A stratigraphical revision for the English Lower Callovian

K. N. Page

PAGE, K. N. 1989. A stratigraphical revision for the English Lower Callovian. *Proc. Geol. Ass.*, 100(3), 363-82. Information from new arid temporary sections and that from many older published sources enables a detailed revision of stratigraphical nomenclature for the Lower Callovian in England. Five formations contain rocks solely, or in part, of Lower Callovian age; the Abbotsbury Cornbrash *(nom. nov. pro* Cornbrash auctt.), Cayton Clay *(nom. nov. pro* Shales-of-the-Cornbrash Member, of J. K. Wright, 1977), the Kellaways and Osgodby Formations, and the basal part of the Oxford Clay. These Formations and their component Members are discussed and, where necessary, formally redefined. A revision of the Standard Ammonite Zonation for the time interval is also possible and a correlation of the lithostratigraphical units is presented.

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1. INTRODUCTION

Major changes occurred in British depositional environments during the late Bathonian and early Callovian reflecting the effects of a marine transgression. The Bathonian/Callovian boundary typically lies within a stratigraphically condensed shallow-water shelly and sandy limestone sequence known as the Cornbrash. Deepening marine conditions and an input of terrigenous sediment are reflected by the overlying clays and sands of the Cayton Clay, Kellaways and Osgodby Formations. The sequence culminates, in southern England, in the bituminous-shale deposits of the Lower Oxford Clay.

In this paper there is a considerable revision and refinement of existing subdivisions and nomenclature which it is hoped will provide a basis for a greater understanding of one of the most important events in British Mesozoic Stratigraphy, the Callovian marine transgression.

2. HISTORY OF RESEARCH

The varied lithologies and rich invertebrate faunas of the English Lower Callovian rocks have long attracted the attention of geologists, professional and amateur alike, and there is space here only to cite the main references. William Smith was the first to describe English rocks of terminal Bathonian and early Callovian age, and he originated the terms, 'Cornbrash' and 'Kellaways Stone' *(in* Townsend, 1813). The former existence of many small stone-pits, and the building of the railways during the nineteenth century enabled private individuals and the officers of the Geological Survey to record many local sections. The former published notes in a wide range of journals while the work of the latter formed the basis of several Survey Memoirs, culminating in the now classic descriptive works on English Jurassic Rocks by Fox-Strangeways (1892) and Woodward (1894,1895)', which summarised effectively all the previous descriptions.

Work in this century has concentrated on more detailed surveys of individual formations and areas, including Douglas & Arkell's study of the Cornbrash (1928,1932, 1935), Cave & Cox's (1975) and Walker's (1972) studies of the Kellaways Formation in Wiltshire and Humberside respectively, and Wright's work on Callovian rocks in North Yorkshire (e.g. 1968, 1977, 1978).

The first detailed Standard Ammonite Zonation for the Lower Callovian was published by Callomon (1955,1964), and has been used widely in Britain and Europe. For example Duff *(in* Cope *et ai,* 1980) applied the scheme to correlate British Callovian rocks. A revised correlation using a further refined Standard Zonation is presented in Section 4.

3. LITHOSTRATIGRAPHICAL NOMENCLATURE: DEFINITIONS

The study of existing sections, and descriptions of those now obscured, has revealed that the currently used lithostratigraphical framework for the Lower Callovian (e.g. in Cope *et al.,* 1980) requires modification. Such modification includes the recognition and separation of correctable units which had previously, and misleadingly, been grouped together under single names. For instance the so called "Kellaways Rock" in Wiltshire, Humberside and North Yorkshire exists as three separate sandstone developments in two formations. Each is lithologically and faunally distinguishable, and is here included in one of three defined members—respectively the Kellaways Sand, Cave Rock and Redcliff Rock. Similarly, the "Kellaways Clay" of authors is separable into two distinct units, as noted by Callomon (1955). The lower unit, here distinguished as the Cayton Clay Formation, is the most widely recognisable, being present through most of the outcrop from north Dorset to North Yorkshire. The higher unit, named the Kellaways Clay Member, is only developed from Dorset to Gloucestershire. It is a

sandy clay or silt, and in part passes laterally into the sands and sandstones of the Kellaways Sand Member.

When naming lithostratigraphical units, two options are available: (1) to use existing names, if these are suitable, or (2) to create new formal Formational names, and recognise Members within these Formations. The recommendations of authors such as Holland *et al.* (1978) who favoured (2), are followed here. These workers recommend a standardisation of stratigraphical nomenclature, which, in lithostratigraphical units, include the definition of a type or reference section, and the provision of a name with a geographical epithet. Confusion can arise when familiar names are replaced and so many workers are reluctant to standardise formational names. The present author, however, believes that stratigraphical conventions are important, since they unify the basis on which units are defined and recognised. Examples of their use in British Mesozoic stratigraphy include Sykes (1975) on the Callovian and Oxfordian of Scotland, and Jarvis & Woodroof (1984), on the Cenomanian and Turonian of south-east Devon. To limit possible confusion, most of the formal names proposed below are simply modifications of existing terms. Synonymous earlier names are given in the descriptions.

The distribution and lateral thickness changes within each unit are shown by the sections of Figs. 2-4. These are drawn to scale, but with a vertical exaggeration, and represent a south to north transect

from Weymouth, in Dorset, to Scarborough, in North

Fig. 1. The distribution of English Lower Callovian rocks, as shown by the line of section of Figs. 2-4; Major Jurassic structural elements are shown.

Yorkshire. The section line is indicated on Fig. 1, which, therefore, shows the general distribution of Lower Callovian rock outcrops.

Although sampling points are numerous, with around 140 sections, only the most important are shown here. Each defined unit has been given an abbreviated title of 3 or 2 letters which is used on the correlation diagrams of Figs. 2-4 and 9-10.

(a) Abbotsbury Cornbrash Formation (ACF)

New name for Cornbrash (Smith *in* Townsend, 1813); formalised as Cornbrash Formation by Wright (1977). *Type locality:* Here proposed, Berry Knap, near Abbotsbury, Dorset. This section was first noted by Douglas & Arkell (1928) and is broadly similar to that described in detail by the same authors at nearby Shipmore Point, Abbotsbury Swannery. However, the former is better exposed and makes the best reference, representing the most complete natural exposure of the Formation. A detailed section is given in the Appendix.

The Formation consists of a complex sequence of both pure carbonate and also calcareous siliclastic deposits. Numerous local non-sequences are indicated by eroded surfaces, pebble beds and biostratigraphic correlations. The Formation is thin but persistant, ranging from a maximum of around 10.5 m to less than 0.5 m in thickness. Two component Members are recognised, broadly equivalent to the Lower and Upper Cornbrash of Douglas & Arkell (1928, 1932, 1935).

Wright (1977) first attempted a formalisation of nomenclature for the Cornbrash. His Cornbrash Formation, however, included the overlying Shales-of-the-Cornbrash as a Member; the latter is now considered to be best treated as a separate Formation (=Cayton Clay Fm.). The desirability of using a geographical prefix in the formalised name is satisfied by the insertion of "Abbotsbury",

(i) *Berry Member (BYM)*

New name for Lower Cornbrash of Douglas & Arkell (1928), *non* Buckman (1922), here emended. *Type-locality:* Berry Knap (as above), Beds 1-3. A high degree of lithological variation is observed within the Member, but very pale coloured bioclastic, micritic and marly nodular limestones are characteristic. Douglas & Arkell (1932, p. 142) gave a generalised summary of typical lithologies and faunas; they recognised two Brachiopod biozones within the unit, a lower with an abundance of *Cererithyris intermedia* (Sowerby) and an upper yielding *Obovothyris obovata* (Sowerby). These and associated species are well illustrated in both parts of their survey of the Cornbrash (1928,1932). The authors also notec several distinct and correlatable units or beds within the Member, these are here formalised as: *Intermedia Bed* (IB), which forms a laterally persistent

