon region.

b. White (1923, pp. 39–40) recorded beds of the lower part of the *Virgatites* zone. This probably refers to the *wheatleyensis* Zone.

c. These horizons are very poorly and infrequently exposed, though White (1923, p. 39) records *Aulacostephanus* from Okeford Fitzpaine.

d. These clays were formerly exposed in a brickpit at Gillingham, now disused.

K6. Swindon

Based on Arkell (1933, 1947*b*), Chatwin & Pringle (1922), Cope (1967, 1978) and Kitchin (1926).

a. The *rotunda* fauna, but not the *fittoni* fauna, is known as a derived element in the Upper Lydite Bed (see Portlandian chart).

b. The specimen of *Pavlovia pallasioides* recorded by Kitchin (1926) was long overlooked, and could have solved the problem over the age of the Swindon Clay. In all its characters this clay seems quite indistinguishable from the Hartwell Clay, but difficulties arising from Neaverson's incorrect placing of the *pallasioides* and *rotunda* Zones led to listing of these two formations as separate (see Arkell 1947*b*, p. 105).

c. The Lower Cemetery Beds were believed by Salfeld to be Portlandian, and he figured *Pectinatites eastlecottensis* from there (1913). However, Chatwin & Pringle later (1922) established their Kimmeridgian age.

d. These beds were formerly exposed in several pits (Arkell 1933, p. 457) but the modern zones have not been identified definitely. The *Gravesia* recorded from the Hudleston collection (Chatwin & Pringle 1922, p. 156) is an obliquely crushed *Pectinatites.* A recent I.G.S. borehole in the area (Gallois 1976) should yield valuable information on zones ana thicknesses.

e. Details of exposures formerly showing these lower horizons were given by Arkell (1933, p. 458).

f. Typical *Rasenia* of the *cymodoce* Zone were found at the Park, Swindon, (850 m south-west of Swindon Station) in a temporary excavation (Oxford University Museum, A. D. Passmore colln 1906). Their preservation is exactly like that of the renowned *Rasenia* fauna from Market Rasen, Lincolnshire. (J.H.C.)

g. The *T. inconstans* Bed, developed exactly as at Ringstead in Dorset, was exposed in a temporary exposure at Blagrove Farm, 5 km west of Swindon, in 1978. It yielded many typical *Pictonia densicostata* and a rich fauna of bivalves. It was overlain by clays rich in *D. delta* (W. Smith) also as in Dorset (J.H.C.)

K7. Oxfordshire/Buckinghamshire

Based on Arkell (1947*b*) and Casey (1967).

a. Remanié faunas of the *rotunda* Zone, but apparently not the *fittoni* Zone, are incorporated in the Upper Lydite Bed (see Portlandian chart).

b. The stratigraphical position of the Hartwell Clay has long been the subject of controversy. The Hartwell Clay of Buckinghamshire provides the type locality for the *pallasioides* Zone, which was placed by Neaverson above the *rotunda* Zone (1925, p. 8). Buckman, duped by a workman over the provenance of some *pallasioides* Zone ammonites, long claimed that that zone lay beneath the *pectinatus* Zone (see Arkell 1933, pp. 464–6 for details). Casey (1967) established the super-position of the *rotunda* Zone above the *pallasioides* Zone. Ammonites from the Hartwell Clay have been figured more recently by Oates (1974).

c. Detailed sections are given by Arkell (1947*b*). There is apparently a great deal of local variation in the succession and thicknesses particularly in the *pectinatus* Zone.

d. Neaverson's (1925) monograph of Upper Kimmeridgian ammonites included much material from the Wheatley Nodule Clays, and from there were figured species of *Virgatosphinctoides* and *Allovirgatites* (now both included in *Pectinatites*). The fauna belongs entirely to the *wheatleyensis* Subzone.

e. These clays probably belong entirely to the *eudoxus* Zone, but the possibility that there may be some representative of the *autissiodorensis* Zone cannot be excluded.

f. Succession from Arkell (1947*b*). *Mutabilis* Zone ammonites were found in temporary sections in the cutting for the Oxford Eastern Bypass road at the base of Shotover Hill (1957) and in a pipe trench at Shabbington, west of Thame. (J.H.C., MS, 1977). (J.H.C.).

K8. Warlingham borehole

Based on Callomon & Cope (1971) and Worssam & Ivimey-Cook (1971).

a. The *rotunda* fauna was incorporated in a typical lydite bed at the base of the presumed Portland Beds. It is therefore likely that these horizons were lacking in the borehole.

b. Below the *mutabilis* Zone (of which 21 m were proved) a fault cut out the rest of the Kimmeridgian.

K9. Wash area

Based on Cope (1974*b*) and Gallois & Cox (1974, 1976).

a. Over much of the Wash area, the Kimmeridge Clay is covered by recent deposits, and exposures are virtually unknown. Details of the succession in the area have been obtained from a series of boreholes sunk by the I.G.S. Evidence for the former existence of higher Kimmeridgian beds than now preserved is contained in derived pavloviids in the base of the Sandringham Sands (Gallois 1973, p. 73).

b. Bed numbers follow Gallois & Cox (1976).

On the north side of the Wash further northwards into Lincolnshire very little is known in detail about the Kimmeridge Clay, the upper part being virtually unknown, although the *wheatleyensis* Zone was formerly exposed in a brick pit at Fulletby, 5 km north-east of Horncastle. In the Lower Kimmeridge Clay north-east of Brigg, a local sandstone, the Elsham Sandstone, contains *Xenostephanus* (Arkell & Callomon 1963: Kent & Casey 1963), thought to be of lower *mutabilis* Zone age.

Numerous small brickyards and railway cuttings in the 19th century yielded fossils now in the museums showing that the Lincolnshire–South Humberside succession is probably largely complete (see Roberts 1889; Woodward 1895). Notable localities include Horncastle (whence came the type of *Aulacostephanoides mutabilis* (Sowerby) and topotypes figured by Ziegler 1962) and Brigg, the source of *Rasenia evoluta* (lectotype in Birkelund *et al.* 1978*b*). The famous fauna of beautifully preserved raseniids from Market Rasen was obtained from long-abandoned brickpits in the area (Woodward 1895, p. 175 and figures in Spath 1935). Birkelund *et al.* 1978*b*, pp. 35, 36) noted that the Market Rasen fauna consists of two assemblages, recognizable by their different types of preservation. They represent Horizons II and III (see Subzonal Scheme note b).

The I.G.S. boreholes in the northern part of the area (South Humberside) have shown a succession from *baylei* to *mutabilis* Zones (Richardson 1979).

The Lower Kimmeridge Clay is worked for cement-making at South Ferriby on the south shore of the Humber. It shows the finest and probably thickest section through the *baylei* Zone in England (5 m) and the lowest part of the *cymodoce* Zone with yet another fauna of raseniids (possibly *R. similis* Spath); the latter is overlain by Cretaceous Carstone (see Cox 1976).

K10. Yorkshire

Based on Arkell (1945), Cope (1974*a*) and Falcon & Kent (1960).

a. Many of the unsolved problems of the Yorkshire Kimmeridgian stem from lack of exposures; the formation is poorly exposed over the region owing to very thick cover of Drift. The Fordon No. 1 borehole (Falcon & Kent 1960, p. 29) proved 385 m of Kimmeridge Clay. When this is compared with the thicknesses observed in the field at existing exposures, it is clear that a very considerable thickness of the Kimmeridge Clay of Yorkshire is virtually unknown. The only permanent coastal exposure is in Filey Bay at the base of Speeton Cliff where beds up to the *eastlecottensis* Subzone are overlain by Speeton Clay (Lower Cretaceous, see Casey 1973, p. 206).

b. The earlier recorded absence of the *hudlestoni* Zone (Cope 1974*a*, p. 219) can no longer be substantiated. Further material has confirmed the *encombensis* Subzone with at least one undescribed species of *Pectinatites* largely homeomorphic with earlier *smedmorensis* Subzone forms. These new forms are associated with *P.* (*V.*) *encombensis* Cope (which is all too readily confused with *P.* (*V.*) *wheatleyensis* when material is incomplete—see Arkell 1947*a*, p. 71). These conchoidal-fracturing clays and hard bands thus correlate with the Basalt Stone Band and Dicey Clays of Dorset (Cope 1967, p. 8) (R. W. Gallois 1978, *pers. comm.*).

c. Callomon (*in* Callomon & Cope 1971, p. 161) recorded details of the *elegans* and *autissiodorensis* Zones; the latter is the source of uncrushed material in many museums including *A. autissiodorensis* (Ziegler 1962, pl. 13, figs 1, 3) and the type of *Subdichotomoceras lamplughi* Spath (Arkell 1957*a*, p. L328, fig. 422).

d. Old collections show that these lower zones were formerly exposed in brickpits in the Malton region, and recent temporary exposures further west in the Vale of Pickering also exposed these horizons (Cope 1974*a*).

*K*11. *East Scotland* (*Eathie*)

Based on Waterston (1951) and Ziegler (1962).

At the base of the succession are green-grey mudstones with some thin limestone nodules and bands. These oldest beds may belong to the *cymodoce* rather than the *baylei* Zone. The higher beds have yielded a fauna of *Amoebites* and raseniids characteristic of the upper parts of the *cymodoce* Zone and the basal *mutabilis* Zone. At Port an Righ, some 10 km to the north along the coast from Eathie, *Pictonia baylei* has been found amongst fossiliferous nodules on the beach showing that the basal Kimmeridgian is preserved offshore in this area.

*K*12. *East Scotland* (*Helmsdale*)

Based on Bailey & Weir (1932) and Linsley (1972, unpublished, and 1977, *pers. comm.*).

The sequence of shales and boulder beds here has long been known and was first described in detail in a classic work by Bailey & Weir (1932), who ascribed the occurrence of the boulder beds to fault movement in Kimmeridgian times. Fault-scarp material of Old Red Sandstone together with a shallow water coral and brachiopod fauna thus became mixed in a deeper water more argillaceous facies with ammonites.

The ammonite faunas obtained by Linsley show that the youngest beds present are considerably younger than the age suggested by Bailey & Weir (see Cope 1967, p. 72). The upper part of the succession is terminated by a fault, but it would appear possible that the top of the Kimmeridgian is preserved. Evidence for the *scitulus* and at least part of the *elegans* Zone is lacking owing to faulting and poor exposure. The *wheatleyensis* Zone was proved at West Helmsdale (Linsley 1972, p. 167). The highest horizons have not yielded ammonites which can be identified, and may represent even younger deposits than top Kimmeridgian.

Lower in the succession it should be noted that the Allt Na Cuile Sandstone is of variable age. Linsley believes that this sandstone facies is developed at various points up to the base of the *eudoxus* Zone and is not uniquely found near the base of the succession (*contra* Brookfield 1976).

*K*13. *West Scotland* (*Skye*)

Based on Arkell & Callomon (1963), Spath (1932) and Wright (1973).

The succession of shales in Staffin Bay has been described by Wright (1973). Higher beds than those exposed may lie hidden beneath large landslips in the region.

*K*14. *West Scotland* (*Mull*)

Based on Arkell & Callomon (1963) and Spath (1932).

The tiny exposure of shales in Mull was first reported to be Callovian. Buckman identified *Kosmoceras* and *Reineckeia* from there. These were reidentified as *Amoeboceras* and *Rasenia* by Spath (1932). A full faunal list was given by Arkell & Callomon (1963, p. 243) who ascribed a *mutabilis* Zone age. Upper and lower boundaries appear to be faulted and the precise age range of the Kimmeridgian on Mull is unknown.

PORTLANDIAN CORRELATION CHART

W. A. Wimbledon

The first use of the term Portlandian was by Brongniart (1829) in an adjectival reference to the limestones of the Portland Stone. This post-dated work on the outline definition of these rocks by William Smith (1815–1816). The names Portland Stone and Purbeck Stone had been in everyday informal usage for several hundred years prior to this time. The first attempt at a comprehensive treatment of localities throughout the entire Portland–Purbeck outcrop was made by Fitton (1836), notably in their thickest developments in the Isle of Purbeck.

A considerable geological and historical background thus existed prior to d'Orbigny's (1842–51) first application of Portlandian in a strict stage sense. His statement that the stage consisted of Fitton's Portland Sand and Portland Stone, but that diagnostic fossils included such typical Kimmeridge Clay forms as *Gravesia* has been the cause of much subsequent confusion amongst continental workers (see Arkell 1935, p. 303; this report p. 77). The later repercussions of d'Orbigny's ignorance of the Dorset sequence caused Arkell (1933, 1946) to strongly urge the proper definition of the stage using the standard sections; later (1947*a*) he proposed *Progalbanites albani* (Arkell) as the index for the basal Portlandian zone.

