A STRATIGRAPHICAL, PALAEOECOLOGICAL AND BIOMETRICAL STUDY OF SOME ENGLISH BATHONIAN GASTROPODA (ESPECIALLY NERINEACEA)

by

M. J. BARKER, B.Sc. (Man.)

Thesis submitted for the degree of

Doctor of Philosophy,

The University of Keele,

1976.

To my wife and son.

CONTENTS

Page

CHAPTER 1 - The gastropod faunas and stratigraphy of the Bathonian White Limestone of the N. Cotswolds and Oxon.

CHAPTER 2 - A taxonomic revision of English Bathonian Nerineacean gastropods (including a non-Nerineacean Homeomorph)

CHAPTER 3 - A biometrical study of the Nerineacea from the White Limestone (Bathonian).

CHAPTER 4 - The internal morphology of the Nerineacea

CHAPTER 5 - The palaeobiology of the Nerineacea

The relationship between the internal anatomy, the folds and the mode of life of the Nerineacea

b) The mode of life -

CHAPTER 6 - Taphonomic processes

Epibiontic colonisation of Nerineid shells

CHAPTER 7 - A brief geological history of the Nerineacea

Abstract

The stratigraphy of the Bathonian White Limestone Formation (M. Jurassic: Subcontractus - Retrocostatum zones) has been re-examined and the Formation is divided into three Members instead of the previous two; the new Excavata Beds at the base, the Ardley Beds and the Bladon Beds at the top. These are based upon gastropod subzones using species of the Nerineid genus *Aphanoptyxis* - *A. excavata* sp. nov., *A. ardleyensis* and *A. bladonensis*. A more precise internal correlation and zonation of the White Limestone, which agrees with the known ammonite distribution both in the White Limestone and elsewhere, is thereby achieved.

The abundant gastropod *Eunerinea arduennensis* has previously been mis-identified as *Eu. eudesii* and considerable taxonomic changes amongst representatives of the genus *Bactroptyxis* and other Nerineacean genera are proposed. A new genus *Zenoplocus* (type-species *Zenoplocus microplicatus* gen. et sp. nov.) is described together with three other new gastropod species; *A. excavata*, *A. compressa* and *Fibula reticulata*. *Rigauxia*, *Endiaplocus* and *Fibuloptyxis*, genera previously best known from the French Bathonian, are shown to be abundant in the English Bathonian.

Biometric analyses indicate that growth in Bathonian Nerineids was essentially isometric. A short evolutionary lineage from *A. excavata* through *A.* cf. *langrunensis* to *A. ardleyensis* has been documented from the Excavata and Ardley Beds and computer studies using multivariate stepwise discriminant analysis have facilitated species descrimination.

The helically coiled duct system in the digestive gland/gonad in Nerineid gastropods has been described. This together with a new interpretation of the biological function of Nerineid folds suggests that these gastropods occupied several ecological niches (both infaunal and epifaunal) in carbonate substrates but were essentially deposit feeders. The stages of epibiontic colonisation, shell destruction and diagenesis have been outlined. *Laevinerinea* and *Aptyxiella* are shown to possess crossed-lamellar shell microstructures.

It is suggested that the Nerineacea may best be regarded as primitive Caenogastropods (Prosobranchs) and problems of their further classification are disucssed.

Introduction

In October 1968, at the suggestion of Dr. H. S. Torrens, the author visited Blisworth quarry (G.R. SP 715533) and there first collected several Nerineid gastropods - specimens of B. implicata. The fascination of these unique gastropods has resulted in this thesis and still continues.

Horizons containing abundant representatives of the Nerineacea are found throughout the Middle Jurassic (Bathonian) White Limestone Formation of England. The paucity of ammonites (the usual zonal indices of the Jurassic) in this geographically widespread and rather thick formation (see Chapter 1) led that revered figure of Jurassic geology - Arkell - to use the ubiquitous Nerineid gastropods found in the White Limestone for its internal correlation and zonation (Arkell, 1931). The White Limestone remains the only formation in the British stratigraphic succession to be zoned using gastropods.

It was immediately apparent that two problems were particularly outstanding;

1) No satisfactory explanation had yet been offered to account for the strange internal morphology of these Nerineid gastropods.
2) The stratigraphical utility of Nerineid gastropods in the White Limestone was urgently in need of reappraisal bearing in mind the recent advances in European Bathonian stratigraphy (largely through the work of Torrens, 1967a and b, 1969).

The solution of these problems involved many facets of palaeontology and inevitably widened the scope of this thesis. A taxonomic revision of the Nerineid gastropod faunas in the White

Limestone was a much-needed, necessary precursor to further work and the problem of species discrimination was partially resolved with the aid of biometrical and statistical analyses.

In palaeontology, speculations upon the former life of an organism must also recognise and take into account post-mortem processes and data-loss consequent upon fossilisation. The study of the destruction, colonisation and alteration of Nerineid gastropod shells after death provided information not only upon their mode of life but also about the depositional regimes of the White Limestone and the broad palaeogeography of Bathonian times. Consideration was also given to the vexed problem of the taxonomic affinities of the Nerineacea and their distribution in time and space. Hence the scope of this thesis.

Natural exposures in the White Limestone are extremely rare and the pits, quarries and cuttings formerly available are not now as numerous as they once were. The increasing ease of communication and transportation together with the decline in the use of lime for agricultural purposes, the contraction of the railway network and especially the increased need for refuse disposal are rapidly depleting inland exposures everywhere. Consequently many of the shallow pits described in the literature (particularly by Richardson, 1929 and 1933) are no longer accessible. However, most of the larger pits are still available for study and the position with respect to exposures in the White Limestone appears to be relatively stable at the present time. Indeed the north-west face of Foss Cross quarry has been designated a site of Special Scientific Interest.

Although the interpretations presented in this thesis are based primarily upon data and specimens collected by the author, taxonomic revisions and the interpretation of those exposures no longer available could only be facilitated by the study of type-specimens and museum collections. In this context the following museums and collections were the principal ones visited.

British Museum (Natural History) - collections of:-

Blake, J.F. - divided between the B.M. and I.G.S.M.

Channon, P.J.

Donovan, D.

Morris, J. - not complete, some specimens reported from as far away as Australia (Torrens, 1975).

Sharp, S.

Slatter, T.J.

Witchell, E. - some of Witchell's types (notably *Ptygmatis velox*) were taken from the Hudleston collection and may now be found at the Sedgwick Museum, Cambridge.

Institute of Geological Sciences Museum - collections of:-

Blake, J.F. - (part).

Geological Society's collections.

Geological Survey official collections.

Lycett, J.

Richardson, L.

Oxford University Museum - collections of:-

Arkell, W.J.

Parker, J.

Sharpe, D. - (part).

Walford, E.A.

Sedgwick Museum, Cambridge - collections of:-

Hudleston, W.H.

Leckenby, J.

Muséum National d'Histoire Naturelle, Paris

Specimens sent by Dr. J.-C. Fischer from the following collections: d'Orbigny, Fischer, J.-C., Fischer, H., Le Mesle, Peron and Piette.

No special techniques were used during the course of this study except perhaps for the use of X-ray radiography. However, the problems of using a fixed focus X-ray source (the only apparatus then available to the author) together with the poor density contrast between the fossils and their matrix, did not produce sufficiently encouraging results to warrant further work at that time.

Median sections of the gastropods were prepared by slicing the specimens on a diamond saw which in the case of the more acicular species was not without considerable digital danger. The specimens were sliced to one side of the columella and the final median section was achieved by using various grades of abrasive grit.

Most of the taphonomic and biometric data were taken from acetate peels or photographic enlargements of these peels but only sections which were truly median were used for biometric analysis. Modal analyses were prepared by point-counting rock slices.

Acknowledgements

This study was undertaken whilst the author was a Demonstrator in the Department of Geology, University of Keele and subsequently a Lecturer in the Department of Geology, Portsmouth Polytechnic.

The financial and technical support provided by Professor F. W. Cope at Keele University, Dr. J. R. Vail at Portsmouth Polytechnic and their respective staffs is gratefully acknowledged.

The staffs of the various museums visited all readily provided access to the collections in their care. Quarry managers, workmen and farmers have allowed necessary access to the many quarries and sections studied and their co-operation is appreciated.

Dr. J.-C. Fischer kindly sent specimens from various French collections in the Muséum National d'Histoire Naturelle, Paris, which together with his researches on the French Bathonian and correspondence with the present author, have proved invaluable during the course of this study.

Discussions with Mr. R. J. Cleevely, Professor A. Graham, Dr. L. Karczewski, Dr. W. S. McKerrow, Dr. N. J. Morris, Dr. T. Palmer, Dr. I. Penn, Dr. J. A. Taylor and J. Wieczorek have helped immeasureably. Drs. T. Getty, D. Hughes and G. Power kindly read sections of the manuscript. To these and many other friends and colleagues not mentioned specifically, I am most grateful for their helpful interest.

The final preparation of the thesis was made easier by the help of Miss E. Dobson and the cartographic skill of Mr. P. Fewings.

Mr. J. Vigay prepared the plates in spite of a broken shoulder and Miss J. Cole efficiently typed and deciphered the manuscript.

Above all I thank Dr. Hugh Torrens for supervising this project and in particular for his bibliographic, taxonomic and stratigraphic expertise.

Finally I thank my wife for her endless patience, encouragement and keen eyesight.

Chapter 1

THE GASTROPOD FAUNAS AND STRATIGRAPHY OF THE BATHONIAN WHITE LIMESTONE OF THE NORTH COTSWOLDS AND OXFORDSHIRE

'If there are obstacles, the shortest line between two points may be the crooked one.'

Bertolt Brecht, 1938.

General stratigraphic framework

The pioneer work of William Smith on the Middle Jurassic of England in the 1790's resulted in a tripartite lithological division of what is now called the Bathonian stage, into the Fullers Earth, the Great Oolite and the Forest Marble. The area to be described lies in the North Cotswolds and in Oxfordshire between Dagham Downs quarry (SP 002061) and Croughton quarry (SP 562336) (see Fig. 1.1). Stratigraphically,the succession studied is the lateral equivalent of the Upper Fullers Earth of William Smith and lies largely within the White Limestone subdivision of Hull (1857, p. 62 and 1859, p. 19).

The full Bathonian sequence in the area is as follows (Torrens, 1968; McKerrow & Kennedy, 1973; Sellwood & McKerrow, 1974):

Lower Cornbrash
Forest Marble
White Limestone
Hampen Marly Formation
Taynton Limestone
Sharps Hill Formation (inc. Stonesfield Slate)
Chipping Norton Formation
? Hook Norton Formation (pars.)

The rapid and complex changes in lithology and associated fauna as one passes from the fully marine sequence in the Cotswolds across the Oxfordshire "shallows" into the fluviatile clastic sequences of the Midland province is scarcely reflected in the above table. Within the area exposures are scarce, frequently temporary, necessitating

1. Dagham Downs quarry (SP 999061) see Fig. 1.6.
2. Foss Cross quarry (SP 055092) see Fig. 1.7.
3. Stony Furlong railway cutting (SP 063105) see Fig. 1.8.
4. Composite section at Signet (SP 248100) see Fig. 1.9.
5. Sturt Farm quarry (SP 271109) see Fig. 1.10.
6. Worsham (Asthall) quarry (SP 300119) see Fig. 1.12.
7. Minster Lovell quarry (SP 318109) see Fig. 1.13.
8. Eton College quarry (SP 297102) see Fig. 1.11.
9. North Leigh (Fish Hill) quarry (SP 389141) see Fig. 1.14.

10. Slape Hill quarry (SP 425196) see Fig. 1.5.

11. Shipton Cement Works (Bunkers Hill) (SP 474175) see Fig. 1.15.

12. Enslow Bridge (Gibraltar) quarry (SP 478186) see Fig. 1.16.

13. Kirtlington old cement works (SP 494199) see Fig. 1.17.

14. Ardley Fields quarry (SP 541265) see Fig. 1.18.

15. Stratton Audley (Elm Farm) quarry (SP 601255) see Fig. 1.20.

16. Croughton quarry (SP 563335) see Fig. 1.19.

17. Great Rollright quarry (SP 323302) see Fig. 1.21.

18. Blisworth quarry (SP 715533) see Torrens, 1967, p. 68.

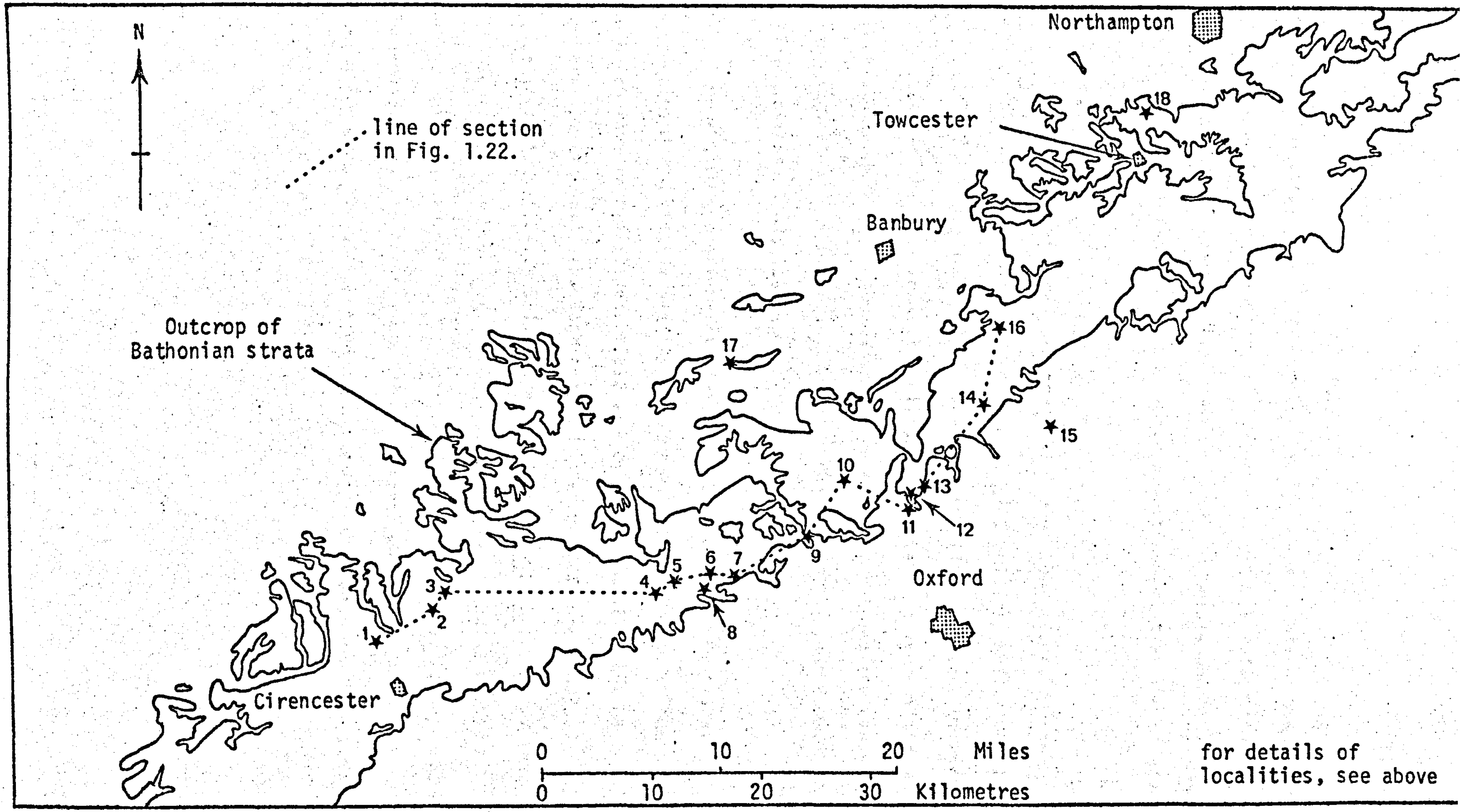


Fig. 1.1. Principal extant sections showing the White Limestone.

a reliance on previous records which are often inadequate or ambiguous in the context of recent advances. Consequently the stratigraphic interpretations of the considerable number of geologists who have worked on these strata, have a variance almost as great as the strata themselves.

The broad temporal relationships of the various formations were established by early workers such as Hull (1857, 1859), Hudleston (1878), Walford (1883), Woodward (1894) and Richardson (1911). Later workers have extended the geographical applicability of the early work and, with increasing knowledge of the major facies changes, refined the classification (e.g. Welch, 1926; Arkell, 1931; Channon, 1950; Worssam & Bisson, 1961; Torrens, 1967; Sellwood & McKerrow, 1974).

However, many problems still exist. Some of the formational boundaries are extremely difficult to recognise other than in the area in which they were first described and the formational status of some members, particularly the Hook Norton Formation (Walford, 1883, p. 237), is still controversial. Sellwood and McKerrow (_op. cit._) suggest that lithologically the Hook Norton Formation is a local, basal member of the Chipping Norton Formation; whereas Torrens (1968, p. 227-8) presents palaeontological evidence (based on ammonites) which indicates the Hook Norton Formation is of Upper Bajocian/Lower Bathonian age with a possible non-sequence between it and the Chipping Norton Formation above.

The lower boundary of the White Limestone Formation.

The predominantly carbonate lithologies of the White Limestone overlie an argillaceous group of strata called the Hampen Marly Formation. They were first described as Marly Beds by Woodward (1894, p. 292) from the Hampen railway cutting near Notgrove and subsequently recognised by Richardson (1929 and 1933) in various localities in the North Cotswolds and West Oxfordshire. In view of the importance of these beds and their wide distribution (see Figs. 1.2 and 1.3) Arkell (1931, p. 612) considered that they warranted a specific name and named them the Hampen Marly Beds with the type section in the Hampen railway cutting.

To the north-east they are assumed to expand into the Upper Estuarine Series of the Midlands (Arkell, Richardson & Pringle, 1933, p. 349), probably at the expense of the lower division of the White Limestone.

In a boring at Latton, south of Cirencester (Arkell, 1933, p. 181-3) no Hampen Marly Beds were recognisable, thus providing a south-western geographical limit. However, they are present in the Stony Furlong railway cutting, 15 kilometres (9.5 miles) north of Latton, but their thickness is difficult to ascertain. According to Richardson (1933, p. 63), a very distinctive bed (bed 33 of Richardson, 1911, p. 111 and the "Organic Bed" of Harker, 1890) containing abundant <u>Praeexogyra hebridica</u> "would appear to be contemporaneous with the Hampen bed, but the upper and lower limits of the Marly beds here (i.e. at Stony Furlong) can only be suggested". Richardson (1933, p. 61)

1. Stony Furlong railway cutting (SP 063105) see Richardson, 1933, p. 61.

2. Hampen railway cutting (type-section) (SP 059202) see Richardson, 1929, pp. 104-5.

3. Windrush quarries (SP 188128) see Richardson, 1933, p. 43).

4. Little Barrington quarries (SP 207123) see Richardson, 1933, p. 44.

5. Taynton quarries (SP 237154) see Richardson, 1933, p. 44.

6.

7.

8.

9.

10.

11.

Groves quarry, Milton-under-Wychwood (SP 256157) see Richardson, 1910, p. 539.

Swinbrook quarry (SP 278124) see Woodward, 1894, p. 305.

Whitehall Wood railway cutting (SP 395156) see Arkell, 1931, pp. 612-3.

Wood Eaton quarry (SP 535122) see Palmer, 1973, p. 59.

Danes Hill (SP 469293) see Torrens in Sylvester-Bradley and Ford, 1968, p. 254.

Ardley railway cutting (SP 529278) see Arkell, Richardson and Pringle, 1933, pp. 344-6.

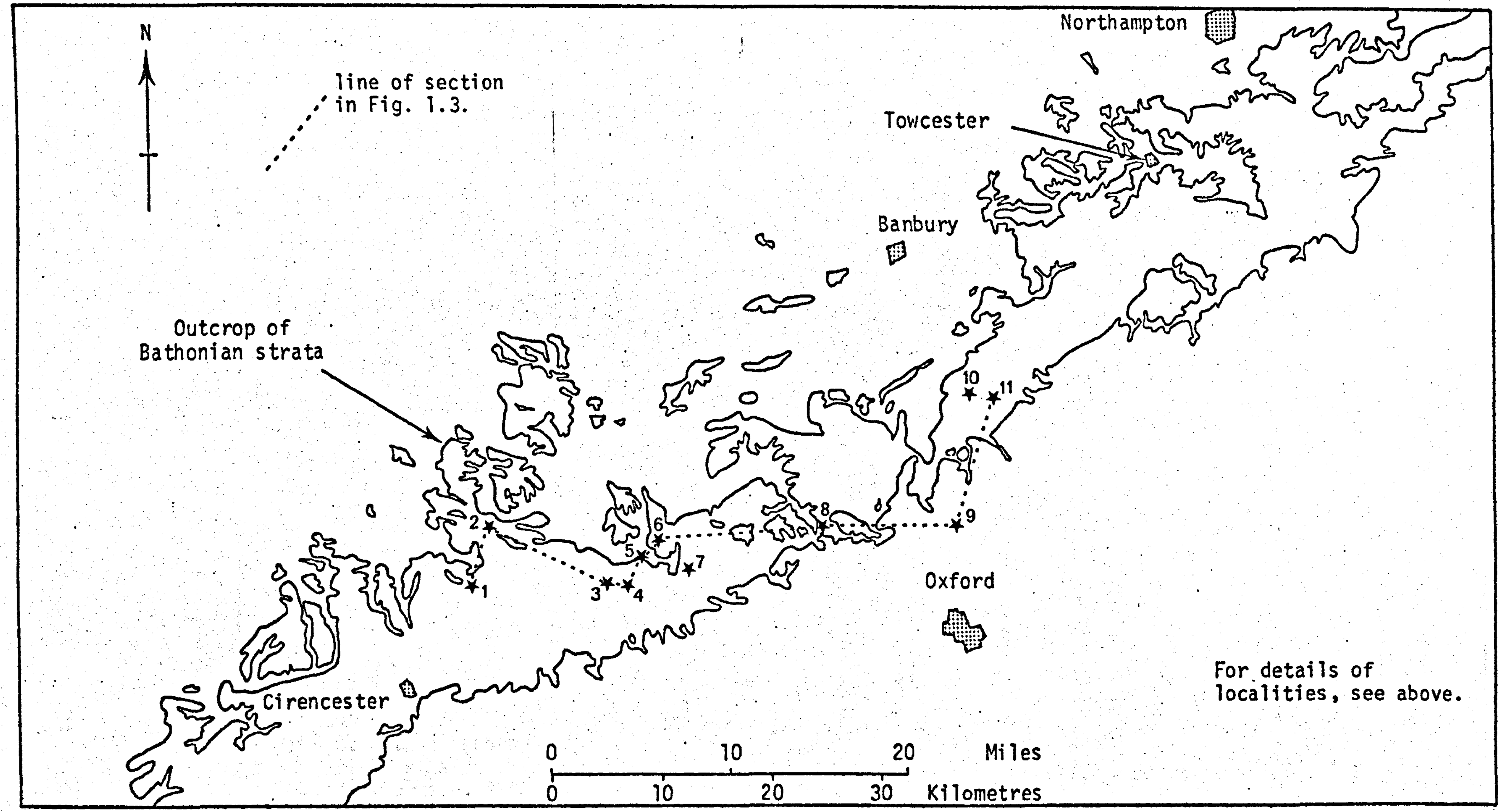
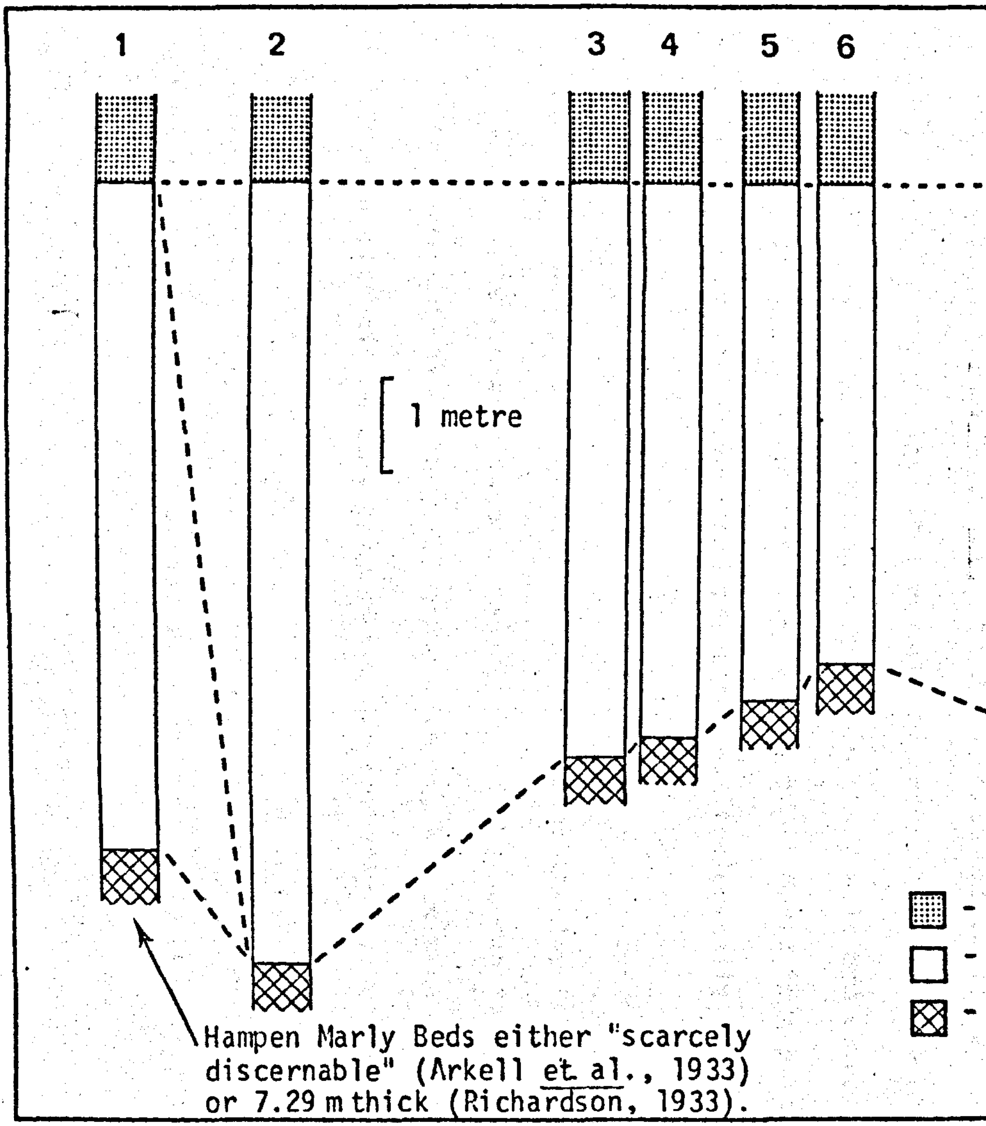
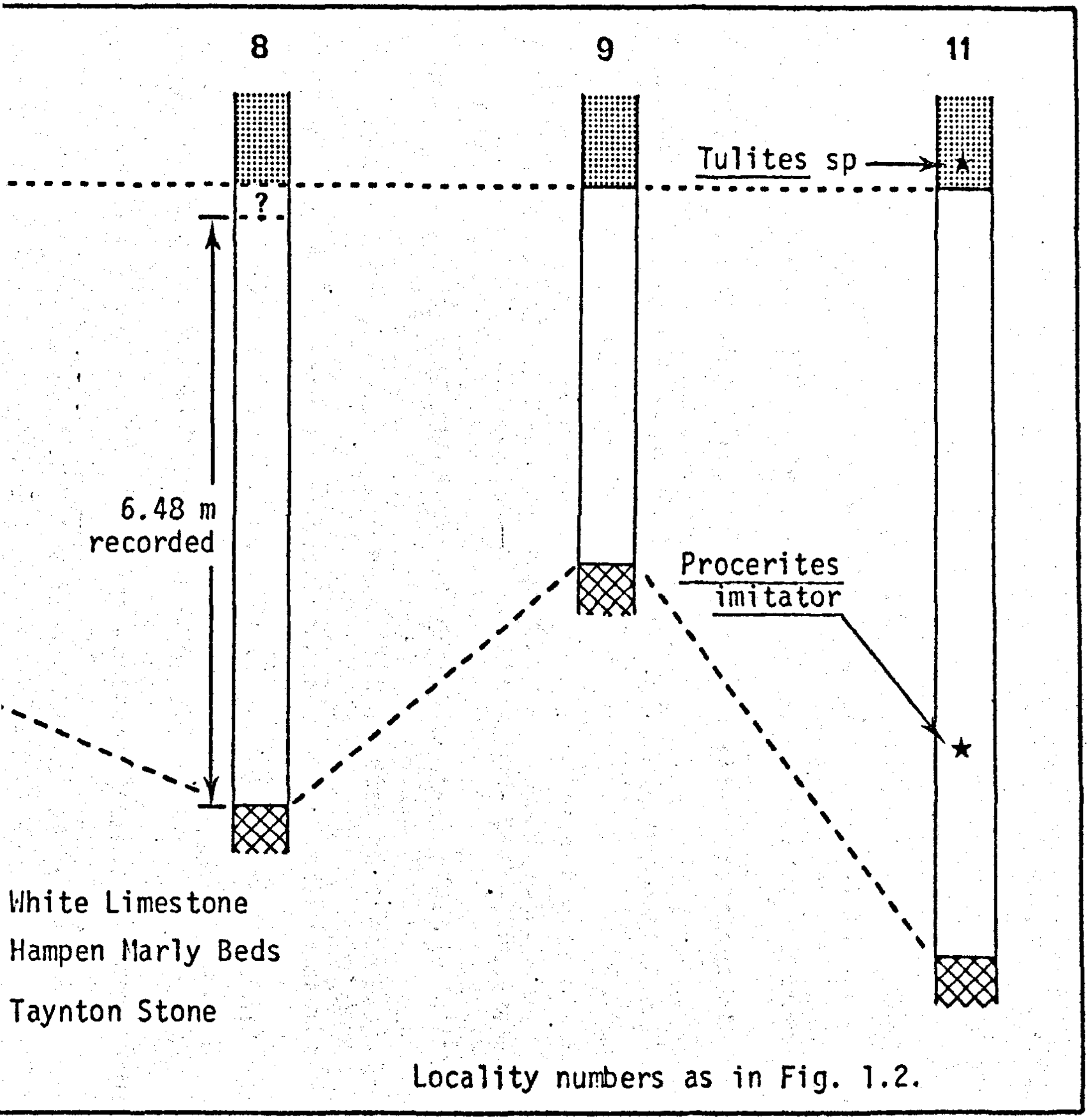