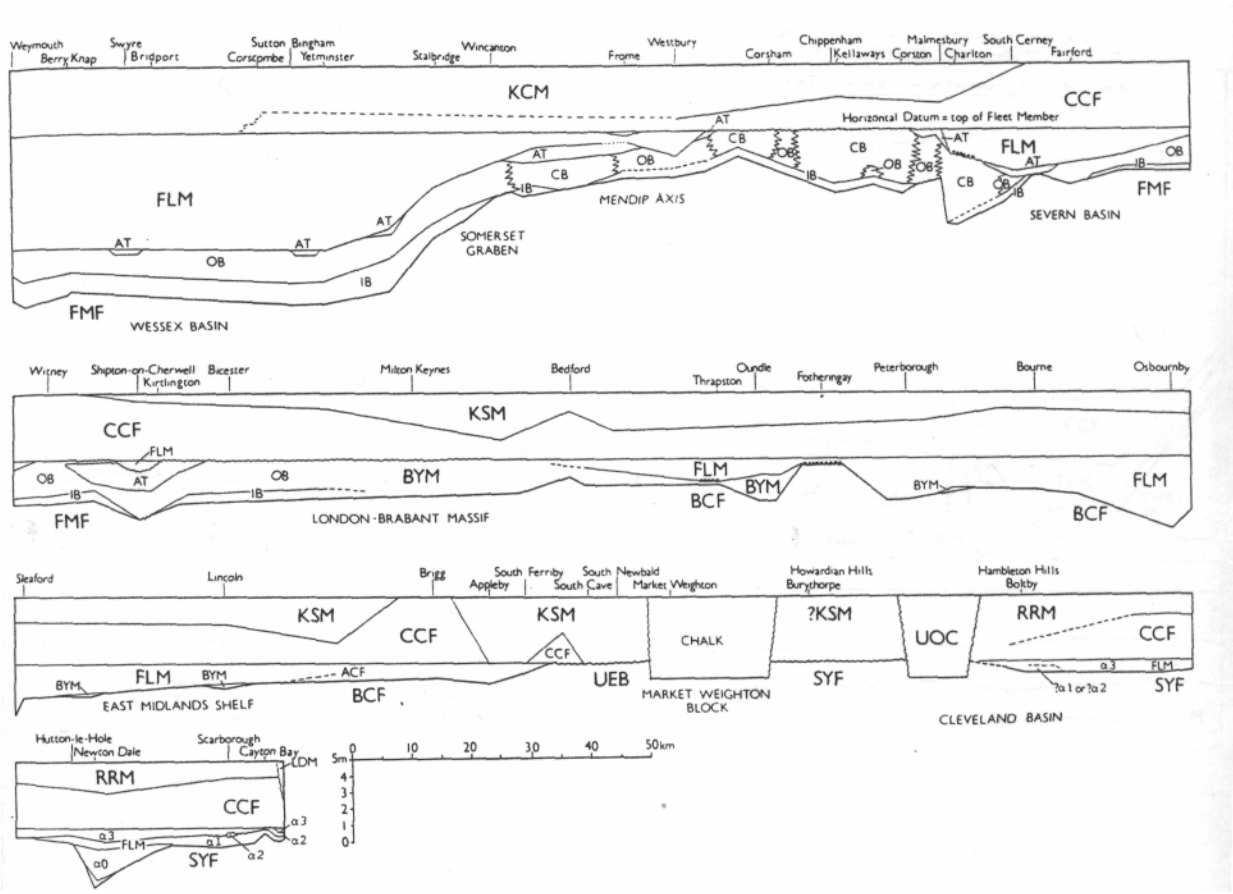

Fig. 2. A lithostratigraphical transect through the Abbotsbury Cornbrash Formation and contiguous deposits. For a full key to symbols and abbreviations, see Fig. 4.

basal part of the Berry Member and is characterised by the frequent abundance of *C. intermedia.* Lithologies are variable but typically a hard calcarenite, less frequently a softer argillaceous or nodular micrite. The bed generally equates with the *intermedia* Biozone as recognised by Douglas & Arkell between the Dorset Coast and Oxfordshire (1928, 1932).
Type-locality: Shipton-on-Cherwell, Cement works, Bedl.

Corston Beds (CB); developed locally, in Somerset and Wiltshire, these typically consist of a series of beds of coarse shell-sand limestone and finer calcarenite; with few recognisable macrofossils. Cross-bedded units are frequent, occasionally in sets UP to 2-3 m in thickness. Generally overlies the Intermedia Bed and is overlain often by an Astarte-Trigonia Bed (described below), but often Passes laterally into more typical *obovata* Biozone •"ubbly and marly limestones (= OB).
Type-locality: Corston, Wiltshire (Douglas & Arkell, 1928, p. 139).

Astarte-Trigonia Bed (AT); frequently forms an upper part to the Berry Member in the Somerset-Oxfordshire area. A typical lithology is a shelly, occasionally argillaceous, micritic limestone containing an abundant molluscan fauna, typified by the association of *Astarte hilpertonensis* Lycett and *Trigonia* spp.
Type-locality: Shipton-on-Cherwell Cement Works, Bed 5 (see Appendix).

The new name Berry Member is a formal replacement for the name Lower Cornbrash *(sensu* Douglas & Arkell). The latter term was applied using both lithological and biozonal criteria and is not, therefore, purely a lithological term.