All but the most recent British publications have tended to use 'Portlandian' synonymously with Portland Beds, but as the topmost Jurassic stage the term should, by definition, encompass everything between the top of the Kimmeridgian and the base of the Cretaceous. Traditionally, the Jurassic–Cretaceous boundary in southern England was for many years placed at the Purbeck–Wealden junction, although historically d'Orbigny had included the Purbeck Beds within the Neocomian. In recent years definition of the boundary at the base of the mid-Purbeck Cinder Bed has become accepted practice (e.g. Rawson *et al.* 1978), following Casey (1963) who believed it to represent a southward incursion by a Spilsby sea; a single correlateable marine 'event'. Ammonites or alternative non-facies controlled fossils are unknown in the Cinder Bed and its presumed correlative the Whitchurch Sands. Lacking a better alternative, however, the Cinder Bed for the time being remains 'an arbitrary and apparently convenient horizon at which to draw the boundary' (Cope & Clements 1969).

The Portlandian ammonite zonation used herein was discussed fully by Wimbledon & Cope (1978). It is an amalgam of recent schemes for the earlier Portlandian of southern England and northern France (Wimbledon & Cope, *op. cit.*) and the later Portlandian ('Volgian') of eastern England (Casey 1973). Overlap of the two schemes is made possible by a correlation between the Portland Stone of the south and the basal Spilsby–Sandringham Sands, based on the presence in both of common pavloviid ammonites. In Dorset ammonite-bearing marine units persist from the *albani* to the *oppressus* Zones when Purbeck Beds conditions set in. In Lincolnshire marine sediments were deposited intermittently, certainly from the *kerberus* Zone and possibly from earlier times through to the Cretaceous.

In southern England, the Portland Beds were formerly divided into three zones (e.g. Arkell 1947*a*; Cope 1969; Anderson 1973; Townson 1975), but a greater understanding of the ammonite faunas has led to the definition of five zonally useful assemblages. The overlying latest Jurassic Purbeck facies is zoned by ostracods, and the integration of these ostracod zones with the later Portlandian ammonite zones of eastern England remains the outstanding problem of Portlandian biostratigraphy.

The stage term 'Portlandian' is here preferred to the Russian name 'Volgian' for a number of reasons. Quite apart from its priority as an original d'Orbigny stage, the Portlandian, based on the sections of the type area in Dorset where there are more than 30 km of coastal cliffs, presents the stratigrapher with an eminently useable and correlateable unit with an unambiguously defined base. The name Volgian is one fraught with complications. Its recent formal modification (Gerasimov & Mikhailov 1966) to include a large proportion of the Kimmeridgian Stage *sensu anglico* complicates matters in that stage as well as with regard to the ultimate Jurassic stage, the Portlandian. The Volgian type localities consist of sections showing demonstrably condensed and incomplete sequences only a few metres in thickness. Correlatives of only three of the nine Portlandian Standard Zones defined in England (Wimbledon & Cope 1978) can be diagnosed in Russia with any degree of certainty.

It is clear that past assumptions about the extreme limitations of Portlandian ammonite faunas, not only areally but also with regard to species diversity, stratigraphical ranges and zonation, are inaccurate. It appears also that a large part of the Portlandian time interval as represented in England and northern France (from the *glaucolithus* to *anguiformis* Zones) has not been recognized in other regions of the Boreal Realm because beds of the appropriate age are not preserved but are represented by non-sequences in condensed successions.

Leaving aside the identification of the problematic '*Paracraspedites*' fauna, on the

Russian platform there is a gap between the presumed equivalent of the *albani* Zone (the *nikitini* Zone) (see Cope 1978, pp. 531–2) and the *primitivus* Zone, equated (Casey 1973) with the *fulgens* Zone. In Greenland (Jameson Land) *Crendonites*—like pavloviids and *Epipallasiceras* of late Kimmeridgian to *albani* Zone age in the Salix Dal Member (Surlyk *et al.* 1973) are succeeded by late Portlandian to Ryazanian?) *Chetaites* and *Subcraspedites* (*preplicomphalus-lamplughi* Zones?) higher in the Raukelv Formation. In Milne Land a similar situation seems to prevail but with an even larger non-sequence involved. Late Kimmeridgian–earliest Portlandian rocks (*fittoni–albani* Zones) are seemingly overlain directly by latest Ryazanian–Valanginian units (Birkelund *et al.* 1978*a*).

*PO*1. *Dorset: Hounstout-St Aldhelms Head*

Based on Arkell (1935), Cope & Wimbledon (1973), Wimbledon (1974*a,b*) and Wimbledon & Cope (1978).

a. Although they contain a number of marine or quasi-marine horizons, the Purbeck Beds have yielded no ammonites; thus no finite correlations with ammonite-bearing rock sequences can be made. In southern England the Purbeck Beds have been zoned by means of ostracods (Anderson 1940, 1958, 1962; Sylvester-Bradley 1949*b*). In addition a succession of faunicycles based on characteristic, salinity controlled ostracod assemblages has been recognized (Anderson 1971, 1973).

Some doubts have arisen over the stratigraphical value of ostracod assemblages. Revised ammonite correlations at the Portland/Purbeck junction suggest that this facies change is a diachronous one, leading one to suppose that the ostracod zonation for the Lower Purbeck Beds may be similarly diachronous. At present ostracod zones cannot be accurately integrated with the ammonite scheme nor can their reliability in a time sense be verified by the use of alternative stratigraphical indicators.

b. The well-established name Portland Freestone or Freestone Series (Woodward 1895) has been emended (Wimbledon & Cope 1978) to Portland Freestone Member, thus maintaining continuity with previous usage.

c. Letters and numbers in brackets in columns 2–5 refer to the bed notation used by Arkell (1935).

d. For the most part lithostratigraphical units employed herein follow Arkell (1933, 1935) who in part followed earlier work by Blake (1880), Woodward (1895) and Buckman (1909–30). Townson (1975), in a sedimentological study of the Portland Beds of Dorset, has set up a new lithostratigraphical nomenclature. As Arkell's well-established scheme is a perfectly usable one the introduction of a new and equally complex set of names is here regarded as unnecessary.

Cherty 'Series' includes an inadmissible chronostratigraphical element so that it is necessary to revert to Cherty Beds (Woodward 1895), with a division into Upper and Lower Cherty Beds (Cope & Wimbledon 1973).

e. Arkell's beds J–J1 in Purbeck are clearly the correlatives of the Basal Shell Bed of Portland and more westerly Dorset outcrops. The similarity is even more striking at Dungy Head (Column PO2) (beds J–K), where the tripartite division of the Basal Shell Bed, typical of the western localities from Ringstead to Portesham, first appears. Cox (1929) noted the absence of the Basal Shell Bed (Blake 1880) at the base of the Portland Stone of St. Aldhelm's Head. It is surprising that the true nature of the Basal Shell Bed in mainland Dorset was not recognized long ago for, disregarding very slight differences of lithology, this composite micritic unit remains more or less the same throughout its outcrop, with identical and abundant diagnostic ammonite faunas. The only author to record the tripartite nature of the bed, on Portland at least, was House (1970, *in* Torrens 1969*a*).

f. In the type Portlandian sequences of Dorset there is a very neat and obvious equivalence between the base of the Portland Sand and the base of the Portlandian Stage. In the most important sections, those at Hounstout to St. Aldhelm's Head and the cliffs of Portland, the ammonite fauna of the *albani* Zone does not occur lower than the Massive Bed and Black Nore Sandstone respectively. Thus the lithostratigraphical and stage boundaries are exactly coincident. Wimbledon & Cope (1978) proposed the base of the Massive Bed on Hounstout Cliff as the type locality for the base of the *albani* Zone, and thus of the Portlandian Stage.

PO2. Dorset: Dungy Head

Based on Arkell (1935), Cope & Wimbledon (1973), Wimbledon (1974*a,b*) and Wimbledon & Cope (1978).

a. See PO1 note b.

b. See PO1 note d.

c. See PO1 note e.

d. 'Dolomite', an informal lithological description, equals beds 8–10 of Arkell (1935) and is obviously to be equated with the West Weare Sandstones of Portland.

e. 'Sandy Clay' is bed 5 of Arkell (1935).

f. 'Lime Mudstone' is bed 4 of Arkell (1935).

PO3. Dorset: Holworth House & Ringstead

Based on Arkell (1935), Wimbledon (1974*a,b*) and Wimbledon & Cope (1978).

a. See PO1 note b.

b. See PO1 note c.

c. See PO1 note d.

d. 'Sandy Clay', beds 1–6 of Arkell (1935).

PO4. Dorset: Portland

Based on Arkell (1933), Cope & Wimbledon (1973), Wimbledon (1974*a,b*) and Wimbledon & Cope (1978).

a. It is probable that a much more complete sequence of Purbeck Beds once existed on Portland. There is clear evidence on the island, in loose material, for horizons at least as high as the Cinder Bed, but only some 30 m or so has been proved *in situ*.

b. See PO1 note b.

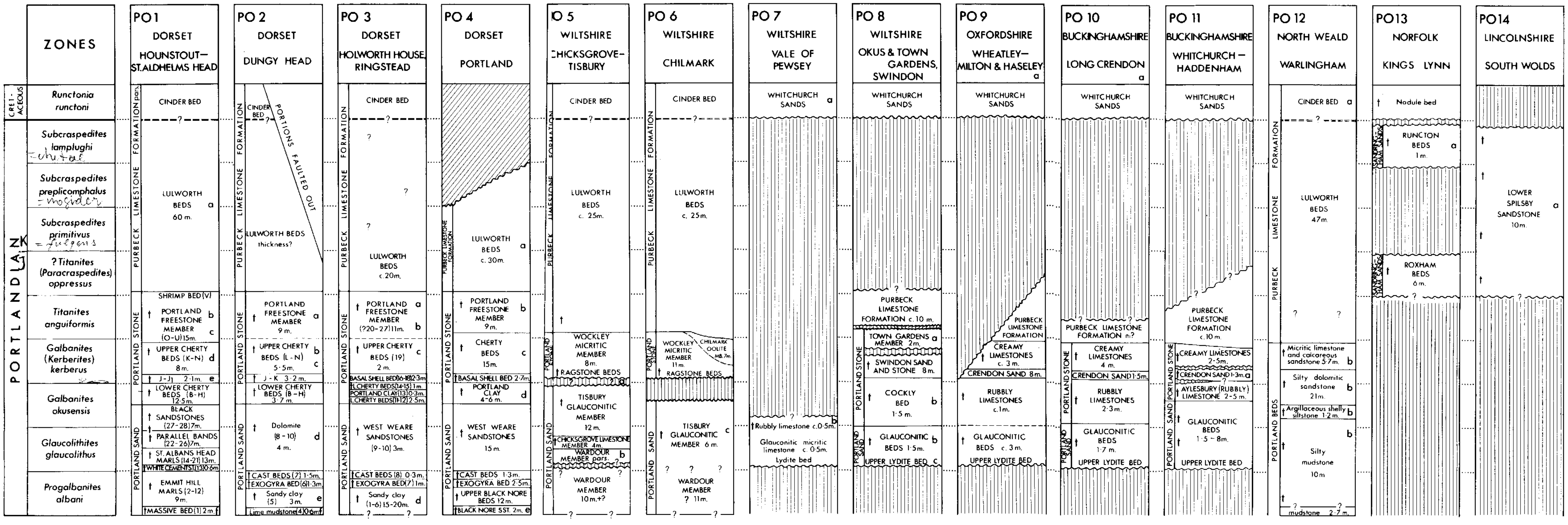


FIG. 15. Correlation of Portlandian rocks. Columns PO1–PO14.

c. The Cherty Beds of Portland are largely equivalent to the Upper Cherty Beds of the more easterly outcrops (PO1–3).

d. The Portland Clay is not restricted to the north of the island as earlier workers (Blake 1880; Arkell 1933) reported. It is equivalent to the Lower Cherty Beds of the more easterly outcrops (PO1–3).

e. See PO1 note f.

PO5. Wiltshire: Chicksgrove–Tisbury

Based on Wimbledon (1974*b*, 1976) and Wimbledon & Cope (1978).

a. The base of the Ragstone Beds at Chicksgrove (Wimbledon 1976, bed 25) is a loose sand resting on a channelled surface of the underlying Tisbury Member. The top of the latter yields poorly preserved inflated *Titanites* of the *okusensis* Zone. The overlying plant-bearing sand contains *Falcimytilus*, crocodile scutes, fish debris and large reptilian limb bones. This unit grades up into a micrite (bed 26) with an abundance of a *Hydrobia*-like gastropod. Above, the Ragstones (beds 27–30) show a reversion to the typical marine bivalve fauna, together with *Titanites* spp. of the *kerberus* Zone. Thus at Chicksgrove the Ragstone Beds incorporate the earliest recorded instance in the Portlandian of a regressive phase with faunas and sediments of Purbeck Beds aspect; this directly overlies an erosion surface at about the junction of the *okusensis* and *kerberus* Zones.

b. A thin lydite horizon occurs 3 m below the top of the Wardour Member at Chicksgrove (this is not the so called Upper Lydite Bed of Arkell (1933) which was composed of occasional pebbles in the Chicksgrove Limestones). The Wardour Member has yielded no ammonites to date, but the Chicksgrove Limestones just above have produced a prolific fauna of glaucolithitids and other ammonites; these are forms which comprise the endemic fauna of the Upper Lydite Bed from Swindon northwards. It is tempting to equate the Wardour Member pebble horizon with the Upper Lydite Bed.