Fig. 1.2. Principal complete sections of the Hampen Marley Beds.



Hampen Marly Beds either "scarcely discernable" (Arkell et al., 1933) or 7.29 m thick (Richardson, 1933).

Fig. 1.3. Variation in thickness of the Hampen Marly Beds.



Locality numbers as in Fig. 1.2.

suggested that their thickness was 24 feet (7.31 metres) although Arkell, Richardson and Pringle (1933, p. 350) regarded the Hampen Marly Beds as, ..."barely discernable in the railway cuttings at Chedworth" (i.e. in the Stony Furlong cutting).

The lithologies of the Hampen Marly Beds reflect a gradual change from the higher energy carbonate deposition of the preceding Taynton Limestone into a quieter depositional regime characterised by clays and marls with, especially in the east, little carbonate material. The source of this fine-grained terrigenous clastic influx was the London-Ardennes landmass to the east (Martin, 1967). The prevailing palaeogeography is reflected in the changing lithologies from the Upper Estuarine Series of the Midlands westwards across the Hampen Marly Beds. In the east the Hampen Marly Beds contain more clay bands, more silt and more carbonaceous material, both as lignite and rootlets. Westwards there is an increase in the carbonate content, with more marls and limestones, and a corresponding decrease in clay, silt and carbonaceous material, until south of Cirencester the Hampen Marly Beds pass into a fully carbonate sequence and cease to be lithologically distinct.

The return to a carbonate depositional regime in the succeeding White Limestone was just as gradual as the demise of the Taynton Limestone sequence. The clastic-argillaceous deposition of the Hampen Marly Beds continued longer in the north-east, closest to the source area and hence the litho-formational boundary between the Hampen Marly Beds and the White Limestone must, to some degree, be diachronous, being older in the west. Because of the transitional nature of the junction, no precise lithological criteria exist to adequately distinguish the Hampen Marly Beds from the

White Limestone. Generally, the junction is taken where a) the greater proportion of the sequence consists of limestones and b) where these limestones become distinctly oolitic and contain only small amounts of clay and silt. In practice however, exposures which show the junction of these two formations are scarce. At present the best section is probably at Woodeaton (SP 535122) (see Palmer, 1973, p. 58-59 for section). The older sections such as the Hampen railway cutting, the Ardley-Fritwell railway cutting and Milton-under-Wychwood are now poorly exposed. McKerrow and Kennedy (1973) suggest that graded sedimentary cycles are present in the Hampen Marly Beds at Milton-under-Wychwood, each consisting of a basal oolitic limestone passing up into a marl.

Palaeontologically the Hampen Marly Beds are of some interest. The most characteristic and commonest species being <u>Praeexogyra hebridica</u> (Forbes) and <u>Kallirhynchia</u> (<u>Burmirhychia</u>) <u>concinna</u> (Sowerby) both of which often occur in large numbers. Salinity is probably the main environmental factor which controls both the species diversity and abundance as well as the overall geographical distribution of the fauna and this fits in well with the palaeogeography outlined above. In the east, at Woodeaton, Palmer (1973, p. 60) reported the presence of <u>Corbula</u>, <u>Protocardia</u>, <u>Lycettia</u>, '<u>Cuspidaria</u>', <u>?Neomiodon</u> and <u>?Viviparus</u> from the Hampen Marly Beds. These genera are probably euryhaline and able to tolerate reduced salinities. Palmer (<u>op</u>. <u>cit</u>.) suggests that the sediment "represents the discharge of a fairly large river into a brackish water lagoon".

In the western part of the outcrop, species have been reported which are normally associated with fully marine conditions, for example T. pullus J. de C. Sowerby, Modiolus imbricatus J. Sowerby, Pholadomya lirata (J. Sowerby) from Windrush near Burford (Worssam & Bisson, 1961, p. 88); Nucleolites sp. from the Hampen railway cutting (Richardson, 1929, p. 105); Chomatoseris porpites at North Cerney (Richardson, 1933, p. 46). Nerineid gastropods have been reported from the Hampen Marly Beds at Danes Hill (Torrens in Sylvester-Bradley & Ford, 1968, p. 254). They are recorded as Cossmannea eudesii but in fact they are Melanioptyxis altararis (Cossmann). Richardson (1933, p. 44, 45) also records 'Nerinea' sp. from the marly beds at Taynton and Pinswell, near Chedworth. There is also a gastropod bed with 'Natica' and Pseudomelania in the Hampen Railway cutting (Richardson, 1929, p. 105). The occurrence of Nerineid gastropods in sequences in which the salinities at the time of deposition were perhaps not fully marine is interesting and will be discussed in Chapter 5.

The Hampen Marly Beds have yielded only one ammonite, the sole specimen being the holotype of Procerites imitator (S. S. Buckman) and this indicates the Hampen Marly Beds, at least in the Ardley-Fritwell railway cutting where the ammonite was found (Arkell, Richardson and Pringle, 1933) belong to the Procerites progracilis zone. The basal bed of the White Limestone in the same railway cutting has provided at least two specimens of Tulites sp. (Torrens in Sylvester, Bradley & Ford, 1968, p. 238); thus the base of the White Limestone falls within the Tulites subcontractus zone in the east but probably passes down into the P. progracilis zone further west. The stratigraphy and other palaeontological aspects of the Hampen Marly Beds have been reviewed by Arkell, Richardson & Pringle (1933); Torrens in Sylvester, Bradley & Ford (1968) and Torrens (1969).

The upper boundary of the White Limestone Formation.

The White Limestone is succeeded by the Forest Marble. This simple statement hides a complicated relationship between the two formations and also a considerable controversy which has existed since 1857. The majority of the numerous exposures in the White Limestone are of the middle and upper parts and frequently show the junction with the overlying Forest Marble. In spite of this geologists have experienced considerable difficulty in accurately placing the boundary, principally due to the lack of a precise internal zonation and stratigraphy in the White Limestone which has hindered accurate correlation between exposures.

The earliest work was by Hull (1857 & 1859), initially in the Cheltenham area, and subsequently around Woodstock. He found no difficulty in adequately defining the boundary between the White Limestone and the Forest Marble: viz; 1857, p. 65; "This limestone (i.e. the highest bed of the White Limestone - present author) is frequently pierced by *Lithodomi* .... it forms a very marked geological horizon, in fact, the only one which offers a line of demarcation between the Great Oolite and the Forest Marble. It is succeeded by a series of very variable strata, which afford evidence of a change of physical conditions and which must all be included in the Forest Marble"; 1857, p. 71; "False bedding is one of the most characteristic features of this formation and one by which it may be contrasted with the beds of the upper zone of the Great Oolite."

and 1859, p. 23; "The lower beds (of the Forest Marble - present author) which rest on the White Limestone of the Great Oolite consist of shelly oolite, much false bedded, splitting into slabs and flags. They are composed principally of enormous quantities of broken oyster shells with a smaller number of other shells, cemented by oolitic limestone."

Thus the criteria used by Hull to identify the Forest Marble are as follows:

1. It is false bedded.
2. There is abundant 'oyster' debris.
3. It is frequently separated from the White Limestone by a hard ground.
4. There is a marked change in lithologies.

Hull's division was accepted and extended by Woodward (1894, pp. 372-7) and also by Pocock and Woodward in the 1908 Geological Survey Memoir of the Oxford Special Sheet (Pocock, 1908 and see Arkell, 1931, p. 564). Odling (1913) described the Bathonian succession in the Ardley-Fritwell railway cutting together with the main quarries in the immediate neighbourhood. As Arkell stressed (1931, p. 564) Odling's important work was more detailed than previous descriptions, dividing the Great Oolite into blocks 1, 2 and 3, but in general terms Odling agreed with the formational boundaries of Hull and later workers. Odling also used the same criteria as Hull to distinguish the Great Oolite from the Forest Marble.

At this time, Phillips (1860) alone disagreed, believing that the boundary between the Great Oolite and the Forest Marble should be drawn at a much lower level. In 1859, Hull (p. 20) described a section in the railway cutting at Kirtlington Station and included his thanks to Professor Phillips for this section. He added in a footnote that Phillips disagreed with him over the junction of the Great Oolite and Forest Marble, considering it to be some 8 feet 4 inches (2.54 metres) lower than Hull had placed it, "occurring at the base of the bed of clay with plants (c - h)".

Subsequently Pringle (1926) and Byzand (in Sollas, 1926) reverted to Phillips classification on the basis of the misidentification of *Epithyris oxonica* Arkell for *Epithyris marmorea* (Oppel) - a Forest Marble species from Pickwick near Corsham (see Arkell, 1931, p. 567-8), and thereby included the whole of Odling's Block 1 in the Forest Marble.

It is unfortunate that further debate was based upon sections around Kirtlington and Enslow Bridge. The upper part of the White Limestone in this region is atypical, containing more clays and marls than is usual. Indeed it sometimes resembles the clayey facies of the Forest Marble to the north-east (Odling, 1913, p. 485). The lack of a detailed stratigraphy within the White Limestone, the atypical facies in the area where much of the research was based and the inadequate palaeontological knowledge resulted in little progress until the publications of Arkell (1931, 33, 46 & 47) and Richardson (1933, 46).

In the vicinity of Oxford, along the south-east margin of the White Limestone outcrop, Arkell (1931) divided the upper part (= Odling's Block 1) into the following beds:

-	Cream Cheese Beds = Kemble Beds	=	Odling's Block 1
Great Oolite	*Fimbriata* - *waltoni* Beds		
(White Limestone)	Middle *Epithyris* Bed		

The Cream Cheese Beds(1) were subdivided into "two very distinct facies; they may be either a solid block of amorphous pure white to grey 'Fossiliferous Cream Cheese' limestone (better called sublithographic stone), sometimes crowded with Epithyrids and corals, or they may be represented by massive, false-bedded, blue-hearted, coarsely oolitic limestones, almost devoid of recognisable fossils, and presenting the aspect of some of the more massive parts of the Forest Marble". Arkell (*op. cit.*, p. 566).

Thus, according to Arkell (*op. cit.*, p. 569), the Kemble Beds are the top part of the Great Oolite; "on the evidence of the correspondence of the fauna of the Fossiliferous Cream Cheese Beds with the fauna of the Kemble Beds at Kemble, *of the lateral passage of both into relatively unfossiliferous false-bedded 'Forest Marble'*, and of

---

Footnote(1)

The term 'Cream Cheese' was first used by Barrow (1907) for a prominent band of sublithographic micritic limestone in the railway cutting at Ardley. Odling (1913, p. 489) described the same bed, containing '*Nerinea eudesii*' Morris & Lycett and *Modiolus imbricata* Sow., as '*Fossiliferous Cream Cheese*'. This is without doubt the *Aphanoptyxis bladonensis* bed. Beds at the Oxford Portland Cement works, Kirtlington Quarry and Gibraltar Quarry (Enslow Bridge) were also described as 'Fossiliferous Cream Cheese' by Odling (*op. cit.*, p. 493, 497). The Kirtlington bed contains corals and the Enslow Bridge bed contains *Epithyris oxonica* Arkell. These are fossils which are not associated with the *A. bladonensis* bed. Research by the present author in the area around Kirtlington and Enslow Bridge has shown the typical *A. bladonensis* bed to be absent. The Kirtlington Cream Cheese bed of Odling is the bed described by Phillips (1860, p. 118) as a "solid shelly bed, top oolitic, middle close grained, base more sandy" and the Enslow Bridge Cream Cheese is the bed described by Hull (1859, p. 21) as "Bed b: hard compact grey limestone with *Terebratula*, *Ostrea*". Neither can be correlated with the 'Cream Cheese' (*A. bladonensis* bed) in the Ardley cutting. Evidently the term 'Cream Cheese' has no stratigraphic value, having been applied to any of a number of beds of fine-grained, white to grey, sublithographic limestones in this area.

the stratigraphical position of both below strata which locally contain at their base the assemblage of the Bradford Clay". Arkell further recommends the removal of the term Forest Marble from stratigraphical literature on the grounds that it is a facies term occurring both in the Great Oolite (Kemble Beds of Forest Marble facies) and in the true Forest Marble above the Bradford Clay. The true Forest Marble he proposes to call Wychwood Beds. Also, the junction between the Forest Marble (Wychwood Beds) and the Great Oolite must be above that proposed by Hull, Woodward and Odling, and therefore most of the Forest Marble described by the earlier authors should be regarded as Kemble Beds of Great Oolite age. The validity of Arkell's subdivisions depends upon two assumptions:

1. That the Bradford Clay is isochronous; constitutes a reliable horizon in correlation, and is at the base of the Forest Marble.
2. That the lateral transition from Forest Marble facies into sub-lithographic Cream Cheese limestones can be proven.

The base of the Bradford Clay around Bradford-on-Avon is a well developed hardground (Palmer & Fürsich, 1974) and presumably a considerable length of time elapsed between the deposition of the underlying, well-sorted, cross-bedded oobiosparites and the deposition of the Bradford Clay. It is likely that during this period sediments were being deposited in other areas. Arkell (op. cit. p. 575) considered the Bradford Clay fauna to be extremely useful, especially in the correlation of the quarry at Islip with other sections in the area, and concluded, "The restricted vertical range of the Bradfordian fauna over a wide area from Buckland Denham near the Mendips to Cirencester and Swindon renders it a valuable datum in the correlation of the Bathonian rocks". (op. cit. p. 567). Other authors did not agree, for example Hull (1857, p. 69) stated, "I may also add, that the supposed Bradford Clay cannot be taken as a true zone of separation between the Great Oolite and Forest Marble, ...". Hull also pointed out that the fossils which were supposedly characteristic of the Bradford Clay had in fact been found at other horizons, a point reiterated over 100 years later by Green and Donovan (1969, p. 24) ... "the fauna (of the Bradford Clay) is not restricted to the base of the Forest Marble". Elements of the Bradford Clay fauna were found by Green and Donovan at least 40 feet above the base of the Forest Marble at Farleigh House and "at a lower level than the Bradford clay of the type area" at Brown's Folly (p. 24). Moreover the Bradford Clay is laterally discontinuous. It wedges out one mile west of Bradford-on-Avon (Green & Donovan op. cit. p. 24) and Richardson (1933) could not find it over much of the area covered in the Cirencester Memoir. In areas where the Bradford Clay is absent, Arkell was forced to admit ..."the line of demarcation (between the Wychwood Beds and the Kemble Beds of Forest Marble facies) is difficult or even impossible." (Arkell op. cit. p. 594).

The importance attributed by Arkell to the Bradford Clay fauna cannot be upheld. It is almost certainly not isochronous and even if it were, it is not unreasonable that true Forest Marble should occur below the Bradford Clay, perhaps being deposited during the time represented by the hard-ground at Bradford-on-Avon.

The occurrence below the Bradford fauna of Cream Cheese limestones at Islip (Arkell *op. cit.* p. 576) and Forest Marble limestones at Crawley Road, Witney (Arkell *op. cit.* p. 591) was interpreted by Arkell as a lateral facies transition.

Yet another lateral change of facies was suggested by Richardson (1933). He accepted the subdivisions proposed by Arkell (1931) and recognised not only Kemble Beds of Forest Marble and Cream Cheese facies but also Kemble Beds of Great Oolite facies in the south-western portion of the area covered by the Cirencester Memoir (Richardson 1933). It is of interest to note that whenever the Kemble Beds of Forest Marble facies occurs with either of the other two facies, it is invariably found above them (Richardson, 1933, p. 57, 60, 64). Furthermore the Kemble Beds of Great Oolite facies and of Cream Cheese facies have never been described together in any section.

The term Kemble Beds was first used by Woodward (1894, p. 250) to describe a group of strata, with a maximum thickness of 30 feet (9.14 metres), found between the top of the White Limestone and the base of the Bradford Clay. His description is as follows "In the neighbourhood of Minchinhampton and for some distance northwards, it becomes a matter of difficulty to separate the Great Oolite and Forest Marble, for in this area there is a considerable development of false-bedded oolites above the White Limestone of the Great Oolite. These oolites are overlaid in places by the Bradford Clay, but on account of its inconstant character it is difficult to fit a definite plane of separation. These upper oolites will for convenience be referred to as the KEMBLE BEDS, as they are well shown near Kemble Station, ...". The fossils quoted by Woodward (1894, p. 272) as occurring abundantly in the Kemble Beds include *Lima cardiiformis*, *Lucina bellona* and *Epithyris oxonica* (recorded as *T. maxillata* by Woodward); species which are typical of the White Limestone below. Indeed the whole fauna has a White Limestone aspect. Woodward gives no criteria to distinguish the White Limestone from the Kemble Beds. From his published descriptions, one may infer that the White Limestone is

a) white

b) fine-grained

c) less false bedded than the Kemble Beds, and

d) contains Dagham stone at various horizons.

In the area covered by Woodward, it is probably true that no precise palaeontological division is possible. However to the north-east, in the area in which the present author has worked, the *Aphanoptyxis bladonensis* bed is taken as a reliable upper boundary of the White Limestone. Unfortunately this bed attenuates or becomes unrecognisable to the south-west around Minchinhampton and Tetbury.

In the absence of the Bradford Clay fauna Woodward admitted (*op. cit.* p. 271) that he found it "exceedingly difficult to fix a recognisable plane of division between the two groups" and furthermore stated, (p. 283) "On the whole the flaggy beds of Great Oolite (Kemble Beds - present author) are not so hard nor so thinly divided, as are those of the Forest Marble; nor when obliquely bedded, are they separated by the even bands of blue and shaly clays that mark the Forest Marble. Again, the

Forest Marble limestones are usually characterised by ochreous clay-galls and they are more often blue in colour, owing to the protecting layers of clay associated with them." In describing the Forest Marble around Blechingdon and Kirtlington, Woodward (op. cit. p. 322-3) concludes "... we have further evidence of the discordance ... ... that the Forest Marble rests on different members of the Great Oolite".

Worssam & Bisson (1961) divided the Kemble beds into a lower subdivision, the Signet Beds, immediately above the White Limestone and a higher Kemble Beds of Forest Marble facies.

Thus the boundary between the White Limestone and the Forest Marble is distinguished above all by confusion and a plethora of names viz; the Kemble Beds of Woodward (1894); the Kemble Beds of Forest Marble facies and Cream Cheese facies of Arkell (1931); the Kemble Beds of Great Oolite facies of Richardson (1933); and the Signet Beds of Worssam & Bisson (1961). The author believes the relationship between these facies can be elucidated and will subsequently attempt to prove, that the Cream Cheese facies, including the Epithyris - coral limestone of Arkell (op. cit.), are the lateral equivalent of the upper part of the White Limestone by virtue of their occurrence below the A. bladonensis bed; the Kemble Beds of Woodward pass laterally into Richardson's (1933) Kemble Beds of Great Oolite facies and the Signet Beds of Worssam & Bisson (1961); the Kemble Beds of Forest Marble facies are true Forest Marble and the base is diachronous becoming older to the north-east. The 30 feet of Kemble Beds at Kemble Station is reduced to nothing in the region of Kirtlington and in places the Forest Marble even cuts into the White Limestone, removing the A. bladonensis bed. This reduction in thickness between the Forest Marble and the White Limestone is probably due to

a) a thinning of the Kemble Beds to the north-east and

b) erosion and channelling associated with the high energy Forest Marble environments.

The evidence for these relationships will be discussed later.

The internal correlation of the White Limestone

Previous work

Of the early workers only Woodward (1894) commented on the possibility of further subdivision of the White Limestone. Woodward (*op. cit.*) clearly thought that further work would be difficult, viz: "None of the subdivisions of the Great Oolite can be regarded as very constant" (p. 249), and "The fossils of the Great Oolite do not lend themselves to particular zonal grouping" (p. 253). Nevertheless, a subdivision of the Great Oolite (i.e. White Limestone) in the Ardley-Fritwell railway cutting was proposed by Barrow (1907) and was subsequently adopted with some revision by Odling (1913) (Fig. 1.4). The beds in the railway cutting section which Odling found most valuable for correlation with nearby quarry sections were the gastropod and brachiopod horizons. The recognition by Barrow and Odling of three units (Blocks 1, 2 and 3) within the White Limestone was a fundamental subdivision which can still be supported today. The Bladon Beds (Arkell, 1947), the Ardley Beds (*pars*. Arkell, *op. cit.*) and the Excavata Beds of the present author (see later) correspond to Blocks 1, 2 and 3 respectively. Odling endeavoured to establish a correlation

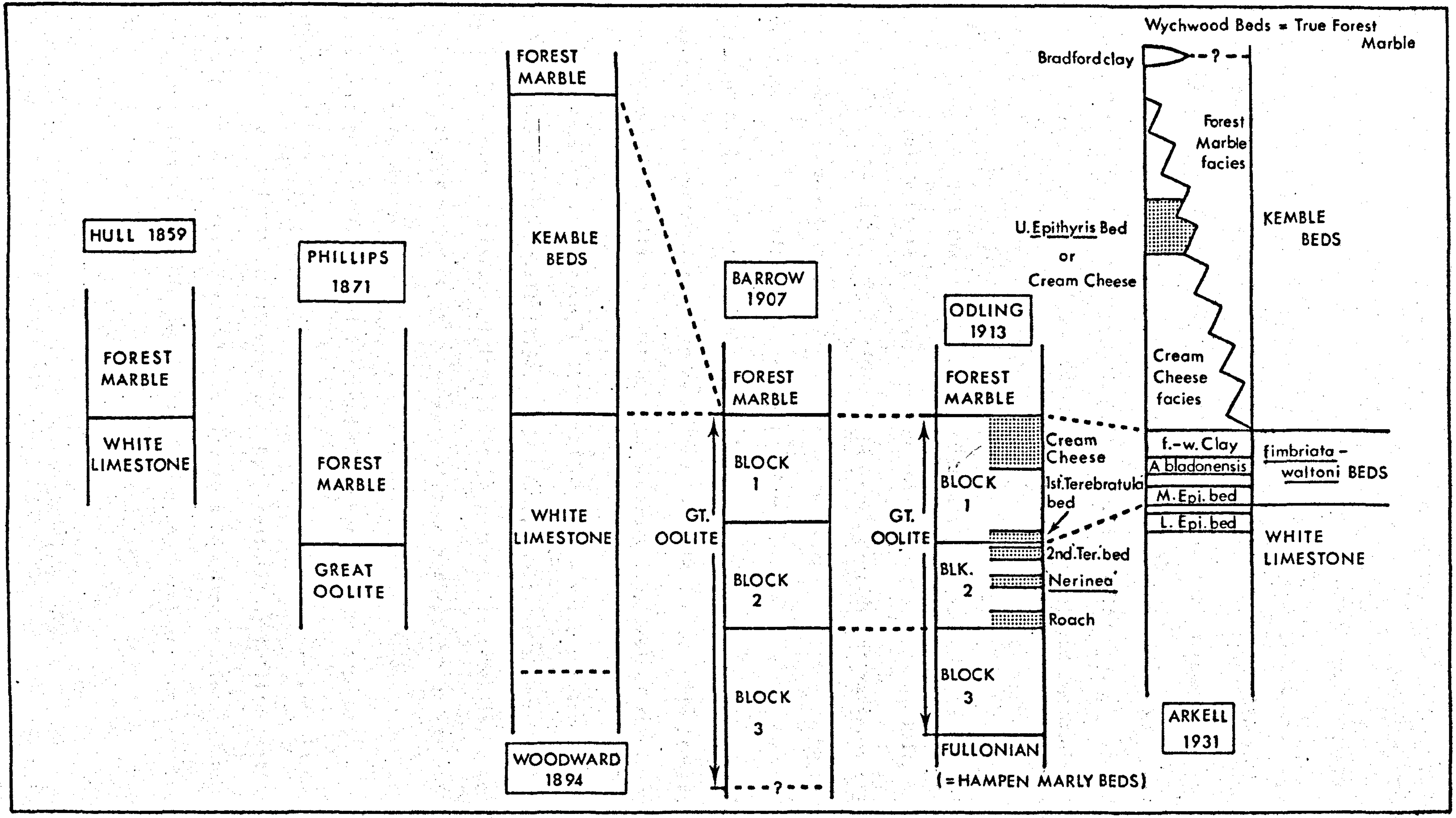


Fig. 1.4. The correlation of the White Limestone — previous authors' upper boundaries and internal subdivisions.

with sections exposed in quarries to the south, especially at Kirtlington, and Enslow Bridge (Gibraltar and Green-Hill Quarries). The misidentification of the Cream Cheese beds in the various quarries resulted in correlations which were only partially successful (see footnote previously) and in conclusion Odling commented (op. cit., p. 510) "The beds of the Great Oolite cannot be correlated in detail; ...".