(«) *Fleet Member (FLM)*
New name for Upper Cornbrash of Douglas & Arkell

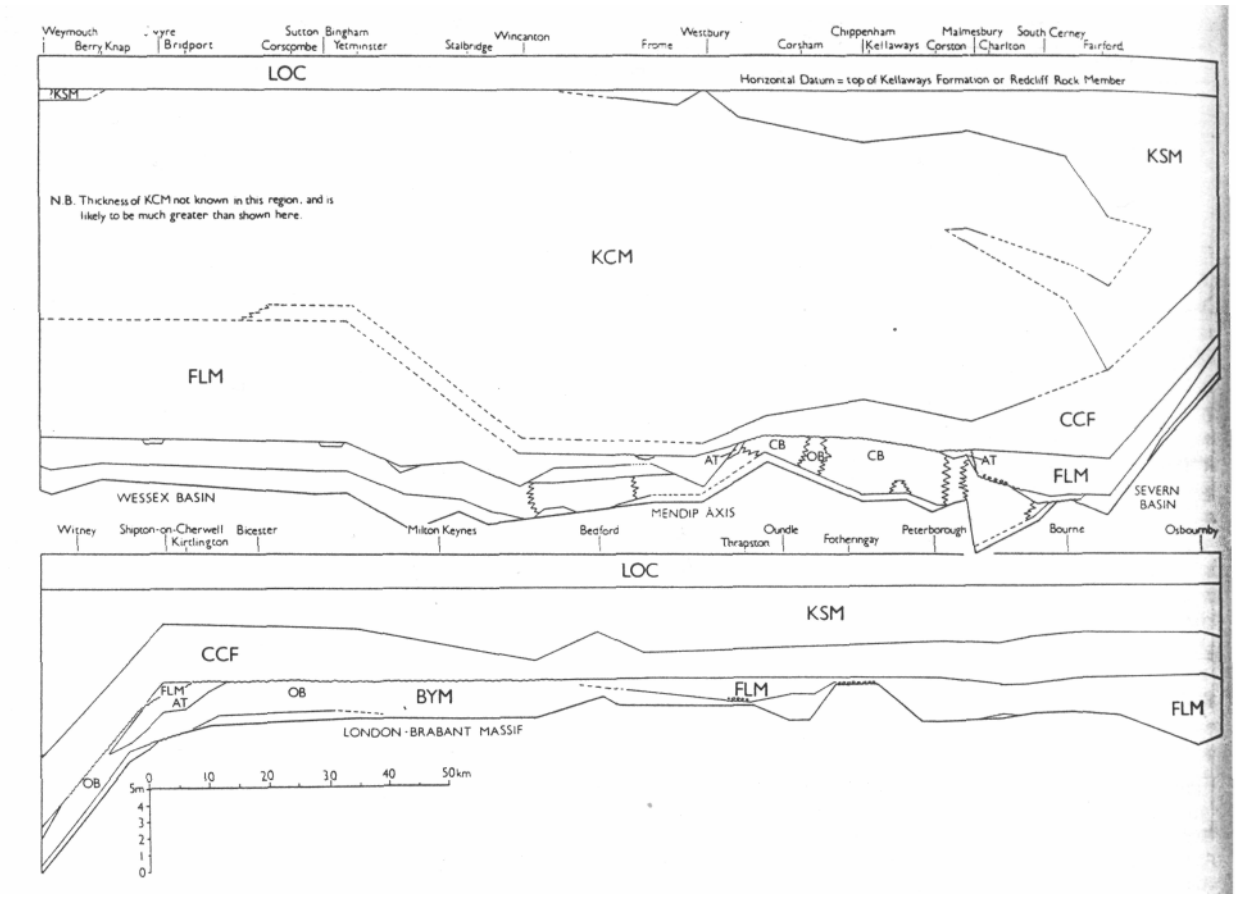

Fig. 3. A lithostratigraphical transect through the Cayton Clay, Kellaways and Osgodby Formations, and contiguous deposits: Part (a) Dorset to mid-Lincolnshire. For a full key to symbols and abbreviations, see Fig. 4.

(1928) *non* Buckman (1922), here emended, (equivalent, in part, to the Cornbrash Limestone Member of Wright, 1977).

Type locality: Berry Knap, near Abbotsbury, Dorset (see Appendix).

A variable sequence of sandy limestones, calcareous sands and calcarenitic limestones. Subordinate other lithologies include chamosite oolites and bioclastic limestones (in North Yorkshire, see Wright, 1977). Douglas & Arkell (1928,1932) recognised two brachiopod Biozones within their Upper Cornbrash, the lower identified by the presence of *Microthyridina siddingtonensis* (Walker) and the upper by *M. lagenalis* Douglas & Arkell *non* Schlotheim and related species. The *siddingtonensis* Biozone occurs in sands and sandy limestones in Dorset and Gloucestershire, but it should be noted that it also occurs within the top of the Berry Member, near Oxford (= Bed 4, Swan Inn Quarry, Long Handborough; Douglas & Arkell, 1928, which caused these authors to refer the bed to their Upper Cornbrash). The *lagenalis* Biozone is geographically more widespread and has been recorded along much of the outcrop from Dorset to Yorkshire. It occurs characteristically in the marls and marly limestones at the junction of the Fleet Member and the overlying Cayton Clay Formation. Wright (1977) recognised four subdivisions within the Fleet Member in North Yorkshire, and denoted these by the numbers a_a to $<x_4$.

The name, Fleet Member, is a formalised replacement for Upper Cornbrash, *sensu* Douglas & Arkell.

(b) Cayton Clay Formation (CCF) New name for Shales-of-the-Cornbrash Member of Wright (1977), equivalent to Clays-of-the-Cornbrash of Wright (1860) and Lower Kellaways Clay of Callomon *(in* Sylvester-Bradley & Ford, 1968). *Type-locality:* Cayton Bay, near Scarborough, North Yorkshire (details given by Wright, 1977, p. 339). This is a widespread unit, recognisable from North Yorkshire to as far south as north Dorset. Typically '

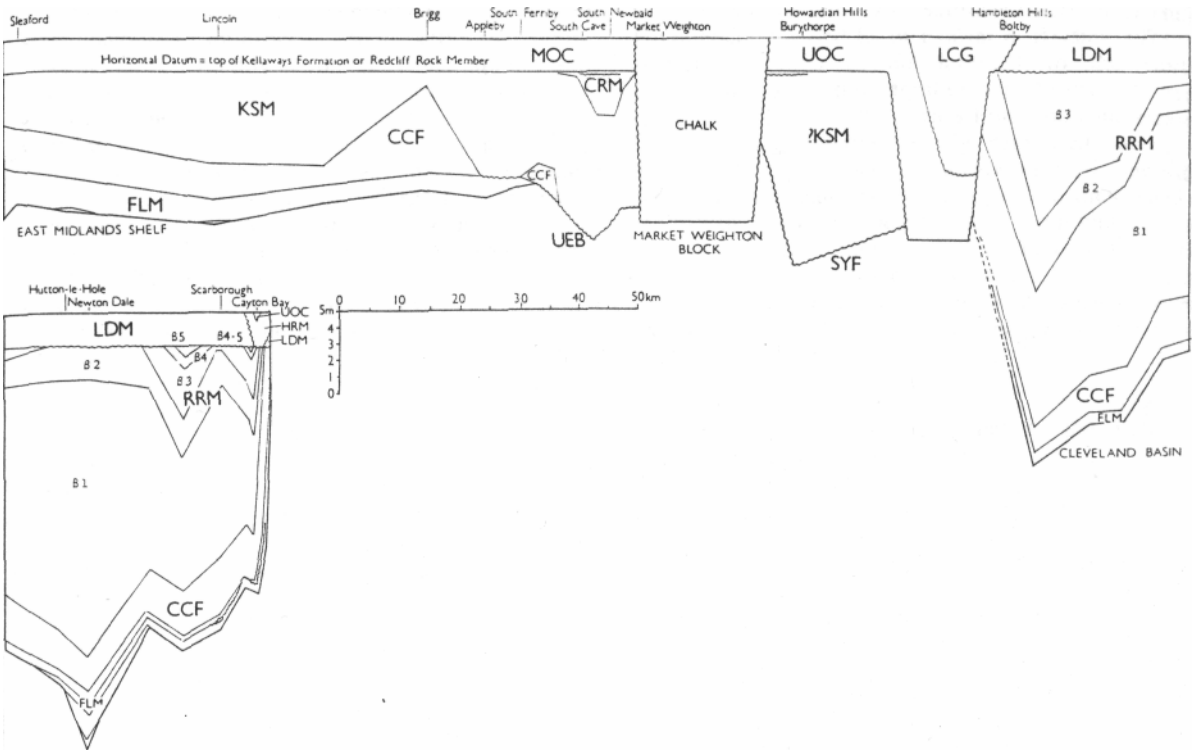

Fig. 4. A lithostratigraphical transect through the Cayton Clay, Kellaways and Osgodby Formations, and contiguous deposits: Part (b) Lincolnshire to North Yorkshire. Key: Dashed lines indicate uncertainties; wavy lines indicate eroded surfaces or non-sequences. Lithostratigraphical abbreviations are as follows: LCG = Lower Calcareous Grit; UOC = Upper Oxford Clay; dOC = Middle Oxford Clay; LOC = Lower Oxford Clay. Osgodby Formation; HRM = Hackness Rock Member; -DM = Langdale Member; RRM = Redcliff Rock Member (with subdivisions j8j_5). Kellaways Formation; CRM = Cave Rock Member; KSM = Kellaways Sand Member; KCM = Kellaways Clay Member. Cayton Clay Formation = CCF. Abbotsbury Cornbrash Formation; FLM = Fleet Member (with subdivisions or_{0_3} in North Yorkshire). Berry Member; AT = Astarte — Trigonia Bed; CB = Corston Beds; IB = Intermedia Bed; *OB* = *obovata* Biozone limestones and marls; 5YM = Berry Member (undifferentiated); ACF = Abbotsbury Cornbrash Formation (undifferentiated). FMF = Forest Marble Formation; BCF = Blisworth Clay Formation; UEB = Upper Estuarine Beds; SYF = Scalby Formation.

the Formation consists of around 3 m of dark grey shaly or silty clay, becoming sandy towards the top. Small, pale greyish phosphatic nodules up to 5 cm in diameter occur, and are characteristic. These contain small quantities of sphalerite and, occasionally, pyrite (Callomon, 1955, p. 236). The benthic macrofauna is of low diversity, and often dominated by the bivalves *Meleagrinella braamburiensis* (Phillips), *Modiolus bipartitus* (Sowerby) and *Nuculana* sp.