PO6. Wiltshire: Chilmark

Based on Wimbledon (1974*b*, 1976, & MS).

a. Although the Portland/Purbeck junction at Chicksgrove lies immediately above strata yielding ammonites (Wimbledon 1976), which were provisionally identified as *Titanites* cf. *anguiformis* Wimbledon, the transition at Chilmark is not well dated. Common *kerberus* Zone ammonites occur in the micrites of the Wockley Member of Chilmark but none have to date been recorded from the Chilmark Oolite. Recent excavations have repeated and further expanded the basal Purbeck section given by Fitton (1836) at Chicksgrove. A number of 'Dirt Beds' (with conifers) exposed there indicate that the Chilmark Oolites, limited to the Chilmark ravine, are the facies equivalents of the upper portion of the Wockley micrites at Chicksgrove and around Tisbury. The possibility that there are two sets of plant-bearing Dirt Beds south of the River Nadder, and only one at Chilmark, is discounted.

b. In the Chilmark complex only one section, on the eastern side of the ravine, presently shows the vertical transition from the Wockley Member to the Chilmark

Member. There is no evidence of a lateral facies change to the Wockley micrites within the ravine. This must seemingly occur in the intervening ground between Upper Chicksgrove and the westernmost Chilmark quarries.

c. Buckman's record of *Glaucolithites polygyralis* (Buckman) from the 'Green Bed' of the Tisbury Member at Chilmark (Buckman 1927), if accurate, is of great value. *Glaucolithites glaucolithus* occurs sparsely in beds below this horizon. Large-scale excavation of the ancient quarries and mines at this level in 1976 re-exposed a shell-bed immediately above the presumed 'Green Bed' and the main body of Tisbury building stone, made up of the true *Laevitrigonia gibbosa* (J. Sowerby) in association with common ammonites of the *okusensis* Zone; and, less than 1 m above, the same plant- and vertebrate-bearing sand seen at Chicksgrove. Thus less than 2 m here represents the *okusensis* Zone beneath the erosive base of the Ragstone Beds.

PO7. Wiltshire: Vale of Pewsey

Based on Casey & Bristow (1964) and Wimbledon (1976).

a. The name Whitchurch Sands has been applied (Casey & Bristow 1964) to discontinuous patches of ferruginous sediments overlying Portland and Lulworth Beds outcrops from Wiltshire to the Boulonnais, and in the past variously placed with the Wealden or Lower Greensand. The Whitchurch Sands have been interpreted as a basal Cretaceous deposit correlated with the Cinder-Bed on the evidence of their bivalve fauna and regional stratigraphical relationships.

b. It would seem likely that the greater part of the Portland and Purbeck Beds, if deposited, were removed by post-lower Purbeck erosion. The few poorly-preserved ammonite specimens collected suggested an *okusensis* Zone age for the 'rubbly limestone'. A basal lydite bed is placed in the *glautholithus* Zone by analogy with the situation at Swindon.

Precise relationships with other more extensive sections remain uncertain.

PO8. Wiltshire: Okus & Town Gardens, Swindon

Based on Sylvester-Bradley (1940), Wimbledon (1974*b*, 1976) and Wimbledon & Cope (1978).

a. The Town Gardens Member (Wimbledon 1976), consisting of the Lower Pebbly Bed–Swindon Roach interval, has yet to yield ammonites. In the much studied north-eastern face of the Great Quarry (Sylvester-Bradley 1940) the basal Lower Pebbly Bed rests with marked unconformity on the Swindon Sand and Stone which elsewhere at Swindon contains a *kerberus* Zone fauna. In a previously unrecorded section in the Great Quarry two separate 'Roach' horizons overlie the Sand and Stone in association with 'birdseye' limestones, and other units with freshwater gastropods. The precise dating of the member and its junction with the succeeding Purbeck Beds remains for the moment a matter for conjecture.

b. The Swindon succession as a whole is a highly episodic one with several non-sequences. Both the Cockly Bed and Glauconitic Beds are thought to contain minor breaks. The former unit, though little more than 1.5 m in thickness, has yielded faunas of two and possibly three zones. The greater part of this thickness falls within the *okusensis* Zone and the horizon is the most prolific source of this fauna in the country.

c. The indigenous fauna of the Upper Lydite Bed in Wiltshire, Oxfordshire and Buckinghamshire is that of the *glaucolithus* Zone (Wimbledon 1974*b*), 1976) characterized by species of the genus *Glaucolithites.* A derived element is also present, consisting predominantly of fragmentary Kimmeridgian material, *Pavlovia* being especially common, and rarer *albani* Zone specimens (Cope 1978, pp. 528–30).

PO9. Oxfordshire: Wheatley–Milton & Haseley

Based on Arkell (1944, 1947*b*) and Wimbledon (1974*b*).

PO10. Buckinghamshire: Long Crendon

Based on Arkell (1947*b*), Buckman (1921–30), Wimbledon (1974*b*) and Wimbledon & Cope (1978).

a. The key localities near Thame, where Buckman gained the majority of the specimens figured in *Type Ammonites*, are no longer available. Rock unit thicknesses follow Buckman's (1921–30) measurements in the Long Crendon quarries. Correlations are tentatively revised following his records of horizons from which ammonites came; records which are for the most part consistent with more recent collecting in Buckinghamshire as a whole. It is noteworthy that the majority of Buckman's hemeral indices are typical members of the *kerberus* Zone assemblage and that the greater part of the Long Crendon section falls within that zone.

PO11. Buckinghamshire: Whitchurch–Haddenham

Based on Arkell (1947*b*), Barker (1966), Wimbledon (1974*b*) and Wimbledon & Cope (1978).

a. The thinning of the Crendon Sand from Oxfordshire into Buckinghamshire may be largely due to the cutting out of strata by the base of the overlying Creamy Limestones. Derived encrusted masses from the sand are found in the base of the Creamy Limestone at several localities. The Crendon Sand is also on occasion seen to cut down markedly into the Aylesbury Limestones. The most marked example of the overall thinning of the Portland Beds into Buckinghamshire noted to date was in the Southern Feeder Gas Trench at Dorton Hill (SP 678131). There all units through the basal Glauconitic Beds (0.3–0.9 m), Aylesbury Limestone (max 1.3 m), Crendon Sand (0.4 m) and Creamy Limestones are represented but in greatly attenuated form. The time involved in these erosional phases cannot have been very great for the Creamy Limestone, Crendon Sand and top part of the Aylesbury Limestone all fall within the span of the *Kerberites kerberus* Zone.

PO12. North Weald: Warlingham borehole

Based on Worssam & Ivimey-Cook (1971), with revised correlations.

a. On the basis of microspore assemblages, it has been suggested that in the Weald the Cinder Bed horizon may well be diachronous (Norris 1969). This contention cannot be tested using other stratigraphically useful fossils, apart from ostracods.

b. Re-examination of the numerous ammonites in the Warlingham borehole proves the presence of the *albani*, *glaucolithus*, *okusensis* and *kerberus* Zones. Although the zonal boundaries are somewhat indistinct the major part of the Portland section of the core, some 28 m, is divided between the *okusensis* and *kerberus* Zones with the remainder (*c.* 9 m) split between the *albani* and *glaucolithus* Zones.

Casey (*in* Worssam & Ivimey-Cook 1971) recorded the Upper Lydite Bed here at a horizon which is the lateral equivalent of the Rotunda Nodule Bed of Dorset. It thus seems that at Warlingham interruption in sedimentation was less pronounced than in the South Midlands where the Upper Lydite Bed marks a major non-sequence (PO7–11).

In the northern Weald (Warlingham) the Portland/Purbeck Beds transition falls immediately above beds containing a *kerberus* Zone fauna; a situation paralleled in Oxfordshire, Buckinghamshire and very probably the Boulonnais.

There are indications from other more southerly boreholes (Portsdown, Hampshire, and Henfield, Sussex) that the Portland Beds/Purbeck Beds facies change may have occurred even earlier in that part of the Weald. At Portsdown a fauna of '*Behemoth*, *Crendonites* and *Kerberites*' was described (Taitt & Kent 1958) somewhat vaguely as a 'Portland Sand fauna' and taken as proof of a major non-sequence between the Portland and Purbeck Beds. In fact the '*Behemoth*' is an undoubted *Glaucolithites* and its presence only 0.15 m below the basal Purbeck evaporites may be just a further indication of the diachronism of this facies change.

At Henfield *Glaucolithites* again occurred immediately below the junction, with the distinctive zonal index *Progalbanites albani* (Arkell) less than 2 m below. There may be a disconformity at the base of the Lulworth Beds or, following the analogy of Portsdown, Warlingham and the outcrop areas of southern England, the change to Purbeck facies may have taken place earlier than the *kerberus* Zone in parts of the basin.

Unlike Warlingham the Portsdown core exhibits two lydite pebble beds, 1.6 m below and 0.6 m above the recorded '*Crendonites*'. One or both of these beds may be of *glaucolithus* Zone age and be coeval with the Upper Lydite Bed of Swindon etc., especially if the '*Crendonites*', a poor specimen, is in reality a *Glaucolithites*.

PO13. Norfolk: King's Lynn

Based on Casey (1973).

a. At King's Lynn the Runcton Beds fall, for the most part, within the *lamplughi* Zone. The presence of the *preplicomphalus* Zone has been 'inferred' in the basal few centimetres (Casey 1973, p. 209). Elsewhere in Norfolk the *lamplughi* Zone occurs only as a remanié in the basal Cretaceous nodule bed.

PO14. Lincolnshire: South Wolds

Based on Casey (1973).

a. The ammonite fauna of the basement bed of the Spilsby Sandstone has been interpreted as a condensed assemblage (Lamplugh 1896). Casey (1973) recognized in these beds an indigenous *oppressus* Zone fauna plus a remanié '*giganteus* Zone' element. With the newly recognized succession of faunas in the southern Portland Beds it is now becoming apparent that the endemic ammonites (including large undamaged and clearly non-derived *Titanites*) within the basement beds at some localities are those of the *kerberus* Zone and possibly even the *okusensis* Zone. Sadly much of the available faunal material comes from glacial erratics, not *in situ* outcrops. Because of the great uncertainties concerning the vertical and areal distribution of the *okusensis*, *kerberus* and *anguiformis* Zones in Lincolnshire, no indication is given in this column of the presence of Lower Spilsby Sandstone below the *oppressus* Zone.

ACKNOWLEDGMENTS. The editor and authors are greatly indebted to the many individuals whose assistance has made this report possible. Dr J. H. Callomon has provided invaluable help and a great deal of otherwise unpublished information. The Institute of Geological Sciences has contributed greatly and we wish to thank Mr G. W. Green, Dr R. Cave, Miss B. M. Cox, Dr T. P. Fletcher, Mr R. Gallois, Mr G. D. Gaunt, Dr H. C. Ivimey-Cook and Dr I. E. Penn. Others whose help has materially contributed to this report include Dr M. Ashton, Dr D. Barker, Dr M. J. Barker, Dr M. J. Bradshaw, Dr. J. P. G. Fenton, Professor J. E. Hemingway, Mr S. Holloway, Sir Peter Kent, Dr P. N. Linsley, Dr N. Morton, Dr T. J. Palmer, Dr R. M. Sykes and Dr I. M. West.

For access to, or donation of, Bathonian fossils Dr Torrens wishes to acknowledge the help of R. Brand, J. C. W. Cope, C. Cornford, M. L. K. Curtis, P. Hackling, D. J. Iles, W. S. McKerrow, G. Osborn, P. Pittham, H. C. Prudden and J. Sedgley. For details and discussions of the Bathonian stratigraphy of Germany and south-east France the help of the late Wolfgang Hahn and the late Carlo Sturani is gratefully acknowledged.

Up to the end of 1978, work on this report was under the coordination of Dr H. S. Torrens, whose efforts the other contributors acknowledge with thanks. It is a pleasure to thank again Mrs D. G. Evans for her clearly apparent skills at the drawing board, and Mrs V. M. Jenkins for her sterling work in producing the typescript from much-altered original copy.

REFERENCES

AGER, D. V. 1956. Field meeting in the central Cotteswolds. *Proc. Geol. Assoc. London*, **66**, 356–65.

—— 1963. Jurassic stages. *Nature, London*, **198**, 1045–6.

—— 1964. The British Mesozoic Committee. *Nature, London*, **203**, 1059.

ALI, O. E. 1977. Jurassic hazards to coral growth. *Geol. Mag.* **114**, 63–4.