Between 1911 and 1946, Richardson published a number of papers on the Great Oolite/White Limestone of the Cotswolds (Richardson, 1911, 1919, 1920, 1929, 1933, 1935, 1946). His work provided no satisfactory basis for the zonation and subdivision of the White Limestone as he confirmed in 1946 (p. 37); "The writer has for many years endeavoured to find in the Great Oolite of the Cotswolds, fossils that are sufficiently restricted in vertical range to be of use in zoning, but, while progress has been made, results have not as yet come up to the desired requirements".

The only real advance in the zonation of the White Limestone was through the work of Arkell (1931, 1933a and b, 1947). His important 1931 paper is a curious mixture of insight and errors but it established for the first time a sequence of Nerineid gastropod horizons which were of zonal value. Based in Oxford, it is perhaps understandable but nevertheless unfortunate that Arkell regarded Kirtlington as the type section of the White Limestone. Sections at Kirtlington and other quarries in the immediate vicinity of Oxford were used by Arkell (1931) to illustrate his solution of the Forest Marble/White Limestone boundary problem and in so doing he tried to use three horizons of abundant Terebratulids (the Upper, Middle and Lower *Epithyris* beds) for local correlation of the Great Oolite (i.e. Arkell's White Limestone + Kemble Beds). However, the *Epithyris* beds show evidence of lateral transition from non-drifted Coral - *Epithyris* assemblages into drifted *Epithyris* beds (McKerrow *et. al.*, 1969). Indeed they can be seen passing laterally into unfossiliferous strata within a single section, as at Kirtlington and Enslow Bridge. Moreover, the three *Epithyris* beds are not stratigraphically distinguishable and in the absence of other evidence, it is impossible to ascertain whether a given *Epithyris* bed is the Upper, Middle or Lower *Epithyris* bed.

During the nineteenth century, the clays occurring above the Middle *Epithyris* bed at Kirtlington (also Gibraltar Quarry, near Enslow Bridge and at Bletchingdon) were the source of many fine bones of *Cetiosaurus oxoniensis* Phillips (Phillips, 1871, p. 245-294). The fauna of these lignitiferous clays and marly limestones was originally recorded by Odling (1913) and enlarged upon by Arkell (1931). Because of the abundance of *Astarte fimbriata* Lycett and *Gervillia waltoni* Lycett in these beds, Arkell (*op. cit.*) proposed the name Fimbriata - waltoni Beds for them. These are the *fimbriatus* - *waltoni* clays of McKerrow *et. al.* (1969), the change in nomenclature being necessitated by the faunal revisions of Cox & Arkell (1948-50). The Fimbriata - waltoni Beds were considered by Arkell (*op. cit.*) to be a distinct, stratigraphically important subdivision between the Kemble Beds and the White Limestone. Consequently horizons which contained a fauna similar to that found in the Fimbriata - waltoni Beds of Kirtlington (i.e. *Eomiodon fimbriatus*, *Bakevillia waltoni*, *Modiolus imbricatus*, *Protocardia lycettia*, *Corbula* *hulliana* etc.) were also classified by Arkell as Fimbriata - waltoni Beds. Unfortunately, the bivalve fauna of these beds is a facies fauna and can be shown to have occurred at several clay and marl horizons within the White Limestone where conditions were ecologically suitable. The use by Arkell (1931) of the Fimbriata - waltoni fauna and the several *Epithyris* horizons in the correlation of the White Limestone resulted in several errors. Some were minor, such as the confusion over the several sections at Bladon (partially corrected by Arkell, 1933 and 1947, p. 56) and the difficulties encountered by Arkell in the interpretation of Eton College Quarry (1931, p. 608 and partially corrected by Worssam & Bisson, 1961, p. 95) whereas others were much more serious. Because Arkell found elements of the Fimbriata - waltoni fauna in the *Aphanoptyxis bladonensis* bed (1931, p. 584), he presumed this bed to be part of the Fimbriata - waltoni Beds. At localities such as Orchard Quarry, Bladon (1931, p. 584), Handborough Station Quarry (1931, p. 586) and Minster Lovell War Memorial Quarry (1931, p. 608) Arkell found coarse, buff, false-bedded, shelly and detrital limestones above a bed (the *A. bladonensis* bed) which he considered to be part of the Fimbriata - waltoni Beds. The unavoidable conclusion reached by Arkell was that the limestones of Forest Marble facies above the *A. bladonensis* bed at Minster Lovell etc. were laterally equivalent to the Cream Cheese facies above the Fimbriata - waltoni Beds at Kirtlington. Arkell (*op. cit.*) could not consider the Forest Marble facies limestones as true Forest Marble because of the absence of the Bradford Clay fauna which he believed to be a necessary precursor to true Forest Marble. Arkell (*op. cit.*) named the Cream Cheese facies, together with the supposed lateral equivalents, Kemble Beds assuming them to be coeval with the Kemble Beds of Minchinhampton, Tetbury and Cirencester (Woodward, 1894).

The much needed revision of the Great Oolite gastropod faunas, especially the Nerineacea, was initiated by Arkell (1931). His work resulted in "... several new gastropods of the foldless genus *Aphanoptyxis*, which can be demonstrated to form definite zones of at least local utility in fieldwork" (Arkell 1931, p. 623). The following sequence of Nerineid gastropods was established within the Fimbriata - waltoni Beds and White Limestone of Arkell (1931).

Gastropod zone	Lithostratigraphic unit
Aphanoptyxis bladonensis Arkell 1931	Fimbriata - waltoni Beds
Aphanoptyxis ardleyensis Arkell 1931	White Limestone
Nerinea eudesii Morris & Lycett 1850	

The Fimbriata - waltoni Beds containing *A. bladonensis* were later included in the White Limestone (Richardson *et. al.*, 1946; Arkell, 1947; Worssam & Bisson, 1961; Palmer, 1973) although McKerrow *et. al.* (1969) continued to use Arkell's earlier (1931) classification and on the basis of oyster abundance assigned a Forest Marble age to the *fimbriatus* - *waltoni* clay and overlying beds at Kirtlington.

Arkell's (1931) gastropod sequence was extended to other White Limestone outcrops, e.g. Hook Norton (Arkell, 1946), Witney (Richardson, 1946), Sherbourne and Burford (Worssam & Bisson, 1961); although no adequate attempt was made to modify or refine the scheme. Arkell (1947) suggested *Ptygmatis* (*Bactroptyxis*) *bacillus* (d'Orbigny), = *B. implicata* (d'Orbigny), found a few feet below the *A. ardleyensis* bed was almost as infallible a subzonal index as *A. ardleyensis*. The White Limestone was thus formally divided into the Bladon Beds at the top and the Ardley Beds below with *A. bladonensis* and *A. ardleyensis* being the gastropod subzonal indices. The White Limestone was considered to form part of the *T. subcontractus* zone (Arkell, 1947, p. 42).

Problems of correlation

Carbonate environments are especially subject to rapid changes in detailed lithology and fauna, posing formidable correlative problems over even short distances. In modern shallow-water carbonate environments the distribution patterns of carbonate grain types (lithofacies) are closely reflected in those of benthonic faunal assemblages (biofacies) (Newell *et. al*., 1959; Bathurst, 1971). This is largely because environmental factors such as salinity, water temperature and circulation, which control the deposition of carbonate grain types also influence the abundance and distribution of the associated benthos. Furthermore accumulating carbonate clasts form substrates of varying texture, sorting and compaction, which in turn determine the organic detritus and water content of the substrate; features important in the distribution of epifaunal and infaunal invertebrates.

Coarse-grained carbonate lithologies are usually relatively devoid of plant and animal life, largely as a result of the mobility of the substrate. Newell *et. al*. (1959, p. 219) found the *Tivela* community in the Bahamas Bank has a low species diversity and abundance and this correlates well with its development in an unstable oolite sand lithofacies. Fossil analogues of such environments are particularly difficult to correlate and usually result in lithostratigraphic classifications. The false bedded, shelly oolites in the Bath area, which are the lateral equivalents of the White Limestone, have been studied by Green & Donovan (1969). Little detailed palaeontological subdivision was possible in these high energy lithologies (e.g. the Combe Down oolite, the Freshford facies of the Twinhoe Beds and the Bath oolite) and the resulting correlation is largely lithologically based. Sellwood and McKerrow (1974) used a lithostratigraphic framework in discussing the palaeogeography of basal Bathonian of the English Midlands. However, lower energy carbonate deposits contain an abundant fauna and flora. This is primarily due to the higher carbonate mud content (providing organic detritus) and the increased substrate stability. Studies in the Gulf of Batabano, Cuba (see summary in Bathurst, 1971) indicate a high molluscan species diversity and abundance (200 - 2,000 specimens per 300 gms. sediment) in areas of sediment with a high carbonate mud content (grain size > 62μ). In the Bahamas bank, Newell _et. al_. (1959) found the areas of stable pellet sand and grapestone sand contained a rich and diverse organic community but the areas of pellet mud west of Andros Island, revealed a sparse epifauna and a low mollusca species diversity and abundance (except for _Cerithidea costata_ and _Pseudocyrena colorata_). They concluded that this was in part controlled by the hypersaline waters in this region.

Nektonic and planktonic organisms have dominated the biostratigraphic zonation of most systems, especially the Jurassic with its dependance on ammonites. Unfortunately nektonic and planktonic organisms suitable for zonation and correlation are uncommon, even rare, in carbonate environments, the White Limestone being no exception. Newell et. al. (1959) noted that fish bones and teeth (i.e. nektonic in origin) were completely lacking or extraordinarly rare throughout the Bahamas bank. The rarity of ammonites in the White Limestone necessitates the use of benthonic organisms in correlation and, hopefully, zonation. Jurassic stratigraphers have in the past tended to ignore benthonic invertebrates, relying heavily on ammonites, whereas Palaeozoic stratigraphers have used mobile benthos, such as trilobites and conodonts, and sessile benthos, such as brachiopods, with considerable success. In general benthonic organisms have been ignored even though they are plentiful in the fossil record, because of the widely held view that they would not spread rapidly enough through a depositional basin to have near-isochronous boundaries.

Kauffman (1970) advocates the use of the total faunal content involving population studies on evolving lineages to establish a biostratigraphy that is not limited by the maximum evolutionary rates of the dominant biostratigraphic indices. He states (1970, p. 626) "Careful systematic studies of Mesozoic Inoceramids throughout the world have shown clearly that in spite of their sessile benthonic living habit, they were for the most part cosmopolitan or intercontinentally distributed at the species and subspecies level, with range boundaries as nearly isochronous as those of ammonites or planktonic Foraminifera".

Within the White Limestone the author considers that the Nerineid gastropods are potentially the most useful organisms for correlation and zonation. Of invertebrates which occur abundantly in the White Limestone, they appear to be the least facies dependant. (Of the five subtidal communities recognised by Newell *et. al*. (1959), three were characterised by gastropods and the *S. costatus* community occupied such differing lithologies as mixed skeletal sand, stable oolite, grapestone sand and pellet sand). Certainly, the non-drifted *Epithyris* assemblages are much more facies dependant than the Nerineids.

The Nerineids are mostly mobile infaunal benthos (see Chapter 5) contrasted with the brachiopod *Epithyris* which is sessile and epifaunal. This means the Nerineids have a greater geographical distribution potential in their adult life than fauna which are sessile and the possibility of post-mortem transportation is minimised. It has long been known that pelagic larval stages are the main means of geographical dispersal in benthonic organisms. Scheltma (1966b, 1968, 1971) recorded telepanic larvae (long ranging larvae from shallow water benthonic gastropods) in the North Atlantic with representatives of the following families: Neritidae, Naticidae, Triphoridae, Lamellariidae, Architectonicidae, Cymatiidae, Cassidae, Tonnidae, Muricidae, Bursidae, Coralliophilidae, Ovulidae and Cypraeidae. Some had pelagic development periods of over three months. If the results of Scheltma's work are in any way applicable to fossil gastropods, it would mean the substrate condition was the major influence in the geographical distribution of the Nerineidae and other gastropods.

Without doubt the Nerineid gastropods are the most abundant macro-invertebrate group within the White Limestone. Not only are they numerically abundant but also taxonomically diverse involving some seven genera and eleven species. Thus it seems reasonable to conclude that the Nerineid gastropods in the White Limestone have a high biostratigraphic potential.

Other authors have hinted at this, for example, Arkell (1931, p. 623) stated that "the gastropod zones have been found to be distributed more consistently than the brachiopod colonies" and Richardson (in Richardon, Arkell & Dines, 1946, p. 37) considered, "The epithyrids, ..., are unreliable for the purpose of extensive correlation. The gastropods prove more satisfactory;...". This potential has not previously been fully exploited.

Given that the gastropod faunas can be used in correlation, the problem of their isochroneity or otherwise still remains. The present author contends that the distribution of the gastropod faunas in the White Limestone is isochronous or nearly so and therefore the faunas are of zonal value. Their stratigraphic distribution is consistent with that of the rare ammonites which have been found in the White Limestone.

The distribution of Gastropods in the White Limestone

Probably the best section for the study of the temporal sequence of Nerineid gastropods in the White Limestone is at Slape Hill Quarry (owned by Soil Fertility Ltd. G.R. - SP 425196). The distinctive succession of gastropod horizons which can be established here is found, with some modification, in all Nerineid bearing White Limetone exposures within the area under consideration. The sequence of gastropod beds at Slape Hill is as follows, in descending order:

1. *Aphanoptyxis bladonensis* Arkell 1931 (bed 18 in Fig. 1.5)
2. Upper *Aphanoptyxis ardleyensis* Arkell 1931 (bed 14 in Fig. 1.5)
3. Lower *Aphanoptyxis ardleyensis* Arkell 1931 (bed 12 in Fig. 1.5)
4. *Bactroptyxis implicata* (d'Orb. 1851) (rare) (bed 9 in Fig. 1.5)
5. *Eunerinea arduennensis* (Buvignier 1852) (bed 7 in Fig. 1.5)
6. *Eu. arduennensis* (Buv.): *Nerinella* cf. *acicula* (d'Archiac 1843) (bed 5 in Fig. 1.5)
7. *Aphanoptyxis excavata* Bed containing: (bed 3 in Fig. 1.5)
    Aphanoptyxis excavata sp. nov.; *Aphanoptyxis compressa* sp. nov.;
    Endiaplocus munieri (Rigaux et Sauvage 1868)
    Eu. arduennensis (Buv.): *Rigauxia varicosa* (Rigaux et Sauvage 1868)

Further details of the fauna and lithologies at this and other exposures are given in Figs. 1.5 to 1.21.

Figure 1.22 shows the proposed correlation of the gastropod horizons in the White Limestone.

Except at Slape Hill and North Leigh (SP 388142), the lowest gastropod bed, containing *A. excavata* sp. nov., is found immediately below a well developed hardground (Type 1/3a of Goldring and Kaźmierczak, 1974). The recognition of this new species (see Chapter 2) and its widespread occurrence below a marked stratigraphic hiatus, suggest that the beds below the hardground should be regarded as a separate lower subdivision of the White Limestone and it is proposed to call them the Excavata Beds.

Major non-Nerineacean fauna at Slape Hill

(within each class species are arranged in decreasing abundance)

Bed 5. Gastropods

Chartroniella infrastriata Cox and Arkell
Neritoma (Neridomus) cf. cooksonii (Eudes-Deslongchamps)
Procerithium (Rhabdocolpus) pulcrum (Lycett)
Dicroloma laevigatum (Morris and Lycett)
Metriomphalus (Metricanthus) altus (Morris and Lycett)
Nummocalcar polygonium (d'Archiac)
Dicroloma cf. pupaeforme (d'Archiac)
Goniocylindrites brevis (Morris and Lycett)
Pseudomelania sp.
Globularia sp.
Discohelix cf. turbiniformis (Lycett)
Procerithum (Cosmocerithum) betulae (d'Orb.)
Ceritella sp.
Amberleya bathonica Cox and Arkell
Naricopsina subcaniculata (Morris and Lycett)
Cylindrites caniculatus

Bed 5. Bivalves

Protocardia cf. buckmanni (Morris and Lycett)
Trigonia (Vaugonia) cf. moretoni (Morris and Lycett)
Praeexogyra hebridica (Forbes)
Cavilucina (Mesomiltha) bellona (d'Orbigny)
Trigonia pullus J. de C. Sowerby
Nucula (Palaeonucula) waltoni Morris and Lycett
Pteroperna sp. cf. costulata (Eudes-Deslongchamps)
Protocardia cf. stricklandi (Morris and Lycett)
Cucullaea cf. minchinhamptonensis Cox and Arkell

Other fauna Chomatoseris porpites (W. Smith)

Asteracanthus sp., Pagurid

Bed 3. Gastropods

Neritoma (Neridomus) cf. cooksonii (Eudes-Deslongchamps)
Procerithium (Rhabdocolpus) sp.
Nummocalcar polygonium (d'Archiac)
Chartroniella infrastriata Cox and Arkell
Procerithum (Cosmocerithum) sp.
Globularia cf. formosa (Morris and Lycett)
Naricopsina subcaniculata (Morris and Lycett)
Ceritella sp.
Metriomphalus sp.
Cylindrites sp.

Bed 3. Bivalves

Nucula (Palaeonucula) waltoni Morris and Lycett
Protocardia stricklandi (Morris and Lycett)
Parallelodon sp.
Modiolus imbricatus J. Sow.
Trigonia pullus J. de C. Sowerby
Isognommon isognommonoides (Stahl)
Modiolus (Inoperna) plicatus J. Sow.
Cavilucina (Mesomiltha) bellona (d'Orb.)
Pteroperna sp.
Entolium sp.

Other fauna Clypeus sp., Acrosalenia sp., Pagurid.

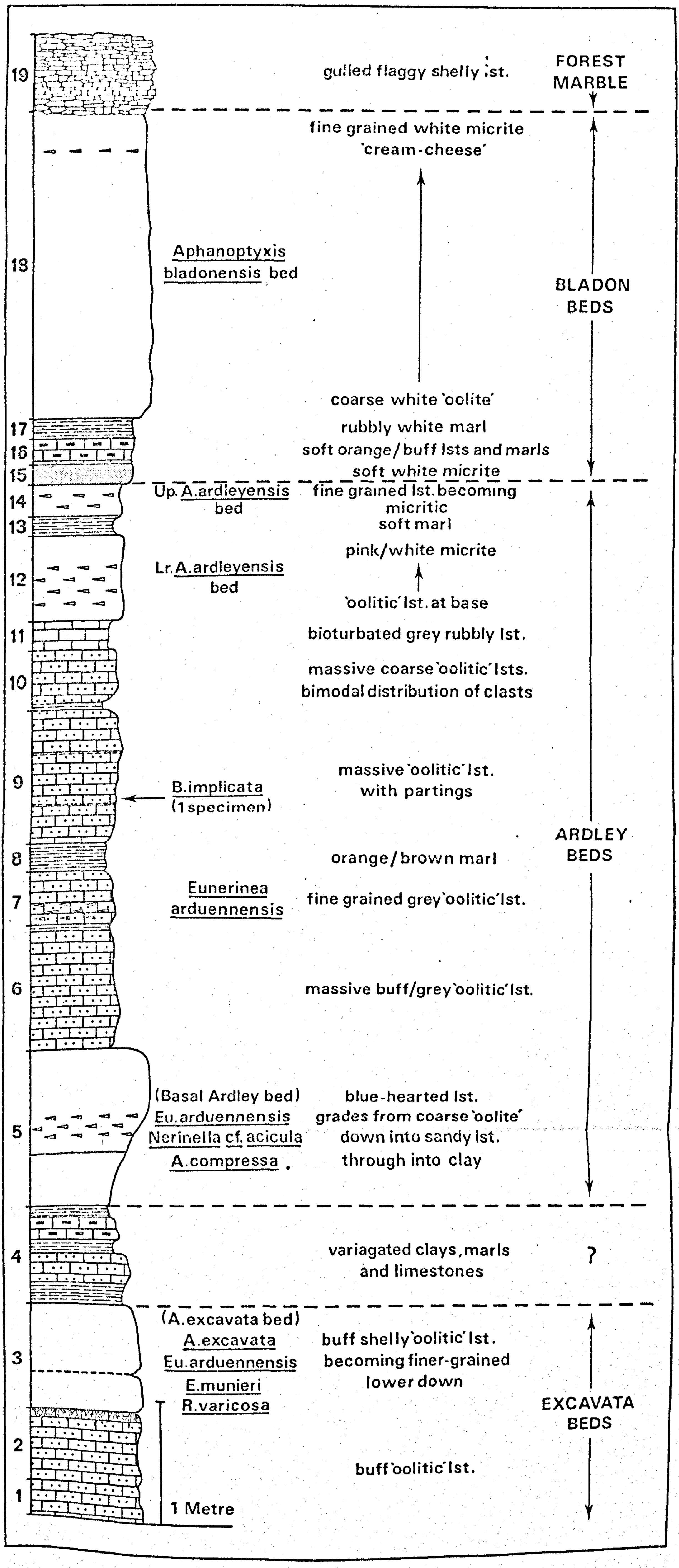


Fig.1.5. Section at Slape Hill Quarry (SP425196)

Major non-Nerineacean fauna at Dagham Downs

(within each class species are arranged in decreasing abundance)

Bed 12. *Gastropods*

Cylindrites angulatus Morris and Lycett
Neritoma (Neridomus) cf. *cooksonii* (Eudes-Deslongchamps)
Pseudomelania (Oonia) sp.
Dicroloma cf. *pupaeforme* (d'Archiac)
Chartroniella infrastriata Cox and Arkell
Globularia cf. *morrisi* Cox and Arkell
Procerithium (Cosmocerithium) cf. *betulae*
Metriomphalus sp.
Globularia formosa (Morris and Lycett)

Bed 12. *Bivalves*

Nucula (Palaeonucula) waltoni Morris and Lycett
Protocardia cf. *stricklandi* (Morris and Lycett)
Protocardia sp.
Meleagrinella echinata (W. Smith)
Trigonia (Vaugonia) cf. *moretoni* (Morris and Lycett)
Cucullaea sp.
Praeexogyra sp.

Bed 7. *Gastropods*

Rigauxia varicosa (Rigaux et Sauvage)
Trochotoma sp.
Dicroloma laevigatum (Morris and Lycett)

Bed 7. *Bivalves*

Lima (Plagiostoma) cardiiformis J. Sowerby
Chlamys (Radulopecten) vagans (J. de C. Sowerby)
Praeexogyra sp.

Other fauna

Burmirhynchia sp.
Solenopora jurassica Brown
Thamnasteria sp., ganoid fish scales.