Wright (1977) included the formalised 'Shales-of-the-Cornbrash Member' within his Cornbrash Formation. He did this largely on the basis of faunal similarities Which included the presence of *Macrocephalites* in torn the Shale and the 'Cornbrash Limestone Member' below. Nevertheless, the lithological distinc-tiveness and wide geographical extent of the Shales is here considered to merit raising them to formational status.

(c) KeUaways Formation (KYF)

Author: Judd (1875) as Kellaways beds.

Type locality: none designated, here suggested- Tytherton No. 3 borehole, near Chippenham (and Kellaways itself), Wiltshire, depths 22.4m to 3.35m (details in Cave & Cox, 1975).

This is a dominantly siliclastic Formation, consisting largely of silty and sandy mudrocks, muddy sands and

occasional calcareous sandstones. Three component members are recognised :-

(0 *Kellaways Clay Member (KCM)*

Author: Woodward (1895) as Kellaways clay (part only, as his unit included beds here assigned to the Cayton Clay Formation) = Upper Kellaways Clay; Callomon *in* Sylvester-Bradley & Ford (1968).

Type locality: Here designated, Tytherton No. 3 borehole (as above), depths 22.4 m to 6.95 m.

The Member consists of dominantly pale to medium grey coloured mudrock, often silty or sandy. Occasional thin muddy sandstone bands are present, and small grey micritic limestone nodules and large septarian concretions are common at certain levels. In contrast to the Cayton Clay Formation, benthic macro-faunas may be relatively diverse, including species of *Myophorella, Thracia, Oxytoma, Pleuromya, Modiolus, Grammatodon, Catinula, Procerithicum,* etc. The presence of white shell-aragonite is typical and pyrite occurs in some shell cavities. The Member is well developed between Dorset and Wiltshire but thins rapidly farther north, in part by lateral passage into Kellaways Sand Member facies. Known lateral thickness variations of this and other units are shown on Fig. 3.

Callomon (1955, p. 258) first noted the possibility of subdividing the 'Kellaways Clay' *(sensu* Woodward, 1895) having recognised an upper pyritic facies (= Kellaways Clay Member) and a lower phosphatic facies (= Cayton Clay Formation). These two divisions are now formally distinguished.

(ii) Kellaways Sand Member (KSM) Author: Ussher (1888), here emended := Kellaways Rock of Smith *in* Townsend (1813) and other authors. *Type locality:* Banks of the River Avon, west of West Tytherton and south of Kellaways, Wiltshire; = Cave & Cox, locality A (1975, p. 46). Equivalent to Tytherton No. 3 borehole, levels 6.95m to 3.35m *(ibid,* 63-4).

This unit consists of sands and silts, often with thin, more or less silty clay bands. Occasional calcareous sandstones may be present which in Wiltshire comprise most of the succession, and contain frequent shelly nests or concretions with a rich molluscan fauna dominated by ammonites and bivalves (listed in part by Cave & Cox, 1975, p. 46, locality A). Southwards and northwards from there, calcareous sandstones become infrequent and softer poorly or uncemented sands are more typical—with a lower-diversity benthos often dominated by *Catinula alimena* (d'Orbigny) or *Gryphaea calloviensis* (Hallam & Gould), *Oxytoma* sp. and various myoid bivalves. In the Humberside area, little mud remains in the succession and the unit is dominated by cross-bedded sands with bands rich in *Gryphaea*—the sedimentol-ogy of this region has been discussed by Brasier & Brasier (1978, Beds A/B to J). The term 'Kellaways Sand' is here preferred to the older one of 'Kellaways Rock', as the latter is only lithologically correctly applicable to the calcareous-sandstone facies developed in Wiltshire. Elsewhere, poorly cemented sands and silts dominate the succession.

(iii) Cave Rock Member (CRM)
New name for Upper Kellaways Rock of Keeping & Middlemiss (1883) and Kellaways Rock of Walker (1972).
Type locality: South Cave Station Quarry, near Hull Humberside (= Bed K, of Brasier & Brasier, 1978). Although limited in development to the North Humberside area, the Member here forms a discrete upper portion to the Kellaways Formation succession. Unlike the underlying poorly cemented sands, it consists of irregular beds of calcareous sandstone with frequent shelly patches. Where calcified, these yield a molluscan fauna including many ammonites. The diversity is, nevertheless, lower than that of the Kellaways Sand Member in Wiltshire, but consists of different taxa — details and some illustrations are given by Walker (1972). Calcitic ooliths are abundant in these calcified cores.

(d) Osgodby Formation (OYF) Author: Wright (1978) equivalent to the Kellaway Rock of Phillips (1829).
Type locality: Osgodby Nab, Cayton Bay, near Scarborough, North Yorkshire. Full details are given by Wright (1968, 1978).
Lithologies of this Formation are dominated by massive sandstones and sands, with several bands of chamosite-oolite sandstone and limestone. Wright (1978) proposed the formational name in order to distinguish the Callovian sands north of the Market Weighton Block from those to the south. Transitional facies do, however, occur and sands at Burythorpe, south of Malton (on the north-side of the Block) appear to be lithologically closer to the Humberside Kellaways Sand Member facies than anything further north (Wright, 1978, p. 250). The Osgodby Formation comprises three Members, named by Wright as the Kellaways Rock, the Langdale Beds and the Hackness Rock (1968, 1978). Only the first contains deposits of lower Callovian age and is renamed the Redcliff Rock Member to distinguish it from the distinct developments of the Kellaways Sand Member in the Wiltshire type area.

(z) *Redcliff Rock Member (RRM)*
New name for Kellaways Rock Member of Wright (1968, 1978).
Type locality: Redcliff, Cayton Bay, details given by Wright (1968, pp 371-72, Beds 3 to 11). This unit consists largely of massive sandstones with occasional calcareous concretions and a bed of chamosite-oolite sandstone and limestone. Wright recognised five correctable subdivisions of the Member, denoted

(e) Lower Oxford Clay (LOC)

No formal lithostratigraphical division of the Oxford Clay is attempted. Nevertheless, the basal part of the Lower Oxford Clay includes, in southern England, deposits of lower Callovian age. Recognised lithologies include:

(i) Dark bituminous shale — Weymouth, south Dorset.

(ii) Bluish grey shale, in part silty—Corscombe area, north Dorset.
(iii) Pale to medium grey mudstone (1.31 m recorded)—Tytherton No. 2 borehole, near Chippenham, Wiltshire (Cave & Cox, 1975).
(iv) Greenish 'greasy' clay with khaki coloured patches (= ? bituminous shale; 1.62m recorded— Kidlington, near Oxford; Callomon, 1955).
(v) Greenish grey shale (0.15m-0.2m)—Peterborough area (Callomon *in* Sylvester-Bradley & Ford, 1968).

Northwards, no further evidence is known of Lower Callovian rocks in Oxford Clay facies, and, in the Humberside area, the entire substage lies within the Kellaways Formation.

4. CHRONOSTRATIGRAPHICAL FRAMEWORK

Ammonites are the tools by which the standard chronostratigraphical correlation of Jurassic rocks is achieved, as they facilitate a much finer resolution than is available using any other fossil group. In the British Lower Callovian, much new information has been obtained on the succession of ammonite faunas and this has facilitated a revision of the standard zonals scheme proposed by Callomon (1955, 1964). Whereas two zones and five subzones were employed formerly, three zones and eight subzones can now be recognised. Even finer scale correlation is possible using horizons (as discussed by Callomon, 1985) and eighteen such units can now be recognised within the eight subzones and this represents nearly a four-fold increase in the stratigraphical resolution previously possible.