ALLORGE, M. M. & BAYZAND, C. J. 1911. Excursion to Oxford University Museum, Enslow Bridge, Kirtlington and Woodstock. *Proc. Geol. Assoc. London*, **22**, 1–5, pls. 1–2.

ALTHOFF, W. 1928. Übersicht über die Gliederung der Mesozoischen Schichten bei Bielefeld. *Ber. naturwiss. Ver. Bielefeld*, **5**, 1–20.

ANDERSON, F. W. 1940. Ostracods from the Portland and Purbeck Beds at Swindon. *Proc. Geol. Assoc. London*, **51**, 373–84, pls. 18–9.

—— 1958. Purbeck Beds. pp. 118–20 *in*: WILSON, V. *et al.*, 1958, *q.v.*

—— 1962. Correlation of the Upper Purbeck Beds of England with the German Wealden. *Liverpool Manchester geol. J.* **3**, 21–32.

—— 1971. The sequence of ostracod faunas in the Wealden and Purbeck of the Warlingham Borehole. Appendix B, pp. 122–36 *to* WORSSAM, B. C. & IVIMEY-COOK, H. C. 1971, *q.v.*

—— 1973. The Jurassic-Cretaceous transition: the non-marine ostracod faunas. *in*: CASEY, R. & RAWSON, P. F. (eds), *The Boreal Lower Cretaceous.* Geol. J. Spec. Iss. **5**, 101–10, Seel House Press, Liverpool.

ARKELL, W. J. 1927. The Corallian rocks of

Oxford, Berkshire and north Wiltshire. *Philos. Trans. R. Soc. London* **B216,** 67–181.

—— 1929–37. A monograph of British Corallian Lamellibranchia. *Monogr. palaeontogr. Soc. London,* xxxviii + 392 pp., 56 pls.

—— 1931. The Upper Great Oolite, Bradford Beds and Forest Marble of south Oxfordshire and the succession of gastropod faunas in the Great Oolite. *Q. J. geol. Soc. London,* **87,** 563–629, pls. 47–51.

—— 1933. *The Jurassic System in Great Britain.* Clarendon Press, Oxford, xii + 681 pp. 41 pls.

—— 1934. The Corallian rocks in the new railway cutting at Westbury, Wiltshire. *Geol. Mag.* **71,** 317–20.

—— 1935. The Portland Beds of the Dorset Mainland. *Proc. Geol. Assoc. London,* **46,** 301–47, pls. 19–26.

—— 1935–48. A monograph on the ammonites of the English Corallian Beds. *Monogr. palaeontogr. Soc. London,* lxxiv + 420 pp., 78 pls.

—— 1936. The ammonite zones of the Upper Oxfordian of Oxford. *Q. J. geol. Soc. London,* **92,** 146–87.

—— 1937*a*. Report on ammonites collected at Long Stanton, Cambridgeshire, and on the age of the Ampthill Clay. *Summ. Prog. geol. Surv. G.B.* **1936,** 64–88.

—— 1937*b*. The zonal position of the Elsworth Rock, and its alleged equivalent at Upware. *Geol. Mag.* **74,** 445–58.

—— 1939*a*. The ammonite succession at the Woodham Brick Company's pit, Akeman Street Station, Buckinghamshire, and its bearing on the classification of the Oxford Clay. *Q. J. geol. Soc. London,* **95,** 135–222, pls. 8–11.

—— 1939*b*. A map of the Corallian Beds between Marcham and Faringdon. *Proc. Geol. Assoc. London,* **50,** 487–509.

—— 1941*a*. The Upper Oxford Clay at Purton, Wiltshire, and the zones of the Lower Oxfordian. *Geol. Mag.* **78,** 161–72.

—— 1941*b*. A map of the Corallian Beds around Highworth. *Proc. Geol. Assoc. London,* **52,** 79–109.

—— 1942. Stratigraphy and structure east of Oxford. *Q. J. geol. Soc. London,* **98,** 79–109.

—— 1944. Stratigraphy and structures east of Oxford; 2, the Miltons and Haseleys; 3, Islip. *Q. J. geol. Soc. London,* **100,** 45–73, pls. 4–5.

—— 1945. The zones of the Upper Jurassic of Yorkshire. *Proc. Yorkshire geol. Soc.* **25,** 339–58.

—— 1946. Standard of the European Jurassic. *Bull. geol. Soc. Am.* **57,** 1–34.

—— 1947*a*. The geology of the country around Weymouth, Swanage, Corfe and Lulworth. *Mem. geol. Surv. G.B.* xii + 386 pp, 19 pls.

—— 1947*b*. *The geology of Oxford,* Clarendon Press, Oxford, vi + 267 pp, 6 pls.

—— 1947*c*. *Oxford stone,* Faber & Faber, London, 185 pp., 37 pls.

—— 1951. The geology of the Corallian ridge between Wootton Bassett and Lyneham, Wiltshire. *Wiltshire Arch. nat. Hist. Mag.* **54,** (194), 1–18.

—— 1951–58. A monograph of English Bathonian ammonites. *Monogr. palaeontogr. Soc. London,* viii + 264 pp, 33 pls.

—— 1954*a*. The ammonites and their place in the Bajocian of the world. *in*: Arkell, W. J. & Playford, P. E. (eds), *The Bajocian ammonites of Western Australia.* Philos. Trans. R. Soc. London, **B237,** 547–605.

—— 1954*b*. Three complete sections of the Cornbrash. *Proc. Geol. Assoc. London,* **65,** 115–22.

—— 1956. *Jurassic Geology of the World.* Oliver & Boyd, Edinburgh & London, xv + 806 pp., 46 pls.

—— 1957*a*. *in*: Arkell, W. J., Kummel, B. & Wright, C. W. *Mesozoic Ammonoidea,* pp. L80–L437, *in*: Moore, R. C. (ed.), *Treatise on invertebrate paleontology. Part L. Mollusca 4, Cephalopoda, Ammonoidea.* Geological Society of America and University of Kansas Press. New York and Lawrence.

—— 1957*b*. Ammonites from the Fuller's Earth Rock, Whatley, Somerset. *Geol. Mag.* **94,** 322–5.

—— & Callomon, J. H. 1963. Lower Kimmeridgian ammonites from the drift of

Lincolnshire. *Palaeontology*, **6**, 219–45, pls. 27–33.

—— & Donovan, D. T. 1952. The Fuller's Earth of the Cotswolds and its relation to the Great Oolite. *Q. J. geol. Soc. London*, **107**, 227–53, pls. 13–6.

Ashton, M. 1975. A new section in the Lincolnshire Limestone of south Humberside and its significance. *Proc. Yorkshire geol. Soc.* **40**, 419–29.

—— 1977. New evidence for the age of the Lincolnshire Limestone Formation (Bajocian) of eastern England. *Trans. Leicester lit. philos. Soc.* **70**, 21–34, pls. 1–3.

Aslin, C. J. 1968. Upper Estuarine Series, pp. 233–7 *in*: Sylvester-Bradley, P. C. & Ford, T. D. 1968, *q.v.*

Aston, M. A. 1974. Stonesfield Slate. *Dept. Mus. Serv. Oxfordshire Co. Council*, Publication **5**, 86 pp.

Bailey, E. B. & Weir, J. 1932. Submarine faulting in Kimmeridgian times in east Sutherland. *Trans. R. Soc. Edinburgh*, **57**, 429–67.

Baker, P. G. 1974. The geology of Westington Hill Quarry, Gloucestershire. *Mercian Geol.* **5**, 133–42.

Barker, D. 1966. Ostracods from the Portland and Purbeck Beds of the Aylesbury District. *Bull. Br. Mus. nat. Hist.* Ser. Geol. **11**, 458–87, pls. 1–9.

Barker, M. J. 1976. *A stratigraphical palaeoecological and biometrical study of some English Bathonian Gastropoda (especially Nerineacea).* Unpublished Ph.D. thesis, Univ. of Keele.

Barker, M. J. & Torrens, H. S. 1971. A new ammonite from the southernmost outcrop of the lower Lincolnshire Limestone (Middle Jurassic). *Trans. Leicester lit. philos. Soc.* **65**, 49–56.

Bate, R. H. 1959. The Yons Nab Beds of the Middle Jurassic of the Yorkshire coast. *Proc. Yorkshire geol. Soc.* **32**, 153–64, pl. 3.

—— 1965. Middle Jurassic Ostracoda from the Grey Limestone Series, Yorkshire. *Bull. Br. Mus. nat. Hist.* Ser. Geol. **11**, 73–134, pls. 1–21.

—— 1967*a*. Stratigraphy and palaeogeography of the Yorkshire Oolites and their relationship with the Lincolnshire Limestone. *Bull. Br. Mus. nat. Hist.* Ser. Geol. **14**, 111–41.

—— 1967*b*. The Bathonian Upper Estuarine Series of eastern England, Part 1 Ostracoda. *Bull. Br. Mus. nat. Hist.* Ser. Geol. **14**, 21–66, pls. 1–22.

—— 1978. The Jurassic. Part II Aalenian to Bathonian. *in*: Bate, R. H. & Robinson, E. (eds.), 1978. *A stratigraphical index of British Ostracoda.* Geol. J. Spec. Iss. **8**, 213–258. Seel House Press, Liverpool.

Birkelund, T., Callomon, J. H. & Fürsich, F. T. 1978*a*. The Jurassic of Milne Land, central East Greenland. *Grønlands. geol. Unders. Rapp.* **90**, 99–106.

—— , Thusu, B. & Vigran, J. 1978*b*. Jurassic-Cretaceous biostratigraphy of Norway, with comments on the British *Rasenia cymodoce* Zone. *Palaeontology*, **21**, 31–63, pls. 1–6.

Black, M. 1929. Drifted plant-beds of the Upper Estuarine Series of Yorkshire. *Q. J. geol. Soc. London*, **85**, 389–437.

—— 1934*a*. The Middle Jurassic rocks. *in*: Wilson, V., Black, M. & Hemingway, J. E. (eds), *A synopsis of the Jurassic rocks of Yorkshire.* Proc. Geol. Assoc. London, **45**, 247–306.

—— 1934*b*. Sedimentation of the Aalenian rocks of Yorkshire. *Proc. Yorkshire geol. Soc.* **22**, 265–79.

Blake, J. F. 1875. On the Kimmeridge clay of England. *Q. J. geol. Soc. London*, **31**, 196–237.

—— 1880. On the Portland rocks of England, *Q. J. geol. Soc. London*, **36**, 189–236, pls. 8–10.

—— & Hudleston, W. H. 1877. On the Corallian rocks of England. *Q. J. geol. Soc. London*, **33**, 260–405.

Bourne, J. C. 1846. *The history and description of the Great Western Railway, including its geology and the antiquities of the district through which it passes.* Boyne, London, iv+76 pp.

Bradshaw, M. J. 1975. Origin of montmorillonite bands in the Middle Jurassic of eastern England. *Earth planet. Sci. Lett.* **26**, 245–52.

Brasier, M. D. & Brasier, C. J. 1978. Littoral and fluviatile facies in the 'Kellaways Beds' on the Market Weighton Swell. *Proc. Yorkshire geol. Soc.* **42,** 1–20.

Bristow, C. R. & Bazley, R. A. 1972. The geology of the country around Royal Tunbridge Wells. *Mem. geol. Surv. G.B.* x + 161 pp., 9 pls.

Brongniart, A. 1829. *Tableau des terrains qui composent l'écorce du globe, ou essai sur la structure de la partie connue de la terre.* Paris & Strasbourg, xxiv + 435 pp.

Brookfield, M. E. 1973*a*. Palaeogeography of the Upier Oxfordian and Lower Kimmeridgian (Jurassic) in Britain. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **4,** 137–67.

—— 1973*b*. The palaeoenvironment of the Abbotsbury Ironstone (Upper Jurassic) of Dorset. *Palaeontology*, **16,** 261–74.

—— 1976. The age of the Allt na Cuile Sandstones (Upper Jurassic, Sutherland). *Scott. J. Geol.* **12,** 181–6.

—— 1978. The lithostratigraphy of the Upper Oxfordian and Lower Kimmeridgian beds of south Dorset. *Proc. Geol. Assoc. London*, **89,** 1–32.

Buch, L. von 1839. *Über den Jura in Deutschland.* König. Akad. Wiss., Berlin 87 pp.

Buckman, J. 1842. Sketch of the Oolite Formation of the Cotteswold range of hills, near Cheltenham. *Geologist*, **1,** 199–208.

Buckman, S. S. 1887–1907. A monograph of the ammonites of the Inferior Oolite Series. *Monogr. palaeontogr. Soc. London*, cclxii + 456 pp., 127 pls.

—— 1888. The Inferior Oolite between Andoversford and Bourton-on-the-Water. *Proc. Cotteswold Nat. Field Club*, **9,** 108–35.

—— 1893. The Bajocian of the Sherborne district: its relation to subjacent and superjacent strata. *Q. J. geol. Soc. London*, **49,** 479–522.