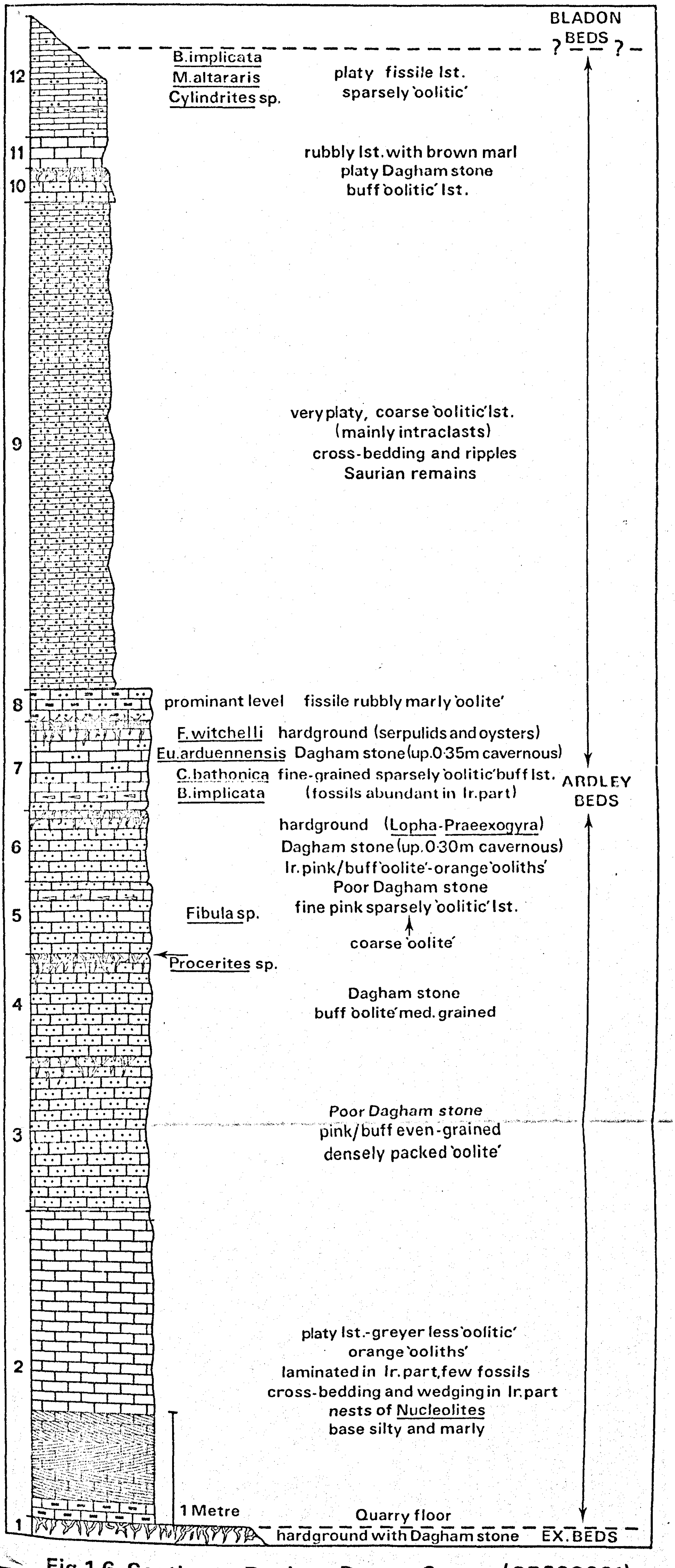


Fig.1.6. Section at Dagham Downs Quarry (SP999061)

Major non-Nerineacean fauna at Foss Cross

(within each class species are arranged in decreasing abundance)

Bed 10. Gastropods

G. minchinhamptonensis (de Loriol)
G. formosa (M. & L.)
P. (R.) cf. pulchrum (Lycett)
M. (M.) hamptonensis (M. & L.)
Trochotoma sp.
D. cf. armatum (M. & L.)
P. (O.) delia (d'Orb.)
C. turris (Cossmann ex Piette)

Bed 10. Bivalves

L. (P.) cardiiformis J. Sow.
C. annulatus (J. de C. Sow.)
C. (M.) bellona (d'Orb.)
P. cf. costatula (E. Desl.)
Pseudotrapezium sp.

Other fauna

Isastraea limitata (Lamouroux)
Lepidotus sp.
Strophodus sp.
Burmirhynichia hopkinsi
Microsolena excellisa Edwards and Haine
?Stylina sp.
Solenopora jurassica Brown

Bed 7. Gastropods

M. altararis (Cossmann) - rare
P. (L.) composita M. & L.
M. (M.) cf. hamptonensis (M. & L.)
F. cf. phasianoides (M. & L.)
Trochotoma sp.
G. formosa (M. & L.)
Globularia sp.
Dicroloma cf. armatum (M. & L.)
C. patruelina (Cossmann)
G. michelini (d'Arciac)
Proconulus sp.

Bed 7. Bivalves

L. (P.) cardiiformis J. Sow.
T. pullus J. de C. Sow.
T. (V.) moretoni M. & L.
M. cf. imbricatus (J. de C. Sow.)
C. (C.) retiferus (M. & L.)
C. concentrica (J. de C. Sow.)
C. (M.) bellona (d'Orb.)
Lopha sp.
C. annulatus (J. de C. Sow.)
Chlamys sp.
Gervillia sp.
Tancredia sp.
P. cf. lirata (J. Sow.)
P. hirsonensis (d'Arc.)
C. undulata (M. & L.)
Praeexogyra sp.
Lithophaga sp.
L. (P.) minchinhamptonensis C. & A.
C. rigidus (J. Sow.)
L. cf. gibbosa (J. Sow.)
Grammatodon sp.

Other fauna

Epithyris oxonica Arkell
Burmirhynchia hopkinsi
D. digonoides (S.S. Buckman)
Stiphrothyris sp.
Strophodus sp.
S. jurassica Brown
C. cf. mulleri Wright
Favreina

Bed 4. Gastropods

Globularia sp.
Ampullospira sp.

Bed 4. Bivalves

M. imbricatus (J. de C. Sow.)
C. (M.) bellona (d'Orb.)
L. (P.) cardiiformis J. Sow.
L. cf. costata (J. de C. Sow.)
Praeexogyra sp.
Chlamys sp.
Astarte sp.

Other fauna

C. porpites (W. Smith)
Cladophyllia sp.
N. woodwardi (Wright)
S. jurassica Brown
Strophodus sp.
Favreina

Bed 2. Gastropods

N. (N.) cooksonii (E. Desl.)
G. formosa (M. & L.)
A. labadeyi (d'Arc.)
Dicroloma sp.
Pseudomelania (Oonia) sp.
Metriomphalus sp.

Bed 2. Bivalves

C. (M.) bellona (d'Orb.)
T. pullus J. de C. Sow.
Anisocardia sp.
C. rigidus (J. Sow.)
M. (I.) plicatus J. Sow.
P. pes-bovis (d'Arc.)

Other fauna

M. (S.) cf. tenuiradiata (de Fromentel et Ferry)
C. porpites (W. Smith)
N. woodwardi (Wright)
Epithyris sp.
Lepidotus sp.

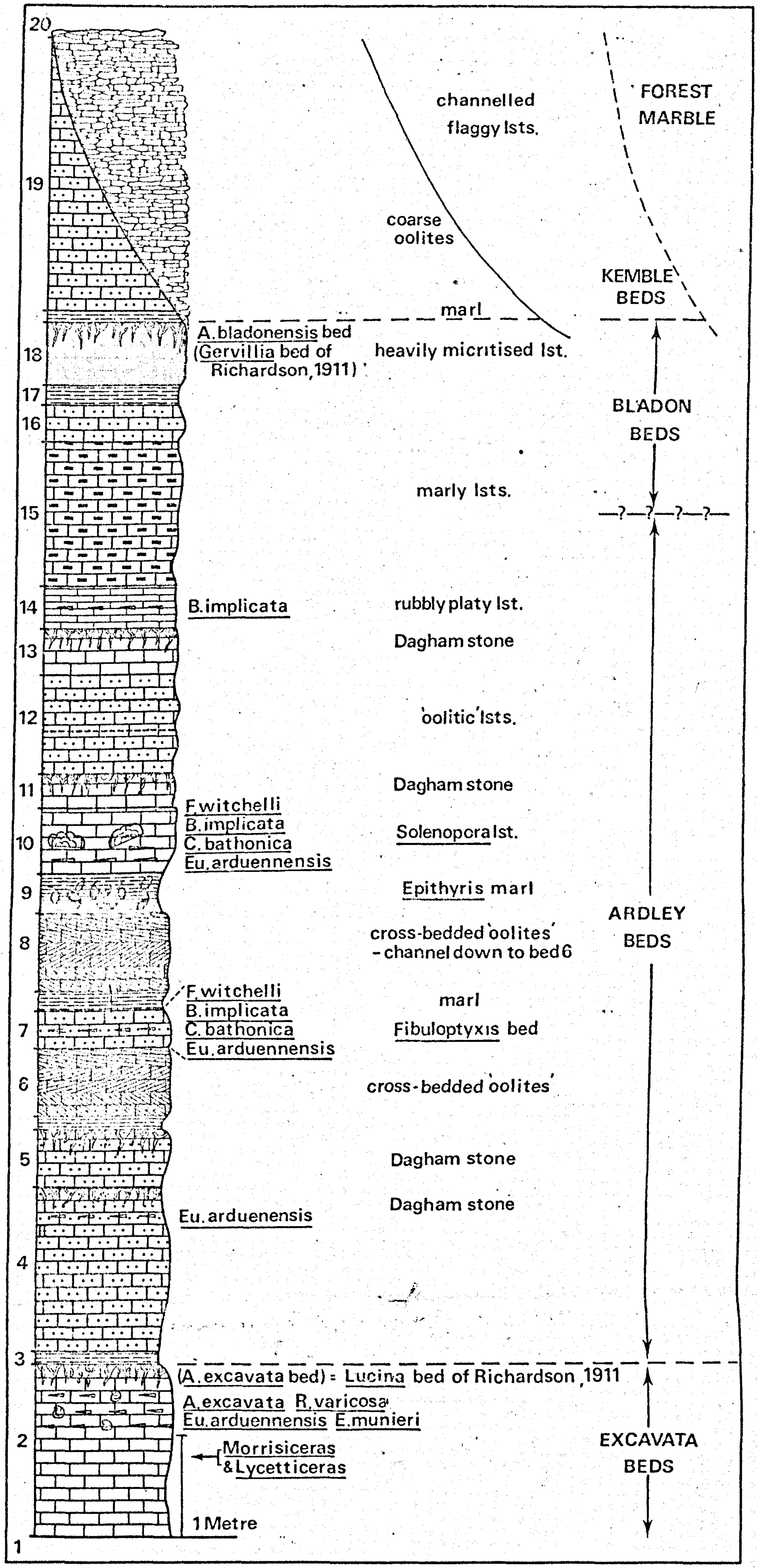


Fig.1.7. Section at Foss Cross quarry (SP 055092) and adjacent railway-cuttings (after Richardson, 1911 & present author)

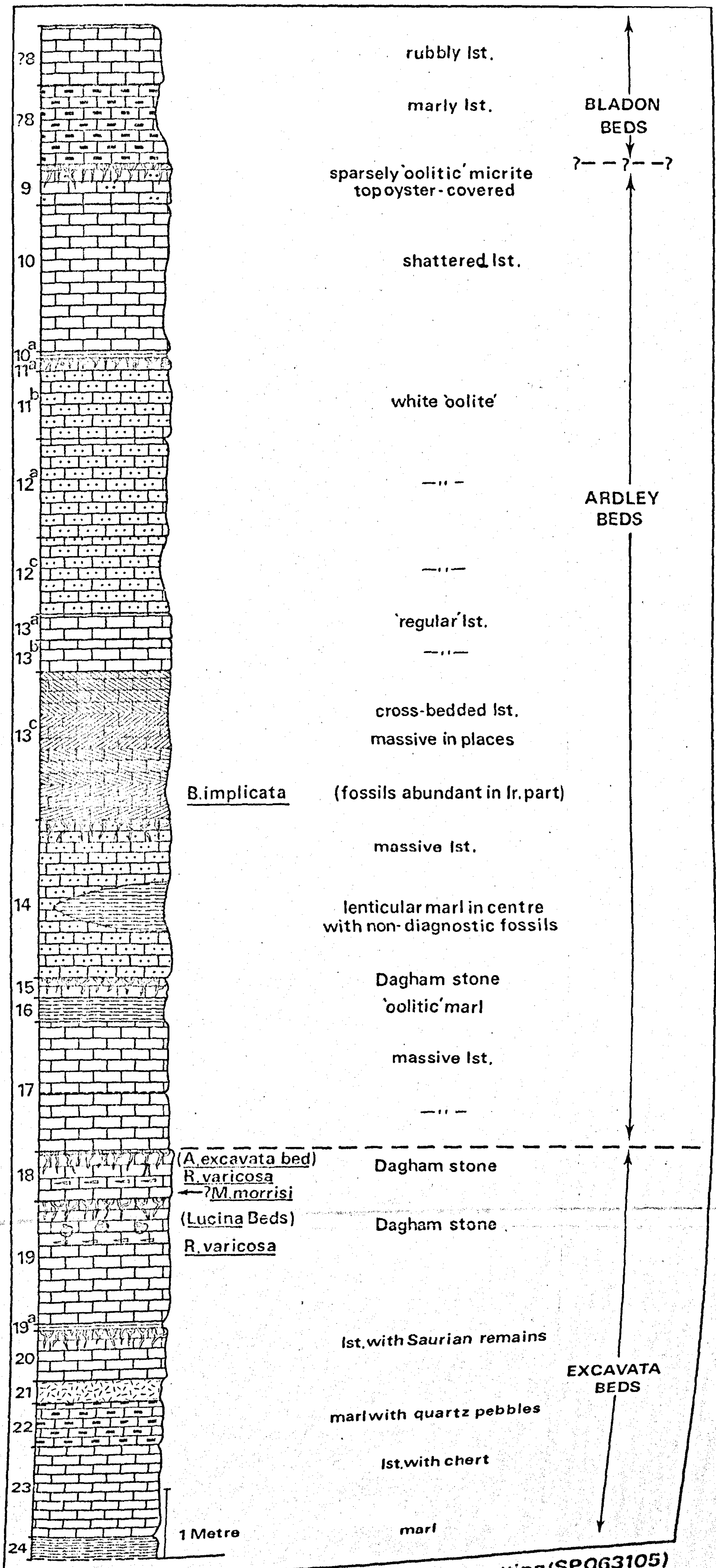


Fig.1.8. Section in Stony Furlong railway-cutting (SP063105) (after Richardson, 1911 & present author)

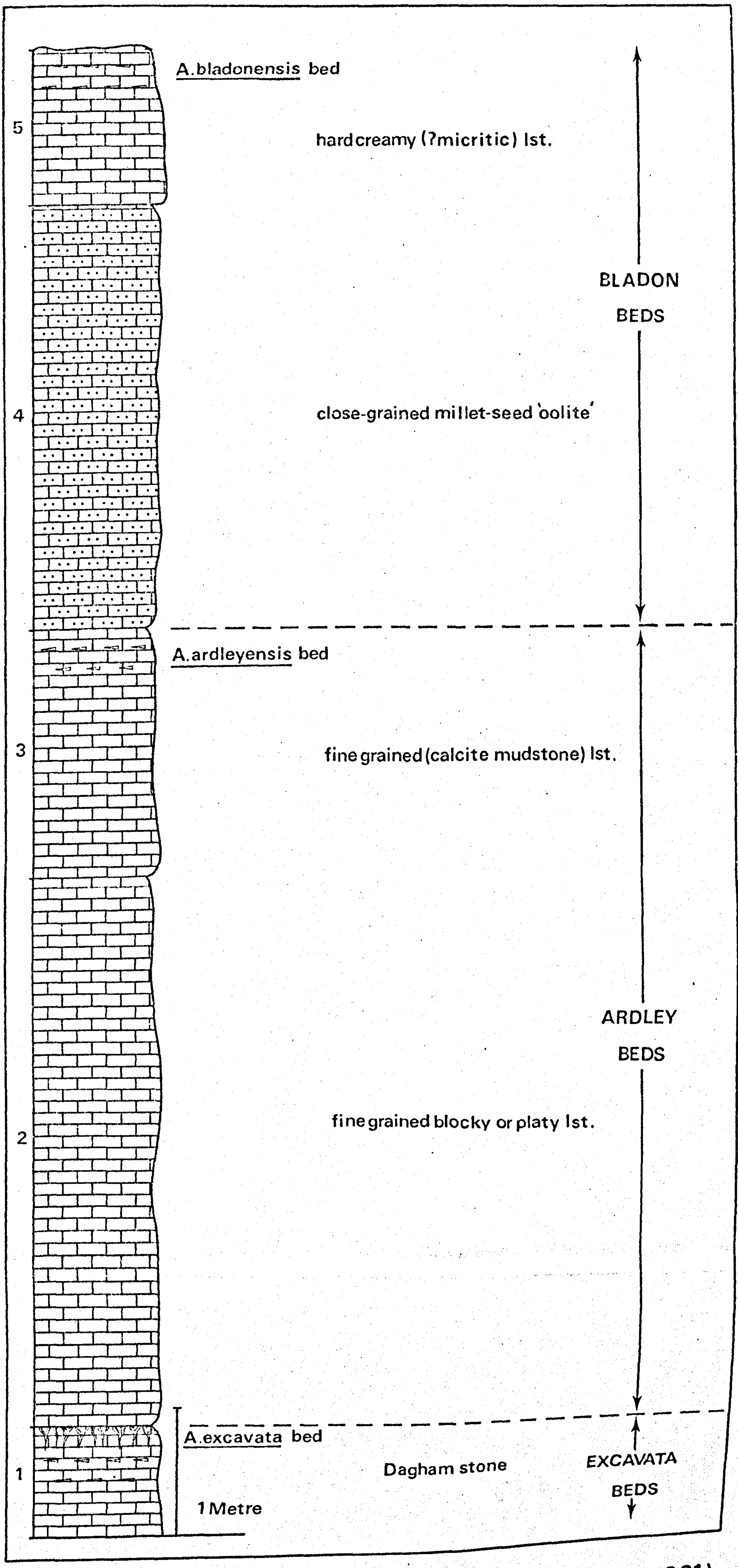


Fig. 1.9 Section at Signet (after Worssam & Bisson, 1961)

Major non-Nerineacean fauna at Sturt Farm

(within each class species are arranged in decreasing abundance)

Bed 5. Gastropods

Amberleya bathonica Cox and Arkell
Neritoma (*Neridomus*) cf. *cooksonii* (Eudes-Deslongchamps)
Globularia formosa (Morris and Lycett)
Paracerithium cf. *costigerum* (Piette)
Pseudomelania (*Oonia*) cf. *leymeriei* (d'Archiac)
Dicroloma sp.
Ceritella actaeoniformis (Piette)
Metriomphalus (*Metriomphalus*) *hamptonensis* (Morris and Lycett)
Ataphrus belus (d'Orb.)
Nummocalcar polygonium (d'Archiac)
Cylindrobullina sp.
Ceritella conica (Morris and Lycett)
Neridomus neritoides (Morris and Lycett)

Bed 5. Bivalves

Cavilucina (*Mesomiltha*) *bellona* (d'Orb.)
Trigonia pullus J. de C. Sowerby
Pteroperna sp.
Camptonectes sp.

Other fauna

Nucleolites woodwardi (Wright)
Chomatoseris porpites (W. Smith)
Burmirhynchia sp.

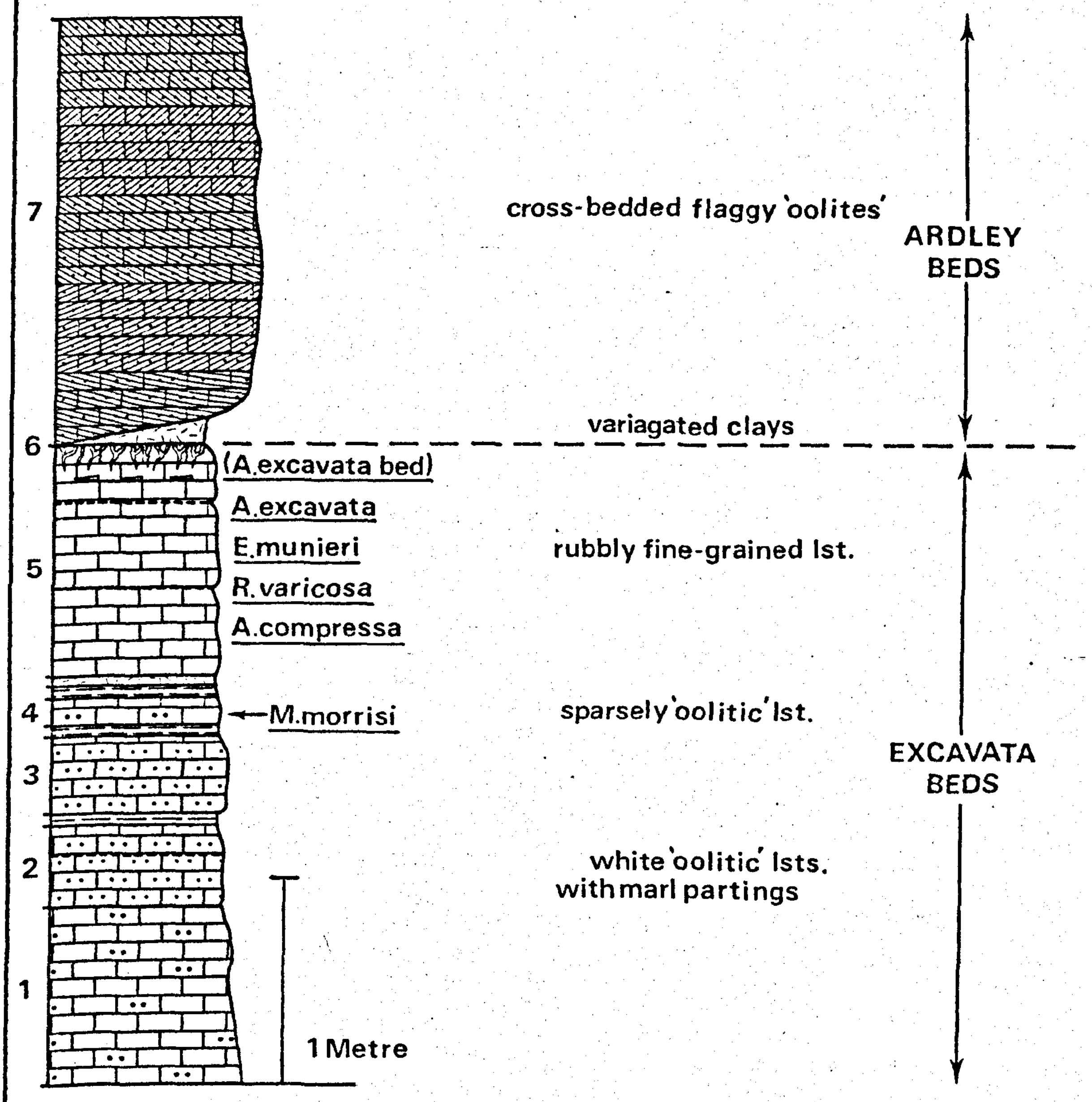


Fig.1.10. Section at Sturt Farm (SP 271109)

Major non-Nerineacean fauna at Eton College

(within each class specimens are arranged in decreasing abundance)

Bed 14 - upper part. Gastropods

Amberlya bathonica Cox and Arkell

Neritoma (Neridomus) cf. *cooksonii* (Eudes-Deslongchamps)

Pseudomelania (Oonia) sp.

Bed 14 - upper part. Bivalves

Modiolus (Inoperna) sp.

Sphaeriola sp.

Anisocardia sp.

For further details of fauna in this section see Arkell, 1931 and Worssam and Bisson, 1961.

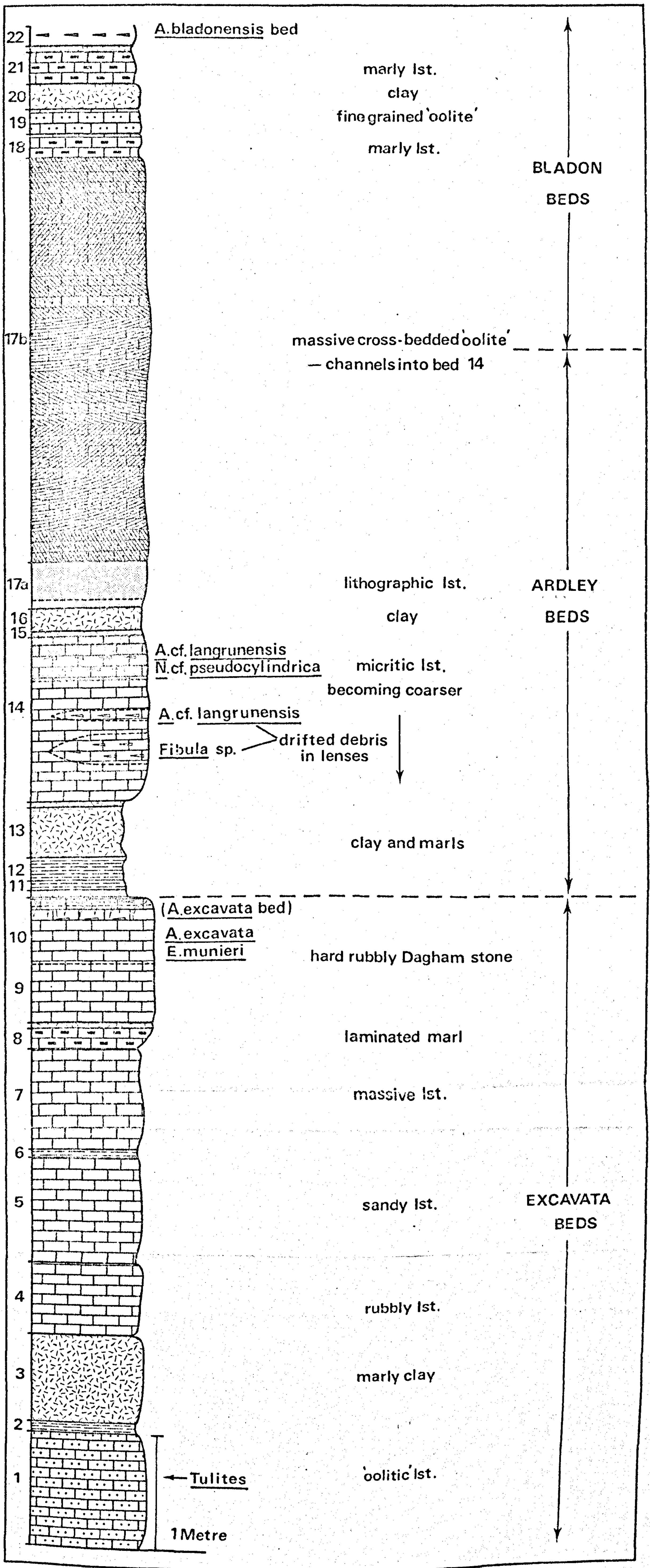


Fig. 1.11. Section at Eton College quarry (SP 297102)

Major non-Nerineacean fauna at Worsdue (Arkell)

(within each class species are arranged in decreasing abundance)

Bed 10. Gastropods

Fibula cf. phasianoides (Morris and Lycett)
Neritoma (Neridomus) cooksonii (Eudes-Deslongchamps)
Procerithum (Cosmocerithium) cf. dorvali (Cossmann)
Procerithium sp.
Ataphrus sp.
Metriomphalus sp.
?Ceritella sp.

Bed 10. Bivalves

Protocardia cf. buckmanni (Morris and Lycett)
Trigonia (Vaugonia) impressa Broderip
Trigonia pullus J. de C. Sowerby
Trigonia (Vaugonia) moretoni (Morris and Lycett)
Eonavicula minuta (J. de C. Sowerby
Chlamys (Radulopecten) cf. vagans (J. de C. Sowerby)
Costigervillia sp.

Bed 6.