Full details of this new zonal scheme will be [published elsewhere, but a summary of the Subzonal I classification is given here so that a correlation of the jlithostratigraphical units described in Section 3 may be presented. A summary of a preliminary version of the sequence of horizons is in press (Callomon, Dietl & Page, 1988) which includes details of the precise level within a subzone that named taxa occur. So that the 'new zonation may be of immediate use, repre- 'sentatives of each subzonal index are illustrated in ;Figs. 5-8. In addition, a list of figures available in i other works is given after each named taxon. Figs 9 & • 10 demonstrate the revised zonation in English Lower Callovian rocks; and it emphasises the main non-sequences associated with this transgressive sequence.

\ (a) Herveyi Zone

Index fossil: Macrocephalites herveyi (J. Sowerby, 1818); Lectotype designated by Spath (1928, legend to plate 43, fig. 29b), based on larger figure of Sowerby (1818, PI. 195).
Author: Spath'(1932, p. 145); = Macrocephalus Zone *sensu* Callomon (1955).

Callomon's index of 1955 can no longer be used for this zone, since it occurs at a higher stratigraphical horizon within his Koenigi Subzone (Callomon *et al.*, 1988). An alternative index, *(M. herveyi)* had been proposed by Spath (1932) and is used here. The Herveyi Zone comprises three Subzones—

(/) *Keppleri Subzone nov.* (Fig. 5,1)
Index fossil: Kepplerites (K.) keppleri (Oppel, 1862). Buckman selected and figured a lectotype for the species (1922, PI. 289, A and B).
Defined base: The base of Bed 4, Berry Member, Swan Inn Quarry, Long Handborough, near Oxford (Douglas & Arkell, 1928, p. 129). Callomon notes *K. keppleri* in this bed (1971, p. 124 = "thin basal Upper Cornbrash").

The fauna is usually dominated by compressed and fine-ribbed macrocephalitid macroconchs belonging to the species *M. jacquoti* (Douville) and *M. verus* Buckman (lectotype of former refigured by Thierry, 1978, PL 27, fig. 1; neotype of latter figured by Callomon, 1971, PI. 17 (holotype lost, J. H. Callomon *pers comm)).* Typical microconchs have been figured by Thierry (1978, PI. 17, figs. 1-6).

Macrocephalitids are rare in the lowest part of the Subzone, but *K. keppleri* itself is typical (see also Tintant, 1963, PI. 1, fig. 1; PI. 2, fig. 1 and PI. 3, figs 1 & 2—the latter is a German specimen, and not from Yorkshire as stated by Tintant).

The perisphinctid *Homeoplanulites homeomorpha* Buckman occurs occasionally (Arkell, 1958, PI. 30 figs 1, 2; PI. 31, fig 4).

This corresponds to the lower part of the Macrocephalus Subzone of Callomon (1955). The Keppleri Subzone, in England, equates approximately with the *siddingtonensis* Biozone of Douglas & Arkell (1928).

(ii) Terebratus Subzone nov. (Fig. 5, 2). *Index fossil: Macrocep halites terebratus* (Phillips, 1829); Neotype selected and figured by Howard (1962, p. 124, PI. 19, fig. 1).
Defined base: Base of Bed <$r_{1(}$ Fleet Member, Cayton Bay, near Scarborough, North Yorkshire (Wright, 1977). Wright's Beds a, and a_2 have yielded, in the past, many examples of *M. terebratus* and most of the specimens in old collections labelled "Yorkshire" or "Scarborough" belong to this species group (the Sedgwick Museum in Cambridge contains a good selection, many *ex* Leckenby collection).

The characteristic ammonites are macroconchs of the index species. These are typified by inflated, relatively fine ribbed forms with very small umbilici and slight mid-ventral arching of the whorl section. Such morphs include the holotype and the specimen figured here. Microconchs now include round whorled relatively evolute variants comparable to the holotype of *M. bedfordensis* (Spath) (figured by Blake, 1905, PI.

4, fig. 1). Compressed variants include the holotype of *M. typicus* (Blake) (1905, PI. 3, fig. 1).

The only other species positively identified from the Terebratus Subzone in Britain is the extremely rare *Cadoceras (Paracadoceras) breve* Blake, known, definitely, from only one locality near Weymouth (1905, PI. 5, fig. 1 = holotype).

This Subzone corresponds to the upper part of Callomon's Macrocephalus Subzone (1955). The characteristic brachiopods of the Subzone are species intermediate in size and morphology between the small *M. siddingtonensis* and the large *M. lagenalis*, these include *M. siddingtonensis* var b (Douglas & Arkell, 1932) and *M. sublagenalis* (Davidson).

| (/«') *Kamptus Subzone* (Fig. 6, 1). *Index fossil: Macrocephalites kamptus* (Buckman
' 1922); Holotype figured originally by Blake (1905, PI.
! 3, fig. 7 and PI. 4, fig. 2) and refigured by Buckman
j (PI. 347). *Author:* Callomon (1955).
\ *Defined Base:* Base of Bed 5, Fleet Member, Thrapston Railway Station Quarry, Northamptonshire (section recorded by Douglas & Arkell, 1932, p. 130). Bed 5 contains an early fauna of *M.* ex grp *kamptus;* beds 2-4 yielding a species similar to M. *terebratus.*

The typical ammonite is a coarsely ribbed microconch variant, this includes the holotype of *M. kamptus* itself and the example figured here. Common more compressed and finer ribbed variants include the holotype of *M. dolius* (Buckman) (1922, PI. 372). Macroconchs are similarly variable, but again, the diagnostic variant is an inflated whorled coarsely-ribbed form. The only other ammonites known from Britain are rare specimens of *Homeoplanulites* sp.

The large brachiopod, *M. lagenalis* Douglas & Arkell *non* Schlotheim is common in and characteristic of the basal part of the Kamptus Subzone.

(b) Koenigi Zone

Index fossil: Proplanulites koenigi (J. Sowerby, 1820), lectotype designated by Buckman (1921, p. 36) and refigured by Arkell (1956, PI. 37, fig. 4). *Author:* Buckman (1913), as full Zone (=Zoenigi Subzone *sensu* Callomon, 1955).

Callomon (1955) demoted Buckman's Zone to the jevel of a Subzone. As further subdivision of the unit K now possible, full zonal status is revived and three component subzones defined.

(0 *Gowerianus Subzone nov.* (Fig. 6, 2).
Index fossil: Kepplerites (Gowericeras) gowerianus (J.
de C. Sowerby, 1827), holotype refigured by Tintant (1963, PI. 7, fig. 1).
Defined base: Base of Kellaways Clay Member, Chippenham (equivalent to Tytherton No. 3 borehole, at a depth of *22Am;* details given by Cave & Cox, 1975). The lowest part of the Kellaways Clay Member was once exposed in railway cuttings around Chippenham in Wiltshire; it here yielded large numbers of typical Gowerianus Subzone ammonites, now to be found in museums the world over (Callomon, 1964, p. 276).

The most abundant ammonites in the lowest part of the Subzone are variants of *P. koenigi* itself (Buckman, 1921-1926, Plates 213, 226-7, 232, 252, 281, 645; Clark, 1982, PI. 1 fig. 8, PI. 2 fig. 1, 6, 7). The diagnostic species nevertheless remain the keppleritids, *K. (G.) gowerianus* and *K. (G.) metorchus* (Buckman) (Buckman, 1921-1922, Plates 254 (holotype), 288, 336: Tintant, 1963, PI. 9, figs. 1-5; PI. 10, figs. 1-3). Macroconchs of both species typically possess round whorled body chambers with closely spaced primary ribs, but have more coarsely ornamented inner whorls with well developed lateral nodes. Only nuclei show well developed ventral tabulation. Microconchs, similarly, have a rounded whorl section and include a specimen figured by Buckman (1922, PI. 336). Two undescribed species of *Cadoceras (C.)* are common associates of the above, and *Chamoussetia* cf. *chamusseti* (d'Orbigny) occurs infrequently (Buckman, 1924, PI. 462 figures a compressed variant). Macrocephalitids are uncommon but include *M. lophopleurus* (Buckman) (1922-1925, Plates 284 (= holotype), 348, 433, 558) and *M.* cf. *macrocephalus* (Schlotheim) (neotype figured by Callomon, 1971, Plates 15, 16). The rarest ammonite in the British succession appears to be *Homeoplanulites* (//.) *lobatus* (Buckman) (1922, PI. 330 = holotype; see also Cox, 1988, PL 6, figs. 1, 3).