—— 1895. The Bajocian of the mid-Cotteswolds. *Q. J. geol. Soc. London*, **51,** 388–462.

—— 1897. Deposits of Bajocian age in the northern Cotteswolds; the Cleeve Hill Plateau. *Q. J. geol. Soc. London*, **53,** 607–29.

—— 1901. The Bajocian and contiguous deposits in the north Cotteswolds: the main hill-mass. *Q. J. geol. Soc. London*, **57,** 126–55.

—— 1910. Certain Jurassic (Lias-Oolite) strata of south Dorset. *Q. J. geol. Soc. London*, **66,** 52–89.

—— 1913. The 'Kelloway Rock' of Scarborough. *Q. J. geol. soc. London*, **69,** 152–68.

—— 1918. The Brachiopoda of the Namyan Beds, Northern Shan States, Burma. *Palaeontol. Indica*, (3) **2,** 1–300, pls. 1–21.

—— 1909–30. *Yorkshire Type Ammonites*, (continued as) *Type Ammonites.* 7 vols. Published by author. London & Thame.

—— 1922. Jurassic chronology: II—Preliminary studies. Certain Jurassic strata near Eypesmouth (Dorset): the Junction Bed of Watton Cliff and associated rocks. *Q. J. geol. Soc. London*, **78,** 378–457.

—— & Wilson, E. 1896. Dundry Hill: its upper portion, or the beds marked as Inferior Oolite (g^5) in the maps of the Geological Survey. *Q. J. geol. Soc. London*, **52,** 669–720.

Callomon, J. H. 1955. The ammonite succession in the Oxford Clay and Kellaways Beds at Kidlington, Oxfordshire, and the zones of the Callovian Stage. *Philos. Trans. R. Soc. London*, **B239,** 215–64, pls. 2, 3.

—— 1960. New Sections in the Corallian Beds around Oxford, and the subzones of the *plicatilis* Zone. *Proc. Geol. Assoc. London*, **71,** 177–208.

—— 1964. Notes on the Callovian and Oxfordian Stages. *C. r. Mem. Colloque du Jurassique, Luxembourg, 1962*, 269–91.

—— 1965. Subdivision of the Jurassic: the Middle-Upper Jurassic boundary. *Rept. Carpatho-Balkan geol. Assoc.* 7th Congress (II) **1,** 87–90.

—— 1968. The Kellaways Beds and the Oxford Clays pp. 264–90, *in*: Sylvester-Bradley, P. C. & Ford, T. D. 1968, *q.v.*

—— 1975. Jurassic ammonites from the northern North Sea. *Nor. geol. Tiddskr*, **55,** 373–86.

—— 1979. Marine boreal Bathonian fossils from the northern North Sea and their palaeogeographical significance. *Proc. Geol. Assoc. London*, **90**, 163–9.

—— & Cope, J. C. W. 1971. The stratigraphy and ammonite succession of the Oxford and Kimmeridge Clays in the Warlingham borehole. *Bull. geol. Surv. G.B.* **36**, 147–76, pls. 8–12.

—— & Torrens, H. S. 1969. Guides to field excursions from London. pp. 8–35, A–C, 1–3, *in*: Torrens, H. S. (ed), 1969*a q.v.*

Casey, R. 1963. The dawn of the Cretaceous period in Britain. *Bull. S.-East Un. scient. Soc.* **117**, 1–15.

—— 1967. The position of the Middle Volgian in the English jurassic. *Proc. geol. Soc. London*, **1640**, 128–33.

—— 1973. The ammonite succession at the Jurassic-Cretaceous boundary in eastern England. *in*: Casey, R. & Rawson, P. F. (eds), *The Boreal Lower Cretaceous.* Geol. J. Spec. Iss. **5**, 193–266, pls. 1–10. Seel House Press, Liverpool.

—— & Bristow, C. R. 1964. Notes on some ferruginous strata in Buckinghamshire and Wiltshire. *Geol. Mag.* **101**, 116–28.

—— & Gallois, R. W. 1973. The Sandringham Sands of Norfolk. *Proc. Yorkshire geol. Soc.* **40**, 1–22.

Cave, R. 1977. Geology of the Malmesbury District. *Mem. geol. Surv. G.B.* viii + 343 pp., 7 pls. (note: published in 1978).

—— & Cox, B. M. 1975. The Kellaways Beds of the area between Chippenham and Malmesbury, Wiltshire. *Bull. geol. Surv. G.B.* **54**, 41–66.

Chandler, R. J., Kellaway, G. A., Skempton, A. W. & Wyatt, R. J. 1976. Valley slope sections in Jurassic strata near Bath, Somerset. *Philos. Trans. R. Soc. London*, **A283**, 527–56, pl. 7.

Channon, P. J. 1950. New and enlarged Jurassic sections in the Cotswolds. *Proc. Geol. Assoc. London*, **61**, 242–60.

—— 1951. A new section at Cowcombe Hill near Chalford Station, Gloucestershire, exposing the junction of the Inferior Oolite and Fuller's Earth. *Proc. Geol. Assoc. London*, **62**, 174–6.

Chatwin, C. P. & Pringle, J. 1922. The zones of the Kimmeridge and Portland rocks at Swindon. *Summ. Prog. geol. Surv. G.B.* **1921**, 162–8.

Contini, D. 1969. Les Graphoceratidae du Jura Franc-comtois. *Ann. sci. Univ. Besançon*, (3) Géologie, **7**, 1–95, pls. 1–24.

—— 1970. L'Aalenien et le Bajocien du Jura Franc-comtois. *Ann. sci. Univ. Besançon*, (3) Géologie, **11**, 1–204.

——, Elmi, S. & Mouterde, R. 1971. Les zones du Jurassique en Iranie: Aalenian. *C. r. Somm. Soc. geol. Fr.* **1971**, 84–5.

Cope, J. C. W. 1967. The palaeontology and stratigraphy of the lower part of the Upper Kimmeridge Clay of Dorset. *Bull. Br. Mus. nat. Hist.* Ser. Geol. **15**, 1–79, pls. 1–33.

—— 1968. *Propectinatites*, a new Lower Kimmeridgian ammonite genus. *Palaeontology*, **11**, 16–8, pl. 1.

—— 1969. The Portland Beds, pp. A53–A57 *in*: Torrens, H. S. (ed), 1969*a*, *q.v.*

—— 1971. 'Geology' *in*: *Dorset natural history reports 1970. Proc. Dorset nat. Hist. archaeol. Soc.* **92**, 41–4.

—— 1974*a*. New information on the Kimmeridge Clay of Yorkshire. *Proc. Geol. Assoc. London*, **85**, 211–21.

—— 1974*b*. Upper Kimmeridgian ammonite faunas of the Wash area and a subzonal scheme for the lower part of the Upper Kimmeridgian. *Bull. geol. Surv. G.B.* **47**, 29–37, pls. 1–3.

—— 1978. The ammonite faunas and stratigraphy of the upper part of the Upper Kimmeridge Clay of Dorset. *Palaeontology*, **21**, 469–533, pls. 45–56.

—— & Clements, R. G. 1969. The Purbeck Beds, pp. A57–A64, *in*: Torrens, H. S. (ed), 1969*a*, *q.v.*

—— & Cox, B. M. 1970. A Kellaways Beds locality in north Dorset. *Proc. Dorset nat. Hist. archaeol. Soc.* **91**, 120–2.

——, Getty, T. A., Howarth, M. K., Morton, N. & Torrens, H. S. 1980. A correlation of Jurassic rocks in the British Isles. 1. Introduction and Lower Jurassic. *Spec. Rep. geol. Soc. London*, **14**.

—— & Torrens, H. S. 1969. The Corallian Beds, pp. A44–7 *in* Torrens, H. S. (ed), 1969*a*. *q.v.*

—— & Wimbledon, W. A. 1973. Ammonite faunas of the uppermost Kimmeridge

Clay, the Portland Sand and the Portland Stone of Dorset. *Proc. Ussher Soc.* **2,** 593–8.

Cox, B. M. 1976. [Description of the Upper Jurassic clays at the Rugby Portland Cement Company's quarry at South Ferriby] pp. 592–3 *in*: Smart, J. G. O. & Wood, C. J. *Report on a field meeting in South Humberside.* Proc. Yorkshire geol. Soc. **40,** 586–93.

Cox, L. R. 1929. Synopsis of the Lamellibranchia and Gastropoda of the Portland Beds of England. *Proc. Dorset nat. Hist. archaeol. Soc.* **50,** 131–202.

—— 1964. The type Bathonian, *in*: Maubeuge, P. L. (ed), *Colloque du Jurassique à Luxembourg 1962.* Publ. Inst. Grand-Ducal, Sect. Sci. nat. Phys. Math. Luxembourg, 265–8.

—— & Arkell, W. J. 1948–50. A survey of the Mollusca of the British Great Oolite Series. *Monogr. palaeontogr. Soc. London,* xxiii + 105 pp.

Curtis, M. L. K. 1978. The Fuller's Earth succession at Dyrham Park, south Cotswolds. *Proc. Cotteswold Nat. Field Club,* **37,** 23–30.

de Boer, G., Neale, J. W. & Penny, L. F. 1958. A guide to the geology of the area between Market Weighton and the Humber. *Proc. Yorkshire geol. Soc.* **31,** 157–209.

Donovan, D. T. 1948. Some exposures in the Jurassic rocks at Bath. *Proc. Bristol. Nat. Soc.* **27,** 329–42.

—— & Hemingway, J. E. 1963. Lexique Stratigraphique *International. Europe.* Fasc. **3a** (*England*) *pt.* **3aX** (*Jurassic*). 394 pp. Paris.

Douglas, J. A. & Arkell, W. J. 1928. The stratigraphical distribution of the Cornbrash. I The South-western area. *Q. J. geol. Soc. London,* **84,** 117–78, pls. 9–12.

—— & —— 1932. The stratigraphical distribution of the Cornbrash. II The North-eastern area. Q. *J.* geol. *Soc. London,* **88,** 112–70, pls. 10–2.

—— & —— 1935. On a new section of fossiliferous Upper Cornbrash of north-eastern facies at Enslow Bridge, near Oxford. *Q. J. geol. Soc. London,* **91,** 318–22.

Duff, K. L. 1974. *Studies on the palaeontology of the Lower Oxford Clay of southern England.* Unpublished Ph.D. thesis, University of Leicester.

Edmonds, E. A. & Dinham, C. H. 1965. The geology of the country around Huntingdon and Biggleswade. *Mem. geol. Surv. G.B.* viii + 90 pp., 3 pls.

Edwards, W. & Pringle, J. 1926. On a borehole in Lower Oolite rocks at Wincanton, Somerset. *Summ. Prog. geol. Surv. G.B.* **1925,** 183–8.

Elmi, S. 1967. Le Lias Supérieur et le Jurassique moyen de l'Ardèche. *Doc. Lab. Géol. Fac. Sci. Lyon,* **19,** (1–3), 1–845.

Engleleart, F. H. A. *c.*1925. *The stratigraphical distribution of the Forest Marble.* MSS 71 pp., in Oxford Univ. Mus. archives.

Ensom, P. C. 1977. A therapsid tooth from the Forest Marble (Middle Jurassic) of Dorset. *Proc. Geol. Assoc. London,* **88,** 201–5, pl. 6.

Evans, W. D. 1952. The Jurassic rocks of the Lincoln district. *Proc. Geol. Assoc. London,* **63,** 316–35.

Eyles, J. M. 1969. William Smith: some aspects of his life and work. *in*: Schneer, C. J., (ed), *Toward a history of geology.* M.I.T. Press. Cambridge. Mass, 142–58.

Fabre, G. 1894. Compte rendu de l'excursion du samedi 23 Sept., à Lanuéjols. *Bull. Soc. géol. Fr.* (3) **21,** 631–40.

Falcon, N. L. & Kent, P. E. 1960. Geological results of petroleum exploration in Britain 1945–57. *Mem. Geol. Soc. London,* **2,** 1–56, pls. 1–5.

Ferguson, J. 1970. *Application of the computer to the interpretation of environments and ecological adaptations in the Middle Jurassic of the English Midlands.* Unpublished Ph.D. thesis, University of London.

—— 1972. Limestones in the Irchester-Wollaston area of Northamptonshire. *J. Northampt. nat. Hist. Soc.* **36,** 828–41.

Fitton, W. H. 1836. Observations on some of the strata between the Chalk and the Oxford Oolite, in the south-east of England. *Trans. geol. Soc. London,* (2) **4,** 103–388.

FOWLER, J. 1957. The geology of the Thornford pipe-trench. *Proc. Dorset nat. Hist. archaeol. Soc.* **78,** 51–7.

FOX-STRANGWAYS, C. 1892. The Jurassic rocks of Britain. I. Yorkshire. *Mem. geol. Surv. G.B.* ix + 551 pp.

FREEMAN, E. F. 1976. A mammalian fossil from the Forest Marble (Middle Jurassic) of Dorset. *Proc. geol. Assoc. London,* **87,** 231–6.