Amberleya bathonica Cox and Arkell
Globularia formosa (Morris and Lycett)
Neridomus (Neritoma) cf. cooksonii (Eudes-Deslongchamps)
Pseudomelania (Oonia) cf. delia (d'Orb.)

Other fauna

Burmirhynchia sp.
Nucleolites sp.

Major non-Nerineacean fauna at Worsham (Asthall)

(within each class species are arranged in decreasing abundance)

Bed 10. Gastropods

Fibula cf. *phasianoides* (Morris and Lycett)
Neritoma (*Neridomus*) *cooksonii* (Eudes-Deslongchamps)
Procerithum (*Cosmocerithium*) cf. *dorvali* (Cossmann)
Procerithium sp.
Ataphrus sp.
Metriomphalus sp.
?*Ceritella* sp.

Bed 10. Bivalves

Protocardia cf. *buckmanni* (Morris and Lycett)
Trigonia (*Vaugonia*) *impressa* Broderip
Trigonia *pullus* J. de C. Sowerby
Trigonia (*Vaugonia*) *moretoni* (Morris and Lycett)
Eonavicula *minuta* (J. de C. Sowerby
Chlamys (*Radulopecten*) cf. *vagans* (J. de C. Sowerby)
Costigervillia sp.

Bed 6.

Amberleya *bathonica* Cox and Arkell
Globularia *formosa* (Morris and Lycett)
Neridomus (*Neritoma*) cf. *cooksonii* (Eudes-Deslongchamps)
Pseudomelania (*Oonia*) cf. *delia* (d'Orb.)

Other fauna

Burmirhynchia sp.
Nucleolites sp.

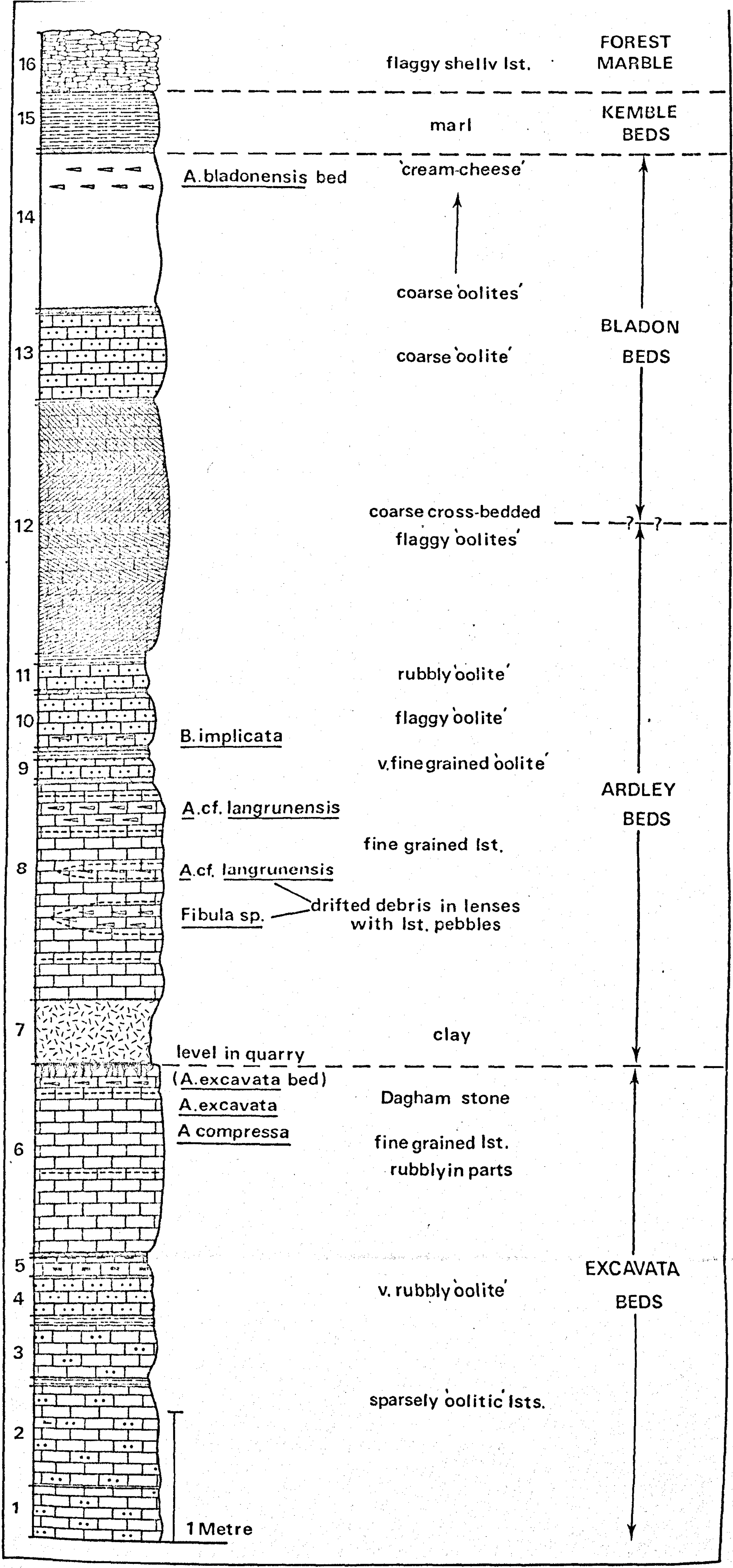


Fig.1.12. Section at Worsham (Asthall) quarry (SP300119)

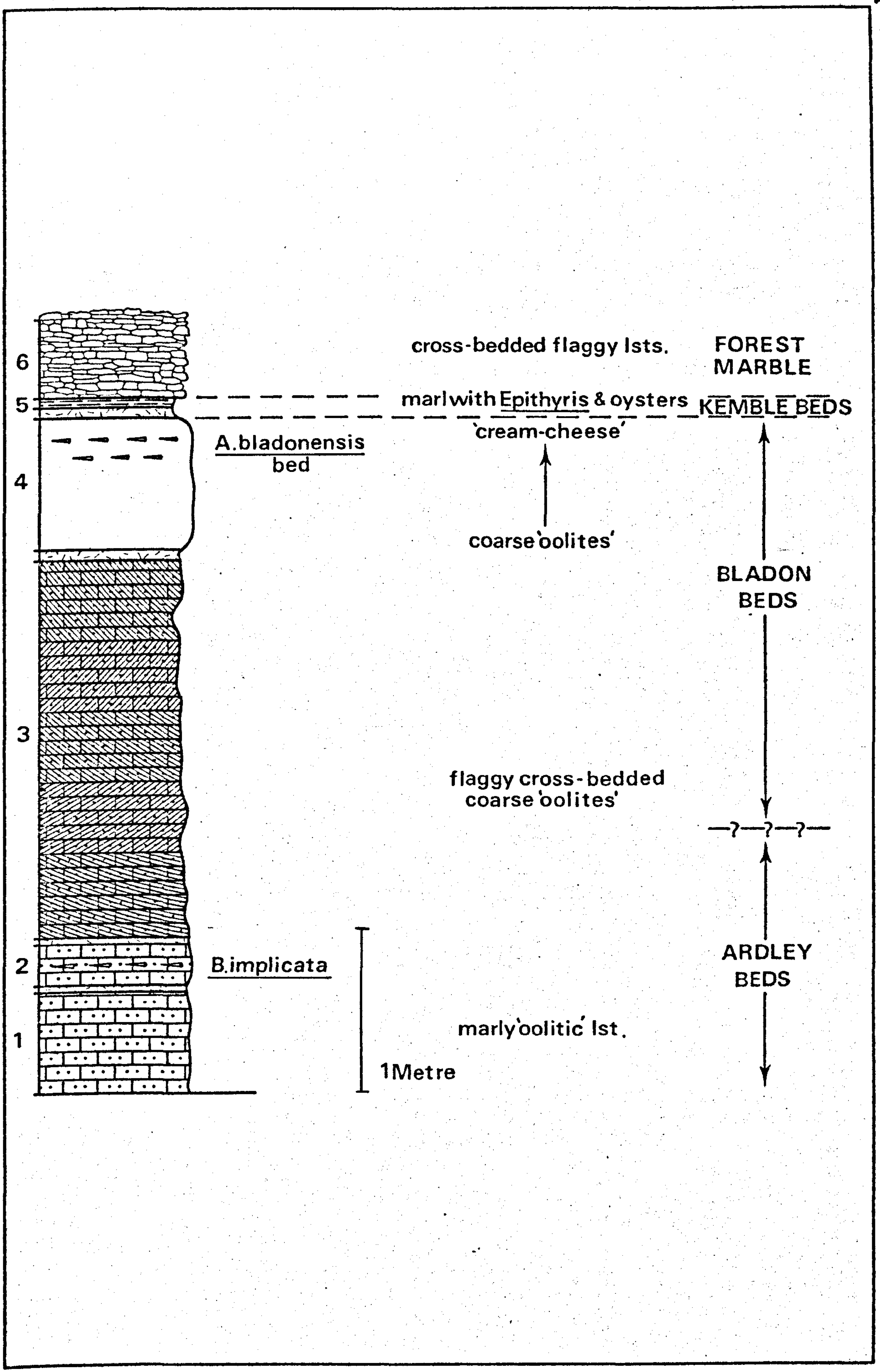


Fig.1.13. Section at Minster Lovell (SP 318109)

Major non-Nerineacean fauna at North Leigh

(within each class specimens are arranged in decreasing abundance)

Bed 17. *Gastropods*

Neritoma (*Neridomus*) cf. *cooksonii* (Eudes-Deslongchamps)

Bed 17. *Bivalves*

Trigonia pullus J. de C. Sowerby

Protocardia cf. *stricklandi* (Morris and Lycett)

Cavilucina (*Mesomiltha*) *bellona* (d'Orb.)

Pteroperna sp.

Pinna sp.

Osteomya dilata (Phillips)

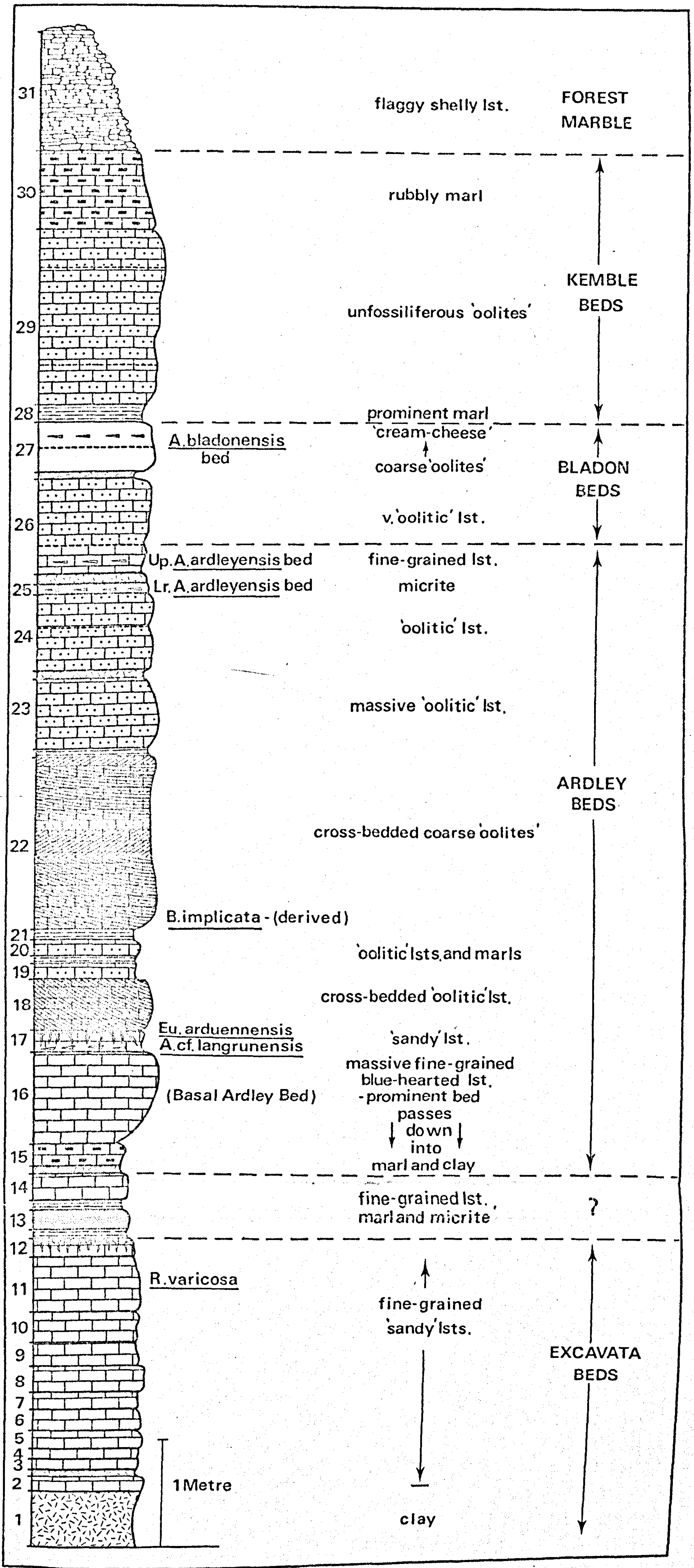


Fig.1.14. Section at North Leigh (SP 389141)

Major non-Nerineacean fauna at Bunkers Hill (Shipton-on-Cherwell Cement Works)

(within each class species are arranged in decreasing abundance)

Bed 21. *Gastropods*

Neridomus (*Neritoma*) cf. *cooksonii* (Eudes-Deslongchamps)

Trochotoma sp.

Bed 21. *Bivalves*

Modiolus imbricatus J. Sowerby

Lima (*Plagiostoma*) *cardiiformis* J. Sowerby

Other fauna

Isastraea sp.

Cyathopora pratti Edwards and Haime

Epithyris oxonica Arkell

Bed 7. *Bivalves*

Lima (*Plagiostoma*) *cardiiformis* J. Sowerby

Praeexogyra sp.

Other fauna

Epithyris oxonica Arkell

Burmirhynchia sp.

Isastraea sp.

Acrosalenia sp.

Bed 6.

As bed 21 together with *Burmirhynchia* sp.

Cavilucina (*Mesomiltha*) *bellona* (d'Orb.) and *Praeexogyra*

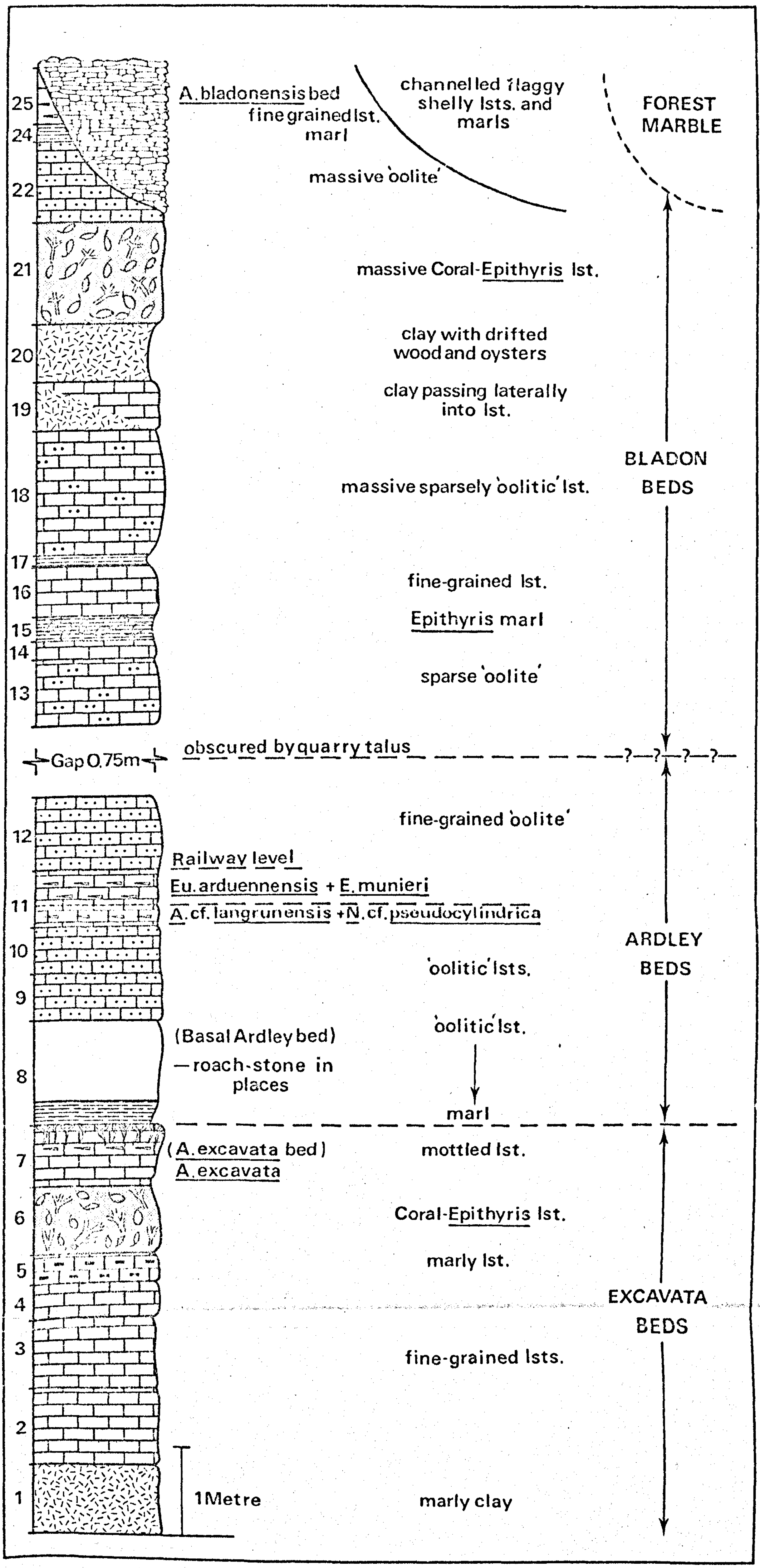


Fig.1.15. Section at Bunkers Hill quarry (SP 474175)

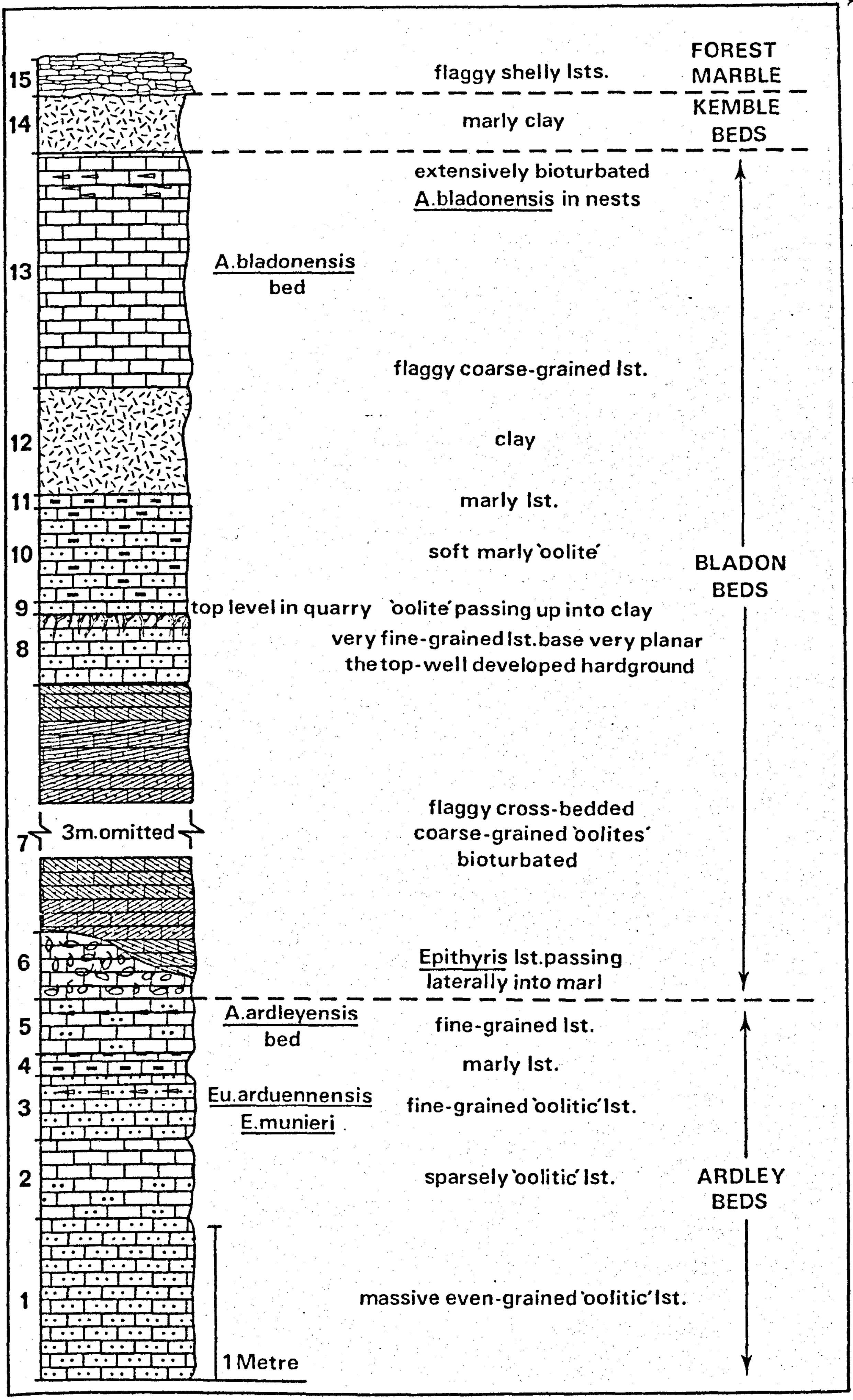


Fig.1.16. Section at Enslow Bridge Quarry (SP478186)

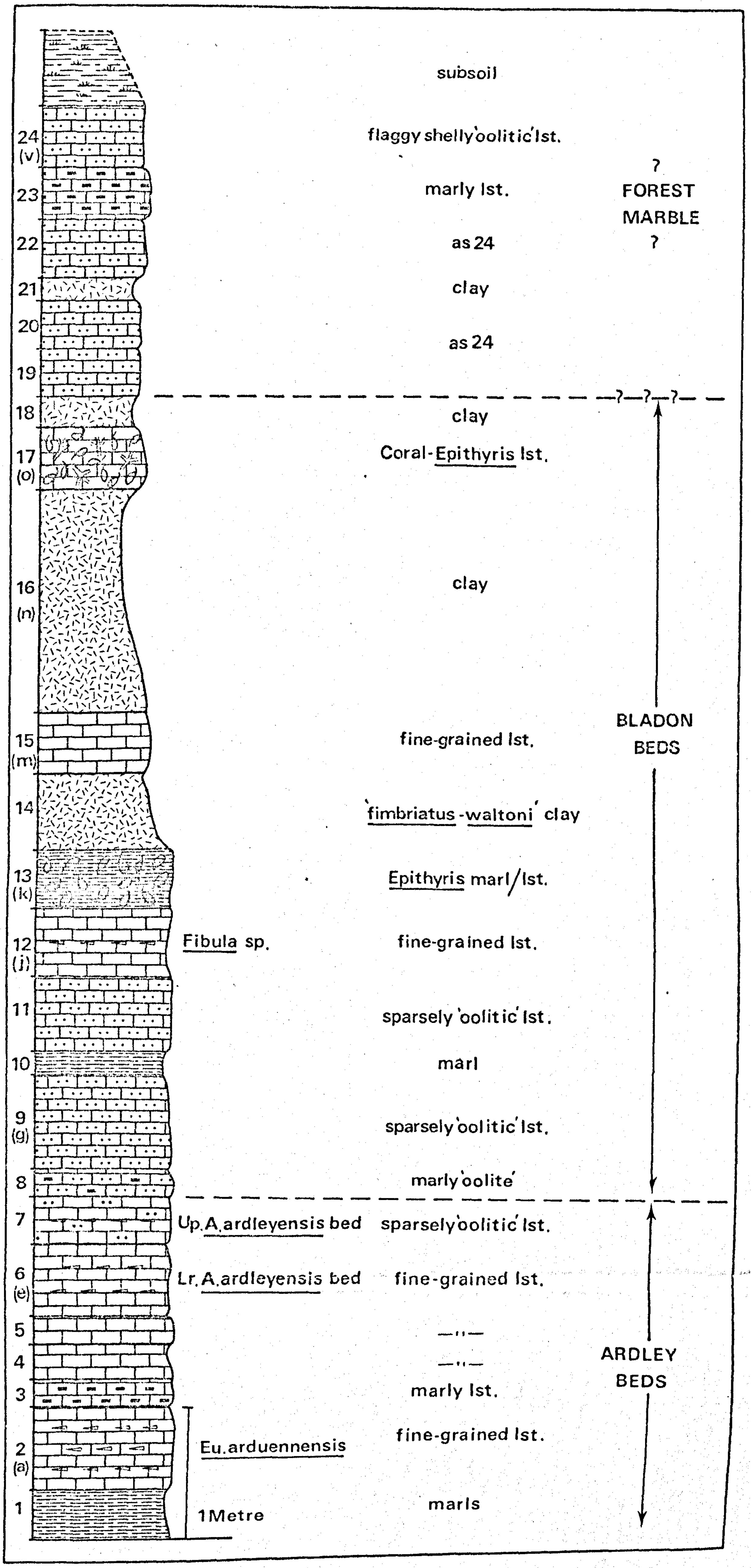


Fig.1.17. Section at Kirtlington Old Cement Works (SP494199) (after McKerrow *et al.*,1969 - their beds shown ( ) - & present author)

Major non-Nerineacean fauna at Ardley Fields Quarry

(within each class species are arranged in decreasing abundance)

Bed 44. Gastropods

Naricopsina subcaniculata (Morris and Lycett)
Trochotoma obtusa Morris and Lycett

Bed 44. Bivalves

Modiolus imbricatus J. Sowerby
Lima (Plagiostoma) subcardiiformis (Greppin)
Praeexogyra hebridica (Forbes)

Other fauna

Epithyris oxonica Arkell
Isastraea sp.