(ii) Curtilobus Subzone nov. (Fig. 7, 1).
Index fossil: Kepplerites (Gowericeras) curtilobus (Buckman 1922). Holotype figured by Buckman (1922, PI. 294).
Defined base: Base of Bed Ib, topmost Kellaways Clay Member, Dairy Farm Pit, Ashton Keynes, Wiltshire (see appendix for section).

The diagnostic ammonites of the Subzone are the keppleritids *K. (G.), curtilobus, K. (G.) indigestus* (Buckman) and *K. (G.) trichophorus* (Buckman) (holotypes of the latter two species figured in 1922, Plates 309 and 291 respectively). The macroconchs of all three species (which includes the holotypes) differ from those of earlier species by having relatively finely ribbed inner whorls but with coarser primary ribs on the body chamber. Ventral tabulation and a flatterning of septate whorl sides is now better developed. Microconchs may even develop a compressed *Sigaloceras-like* morphology, an example is figured by Buckman (1925, PI. 604). Cadoceratids are common or even locally abundant and include the doubtfully distinguishable *C. boreale* (Buckman) and *C. tolype* (Buckman). The holotypes of these two

species are, respectively, a micro- and a macroconch and were figured by Buckman (1919, PI. 21; 1923. PI. 406). Proplanulitids are also common and belong to *P. ferruginosus* (Buckman) (Buckman, 1921, PI. 253; Clark, 1982, P1.2, figs. 8 (=holotype), 3 and 7). Rare *Chamoussetia hyperbolicus* (Leckenby) also occurs, but primarily in North Yorkshire (the lectotype is here taken to be the specimen figured by Buckman, 1914, PI. 98 A and B).

The well-known fauna of division /3_2 of the Redcliff Rock Member, on the Yorkshire coast, belongs entirely to this Subzone.

(HI) *Galilaeii Subzone nov.* (Fig. 7, 2). *Index fossil: Kepplerites (Gowericeras) galilaeii* (Oppel, 1862)—lectotype designated and figured by Buckman (1922, PI. 290).

Defined base: Base of Bed 7, Kellaways Sand Member, South Cerney Railway Cutting (section described by Harker, 1884). Evidence from old collections, made in the cutting itself, and from recent temporary excavations around South Cerney, incicate that this bed yields abundant faunas of both the Galilaeii and the later Calloviense Subzones. The section recorded by Harker is the best available in the area and, therefore, is used as the boundary stratotype for the Subzone.

The large keppleritid *K. (G.) galilaeii* is typical, and shows many features transitional to *Sigaloceras* of the Calloviense Subzone. In macroconchs this includes very finely ribber inner whorls with a degree of flattening of the whorl sides and venter throughout ontogeny (examples figured by Buckman, 1922, PI. 293: Tintant, 1963, PI. 4, figs. 1, 2; PI. 5, figs. 1, 2; PI. 6, figs. 1, 2). Microconchs of *K. galilaeii* can be virtually indistinguishable from those of 5. *calloviense.*

Two other diagonostic species are abundant, these are the heteromorph *Parapatoceras distans* (Baugier & Sauze), which includes *P. crioconus* (Buckman, 1925, PI. 538 A and B), and also a small smooth undescribed *Cadoceras,* with finely ribbed inner whorls which was compared by Spath to the Middle Callovian *C. tchefkini* (d'Orbigny) (1926, p. 60). Rare specimens of an undescribed species of *Macrocephalites* are also known at this level.

(c) Calloviense Zone

Index fossil: Sigaloceras (S.) calloviense (J. Sowerby, 1815). Lectotype selected and figured by Arkell (1933, PI. 36, fig 5). *Author:* Oppel (1856).

The Calloviense Zone, as used here, equates broadly with that used originally by Oppel himself, and not the expanded zone of Callomon (1955). The current usage is essentially Callomon's zone minus his Koenigi Subzone.

(/) *Calloviense Subzone* (Fig. 8, 1).

Index fossil: as for full Zone.

Defined Base: Base of the Kellaways Sand Member banks of the River Avon, west of West Tytherton' (and south of Kellaways), Wiltshire (see definition of the Member for further details). *S. (S.) calloviense* and 5. *(S.) micans* Buckman are the diagnostic species of the Subzone (holotype of latter figured Buckman 1921, PI. 255). Both the macro and microconchs of these species are involute compressed and fine ribbed forms, with flattened whorl sides and a well developed tabulate venter. A typical microconch of 5. *(S.) calloviense* was figured by Buckman (1925, PI. 586). Other specimens illustrated by Tintant (1963, PI. 23, figs. 1 & 2) appear to be microconchs of 5. *micans.* Additional figures of macroconchs of *S. calloviense* and 5. *micans* can also be found in Tintant's work (PI. 19, fig. 1 and PI. 22, fig. 1 respectively). *Proplanulites petrosus* Buckman is a common associate of *Sigaloceras (S.);* this species probably includes all the nominal species described from the Wiltshire "Kellaways Rock" by Buckman (1921-4; Plates 228, 260, 399, 507: Clark, 1982, PI. 1. figs. 3-6, 9, 11; PI. 2, figs. 2, 3, 5). *Cadoceras sublaeve* (J. Sowerby) also occurs commonly (lectotype of *sublaeve* refigured by Callomon, 1985, text fig. 8.N; see also Buckman, 1922, PI. 275).

The Subzone contains the greatest number of Tethyan elements known in the British Lower Callovian, these include *Parapatoceras calloviense* (Morris) (lectotype figured by Buckman, 1925, PI. 537), *Reineckeia britannica* Zeiss 1956 (holotype figured by Buckman, 1925, PI. 587), *Homeoplanulites (lAnaplanulites)* sp., *Paralcidia* sp. and *Macrocephalites* sp. Only *P. calloviense* is ever common; all the other species are rather rare.

(H) *Enodatum Subzone* (Fig. 8, 2-3). *Index fossil: Sigaloceras (Catasigaloceras) enodatum* (Nikitin, 1881).? Lectotype refigured by Tintant (1963, PI. 24. fig. 1).

Defined Base: Base of lower "oyster" band, topmost Kellaways Sand Member, South Newbald Quarry, (section briefly described and illustrated by Walker, 1972, p. 114 and Fig. 3.A).

The fauna of this unit is dominated by 5. *(C-) enodatum* and similar species (including 5. *anterior* (Brinkmann)) (holotype of latter (a microconch), figured Brinkmann 1929, PI. 3, fig. 1), which are all smaller than those found in the Calloviense Subzone. Macroconchs have round ventered body chambers and microconchs a smooth mid-ventral band flanked by nodes, and these features are also typical of their immediate descendants e.g. *Kosmoceras (Gulielmiceras)* spp. Additional specimens figured by Tintant (1963) include macroconchs (PI. 24, figs. 2, 3, 5; PI. 33, figs. 1-3) and microconchs (P1.51, figs. 5-6) of *S. (C.) enodatum* and other species. Other typical

species of the British succession are the locally common *Homeoplanulites (Anaplanulites) difficilis* (Buckman) (1922, PI. 329 = holotype; well illustrated by Cox, 1988, P1.2, figs. 1-6, PI. 3, figs. 1-3, PI. 4, fig. 1, PI. 5, fig. 2) and *Cadoceras (C.) durum* (Buckman) (1922, PI. 283 = holotype). Only one other taxon has been recorded in England, a macrocephalitid provisionally referred to *M. tumidus* (Reinecke) and this species is discussed by Callomon, 1971, p. 122.

MIDDLE CALLOVIAN

(d) Jason Zone
Index fossil: Kosmoceras (Gulielmiceras) jason (Reinecke 1818). *Author:* d'Orbigny (1852).