—— 1979. A Middle Jurassic mammal bed from Oxfordshire. *Palaeontology,* **22,** 135–66, pls. 15–21.

FÜRSICH, F. T. 1977. Corallian (Upper Jurassic) marine benthic associations from England and Normandy. *Palaeontology,* **20,** 337–85.

GABILLY, J. 1964. Le Jurassique inférieur et moyen sur le littoral Vendéen. *Trav. Inst. Géol. Anthropol. préhist. Fac. Sci. Poitiers,* **5,** 69–107.

—— 1974. Methodes et modeles en stratigraphie du Jurassique. *in*: Colloque du Jurassique, Luxembourg 1967. *Mém. Bull. Rech. geol. minières,* **75,** 5–16.

GALLOIS, R. W. 1973. Some detailed correlations in the Upper Kimmeridge Clay in Norfolk and Lincolnshire. *Bull. geol. Surv. G.B.* **44,** 63–75.

—— 1976. The Kimmeridge Clay oil shale project. *in*: I.G.S. Boreholes 1975. *Rep. Inst. geol. Sci. London,* **76/10,** 22–4.

—— & COX, B. M. 1974. Stratigraphy of the Upper Kimmeridge Clay of the Wash area. *Bull. geol. Surv. G.B.* **47,** 1–28.

—— & —— 1976. The stratigraphy of the Lower Kimmeridge Clay of eastern England. *Proc. Yorkshire geol. Soc.,* **41,** 13–26.

—— & —— 1977. The stratigraphy of the Middle and Upper Oxfordian sediments of Fenland. *Proc. Geol. Assoc. London,* **88,** 207–28.

GATRALL, M., JENKYNS, H. C. & PARSONS, C. F. 1972. Limonitic concretions from the European Jurassic with particular reference to the 'snuff-boxes' of southern England. *Sedimentology,* **18,** 79–103.

GAUNT, G. D., IVIMEY-COOK, H. C., PENN, I. E. & COX, B. M. 1980. Mesozoic rocks proved by I.G.S. boreholes in the Humber and Acklam areas. *Rep. Inst. geol. Sci. London,* **78/13**

GEORGE, T. N. *et al.* 1969. Recommendations on stratigraphical usage. *Proc. geol. Soc. London,* **1656,** 139–66.

GERASIMOV, P. A. & MIKHAILOV, N. P. 1966. Volgian Stage and a geostratigraphical scale for the upper series of the Jurassic System. *Izv. Akad. Nauk SSSR,* **2,** 118–38. (in Russian).

GRAY, D. A. 1955. The occurrence of a Corallian limestone in east Yorkshire south of Market Weighton. *Proc. Yorkshire geol. Soc.* **30,** 25–34.

GREEN, G. W. & DONOVAN, D. T. 1969. The Great Oolite of the Bath Area. *Bull. geol. Surv. G.B.* **30,** 1–63.

—— & MELVILLE, R. V. 1956. The stratigraphy of the Stowell Park Borehole. *Bull. geol. Surv. G.B.* **11,** 1–66.

GUTMAN, K. 1970. The Corallian Beds at Todber and Whiteway Hill in north Dorset. *Proc. Dorset nat. Hist. archaeol. Soc.* **91,** 123–33, pls. 1–5.

HAHN, W. 1968. Die Oppeliidae Bonarelli und Haploceratidae Zittell (Ammonoidea) des Bathoniums (Brauner Jura ε) im südwestdeutschen Jura. *Jahresh. geol. Landesamts Baden-Württemburg,* **10,** 7–72, pls. 1–5.

—— 1969. Die Perisphinctidae Steinmann (Ammonoidea) des Bathoniums (Brauner Jura ε) im südwestdeutschen Jura. *Jahresh. geol. Landesamts Baden-Württemberg,* **11,** 29–86, pls. 1–9.

—— 1971. Die Tulitidae S. Buckman, Sphaeroceratidae S. Buckman und Clydoniceratidae S. Buckman des Bathoniums (Brauner Jura ε) im südwestdeutschen Jura. *Jahresh. geol. Landesamts Baden-Württemberg,* **13,** 55–122, pls. 1–9.

—— 1972. *Neue Ammonitenfunde aus dem Ober-Bathonium (Mittleren Jura) der Ziegeler Lechstedt bei Hildesheim und Gliederung der nordwestdeutschen Ober-Bathoniums in Standardzonen.* 40 p, 4 pls. MSS.

—— & SCHREINER, A. 1971. Neue Zachen und Benennungen der Jura Schichten auf der geologischen karten Baden-Württembergs. *Jahresber. Mitt. oberrhein. geol. Ver.* N.S. **53,** 275–9.

HALLAM, A. 1975. *Jurassic Environments.*

Cambridge University Press, Cambridge. ix+269 pp.

HANCOCK, J. M. 1954. A new Ampthill Clay fauna from Knapwell, Cambridgeshire. *Geol. Mag.* **91,** 249–54.

HARRIS, J. P. & HUDSON, J. D. 1980. Lithostratigraphy of the Great Estuarines Group (Middle Jurassic), Inner Hebrides. *Scott. J. Geol.* **16,** 231–50.

HEMINGWAY, J. E. 1949. A revised terminology and subdivision of the Middle Jurassic of Yorkshire. *Geol. Mag.* **86,** 67–71.

—— 1974. *Jurassic* 161–223 *in*: RAYNER, D. H. & HEMINGWAY, J. E. (eds), *The geology and mineral resources of Yorkshire*, Yorkshire Geol. Soc. Leeds, 405 pp.

—— & KNOX, R. W. O'B. 1973. Lithostratigraphical nomenclature of the Middle Jurassic of the Yorkshire Basin of north-east England. *Proc. Yorkshire geol. Soc.* **39,** 527–35.

—— & TWOMBLEY, B. N. 1964. Rosedale and Pickering. [report of field meeting]. *Proc. Yorkshire geol. Soc.* **34,** 465–8.

HOLLAND, C. H. *et al.* A guide to stratigraphical procedure. *Spec. Rep. geol. Soc. London,* **11,** 1–18.

HOLLINGWORTH, S. E. & TAYLOR, J. H. 1951. The Northampton Sand Ironstone: stratigraphy, structure and reserves. *Mem. geol. Surv. G.B.* 211 pp.

HORTON, A. 1977. The age of the Middle Jurassic 'White Sands' of north Oxfordshire. *Proc. Geol. Assoc. London,* **88,** 147–62.

—— , LAKE, R. D., BISSON, G. & COPPACK, B. C. 1974. The geology of Peterborough. *Rep. Inst. geol. Sci. London,* **73/12,** 86 pp.

—— , SHEPHARD-THORN, E. R. & THURRELL, R. G. 1974. The geology of the new town of Milton Keynes. *Rept. Inst. geol. Sci. London,* **74/16,** 102 pp.

HOUSE, M. R. 1957. The Fuller's Earth outcrop in south Dorset. *Proc. Dorset nat. Hist. archaeol. Soc.* **78,** 64–70.

—— 1958. Geology of the Dorset coast from Poole to the Chesil Beach. *Geol. Assoc. London Guide No.* **22,** 21 pp.

—— 1961. The structure of the Weymouth anticline. *Proc. Geol. Assoc. London,* **72,** 221–38.

—— 1970. Portland Stone on Portland *in*: Geology *in*: The Natural Sciences 1969. *Proc. Dorset nat. Hist. archaeol. Soc.* **91,** 38–9.

HUDLESTON, W. H. 1874. The Yorkshire Oolites. Part I. *Proc. Geol. Assoc. London,* **3,** 283–333.

—— 1876. The Yorkshire Oolites. Part II: The Middle Oolites. *Proc. Geol. Assoc. London,* **4,** 353–410.

—— 1884. Contributions to the palaeontology of the Yorkshire Oolites. *Geol. Mag.*, (3), 1, 49–64, pl. 3; 107–115, pl. 4; 145–154, pl. 6; 193–204, pl. 7; 241–252, pl. 8; 293–303, pl. 9.

—— 1886. Excursion to Sherborne and Bridport. *Proc. Geol. Assoc. London,* **9,** 187–99.

—— 1887–96. Monograph of the British Jurassic Gasteropoda. *Monogr. palaeontogr. Soc. London,* 509 pp., 44 pls.

HUDSON, J. D. 1962. The stratigraphy of the Great Estuarine Series (Middle Jurassic) of the Inner Hebrides. *Trans. geol. Soc. Edinburgh,* **19,** 139–65.

—— 1963. The ecology and stratigraphical distribution of the invertebrate fauna of the Great Estuarine Series. *Palaeontology,* **6,** 327–48.

—— 1970. Algal limestones with pseudomorphs after gypsum from the Middle Jurassic of Scotland. *Lethaia,* **3,** 11–40.

—— & MORTON, N. 1969. *International Field Symposium on the British Jurassic.* Excursion No. 4. Guide for western Scotland. pp. D1–D47. University of Keele.

—— & PALMER, T. J. 1976. A euryhaline oyster from the Middle Jurassic and the origin of the true oysters. *Palaeontology,* **19,** 79–93, pls. 14–5.

HULL, E. 1857. The geology of the country around Cheltenham. *Mem. geol. Surv. G.B.* 104 pp.

IBBETSON, L. L. B. & MORRIS, J. 1848. Notice of the geology of the neighbourhood of Stamford and Peterborough. *Rept. Brit. Assoc. Adv. Sci.* (1847), 127–31.

JEANS, C. V., MERRIMAN, R. J. & MITCHELL, J. G. 1977. Origin of Middle Jurassic and Lower Cretaceous Fuller's Earths in

England. *Clay. Miner. Oxford,* **12,** 11–44.

JUDD, J. W. 1875. The geology of Rutland and the parts of Lincoln, Leicester, Northampton, Huntingdon and Cambridge included in sheet 64 of the one-inch map of the Geological Survey. *Mem. geol. Surv. G.B.* 320 pp. 3 pls.

—— 1878. The secondary rocks of Scotland. III. The strata of the western coast and islands. *Q. J. geol. Soc. London,* **34,** 660–743, pl. 31.

KELLAWAY, G. A. & TAYLOR, J. H. 1968. The influence of landslipping on the development of the city of Bath. *23rd Int. geol. Congr.* **12,** 65–76.

—— & WILSON, V. 1941. An outline of the geology of Yeovil, Sherborne and Sparkford Vale. *Proc. Geol. Assoc. London,* **52,** 131–74, pls. 8–10.

KENT, P. E. 1941. A short outline of the stratigraphy of the Lincolnshire Limestone. *Trans. Lincolnshire Nat. Union,* **1940,** 1–10.

—— 1966. The classification and nomenclature of the Lincolnshire Limestone. *Trans. Leicester lit. philos. Soc.* **60,** 57–69.

—— 1968. Fossiliferous Dogger in north Lincolnshire. *Trans. Lincolnshire Nat. Union,* **17,** 28–29.

—— 1971. Lincolnshire geology in its regional setting. *Trans. Lincolnshire Nat. Union,* **17,** i–vi.

—— 1975. The Grantham Formation in the east Midlands: revision of the Middle Jurassic Lower Estuarine Beds. *Mercian Geol.* **5,** 305–27.

—— & BAKER, F. T. 1938. Ammonites from the Lincolnshire Limestone. *Trans. Lincolnshire Nat. Union,* **1937,** 169–70.

—— & CASEY, R. 1963. A Kimmeridge sandstone in north Lincolnshire. *Proc. geol. Soc. London,* **1606,** 57–62.

KITCHIN, F. L. 1926. A new genus of lamellibranchs (*Hartwellia* gen. nov.) from the Upper Kimmeridge Clay of England, with a note on the position of the Hartwell Clay. *Ann. Mag. nat. Hist. London,* **18,** 433–55.

KLEIN, G. DE V. 1965. Dynamic significance of primary structures in the Middle Jurassic Great Oolite Series, southern England. *Spec. Publ. Soc. Econ. Pal. Min.* **12,** 173–91.

KNOX, R. W. O'B. 1974. The Eller Beck Formation (Bajocian) of the Ravenscar Group of northeast Yorkshire. *Geol. Mag.* **110,** 511–33.

KUMM, A. 1952. Das Mesozoikum in Wiedersachsen: der Dogger. *Geol. Lagerstatten Niedersachsen,* **2,** 329–509.

LAMPLUGH, G. W. 1896. On the Speeton Series in Yorkshire and Lincolnshire. *Q. J. geol. Soc. London,* **52,** 179–220.

—— & KITCHIN, M. A. 1911. On the Mesozoic rocks in some of the coal explorations in Kent. *Mem. geol. Surv. G.B.* 212 pp. 5 pls.

—— , —— & PRINGLE, J. 1923. The concealed Mesozoic rocks in Kent. *Mem. geol. Sur. G.B.* 248 pp., 2 pls.

LECKENBY, J. 1859. On the Kelloway Rock of the Yorkshire coast. *Q. J. geol. Soc. London,* **15,** 4–15.