Bed 41. Gastropods

Cylindrobullina luidii (Morris)
Amberleya bathonica Cox and Arkell
Naricopsina cotswoldensis Cox and Arkell
Neritoma (Neridomus) cf. cooksonii (Eudes-Deslongchamps)
Procerithium (Rhabdocolpus) variabile (Morris and Lycett)
Ataphrus cf. ovulatus (Héb et Deslongchamps)

Bed 41. Bivalves

Protocardia cf. stricklandi (Morris and Lycett)
Mactromya varicosa (J. Sowerby)
Cavilucina (Mesomiltha) bellona (d'Orb.)

Bed 32a.

see text (Tables 5.E and 5.F)

Bed 30. Gastropods

Amberleya bathonica Cox and Arkell
Neritoma (Neridomus) cf. cooksonii (Eudes-Deslongchamps)
Globularia cf. formosa (Morris and Lycett)

Bed 30. Bivalves

Protocardia sp.
Nucula (Palaeonucula) waltoni Morris and Lycett
Modiolus imbricatus J. Sowerby
Modiolus (Inoperna) plicatus
Pteroperna cf. costulata (Eudes-Deslongchamps)
Anisocardia sp.
Astarte sp.
Lima (Plagiostoma) subcardiiformis (Greppin)
Cavilucina (Mesomiltha) bellona (d'Orb.)
Praeexogyra hebridica (Forbes)
Trigonia pullus J. de C. Sowerby
Eonavicula minuta J. de C. Sowerby
Pholadomya sp.
Ceratomya sp.

Other fauna

Clypeus mülleri Wright
Kallirhynchia sp.
Indet. Terebratulid - see Arkell, Richardson and Pringle, 1933
Isastraea sp.

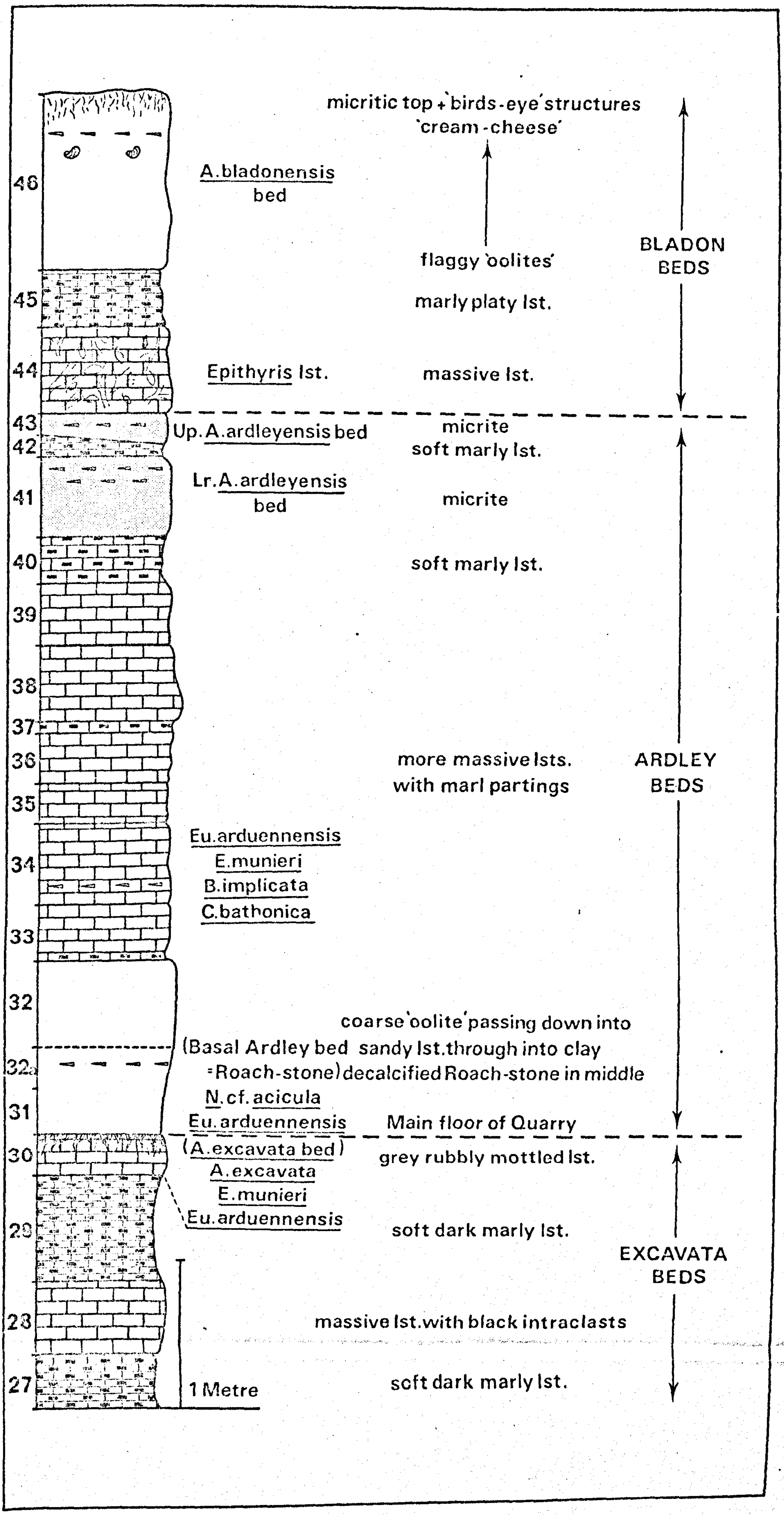


Fig.1.18. Section at Ardley Fields Quarry (SP541265)

Major non-Nerineacean fauna at Croughton

(within each class species are arranged in decreasing abundance)

Bed 10.

Anisocardia sp.

Stiphrothyris sp.

Nucleolites sp.

Acrosalenia sp.

Bed 7. *Gastropods*

Globularia sp.

Bed 7. *Bivalves*

Trigonia (*Vaugonia*) cf. *moretoni* (Morris and Lycett)

Trigonia pullus J. Sowerby

Pholadomya sp.

Grammatodon sp.

Chlamys (*Radulopecten*) *vagans* (J. de C. Sowerby)

Praeexogyra sp.

Lopha sp.

Protocardia sp.

Other fauna

Chomatoseris sp. Pagurid, serpulids and echinoid debris.

Bed 3. *Gastropods*

Amberleya bathonica Cox and Arkell

Globularia sp.

Bed 3. *Bivalves*

Trigonia pullus J. Sowerby

Pholadomya sp.

Homomya sp.

Other fauna

Clypeus mülleri Wright

Nucleolites sp.

Pagurid and serpulids. Indet. Terebratulid as at Ardley Fields Quarry, bed 30.

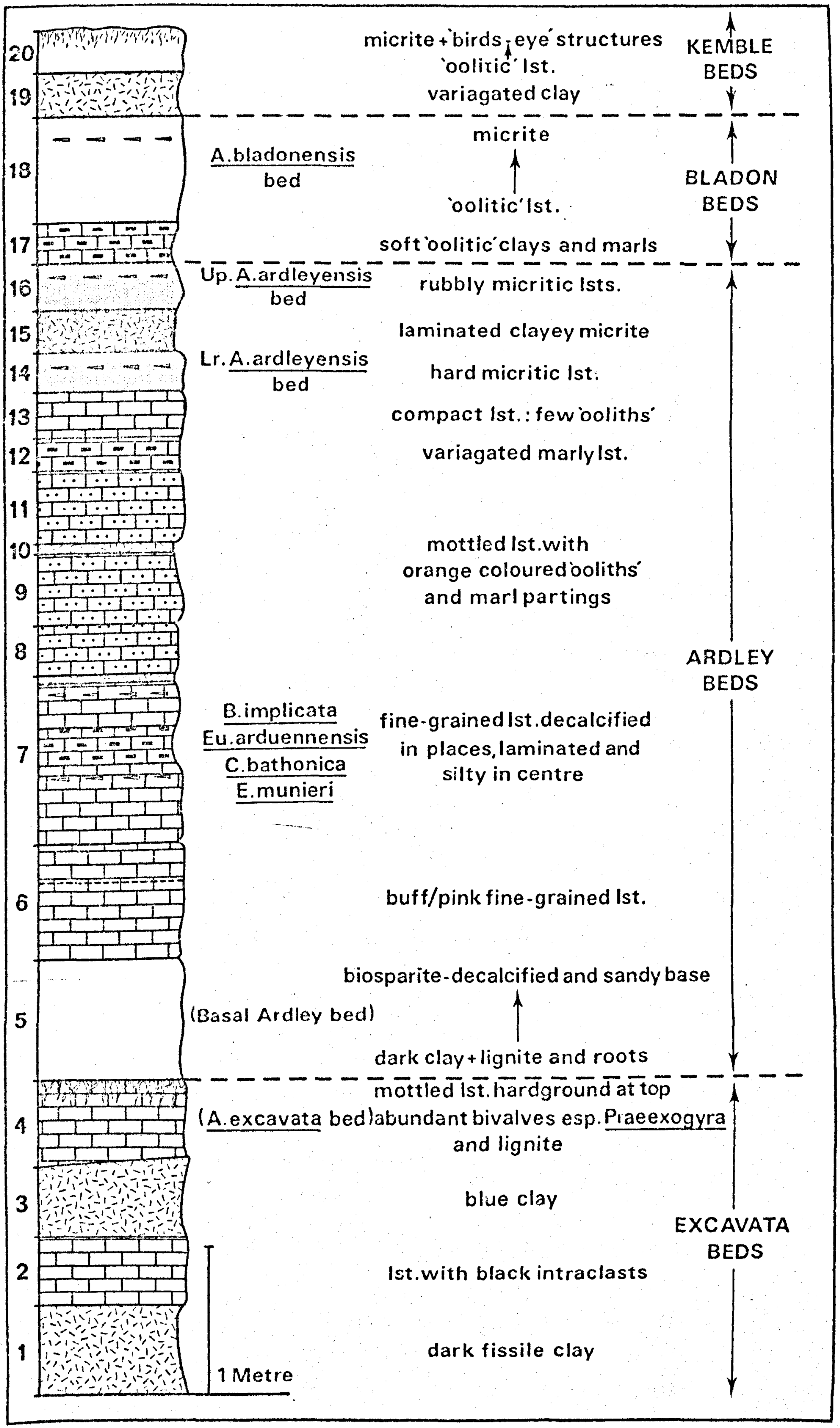


Fig.1.19. Section at Croughton Quarry (SP563335)

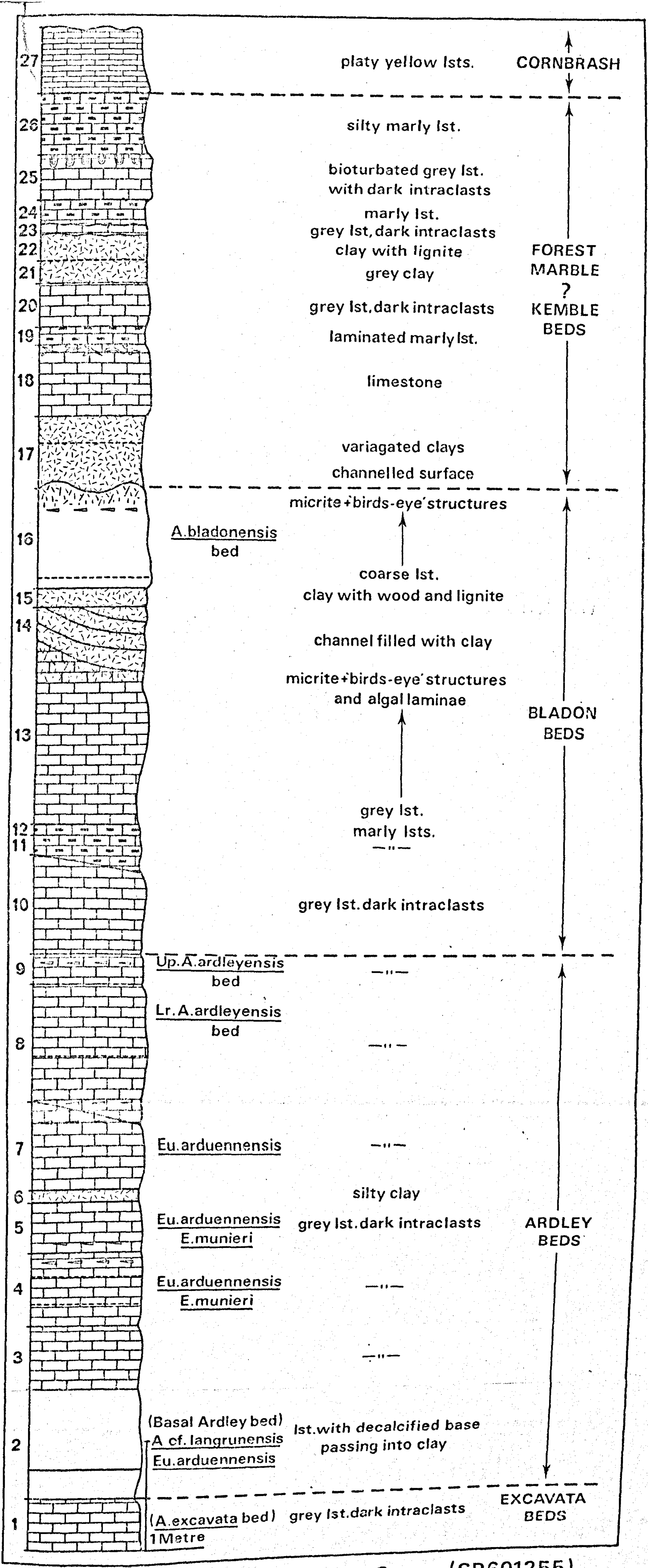


Fig.1.20. Section at Stratton Audley Quarry (SP601255)

Major non-Nerineacean fauna at Great Rollright

(within each class species are arranged in decreasing abundance)

Bed 1. Gastropods

Neritoma (Neridomus) cf. cooksonii (Eudes-Deslongchamps)

Globularia sp.

Dicroloma laevigatum (Morris and Lycett)

Amberleya bathonica Cox and Arkell

Fibula sp.

Bed 1. Bivalves

Fimbria lajoyei (d'Archiac) abundant

Trigonia (Vaugonia) moretoni (Morris and Lycett)

Protocardia sp.

Pteroperna costulata (Eudes-Deslongchamps)

Chlamys (Radulopecten) sp.

Modiolus imbricatus J. Sow.

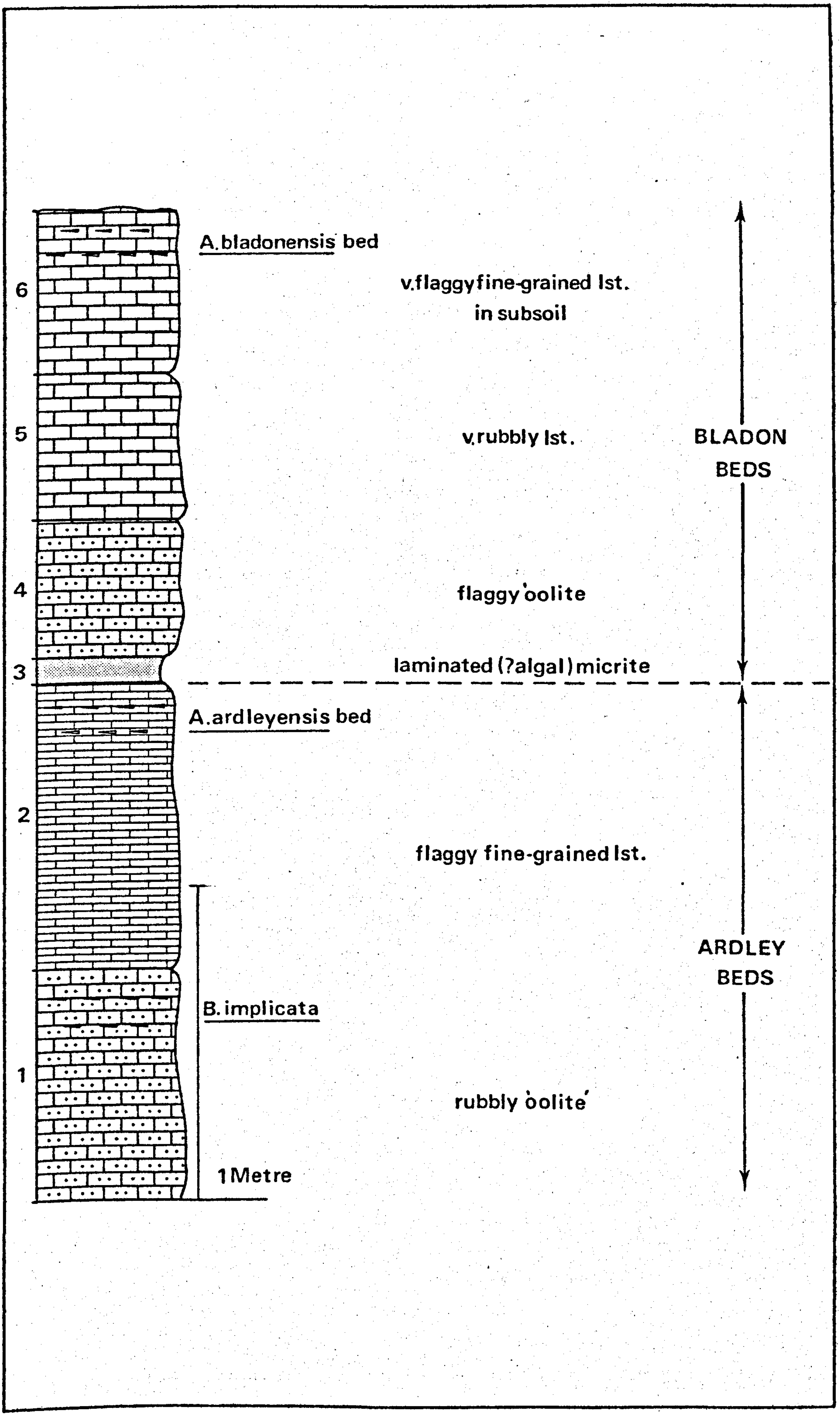


Fig.1.21. Section at Great Rollright (SP 323302)


A proposed correlation of the White Limestone

Fig.1·22

Faunal characteristics of the Excavata Beds

A) The *A. excavata* bed

The fauna of the *A. excavata* bed has been studied at five localities, viz. Foss Cross, Sturt Farm, Worsham, Slape Hill and Ardley Fields Quarry (see Fig. 1.1 for localities; Figs. 1.23 - 1.27 for details of fauna and Figs. 1.7, 1.10, 1.12, 1.5 and 1.18 for details of sections).

A. excavata and the pseudo Nerineid *Rigauxia varicosa* (Rigaux et Sauvage) (a genus not previously recorded from this country) are the commonest and most characteristic species of this horizon. Details of the morphology and taxonomy of these and other species are given in Chapter 2. *Rigauxia varicosa* is also found at Dagham Downs but at stratigraphically higher horizons and in much smaller numbers. This is the only additional occurrence of *Rig. varicosa* known to the author other than in the *A. excavata* bed. *Neridomus (Neritoma) cooksonii* (Desl.) and *Globularia formosa* (Morris & Lycett) are also common and widely distributed throughout the *A. excavata* bed but their widespread occurrence at other horizons in the White Limestone suggests they are of little stratigraphic value. The distribution of *Amberleya bathonica* Cox & Arkell is very similar to that of *N. cooksoni* and *G. formosa* but although this species is especially abundant at Sturt Farm and Ardley Fields Quarry, it also is sporadically ubiquitous throughout the White Limestone. Two other Nerineid gastropods *A. compressa* sp. nov. and *Endiaplocus munieri* (a genus not previously recorded from this country) occur within the *A. excavata* bed in small numbers and over a wide area, although

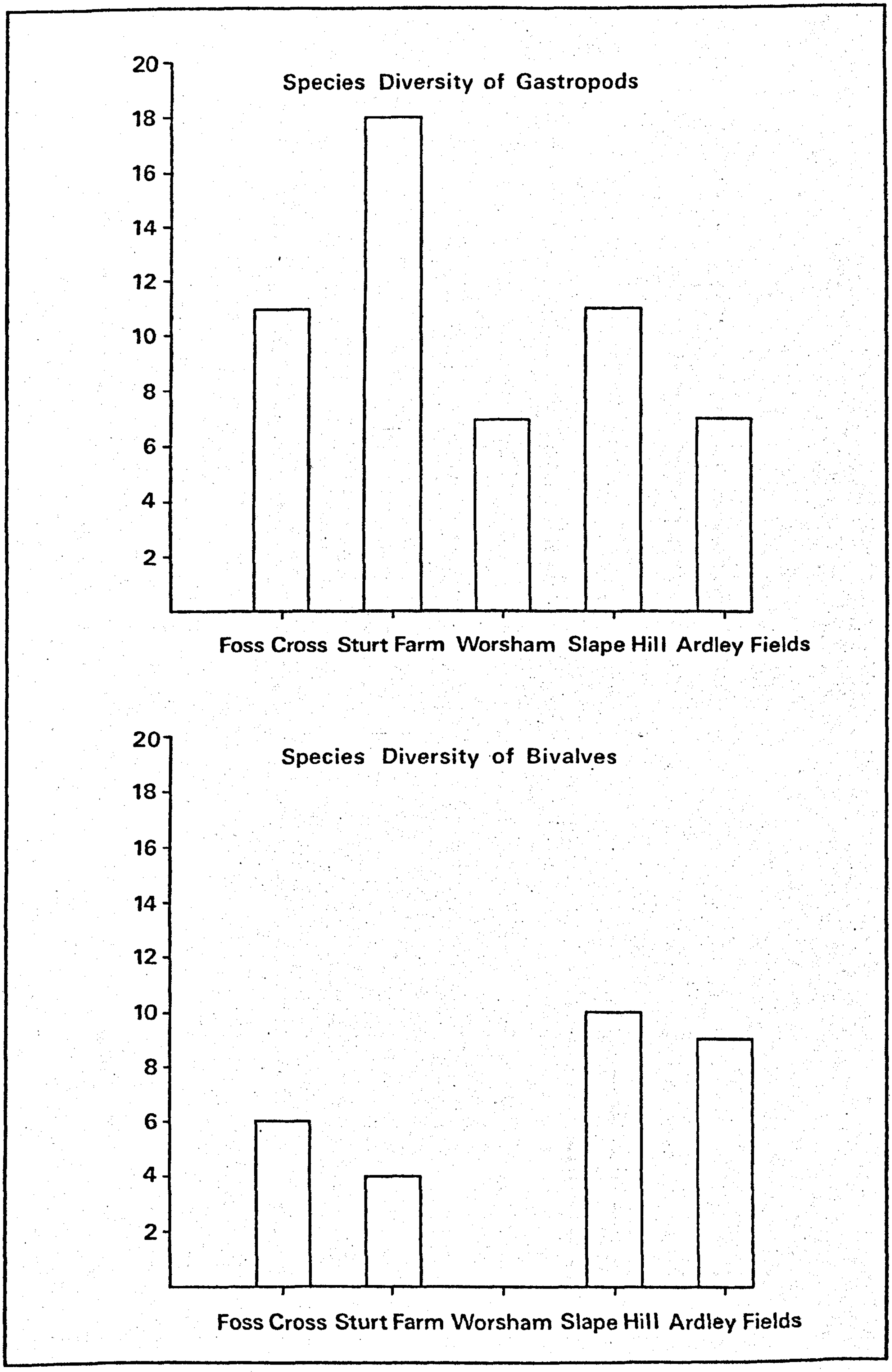


Fig 1.23.The Fauna of the A. excavata bed.

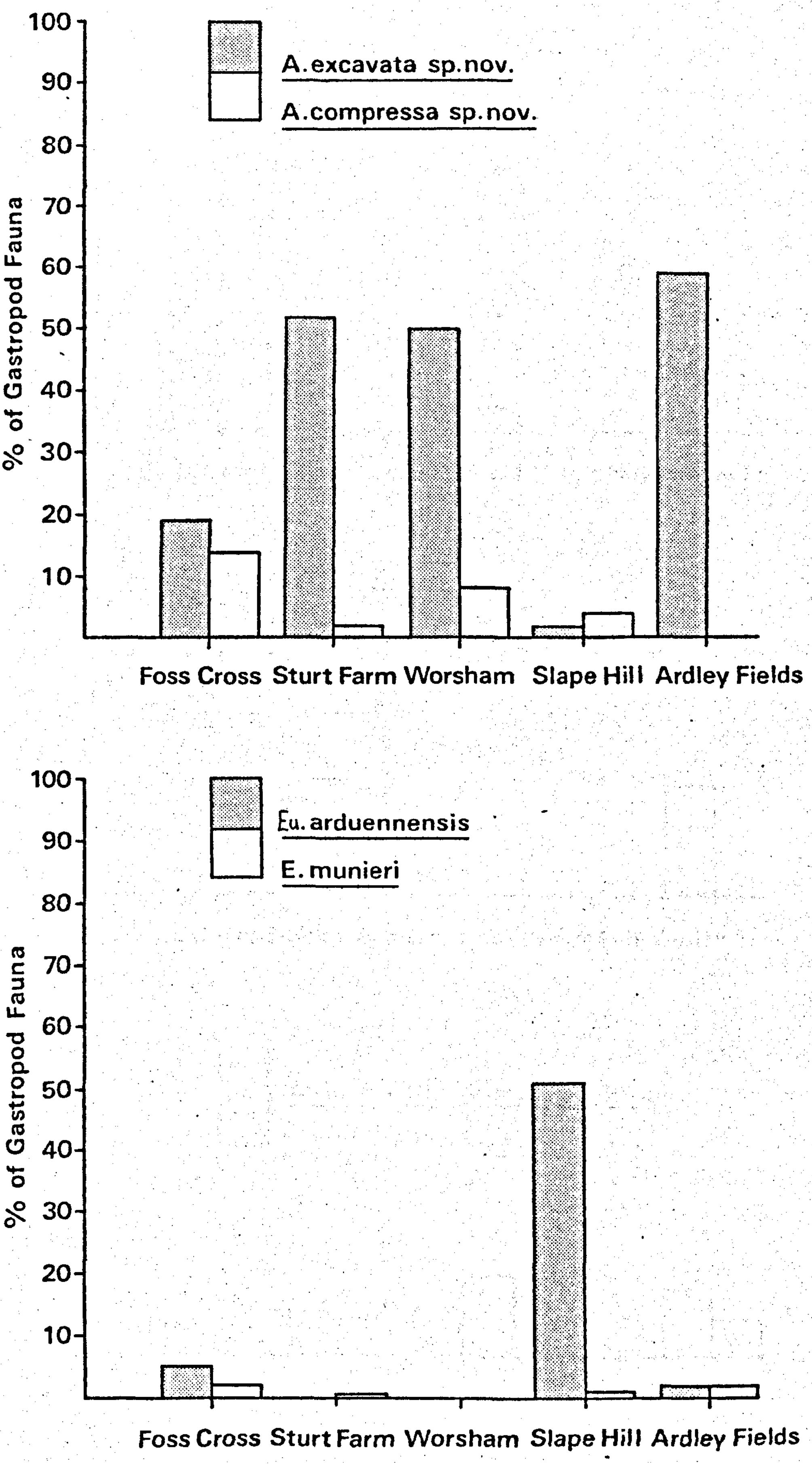


Fig 1.24. The Fauna of the A. excavata bed.