(«') *Medea Subzone*
Index fossil: Kosmoceras (Gulielmiceras) medea (Callomon), (1955, PI. 2, fig. 1 = holotype).
Author: Callomon (1955)
Defined Base: Base of Bed 9, Lower Oxford Clay, Kidlington, near Oxford (Callomon, 1955).
The first occurrence of *Kosmoceras sensu stricto* at the
base of Medea Subzone correlates the base of the Middle Callovian and, therefore, defines the top of the Lower Callovian.

5. HISTORY OF SEDIMENTATION

Late Bathonian sedimentation in northern England took place in an estuarine or deltaic environment and created the Scalby Formation. Southwards a lateral passage occurs through brackish marine deposits of the Blisworth Clay Formation in the East Midlands into the less restricted environments of the Forest Marble Formation from Oxfordshire to Dorset. The subsequent establishment of normal salinity shallow-marine conditions over most of England led to the deposition of the Berry Member. Only in North Yorkshire do restricted conditions appear to have persisted until later. The evidence suggests that a broad shelf existed north of Oxford since the total thickness of the Abbotsbury Cornbrash and Kellaways Formations is remarkably uniform over this area. In the mid-Somerset to mid-Wiltshire area, however, some form of structural high, or perhaps the shelf edge, appears to have been developed and deposits are often dominated by the cross-bedded coarse shell sands of the Corston Beds. Evidence of submarine erosion in this region includes common hardgrounds and even "boulder-beds" (Douglas & Arkel, 1928, p. 136).

Further south, the combined Fleet Member/Berry Member succession thickens into the Wessex Basin and non-sequences become less important. A widespread non-sequence at the Fleet/Berry Member junction exists over most of England north of mid-Somerset, and it is only in the more southerly areas that deposits of Lower Callovian, Keppleri Subzone age remain widespread—although sporadic occurrences exist in Gloucestershire and Oxfordshire. A sudden influx of muddy sediment abruptly termined Fleet Member deposition during the Kamptus Subzone. The dark shales, phosphatic nodules and comparatively low-diversity benthos of the Cayton Clay Formation suggest some form of environmental restriction.

In southern England, the overlying Kellaways Formation consists largely of sandy or silty clays with a richer bivalve fauna. This passes upwards and northwards into the more sandy deposits of the Kellaways Sand Member. Although information is limited regarding the thickness of the Kellaways Formation in the south (between north Wiltshire and Oxford) a remarkable thinning occurs, which appears related to the edge of the London-Brabant Massif. To the north, a broad shelf is again suggested by thin deposits of very uniform thickness. Environmental instability with possible sediment reworking is indicated by opportunistic benthic assemblages of gryphaeate oysters *(Catinula* and *Gryphaea* spp.) and byssally attached bivalves *(Oxytoma* and *Meleagrinella* spp.). Ammonites are generally rare or poorly preserved, so that the probable large number of local non-sequences cannot yet be chronostratigraphically identified.

Equivalent strata in North Yorkshire are isolated from those further south by the tectonic activity associated with the Market-Weighton Block. A long seafloor residence time appears to be indicated in the region by the chamosite-ooliths which typify the Yorkshire Callovian succession. In southern England, increased deepening led to the deposition of the Lower Oxford Clay and the basin was sufficiently restricted to allow stratification of the water column and laminated bituminous shale to be deposited. The sequence is interupted in northern England by a disconformity which cuts out the highest part of the Lower Callovian. The distinctly flexed appearance of the Redcliff Rock Member on Fig. 4 suggests that syn-sedimentary tectonic activity is, at least in part, responsible for this non-sequence.

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APPENDIX

New **or undescribed Lower Callovian Sections of nomenclatorial importance**

A. Berry Knap, near Abbotsbury, Dorset (SY 585830)

Abbotsbury Cornbrash Formation-Fleet Member

14. Band of irregularly sized and rounded sandy limestone concretions, often with fossiliferous *c.* 0.1 m
cores-Microthyridina cf. lagenalis and *Entolium* sp. abundant, also rare *Macrocephalites* sp., aff *terebratus* (Top of *in-situ* section).
13. Silty sand, brownish coloured. c. 0.3m
12. Calcareous sandstone. Top of bed irregular (with *Thalassinoides* burrows?); base of bed passes into a 0.4 m
concretionary sandy limestone band. Buff to pale grey colour.
11. (as 13).
10. Sandy limestone, burrowed: rhynchonellid brachiopods present. Buff to pale grey colour. 0-2 m
9. (as 13).
8. Sandy limestone with undulating surfaces. *Microthyridina* cf. *siddingtonensis* present. Buff to pale grey colour. 0.3 m 7. Silty sand, brownish coloured with flaggy bedding and burrows.
6. Double row of irregularly sized concretions of greyish sandy limestone; *M. siddingtonensis.* *c.* 0.4 m
5. Sand, flaggy bedded, burrows and *Liostrea* sp. present. 1.6 m
4. Irregular beds of sandy limestone with thin sandy seams. Buff colour. Serpulids and burrows present. 0.7 m

Berry Member

3. Marly and rubbly limestone; consists of small concretionary lumps of micritic and bioclastic limestone in a marly matrix rich in shell fragments. Pale greyish to white colour. *Clydoniceras discus* (Sowerby) collected *in-situ*, also *Obovothyris obovata*, *Kallirhynchia yaxleyensis* (Davidson), *Meleagrinella echinata* (Sowerby), *Modiolus* sp., *Pleuromya* sp. and *Liostrea* sp. Douglas and Arkell's records (1928, p. 153) suggest the following also occur in this bed: *Homeoplanulites* sp., *Obovothyris grandobovata* (Buckman) and *Ornithella classis* Douglas & Arkell. 1.45 m

Berry Member; Intermedia Bed

2. Bioclastic and micritic limestone, flaggy bedded, in up to four bands separated by marl with shell-grit. Pale buff to yellowish or pale greyish in colour. *Meleagrinella echinata* abundant at top, with *Liostrea, Pleuromya* and other poorly preserved bivalves throughout. 1.25 m

1. Rubbly and marly limestone, generally similar to Bed 3, but sandy in part and containing common *Cererithyris intermedia* and *K yaxleyensis;* also *Pleuromya* cf. *uniformis* (Sowerby), *Liostrea* sp., *Chlamys (Radulopecten)* sp. and serpulids. 0.45 m seen

Gap in exposure, Forest Marble Formation Clays seen below.

It should be noted that the above exposure lies within the Abbotsbury Swannery Nature Reserve which restricts access.

B. Dairy Farm Pit (Morelon C. Cullimore Ltd.), Ashton Keynes (SU 03759400)

River gravel with derived fossiliferous blocks of Kellaways Formation and other Jurassic Rocks.

Kellaways Formation; Kellaways Sand Member.

3c. Calcareous sandstone, thin to flaggy bedded. Largely decalcified but containing occasional weathered shelly concretions. Rusty to buff coloured. Oysters and crinoid debris present, also fragmentary ammonites including *K. (Gowericeras) trichophorus, Proplanulites* aff. *ferruginosus* and *Cadoceras* sp. 0.3 m seen

3b. Calcareous sandstone, often iron-stained, grey when fresh. Passes down into bed below. Local masses of *Microthyridina* ex grp *calloviensis* (Douglas & Arkell) present and occasional bivalves—*K. (Gowericeras) indigestus* and *P. ferruginosuks* common, also *Cadoceras* sp. present. 0.25 m

3a. Calcareous sandstone, massive, medium to bluish grey colour. Shelly accumulations towards the centre of the bed contained mainly *Cadoceras tolype,* with occasional *K.* (G.) *indigestus* and *P. cfferruginosus,* also *Belemnoteuthis* sp. *Pinna* sp. and some patches of *Bositra* sp. 0.3-0.35 m

2. Sandstone, relatively soft and argillaceous, with harder and better cemented lenticles and occasional black phosphate concretions — *K. (Gowericeras) curtilobus, P.* cf. or aff. *ferruginosus* and *Cadoceras* sp. nov. present. Large specimens of the of the latter may be partially embedded in the base of bed 3a. 0.35-0.4m

Kellaways Clay Member

Ib. Fine grained silty sand—medium to pale grey colour. Contains ammonite body chambers preserved in pale-brownish phosphate—*K.* (G.) cf. *curtilobus, Cadoceras* sp. *c.* 0.6 m

la. Fine grained silty sand, becoming more muddy in lower part.

waterlevel

c. 3.5m seen

The above exposure was seen in 1985-86 in an excavation in the base of a gravel pit. By mid 1987, however, work has ceased and the pit is now entirely flooded.