LEE, G. W. 1925*a*. *in*: LEE, G. W. & BAILEY, E. B. The pre-Tertiary geology of Mull, Loch Aline and Oban, *Mem. geol. Surv. G.B.,* 140 pp.

—— 1925*b*. Mesozoic rocks. 65–115 *in*: READ, H. H., ROSS, G. & PHEMISTER, J. (eds), The geology of the country around Golspie, Sutherlandshire. *Mem. geol. Surv. G.B.,* 143 pp.

—— & BAILEY, E. B. 1930. pp. 44–49. *in*: RICHEY, J. E. & THOMAS, H. H., 1930, *q.v.*

LEEDER, M. R. & NAMI, M. 1979. Sedimentary models for the non-marine Scalby Formation (Middle Jurassic) and evidence for late Bajocian/Bathonian uplift of the Yorkshire Basin. *Proc. Yorkshire geol. Soc.* **42,** 461–82.

LINSLEY, P. N. 1972. *The stratigraphy and sedimentology of the Kimmeridgian deposits of Sutherland, Scotland.* Unpublished Ph.D. thesis, University of London.

LYCETT, J. 1863. Supplementary monograph on the Mollusca from the Stonesfield Slate, Great Oolite, Forest Marble and Cornbrash. *Monogr. palaeontogr. Soc. London,* 1–129, 15 pls.

McKERROW, W. S. 1955. Field meeting to examine the Great Oolite Series of Oxfordshire. *Proc. Geol. Assoc. London,* **66,** 353–5.

Somerset. *Summ. Prog. geol. Surv. G.B.* **1908,** 83–6.
—— 1922. On a boring for coal at Westbury, Wiltshire. *Summ. Prog. geol. Surv. G.B.* **1921,** 146–53.
—— 1928. The Adisham borehole, Kent. *Summ. Prog. geol. Surv. G.B.* **1927,** 78–80.
PYRAH, B. J. 1977. An exposure of Upper Oxfordian clays in the Vale of Pickering, Yorkshire. *Proc. Yorkshire geol. Soc.* **41,** 197–8.
RASTALL, R. H. & HEMINGWAY, J. E. 1940. The Yorkshire Dogger. 1, The coastal region. *Geol. Mag.* **77,** 177–97.
RAWSON, P. F., CURRY, D., DILLEY, F. C., HANCOCK, J. M., KENNEDY, J. W., NEALE, J. W., WOOD, C. J. & WORSSAM, B. C. 1978. A correlation of Cretaceous rocks in the British Isles. *Spec. Rep. geol. Soc. London,* **9,** 70 pp.
REYNOLDS, S. H. & VAUGHAN, A. 1902. On the Jurassic strata cut through by the South Wales Direct line between Filton and Wootton Bassett. *Q. J. geol. Soc. London,* **58,** 719–52.
REEVES, M. J., PARRY, E. L. & RICHARDSON, G. 1978. Preliminary evaluation of the groundwater resources of the western part of the Vale of Pickering. *Q. J. eng. Geol. London,* **11,** 253–62.
RHYS, G. S. (compiler) 1974. A proposed standard lithostratigraphic nomenclature for the southern North Sea and an outline structural nomenclature for the whole of the (U.K.) North Sea. *Rep. Inst. geol. Sci. London,* **74/8,** 14 pp.
RICHARDSON, G. 1979. The Mesozoic stratigraphy of two boreholes near Worlaby, Humberside. *Bull. geol. Surv. G.B.* **58,** ii+20 pp.
RICHARDSON, L. 1904. *The geology of Cheltenham.* Sayer, Cheltenham, 303 pp.
—— 1907. The Inferior Oolite and contiguous deposits of the Bath-Doulting district. *Q. J. geol. Soc. London,* **63,** 383–436, pls. 28–29.
—— 1908. On the Phyllis collection of Inferior Oolite fossils from Doulting. *Geol. Mag.* (5), **5,** 509–17.
—— 1909. Excursion to the Frome district, Somerset. *Proc. Geol. Assoc. London,* **21,** 209–28.
—— 1910*a*. On the sections of Inferior Oolite on the Midford-Camerton section of the Limpley Stoke railway, Somerset. *Proc. Geol. Assoc. London,* **21,** 97–100.
—— 1910*b*. The Inferior Oolite and contiguous deposits of the south Cotteswolds. *Proc. Cotteswold Nat. Field Club,* **17,** 63–136.
—— 1910*c*. On a Fuller's Earth section at Combe Hay, near Bath. *Proc. Geol. Assoc. London,* **21,** 425–8.
—— 1911*a*. The Inferior Oolite and contiguous deposits of the Chipping Norton district, Oxfordshire. *Proc. Cotteswold Nat. Field Club,* **17,** 195–231.
—— 1911*b*. On the sections of Forest Marble and Great Oolite on the railway between Cirencester and Chedworth, Gloucestershire. *Proc. Geol. Assoc. London,* **22,** 95–115, pls. 15–9.
—— 1912. The Lower Oolitic rocks of Yorkshire. *Proc. Yorkshire geol. Soc.* **17,** 184–215, pls. 22–4.
—— 1916. The Inferior Oolite and contiguous deposits of the Doulting-Milborne Port district (Somerset). *Q. J. geol. Soc. London,* **71,** 473–520.
—— 1919. The Inferior Oolite and contiguous deposits of the Crewkerne district (Somerset). *Q. J. geol. Soc. London,* **74,** 145–73.
—— 1926. Certain Jurassic strata of the Duston area, Northamptonshire. *Proc. Cotteswold Nat. Field Club,* **22,** 137–52.
—— 1928–30. The Inferior Oolite and contiguous deposits of the Burton Bradstock-Broadwindsor district (Dorset). *Proc. Cotteswold Nat. Field Club,* **23,** 35–68; 149–85; 253–64.
—— 1929. The country around Moreton in Marsh. *Mem. geol. Surv. G.B.,* xi+162 pp., 6 pls.
—— 1930. The Fosse Lime and Limestone Quarry and Works. *Proc. Cotteswold Nat. Field Club,* **23,** 269–72.
—— 1932. The Inferior Oolite and contiguous deposits of the Sherborne district, Dorset. *Proc. Cotteswold Nat. Field Club,* **24,** 35–85.
—— 1933. The country around Cirencester. *Mem. geol. Surv. G.B.,* xi+119 pp., 7 pls.
—— 1935. Some sections of the Fuller's

Earth in the south Cotteswolds. *Proc. Cotteswold Nat. Field Club*, **25**, 279–82.
—— 1939*a*. Weekend field meeting in the Grantham district. *Proc. Geol. Assoc. London*, **50**, 29–45.
—— 1939*b*. Weekend field meeting in the Stamford district. *Proc. Geol. Assoc. London*, **50**, 463–86.
—— 1940. Field meeting at Lincoln. *Proc. Geol. Assoc. London*, **51**, 246–56.
—— & Thacker, A. G. 1920. On the stratigraphical and geographical distribution of the sponges in the Inferior Oolite of the west of England. *Proc. Geol. Assoc. London*, **31**, 161–86, pls. 12–3.
Richey, J. E. 1933. Summary of the geology of Ardnamurchan. *Proc. Geol. Assoc. London*, **44**, 1–56.
—— & Thomas, H. H. 1930. The geology of Ardnamurchan, north-west Mull and Coll. *Mem. geol. Surv. G.B.* viii+393 pp., 7 pls.
Rieber, H. 1963. Ammoniten und Stratigraphie des Braunjura β der Schwäbischen Alb. *Palaeontographica*, **A122**, 1–89, pls. 1–8.
Roberts, T. 1889. The Upper Jurassic Clays of Lincolnshire. *Q. J. geol. Soc. London*, **45**, 545–60.
Salfeld, H. 1913. Certain Upper Jurassic strata of England. *Q. J. geol. Soc. London*, **69**, 423–32, pls. 41–2.
—— 1914. Die Gliederung des oberen Jura in Nordwesteuropa. *Neues Jahrb. Mineral. Geol. Palaeontol.* **37**, 125–246.
Schmidt-Kaler, H. & Zeiss, A. 1973. Die Juragliederung in Süddeutschland. *Geologica Bav.* **67**, 155–61.
Sellwood, B. W. & McKerrow, W. S. 1974. Depositional environments in the lower part of the Great Oolite Group of Oxfordshire and north Gloucestershire. *Proc. Geol. Assoc. London*, **85**, 189–210.
Senior, J. R. 1975. The Middle and Upper Jurassic succession at Boltby Moor, near Thirsk, Yorkshire. *Proc. Yorkshire geol. Soc.*, **40**, 289–95.
—— & Earland-Bennet, P. M. 1973. The Bajocian ammonite *Hyperlioceras rudidiscites* S. Buckman in eastern England and its significance. *Proc. Yorkshire geol. Soc.* **39**, 319–26.
—— , Parsons, C. F. & Torrens, H. S. 1970. New sections in the Inferior Oolite of south Dorset. *Proc. Dorset nat. Hist. archaeol. Soc.* **91**, 114–9.
Sharp, S. 1870. The Oolite of Northamptonshire. *Q. J. geol. Soc. London*, **29**, 354–93.
Smart, J. G. O., Bisson, G. & Worssam, B. C. 1966. The geology of the country around Canterbury and Folkestone. *Mem. geol. Surv. G.B.*, x+337 pp., 6 pls.
—— & Wood, C. J. 1976. Field excursion to south Humberside. *Proc. Yorkshire geol. Soc.* **40**, 586–93.
Smart, P. J. 1959. Reports of recorders for 1958: Palaeontology. *Beds. Nat.* **13**, 22–4.
—— 1961*a*. Reports of recorders for 1960: Geology and palaeontology. *Beds. Nat.*, **15**, 19–21.
—— 1961*b*. An important geological site near Bromham. *Beds. Mag.* **7** (56), 311–312.
Smith, R. T. 1969 *in* Cope, J. C. W. The Kellaways Beds and the Oxford Clay *in*: Torrens H. S. (ed), 1969*a*, *q.v.*
Smith, W. 1815. *A memoir to the map and delineation of the strata of England and Wales, with part of Scotland.* xi+51 pp., 2 tabs. John Cary, London.
—— 1816. *Strata identified by organized fossils containing prints on coloured paper of the most characteristic specimens in each stratum.* 32 pp., 18 pls. E. Williams, London.
Spath, L. F. 1932. The invertebrate faunas of the Bathonian-Callovian deposits of Jameson Land (East Greenland). *Medd. Grønland*, **87**, (7).
—— 1935. The Upper Jurassic Invertebrate faunas of Cape Leslie, Milne Land; 1. Oxfordian and Lower Kimmeridgian. *Medd. Grønland*, **99** (2), 1–82, pls. 1–15.
—— 1936. The Upper Jurassic invertebrate faunas of Cape Leslie, Milne Land; 2. Upper Kimmeridgian and Portlandian. *Medd. Grønland*, **99** (3), 1–180, pls. 1–50.
Stinton, F. C. & Torrens, H. S. 1968. Fish otoliths from the Bathonian of southern England. *Palaeontology*, **11**, 246–58.
Sturani, C. 1967. Ammonites and stratigraphy of the Bathonian in the Digne-Barreme area (S.E. France). *Boll. Soc. palaeontol. Ital.* **5**, 3–57, pls. 1–24.

SURLYK, F., CALLOMON, J. H., BROMLEY, R. G. & BIRKELUND, T. 1973. Stratigraphy of the Jurassic-Lower Cretaceous sediments of Jameson Land and Scoresby Land, East Greenland. *Bull. Grønlands geol. Unders.*, **105,** 1–76, pls. 1–11.

SWINNERTON, H. H. & KENT, P. E. 1976. *The geology of Lincolnshire.* Lincolnshire Naturalists' Union, Lincoln, 2nd ed. xiv + 130 pp. 15 pls.

SYKES, R. M. 1975. The stratigraphy of the Callovian and Oxfordian Stages (Middle and Upper Jurassic) in northern Scotland. *Scott. J. Geol.* **11,** 51–78.

—— & CALLOMON, J. H. 1979. The *Amoeboceras* zonation of the Boreal Upper Oxfordian. *Palaeontology,* **22,** 839–903, pls. 111–21. [n.b. this work covers both Middle and Upper Oxfordian.]

SYLVESTER-BRADLEY, P. C. 1940. The Purbeck Beds of Swindon. *Proc. Geol. Assoc. London,* **50,** 349–72.

SYLVESTER-BRADLEY, P. C. 1949*a*. Revised nomenclature for Yorkshire Estuarine Series. *Geol. Mag.* **86,** 263.

—— 1949*b*. The ostracod genus *Cypridea* and the zones of the Upper and Middle Purbeckian. *Proc. Geol. Assoc.* London, **60,** 125–53, pls. 3–4.

—— 1953. A stratigraphical guide to the fossil localities of the Scarborough district. *in*: *The natural history of the Scarborough district.* **1**. Geology and botany. Scarborough Field Naturalist's Society. Scarborough. xii + 296 pp., 8 pls.