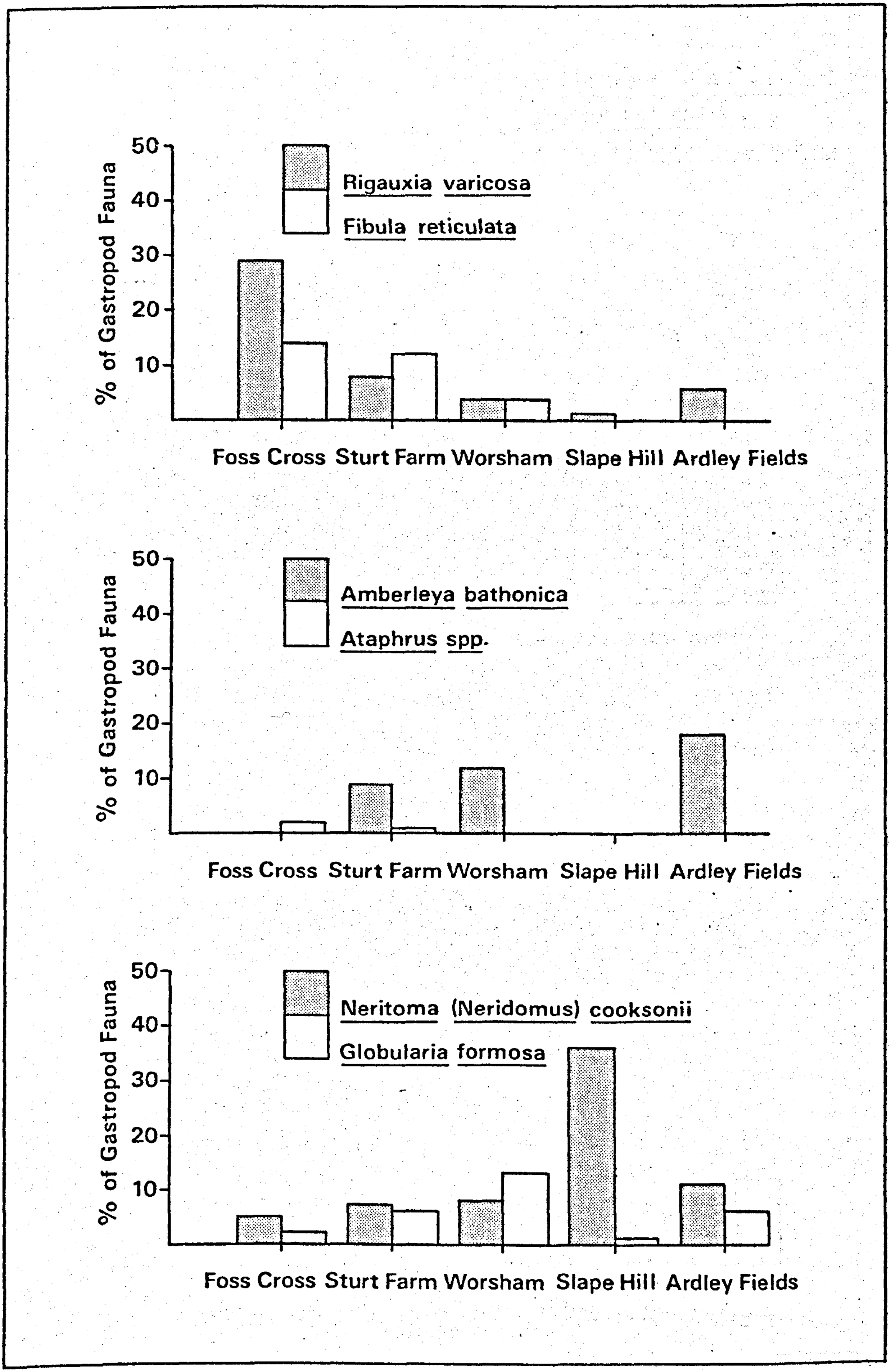
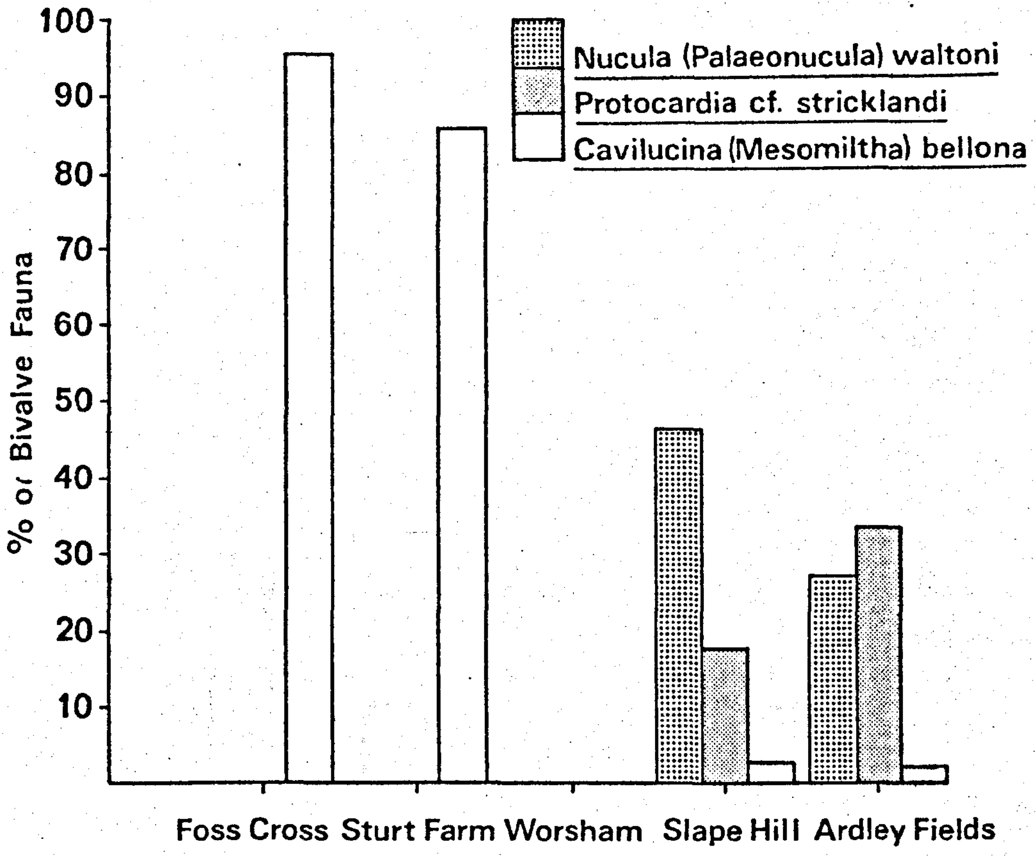


Fig1.25.The Fauna of the *A.excavata* bed.



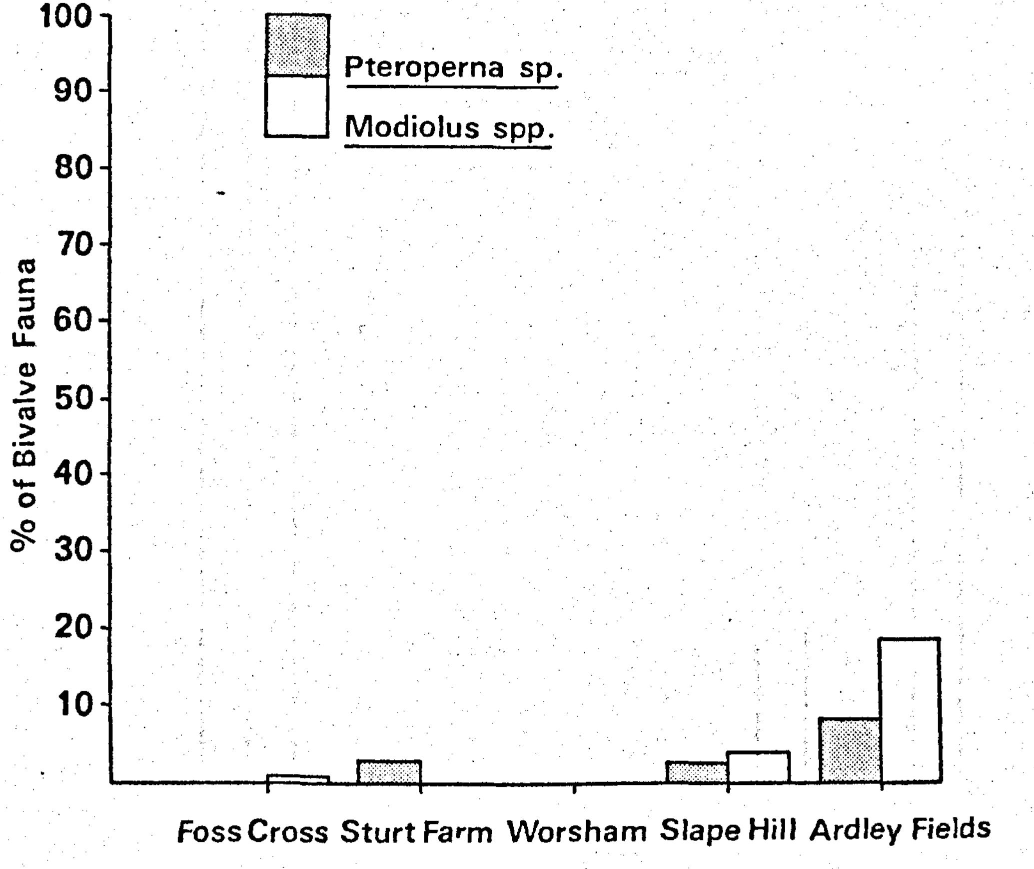


Fig 1.26. The Fauna of the A. excavata bed.

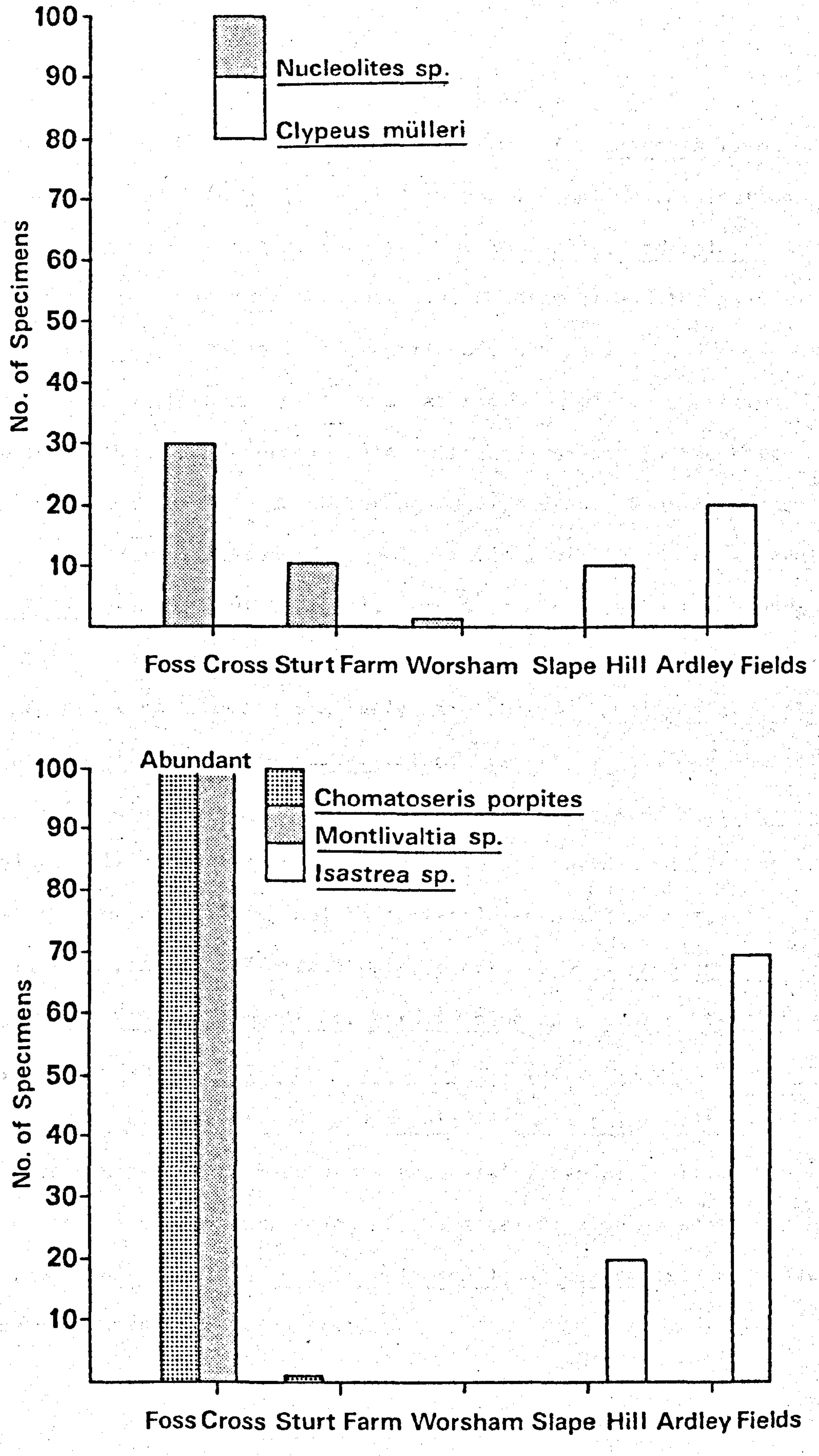


Fig 1.27. The Fauna of the A. excavata bed.

neither are restricted to this horizon. However, *A. compressa* is much rarer above this level (e.g. Slape Hill bed 5). The unique combination of four Nerineid gastropods (*A. excavata*, *A. compressa*, *Endiaplocus munieri* and *Fibula reticulata* sp. nov. (see Chapter 2) and the pseudo Nerineid *R. variosa* is faunally diagnostic of this horizon and does not occur in the White Limestone other than at the base of the formation. This bed forms the lowest correlatable gastropod horizon in the White Limestone and is a valuable datum throughout the area. Examination of Figs. 1.24 - 1.27 reveal several faunal gradients within the *A. excavata* bed. *Nucleolites woodwardi* (Wright), common in the south-western part of the outcrop, decreases in abundance to the north-east whilst *Clypeus mülleri* becomes more common. Similarly, the corals *Chomatoseris porpites* (Smith) and *Montlivaltia* (*Stereophyllia*) cf. *tenuiradiata* (de Fromentel et Terry) which are abundant in the south-west are replaced by *Isastrea* sp. at Slape Hill and Ardley Fields Quarry in the north-east. Amongst the Bivalves many were either not sufficiently abundant or not sufficiently widespread to establish definite density gradients e.g. *Camptonectes rigidus*, *Isognommon isognomonoides*, *Parallelodon* sp., *Lima subcardiiformis*. However, *Pteroperna* sp. *Modiolus imbricatus* (J. Sow.) *Modiolus* (*Inoperna*) sp., *Protocardia* cf. *stricklandi* and *Nucula* (*Palaeonucula*) *waltoni* were all found to decrease south-westwards from Ardley Fields Quarry, both in total abundance and as a percentage of the total Bivalve population. Amongst the Bivalves only *Ca-vilucina* (*Mesomiltha*) *bellona* showed a decrease in abundance towards the north-east.

The distribution patterns amongst the Gastropods are somewhat more complex. A few show relatively simple gradients, for example *F. reticulata* sp. nov. and *Ataphrus* spp., both decreasing to the north-east. *A. compressa* and *Rig. variosa* also show a somewhat similar trend. The more complex distribution of *Eu. arduennensis* shows a distinct inverse relationship to that of *A. excavata*. This is found to be generally true throughout the White Limestone; either *Eunerinea* sp. greatly outnumbers the *Aphanoptyxis* sp. or vice versa. The two genera are rarely found in equal abundance in the same bed. Almost certainly this relationship is ecologically based and is discussed in Chapter 5. Both *A. bathonica* and *G. formosa* show similar distribution patterns to that of *A. excavata*. The modern *Globularia* is a predaceous carnivore feeding mainly on bivalves. Palmer (1973, p. 57) found a *Globularia*/*Pholadomya* ratio of 1:10 in the *Pholadomya* marl at Ardley Fields Quarry. In a modern living assemblage this is approximately the ratio between carnivore and prey of roughly the same size (Palmer *op. cit.* p. 57). The ratio of *Globularia* to *Aphanoptyxis* spp. in the *A. excavata* bed is shown below.

Foss Cross	Sturt Farm	Worsham	Slape Hill	Ardley	Mean
1:16.7	1:9.2	1:4.7	1:8	1:20.3	1:11.8

It is possible that these ratios may also represent a predator/prey relationship between *Globularia* and *Aphanoptyxis* spp.

It was possible to establish the *A. bathonica*/*Aphanoptyxis* ratios in the *A. excavata* bed in only three localities. They are as follows:-

Sturt Farm	Worsham	Ardley
1:5.8	1:4.7	1:3.4

The morphology of *A. bathonica* suggests an epifaunal browsing mode of life but the significance of large numbers of *A. bathonica* associated with abundant *Aphanoptyxis* spp. is as yet unknown.

The fauna of the *A. excavata* bed is not everywhere abundant. The diagnostic gastropod fauna appears to be absent at Croughton and is only poorly represented at North Leigh and Worsham. In the Chedworth Cuttings, the abundance of *Cavilucina* (*Mesomiltha*) *bellona* at this level led Richardson (1911, p. 111) to name this bed, and those below, the *Lucina* Beds. He further stated (Richardson, 1933, p. 63), "The *Lucina* beds constitute a notable palaeontological horizon in this cutting and in the neighbourhood".

B) The horizons below the *A. excavata* bed

The lower horizons of the Excavata Beds are only sporadically fossiliferous. Gastropods are rare and irregularly distributed. Bivalves and Echinoids are more common but never abundant. Infaunal bivalves (*T. pullus*, *C. (M.) bellona*, *Gervillia* and *Myaceans*) are more frequent than epifaunal forms (*Camptonectes*, *Plagiostoma*, *Modiolus* and *Praeexogyra*) and amongst the Echinoids, *C. mülleri* is commonly found in the north-east whilst *Nucleolites* is rather more widespread. Some Rhynchonellids, Terebratulids (? *Stiphrothyris*; see Arkell, Richardson & Pringle, 1933, p. 347), coral debris and lignite/wood also occur, mainly in the north-east. See Figs. 1.5 - 1.20 for details.

The lithologies of the Excavata Beds

A) The A. excavata bed

The sediment was originally a biopel/intra micrite which has subsequently undergone considerable diagenetic alteration. At Ardley Fields Quarry and Sturt Farm the sediment has been very heavily micritised and the margins of the original pellets/intraclasts, which are distinctly smaller at these two localities, are obscure. The matrix at Ardley Fields Quarry contains abundant ostracod valves and Nodosariid foraminifera which appear to have been replaced by neomorphic spar, but no silt sized quartz grains were found in the matrix. At Slape Hill the pellets/intraclasts are slightly larger and occasional silt-sized quartz grains are encountered in the micritic matrix. Molluscan shell debris is common here and replaced by sparry calcite cement via a cavity stage (see Chapter 6). Small patches of neomorphic spar replacing the original micritic matrix can also be seen.

The largest clasts in the excavata bed, which represent the coarsest original sediment, were found at Worsham and North Leigh and are associated with abundant silt-sized quartz grains in the matrix. Occasional original cavities in the interstices between clasts are now filled with sparry cement but most of the matrix is micritic or neomorphic spar replacement of the original micritic matrix. The neomorphic spar often seems to spread into the micritic matrix from areas of cavity filled sparry calcite (see plate 1:A). In areas of micrite the clasts are obscure but in the regions of neomorphic spar they are distinct. The following criteria were used to distinguish originally micritic matrix now altered to spar by aggrading neomorphism:

a) intercrystalline boundaries non planar;

b) enfacial junctions rare;

c) clasts 'floating' in spar;

d) quartz grains 'trapped' in spar (see Bathurst, 1971, p. 476-516).

The appearance in thin section approaches that of 'structure grumeleux' (Cayeux, 1935; Bathurst, op. cit., p. 511). Further to the south-west at Sturt Farm the sediment becomes finer-grained, with less quartz and finally at Foss Cross no quartz was found in the matrix.

The hardground at the top of the A. excavata bed is not apparent at Slape Hill and North Leigh (although a poorly developed one is found 0.13 m above the top of the A. excavata bed at North Leigh and this may indicate the top of the Excavata Beds). The absence of the hardground is probably due to the more continuous sedimentation in this region. The sediment at Worsham, North Leigh and Slape Hill is coarser and contains more silt-sized quartz than elsewhere and was presumably deposited under higher hydrodynamic regimes. Signs of local post-mortal transport, for example, damage to the whorl sides of Gastropods, disarticulation of Bivalves, and abrasion and slight orientation of the turretted Gastropods Eunerinea and Aphanoptyxis, are found in the faunas at Sturt Farm and Slape Hill. However, the coarsest sediment, at Worsham and North Leigh, contains only a very sparse fauna. This is summarised in Figure 1.28.

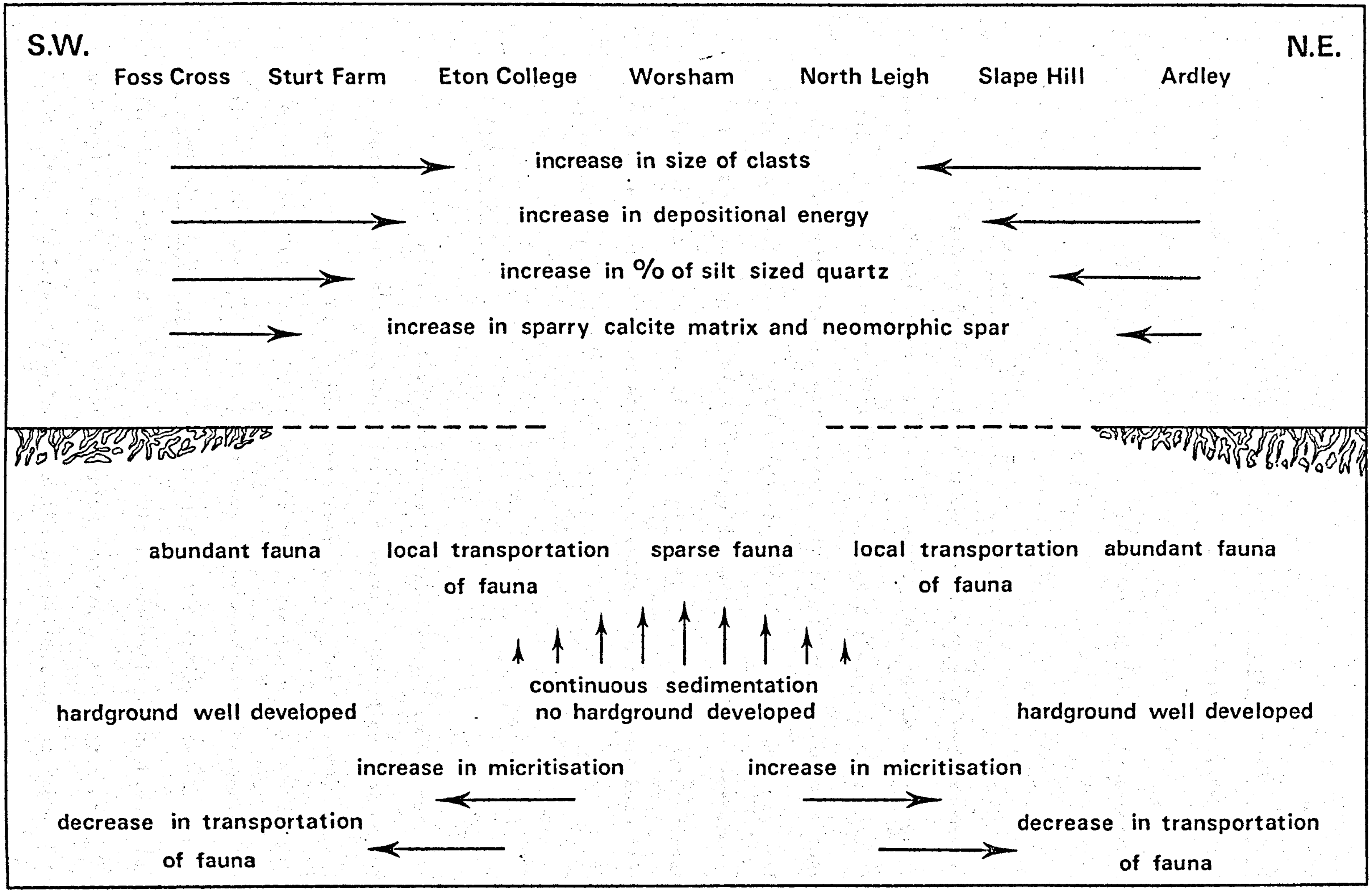


Fig.128.The Sedimentology of the *A. excavata* bed.

The distribution patterns of Aphanoptyxis excavata and Eunerinea arduennesis can probably be related to the depositional environments. Aphanoptyxis apparently preferred the quieter regimes and finer sediment. This is confirmed by the distribution of other species of Aphanoptyxis at higher levels in the White Limestone.

B) The horizons below the A. excavata bed

The remaining Excavata Beds below the A. excavata bed are mostly fine-grained biopel/intramicrites and marls. The beds become very rich in clay (presumably detrital terrigenous clay derived from the London-Ardennes land mass) to the north-east. It is of interest to note that all the Excavata Beds at North Leigh are conspicuously sandy, suggesting this had been an area of higher energy depositional regimes for some time before the deposition of the A. excavata bed. Minor hard-grounds appear more frequently and are better developed in the Lower Excavata Beds to the south-west.