C. Shipton-on-Cherwell Cement-works Quarry (= Blue Circle Oxford Works).

The following is a generalised section, measured between SP 477171 and 476173.

Cayton Clay Formation

Traces of medium-grey coloured clay seen above *in-situ* exposure.

Abbotsbury Cornbrash Formation; Fleet Member

8. Limestone, sandy and calcarenitic. Brownish coloured—recognisable fossils uncommon. c. 0.25m seen

7. Marl, brownish and rusty-coloured; fauna includes: *Mi.* cf. *lagenalis, Rhychonelloidea cerealis* Buckman and *Lopha* cf. *marshii* (Sowerby). 6. The top surface of Bed 7 is, locally, a thin layer of brownish coloured, dark flecked, argillaceous limestone. It is firmly cemented to Bed 5 below and infills borings in that bed. It also contains small (<1 cm) pebbles of Bed 5. A fragmentary ammonite is present, possibly a macrocephalitid.

***Berry** Member; Astarte-Trigonia Bed*

5. Shelly and micritic limestone, slightly argillaceous in places; grey in colour when unweathered. Contains abundant shells (especially towards the top) best seen on weathered surfaces, which include *Astarte hilpertonensis, Trigonia* s.s., *Mel. echinata,* etc., also *Anabacia* sp., a terebratulid and *Clydoniceras discus.* Top surface is a hardground, with borings. 0.7-1.05 m

Berry Member (obovata Biozone)

4. Limestone, marly and rubbly, with some marl seams. Common bivalves include: *Mel. echinata, Gresslya* sp. and *Pleuromya* sp. 0.95-1.05 m

3. Limestone, calcarenite, buff coloured and shelly, passes up into more flaggy and marly limestone. Many shells, including *O. obovata, Mel. echinata* and *Liostrea*, sp. and serpulids. 0.35-0.5 m

2. Marl seam, passes up from bed below, abundant shells include *C. intermedia, Mel. echinata* and *Liostrea* sp. 0.05 m

Berry Member; Intermedia Bed

1. Limestone, calcarenitic with some micritic patches—buff coloured. Contains many "nests" of *C. intermedia,* 0.1-0 2m also *Mel. echinata, Chlamys (Radulopecten)* sp., *Pleuromya,* etc. A *Thalassinoides* burrow system is locally developed on the base of the bed.

Forest Marble Formation

Clay, pale greenish grey colour. Immediately below the Abbotsbury Cornbrash Formation, scattered chalky c. 1 m
nodules, up to 5cm in diameter, are developed.

(Shelly limestone band below)

Although noted previously by Arkell (1947, p. 58), a section was not given as the exposure was regarded at that time as being inaccessible and duplicated elsewhere. The absence of the Intermedia Bed at neighbouring localities is, however, noteworthy (e.g. absent at Upper Greenhill Quarry; 1947, p. 59).

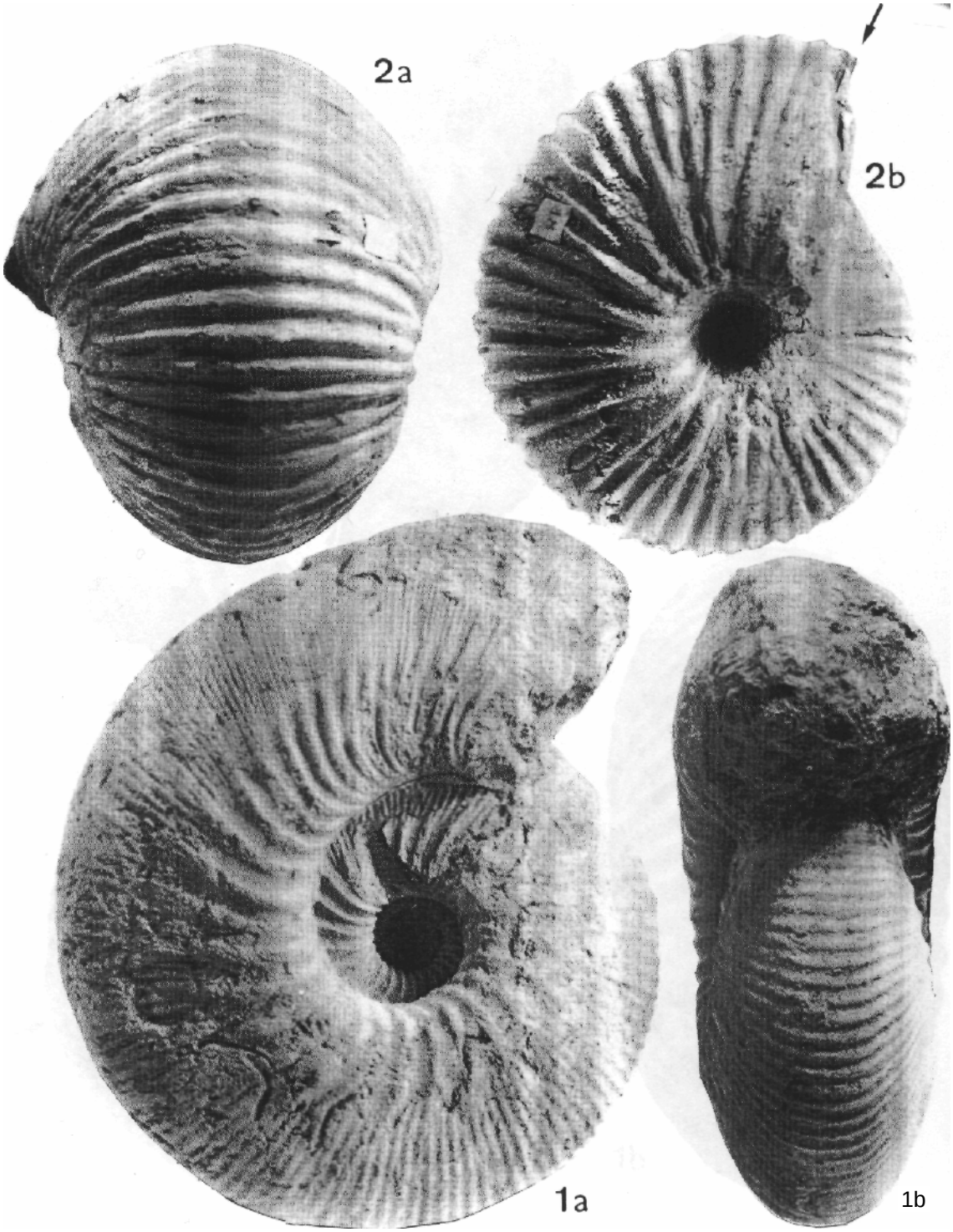

Fig. 5. KEPPLERI SUBZONE. la,b *Kepplerites (K.) keppleri* (Oppel, 1862), Oxford University Museum collections J14014); macroconch, mature, small variant (specimens typically mature at up to 150 mm diameter). Topmost Berry Member, Long Handborough, near Oxford; probably from a level equivalent to Bed 4 at the Swan Inn quarry (Douglas & Arkell, 1928. p. 129).
TEREBRATUS SUBZONE. 2a,b *Macrocephalites terebratus* (Phillips, 1829), Sedgwick Museum Cambridge, Jl^3 (Leckenby collection). Inner whorls of typical macroconch (septation not visable). Fleet Member, Scarborough, Noru> Yorkshire; probably from bed a_2 of Wright (1977).