—— 1964. Type sections of Bathonian, Portlandian and Purbeckian stages and the problem of the Jurassic–Cretaceous boundary. *in*: MAUBEUGE, P. L. (ed), *Colloque du Jurassique à Luxembourg 1962.* Publ. Inst. Grand-Ducal, Sect. Sci. nat. Phys. Math. Luxembourg, 259–63.

—— & FORD, T. D. (eds.) 1968. *The geology of the east Midlands.* University Press, Leicester, 400 pp.

—— & HODSON, F. 1957. The Fuller's Earth of Whatley, Somerset. *Geol. Mag.* **94,** 312–22.

TAITT, A. H. & KENT, P. E. 1958. *Deep boreholes at Portsdown (Hampshire) and Henfield (Sussex).* British Petroleum, London, 41 pp.

TALBOT, M. R. 1973. Major sedimentary cycles in the Corallian Beds (Oxfordian) of southern England. *Palaeogr. Palaeoclimatol. Palaeoecol.* **14,** 293–317.

TAN, F. C. & HUDSON, J. D. 1974. Isotopic studies of the palaeoecology and diagenesis of the Great Estuarine Series (Jurassic) of Scotland. *Scott. J. Geol.* **10,** 91–128.

TAYLOR, J. H. 1963. Geology of the country around Kettering, Corby and Oundle. *Mem. geol. Surv. G.B.* ix + 149 pp., 6 pls.

THIERRY, J. 1976. Paleobiogéographie de quelques Stephanocerataceae (Ammonitina) du Jurassique moyen et supérieur; une confrontation avec la théorie mobiliste. *Geobios,* **9,** 291–331.

THOMPSON, B. 1927. *Lime resources of Northamptonshire.* Northampton County Council, 88 pp.

—— 1930. The Upper Estuarine Series of Northamptonshire and Northern Oxfordshire. *Q. J. geol. Soc. London,* **86,** 430–62, pls. 50–51.

TORRENS, H. S. 1964. Two geological exposures at Sherborne. *Proc. Dorset nat. Hist. archaeol. Soc.* **85,** 38–9.

—— 1966. *English and European Bathonian stratigraphy.* Unpublished Ph.D. thesis, University of Leicester.

—— 1967. The Great Oolite Limestone of the Midlands. *Trans. Leicester lit. philos. Soc.* **61,** 65–90.

—— 1968*a*. *in*: 'Geology' *in*: Dorset natural history reports 1967. *Proc. Dorset nat. Hist. archaeol. Soc.* **89,** 42.

—— 1968*b*. Some Fuller's Earth sections in the south Cotswolds. *Proc. Bristol Nat. Soc.* **31,** 429–38.

—— 1968*c*. The Great Oolite Series pp. 227–63 *in* SYLVESTER-BRADLEY, P. C. & FORD, T. D. 1968 (eds), *q.v.*

—— (ed) 1969*a*. *International Field Symposium on the British Jurassic.* Excursion No. 1. Guide for Dorset and south Somerset. pp. A1-A71. Excursion No. 2. Guide for north Somerset and Gloucestershire. pp. B1-B43 + 1–3. Guides to field excursions from London. pp. A-C + 8–35 + 1–3. University of Keele.

—— 1969*b*. Field meeting in the Sherborne-Yeovil district. *Proc. Geol. Assoc. London,* **80,** 301–30.

—— 1969*c*. The stratigraphical distribution of Bathonian ammonites in central England. *Geol. Mag.* **106,** 63–76.

—— 1974*a*. Standard Zones of the Bathonian. *Mem. Bur. Rech. geol. minières,* **75,** 581–604.

—— 1974*b*. Collections at Northampton (Central Museum). *Newsl. Geol. Cur. Grp.* **1** (2), 46–51.

—— & CALLOMON, J. H. 1968. The Corallian Beds, the Ampthill Clay and the Kimmeridge Clay *in*: SYLVESTER-BRADLEY, P. C. & FORD, T. D. (eds) 1968, *q.v.*

TOWNSEND, J. 1813. *The character of Moses established for veracity as an historian, recording events from the creation to the deluge.* **1.** Gye, Bath; Longman, London, vi+436 pp.

TOWNSON, W. G. 1975. Lithostratigraphy and deposition of the type Portlandian. *J. geol. Soc. London,* **131,** 619–38.

TWOMBLEY, B. N. 1965. *Environmental and diagenetic studies of the Corallian rocks in Yorkshire, west of Thornton Dale.* Unpublished Ph.D. thesis, University of Newcastle.

USSHER, W. A. E. 1890. The geology of parts of north Lincolnshire and south Yorkshire. *Mem. geol. Surv. G.B.* viii+231 pp.

WALFORD, E. A. 1895–7. *in*: *Rept. Brit. Assoc.* **1894,** 304; **1895,** 415; **1896,** 356.

WALKER, K. G. 1972. The stratigraphy and bivalve fauna of the Kellaways Beds (Callovian) around South Cave and Newbald, East Yorkshire. *Proc. Yorkshire geol. Soc.* **39,** 107–38, pls. 7–8.

WATERSTON, C. D. 1951. The stratigraphy and palaeontology of the Jurassic rocks of Eathie (Cromarty). *Trans. R. Soc. Edinburgh,* **62,** 33–51.

WEBSTER, T. 1816. *in*: ENGLEFIELD, H. C., *A description of the principal picturesque beauties, antiquities, and geological phenomena of the Isle of Wight. With additional observations on the strata of the island, and their continuation in the adjacent parts of Dorsetshire.* London, xxvii+238 pp., 48 pls.

WEDD, C. B. 1920. *in*: LAMPLUGH, G. W., WEDD, C. B. & PRINGLE, J. Special reports on the mineral resources of Great Britain. XII. Iron ores (contd.)—Bedded ores of the Lias, Oolites and later formations in England. *Mem. geol. Surv. G.B.* iv+240 pp., 8 pls.

WESTERMANN, G. E. G. 1954. Monographie der Otoitidae (Ammonoidea). *Beih. geol. Jahrb.* **15,** 1–364, pls. 1–33.

—— 1958. Ammoniten fauna und Stratigraphie des Bathonien N.W. Deutschlands. *Beih. geol. Jahrb.* **32,** 1–103, pls. 1–49.

WHITE, H. J. O. 1923. Geology of the country south and west of Shaftesbury. *Mem. geol. Surv. G.B.* iv+112 pp., 4 pls.

—— 1925. The geology of the country around Marlborough. *Mem. geol. Surv. G.B.* xi+112 pp., 3 pls.

WHITEAVES, J. F. 1861. On the invertebrate fauna of the Lower Oolites of Oxfordshire. *Rept. Br. Assoc. Adv. Sci.* **1860,** 104–8.

WILSON, R. C. L. 1968*a*. Upper Oxfordian palaeogeography of southern England. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **4,** 5–28.

—— 1968*b*. Carbonate facies variation within the Osmington Oolite Series in southern England. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **4,** 89–123.

WILSON, V., WELCH, F. B. A., ROBBIE, J. A. & GREEN, G. W. 1958. Geology of the country around Bridport and Yeovil. *Mem. geol. Surv. G.B.,* xii+239 pp., 7 pls. (note: published in 1959).

WIMBLEDON, W. A. 1974*a*. The Basal Shell Bed of the Portland Stone *in*: COPE, J. C. W. (ed), *Geology in The Natural Sciences* 1973. Proc. Dorset nat. Hist. archaeol. Soc. **95,** 105–6.

—— 1974*b*. *The stratigraphy and ammonite faunas of the Portland Stone of England and northern France.* Unpublished Ph.D. thesis. University of Wales.

—— 1976. The Portland Beds (Upper Jurassic) of Wiltshire. *Wiltshire archaeol. nat. Hist. Mag.* **71,** 3–11.

—— & COPE, J. C. W. 1978. The ammonite faunas of the English Portland Beds and the zones of the Portlandian Stage. *J. geol. Soc. London,* **135,** 183–90, pls. 1–3.

WITCHELL, E. 1882. *The geology of Stroud and the area drained by the Frome.* G. H. James. Stroud. 108 pp., 3 pls.

—— 1886*a*. On the basement beds of the Inferior Oolite of Gloucestershire. *Q. J. geol. Soc. London*, **42**, 267–71.

—— 1886*b*. On the Forest Marble and upper beds of the Great Oolite between Nailsworth and Wotton-under-Edge. *Proc. Cotteswold Nat. Field Club*, **8**, 265–80.

WOODWARD, H. B. 1894. The Jurassic rocks of Britain. 4. The lower Oolitic rocks of England (Yorkshire excepted). *Mem. geol. Surv. G.B.* xiv + 628 pp., 2 pls.

—— 1895. The Jurassic rocks of Britain. 5. The Middle and Upper Oolitic rocks of England (Yorkshire excepted). *Mem. geol. Surv. G.B.*, xiv + 499 pp.

—— 1904. Note on a small anticline in the Great Oolite Series at Clapham, north of Bedford. *Geol. Mag.* (5), **1**, 439–41.

WORSSAM, B. C. & BISSON, G. 1961. The geology of the country between Sherborne, Gloucestershire, and Burford, Oxfordshire. *Bull. geol. Surv. G.B.* **17**, 75–115, pl. 3.

—— & IVIMEY-COOK, H. C. 1971. The stratigraphy of the Geological Survey borehole at Warlingham, Surrey. *Bull. geol. Surv. G.B.* **36**, 1–111, pls. 1–3.

—— & TAYLOR, J. H. 1969. Geology of the country around Cambridge. *Mem. geol. Surv. G.B.* x + 159 pp., 7 pls.

WRIGHT, C. D. 1976. New outcrops of the Ampthill Clay north of Market Weighton, Yorkshire, and their structural implications. *Proc. Yorkshire geol. Soc.* **41**, 127–40.

WRIGHT, J. K. 1968*a*. The stratigraphy of the Callovian rocks between Newtondale and the Scarborough coast, Yorkshire. *Proc. Geol. Assoc. London*, **79**, 363–99.

—— 1968*b*. The Callovian succession at Peckondale Hill, Malton, Yorkshire. *Proc. Yorkshire geol. Soc.* **37**, 93–7.

—— 1969. Callovian *in*: HEMINGWAY, J. E., WRIGHT, J. K. & TORRENS, H. S. (eds), *International Field Symposium on the British Jurassic*. Excursion no. **3**. Guide for north-east Yorkshire. University of Keele, C1–C47.

—— 1972. The stratigraphy of the Yorkshire Corallian. *Proc. Yorkshire geol. Soc.* **39**, 225–66.

—— 1973. Middle and Upper Oxfordian and Kimmeridgian Staffin Shales at Staffin, Isle of Skye. *Proc. Geol. Assoc. London*, **84**, 447–57.

—— 1977. The Cornbrash Formation (Callovian) in North Yorkshire and Cleveland. *Proc. Yorkshire geol. Soc.* **41**, 325–46, pls. 15–6.

—— 1978*a*. The Callovian succession (excluding Cornbrash) in the western and northern parts of the Yorkshire Basin. *Proc. Geol. Assoc. London*, **89**, 239–61.

—— 1978*b*. The Corallian succession in the Malton Bypass. *Circ. Geol. Assoc. London*, **807**, 9–10.

WRIGHT, T. 1860. On the subdivisions of the Inferior Oolite in the south of England, compared with the equivalent beds of that formation on the Yorkshire coast. *Q. J. geol. Soc. London*, **16**, 1–48.

WYATT, R. J. & PENN, I. E. 1975. *in*: Southern England and Wales, Central and South Midlands District: Other work. *Annu. Rept. Inst. geol. Sci. London*, **1974**, p. 19.

YOUNG, G. 1817. *A history of Whitby and Streoneshalh Abbey, with a statistical survey of the vicinity to the distance of twenty-five miles*. 2 vols. Clark & Medd. Whitby.

ZIEGLER, B. 1962. Die Ammoniten–Gattung *Aulacostephanus* im Oberjura. *Palaeontographica*, **A119**, 1–172, pls. 1–22.

—— 1977. The White (Upper) Jurassic in southern Germany. *Stuttgarter, Beitr. Naturk.* **B26**, 1–79, pls. 1–11.

J. C. W. COPE, Department of Geology, University College, Singleton Park, Swansea SA2 8PP.

K. L. DUFF, Nature Conservancy Council, Foxhold House, Thornford Road, Crookham Common, Newbury, Berks. RG15 8EL.

C. F. PARSONS, 78 Runnells Lane, Thornton, Liverpool L23 1TR.

H. S. Torrens, Department of Geology, The University, Keele, Staffs. ST5 5BG.

W. A. Wimbledon, Nature Conservancy Council, Pearl House, Bartholomew Street, Newbury, Berks. RG14 5LS.

J. K. Wright, Department of Geology, Chelsea College, 271 King Street, London W6 9LZ.