The Ardley Beds

At Slape Hill the five gastropod horizons from 2 to 6 constitute the most complete and most fossiliferous section of Ardley Beds known to the author. The Ardley Beds were described by Arkell (1947, p. 42) as comprising "the lower two-thirds of the White Limestone and are defined upward by a limestone near the top crowded with the gastropod Aphanoptyxis ardleyensis....". The base of the Ardley Beds was not defined. Arkell's division of the White Limestone into the Bladon Beds and Ardley Beds is replaced in the present work by the Bladon Beds, Ardley Beds and Excavata Beds. Thus the lower limit of the redefined

Ardley Beds is taken as the marl/clay on top of the *Aphanoptyxis excavata* bed.

In the area to the north-east of Sturt Farm, the Ardley Beds are well defined and a satisfactory correlation of the gastropod horizons can be achieved. South-west of Sturt Farm the correlation of the Ardley Beds with the sections at Dagham Downs, Foss Cross and the nearby railway cuttings is difficult and will be discussed later.

The Ardley Beds north east of Sturt Farm

1. The base of the Ardley Beds

The base of the Ardley Beds consists of a highly characteristic and uniform sedimentary sequence (the basal Ardley bed) which everywhere commences with a thick clay layer containing *Praeexogyra* (especially at Croughton and Ardley) and lignite. *Bakevellia waltoni* (Lycett) and ?*Tancredia* have been found at Eton College Quarry (Arkell, 1931, p. 607) and rootlets occur at Croughton. Vertebrate remains are commonly found at Worsham and North Leigh and include *Asteracanthus magnus* (Agassiz), palatal teeth of *Eomesodon*, ganoid fish scales (?Holostean) and teeth of *Pliesiosaurus* sp. The clay layer gradually becomes silty, passes up into a decalcified sandy limestone and finally merges into a massive limestone stratum. The transition is so gradual that it is impossible to satisfactorily subdivide this lithological unit.

The decalcified sandy base of the limestone contains poorly preserved bivalves such as *Protocardia* cf. *stricklandi*, *Pinna*, *Trigonia*, *Cavilucina*, *Bakevellia* and *Praeexogyra*. Above the clay base, the limestone at North Leigh, Bunkers Hill and Croughton is unfossiliferous.

At Eton College and Worsham the limestone portion of the basal Ardley bed is much coarser containing large clasts of limestone (up to 0.03 m diameter) and lenses of gastropod debris with occasional large Fibula cf. varians. At Slape Hill and Ardley Fields Quarry, this bed is extremely fossiliferous at the base passing into barren 'oolite' higher up and, although the fauna is somewhat reduced, the bed can be traced to Stratton Audley (see Figs. 1.20 and 1.22) in spite of reports to the contrary (Palmer, 1973, p. 58). The extremely uniform lithology over such a wide area (except for the higher energy depositional conditions at Eton College and Worsham, associated with the limestone pebbles) and the presence of an abundant fauna only at the base of the limestone at Slape Hill and Ardley suggests that

a) depositional conditions were both quiet and widespread and

b) that a close relationship existed between the fauna and the sediment.

The decalcification of the base of the limestone has evidently progressed much further at Ardley Fields Quarry and the fossils are found as moulds and casts in a well developed roach stone. This is the Roach Bed of Arkell, Richardson and Pringle (1933, p. 343) which Arkell described as "Siliceous brown limestone, in the lower part of which fossils have abounded but have been dissolved out probably by water held up by the subjacent clay." Only the aragonitic shells have been dissolved, the calcite ones (e.g. Praeexogyra) not being affected. As noted by Palmer (1973, p. 58) the resulting cavity is usually infilled by sparry calcite cement but he concluded that this process had not taken place in the Roach Bed at Ardley. The present author is of the opinion that the fossils of the Roach Bed were secondarily infilled by cavity spar and that the subsequent decalcification was a later diagenetic process. The occasional occurrence within the Roach Bed of small areas of fossils with a sparite cement and the invariable occurrence of them above the Roach Bed tends to support this hypothesis.

The Roach Bed is found as scattered blocks in Ardley Fields Quarry and the nearby Ardley station Quarry (SP 539269). With a little excavation it can also be examined *in situ* in Ardley Fields Quarry and in the nearby Railway cutting. At Slape Hill the equivalent bed is well exposed in the working quarry and beautifully weathered out specimens with an extensive fauna can be obtained from joint faces. A detailed study of the relationship between the sediment and the fauna in the basal Ardley bed at these two localities is given in Chapter 5.

2. Strata between the basal Ardley bed (i.e. Ardley Roach Bed and lateral equivalents) and the *Aphanoptyxis ardleyensis* beds

a) Eton College, Worsham & North Leigh.

Another gastropod horizon occurs at the top of the basal Ardley bed at these three localities (see Figs. 1.11, 1.12 and 1.14). The gastropods in this horizon are distributed as follows:

Eton College	*Nerinella* cf. *pseudocylindrica* (d'Orb.) *Aphanoptyxis* cf. *langrunensis* (d'Orb.)	) Equal numbers) and very) abundant
	G. formosa	
	A. bathonica	
Worsham	**No** *Nerinella* or *Eunerinea*	
	A. cf. *langrunensis*	V. abundant
	G. formosa	
	A. bathonica	
	N. (*N.*) *cooksonii*	
North Leigh	*Eunerinea arduennensis*	V. abundant
	A. cf. *langrunensis*	Rare

Other fauna is given in Figs. 1.11, 1.12 and 1.14.

The changes in the gastropod faunas is once again associated with changes in the lithology. At North Leigh the *Eunerinea* is found in a fine-grained but very well sorted intrabiosparite which contains approximately 15% detrital quartz. *Aphanoptyxis* cf. *langrunensis* occurs abundantly at Worsham in a sediment very similar to the *A. excavata* bed at Sturt Farm. The sediment at Worsham is coarser than at North Leigh, of the same general petrographic type but with only 1 or 2% detrital quartz. At Eton College both *A.* cf. *langrunensis* and *Nerinella* cf. *pseudocylindrica* are found in equal abundance in a sub-lithographic limestone. The sediment has been intensely micritised and the clasts are indistinguishable in hand specimen. In spite of changes in the gastropod fauna and lithology, there can be little doubt that at these three localities, these beds are laterally equivalent and correlatable.

b) Slape Hill, Bunkers Hill, Kirtlington, Ardley Fields and Croughton.

At these localities a correlatable gastropod bed occurs between 0.36 metres and 0.90 metres above the top of the basal Ardley bed (Fig. 1.22). *Eunerinea arduennensis* is common throughout. *Melanioptyxis altararis* is found at Ardley Fields Quarry in association with *Bactroptyxis implicata* (d'Orb.), which is also found at Croughton. *E. munieri* is common at both these localities and at Bunkers Hill. The lithology is a rather coarse intrabiosparite with considerable amounts of comminuted shell debris in some places (Croughton) and detrital quartz in others (10-15% at Ardley).

This bed is, in part, the *Nerinea eudesii* bed of Arkell and others (Arkell, 1931; Arkell, Richardson & Pringle, 1933; Richardson, 1946). It is tentatively correlated with the gastropod bed occurring at the top of the basal Ardley bed at Eton College, Worsham and North Leigh (see previously). At Bunkers Hill the *Eu. arduennensis* bed is divided into two by a thin marl parting. The lower part of the bed contains *Nerinella* cf. *pseudocylindrica* and *A.* cf. *langrunensis* in a lithology almost identical to that at Eton College. Since the only other occurrence of *N.* cf. *pseudocylindrica* in the White Limestone is at Eton College and *A.* cf. *langrunensis* occurs only at Eton College, Worsham and North Leigh, there is some evidence to suggest a correlation of these two gastropod horizons.

c) Bactroptyxis implicata bed.

Arkell (1947, p. 43) stated "A few feet below the Ardleyensis bed another gastropod, Ptygmatis (Bactroptyxis) bacillus, (= B. implicata), provides almost as infallible a subzonal index as the name-fossil" whereas Richardson (1946, p. 37) considered "Ptygmatis bacillus (= B. implicata) marks a horizon in either the bottom part of the Nerinea eudesii Beds or just below".

The author has found that neither statement satisfactorily accounts for the distribution of Bactroptyxis implicata. The gastropod occurs at Minster Lovell War Memorial Quarry below the A. bladonensis bed and at the base of coarse white oolites which are cross-bedded in places. This occurrence was described by Arkell (1931, p. 608) who also noted the occurrence of N. eudesii at a lower horizon, exposed in a nearby road excavation. This N. eudesii horizon is the Nerinella/Aphanoptyxis/Eunerinea bed of Eton College, Worsham and North Leigh (see Fig. 1.22). There, B. implicata should occur above the N. eudesii bed of Arkell (op. cit.) and indeed does so at North Leigh, Slape Hill and Worsham. B. implicata occurs only rarely at North Leigh and Slape Hill at the base of thick cross-bedded limestone units and the gastropods show damage and abrasion associated with transport.

The occurrence of B. implicata at Worsham is again associated with high energy depositional regimes. The gastropods show obvious signs of exhumation and erosion after an earlier phase of lithification (see Chapter 6). Furthermore, most specimens show evidence of shell-boring algae, oncolite encrustation and Ectoproct colonisation.

It is difficult to imagine how Arkell (op. cit.) came to regard the occurrence of B. implicata below the Ardleyensis bed as a good stratigraphic index. He quotes just two occurrences of B. implicata below the A. ardleyensis bed: one at Grintleyhill Bridge, Coombe (Arkell, 1931, p. 611; 1947, p. 54: see also Richardson 1946, p. 60) and the other at Rollright Halt (Arkell, 1947, p. 64). The Grintleyhill Bridge section is only 2.25 km north-east of North Leigh and correlates well with the section there. Arkell (op. cit.) did not record the presence of B. implicata in the type section of the Ardley Beds in the Ardley-Fritwell railway cutting (Arkell, Richardson & Pringle, 1933). However, B. implicata is present at nearby Ardley Fields Quarry and Croughton, but only as a minor constituent of the fauna in the Eunerinea bed (Figs. 1.18 and 1.19).

It is therefore suggested that B. implicata should not be regarded as a good stratigraphic index fossil because:

a) Its distribution in the north-eastern part of the White Limestone is impersistent.

b) It occurs at three separate stratigraphic horizons in the south-western part of the outcrop.

c) It also occurs widely in the Bajocian strata of England (e.g. Clypeus Grit at Aston Blank, SP 146195 and Golden Valley SO 902022) (see Chapter 2).

The detailed correlation of Sturt Farm, Eton College, Worsham and Minster Lovell is of interest in view of previous authors' interpretations of the Eton College section (Arkell, 1931, p. 607-8; Richardson, 1946, p. 48-49; Worssam & Bisson, 1961, p. 95) and the absence of gastropod beds above the Excavata Beds at Sturt Farm.

Eton College Quarry was first described by Arkell (1931, p. 607-8) who believed the section showed, in descending order, the *Aphanoptyxis bladonensis* bed, the *fimbriatus-waltoni* Clay and the *A. ardleyensis* bed. It is difficult to imagine how Arkell, who named the two gastropod species involved, could have mis-identified both of them at this locality.

The present author believes that having mid-identified *A. excavata* as *A. ardleyensis*, Arkell examined the clays above and, upon finding *G. waltoni*, believed them to be the *fimbriatus-waltoni* clay. He further expected to find the *A. bladonensis* bed above. The gastropod bed above the supposed *fimbriatus-waltoni* clays is in fact the basal Ardley bed (see previously) and contains drifted lenses of shell debris (mainly *A.* cf. *langrunensis* with occasional large specimens of *Fibula varians*). On top of this is the *A.* cf. *langrunensis*/*Nerinella* cf. *pseudocylindrica* sublithographic limestone. It is probable that Arkell (*op. cit.*) saw fragments of *A.* cf. *langrunensis* and oblique sections of *F. varians* and mistook them for *A. bladonensis*. He did not record the presence of *N.* cf. *pseudocylindrica* from the section.

However, Arkell (*op. cit.*, p. 608) was puzzled by the absence of "the ubiquitous *N. eudesii* beds" below his supposed *A. ardleyensis* Bed. Richardson (1946) accepted Arkell's classification of Eton College Quarry and reiterated Arkell's statement about the absence of *N. eudesii* beds in the lower part of the section. The situation was partially corrected by Worssam & Bisson (1961, p. 95, 96). They found the true *A. bladonensis* bed at the top of the Quarry and considered that the *A. bladonensis* bed of Arkell (*op. cit.*) was predominantly *A. ardleyensis* and a *Nerinella* sp.

A revised classification of the succession at Eton College Quarry and the correlation with nearby sections is shown in Fig. 1.29. The recognition of the *A. excavata* bed in the lower horizons of these sections removes the problem of Arkell (*op. cit.*) concerning the absence of the "ubiquitous *N. eudesii* beds". The proposed correlation also agrees with the available ammonite evidence:- a specimen of *T. subcontractus* from the base of the Eton College section (Arkell, 1931, p. 608) and a speciment of *Morrisiceras morrisi* from just below the *A. excavata* bed at Sturt Farm.

Arkell (1931, p. 607) noted that the false-bedded "oolites" (his Kemble Beds) at Eton College Quarry occurred above a marked plane of erosion and they channelled down onto his *A. bladonensis* bed. Examination of Fig. 1.29 suggests that this is part of a larger feature in this area. The sequence of gastropod beds below the true *A. bladonensis* bed is terminated by false-bedded, coarse-grained, intrasparites at increasingly lower levels as one passes from Worsham to Sturt Farm, where they finally

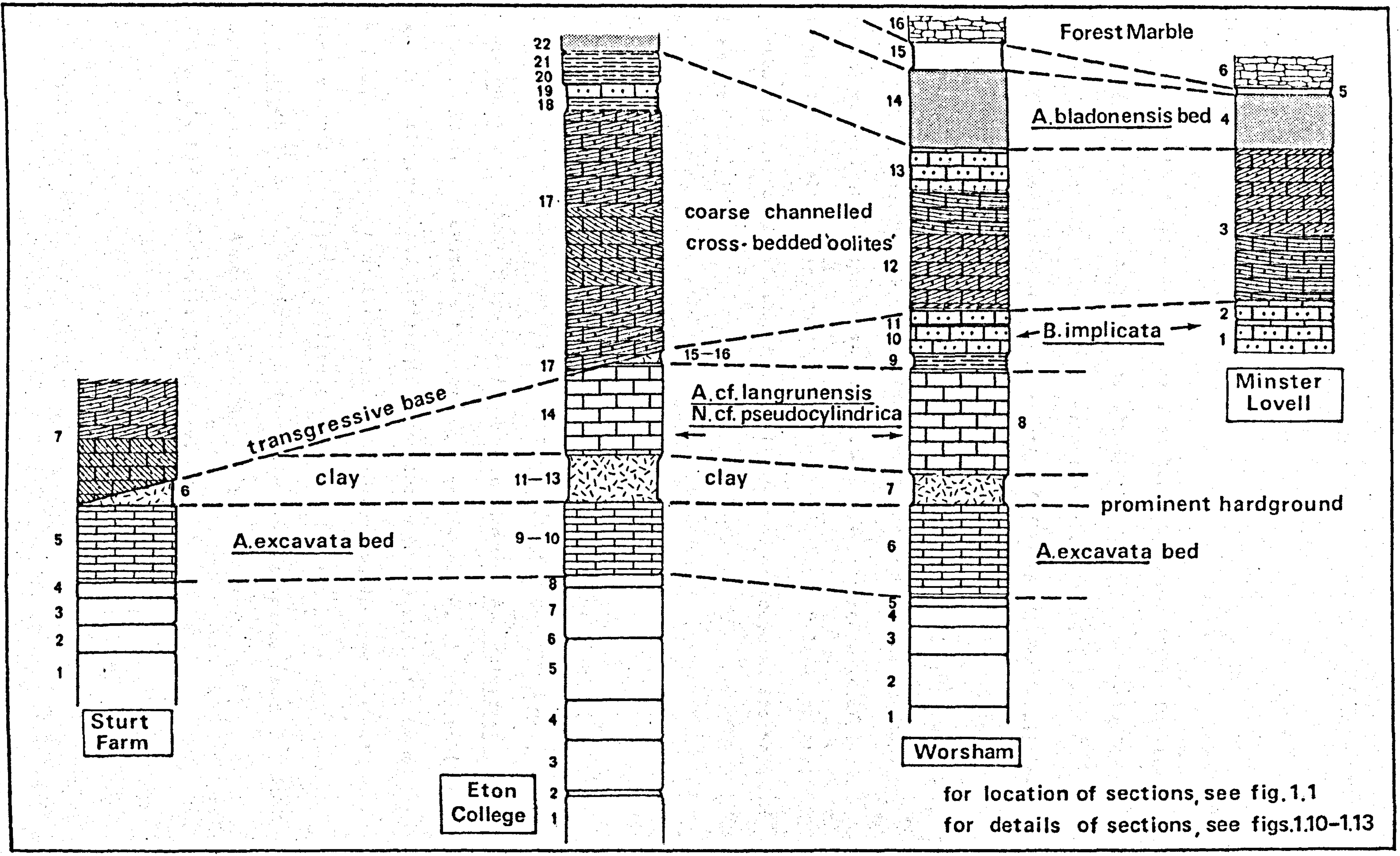


Fig.1.29 The correlation of sections at Sturt Farm, Eton College, Worsham and Minster Lovell

channel down onto the A. excavata bed.

It is these false-bedded units at Sturt Farm and nearby Shilton which Palmer and Jenkyns (1975, p. 128-9) correlate (erroneously in the opinion of the present author) with the stratigraphically much higher Cream Cheese Limestones of Stratton Audley and other localities to the north-west. This horizon, associated with channelling, false-bedding and coarse-grained sediments, is approximately in the middle of the White Limestone and probably represents the highest energy depositional regimes within the White Limestone sequence north-west of Sturt Farm. It can also be traced to North Leigh and Slape Hill where transported and abraded specimens of B. implicata can be found at its base (see previously).

3. The A. ardleyensis beds

The upper limit of the Ardley Beds was defined by Arkell (1947, p. 42) as "a limestone near the top crowded with the gastropod A. ardleyensis". In fact there are two beds containing A. ardleyensis but only the lower one contains the gastropod in abundance. In places (for example North Leigh and Kirtlington) the two beds are separated by a thin marl parting but at Croughton a well-developed laminated algal micrite containing birds-eye structures separates the upper and lower A. ardleyensis beds. The upper bed contains only a sparce fauna and is easily overlooked. A hardground occurs at the top of the Upper A. ardleyensis bed in Ardley Fields Quarry.

The present author is of the opinion that the Upper *A. ardleyensis* bed should be taken as the upper boundary of the Ardley Beds.

In the Lower *A. ardleyensis* bed, the name species is by far the most abundant fossil. Associated fauna includes *Cylindrobullina luidii*, *Amberleya bathonica*, *Naricopsina cotswoldensis*, *N.* (*N.*) *cooksonii* and *Protocardia* cf. *stricklandi*.

The most south-westerly occurrence of *A. ardleyensis* seen by the present author is at North Leigh (see Figs. 1.14 and 1.30). The absence of this gastropod at Minster Lovell, Worsham and Eton College Quarry to the south-west of North Leigh is not surprising. The upper part of the Ardley Beds at these localities is part of the false-bedded, high energy lithologies discussed previously. These sediments contrast markedly with the fine-grained biointra/pel micrites of the *A. ardleyensis* beds to the north-east. Therefore, it is impossible to say whether the *A. ardleyensis* beds at these localities were deposited and subsequently eroded, or were not deposited at all because of local higher energy regimes. Worssam and Bisson (1961, p. 90) reliably record the presence of *A. ardleyensis*, at Signet and Leyes Farm,south of Little Barrington(south-west of Minster Lovell and nearby localities: for Signet section, see Fig. 1.9). Their lowermost *A. ardleyensis* bed in a Dagham stone is undoubtedly the *A. excavata* bed and, on this basis, their section fits in well with the present author's correlations. No reliable records of *A. ardleyensis* further south-west than those of Worssam & Bisson (*op. cit.*) are known to the present author.

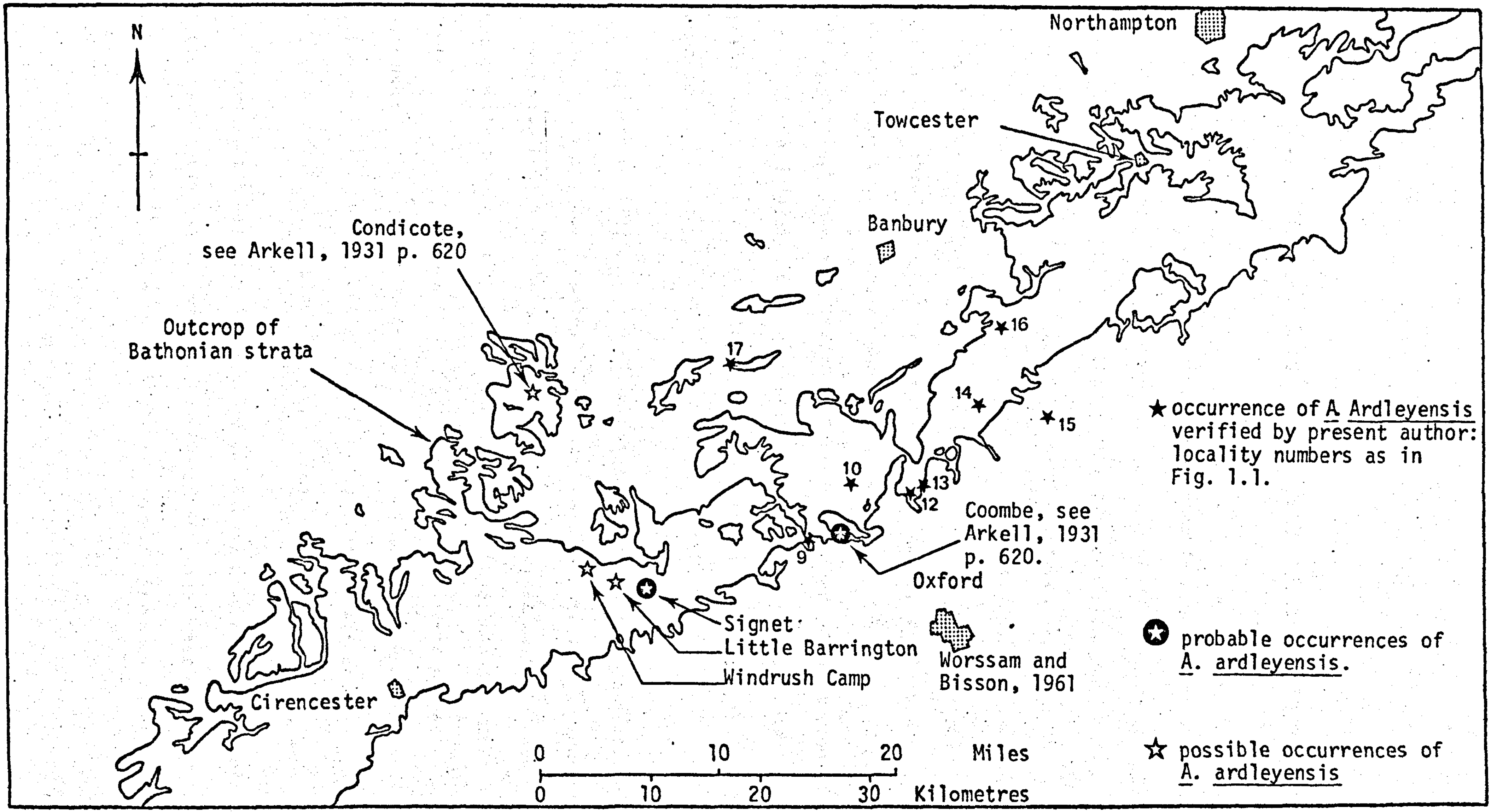


Fig. 1.30. The geographical distribution of A. ardleyensis.

The correlation of the Ardley Beds with sections to the south-west of Sturt Farm.

South-west of Sturt Farm the only reasonably complete sections of the White Limestone within the area studied are around Cirencester. Dagham (or Daglingworth) Downs Quarry is still in active use (owner W. H. Iles & Sons; SP 999061) and has been described by Richardson (1933, p. 68) and more recently by Channon (1950, p. 258) and Torrens (1967, p. 87). A revised section is given in Fig. 1.6. The other sections are Foss Cross Quarry, Calmsden (SP 056092), which is disused but now under the auspices of the Nature Conservancy, and the nearby railway cuttings (now abandoned) which were described by Richardson (1911, 1930 and 1933). Exposures between the most north-easterly railway cutting (at Chedworth) and Sturt Farm are infrequent, usually shallow and temporary.

Richardson (1933) in the Cirencester Memoir described a number of shallow quarries, ca. 2 metres in depth, from this intervening area but an extensive search by the author showed that the vast majority have subsequently been infilled. The research for Richardson's Cirencester Memoir (*op. cit.*) predated Arkell's (1931) taxonomic revisions and the gastropods are usually inadequately identified as Nerineae or, at best, *Nerinea eudesii*. Consequently few of the sections of Richardson (*op. cit.*) can, with certainty, be placed in the proposed correlation.

Worssam & Bisson (1961) figure a section at Leys Farm (south of Little Barrington and 7.5 km. west of Sturt Farm) and describe a composite section at Signet (4 km. west of Sturt Farm) which is shown in Figure 1.9.

These sections agree with the authors correlations.

The top of the Excavata Beds is easily recognised in Dagham Downs, Foss Cross and the Railway cuttings and provides a basal datum for the Ardley Beds. Unfortunately *Aphanoptyxis ardleyensis* has not been found in this region (see Fig. 1.30) and it is impossible to accurately place the top of the Ardley Beds and hence the Ardley/Bladon Beds junction. The top of the Bladon Beds (and therefore the top of the White Limestone) can be established from the sporadic occurrence of the *Aphanoptyxis bladonensis* bed (see later).

The correlation of the above localities and the north-east region is shown in Fig. 1.22. It is of interest to note that *Bactroptyxis implicata*, *Melanioptyxis altararis* and *C. bathonica* are much more abundant in the south-east. *Fibuloptyxis witchelli* is only found in this region and at Minchinhampton (see later).

The Bladon Beds

The Bladon Beds were defined by Arkell (1947, p. 43) as being "characterised by *beds* of white sublithographic limestone ('cream cheese') packed with the subzonal gastropod....". Significantly, no upper datum was given to either the Bladon Beds or the White Limestone (see previously).

The present author has found that the index gastropod *A. bladonensis* is confined to a single bed, the *A. bladonensis* bed, and believes that this bed should be regarded as the top of the White Limestone. Only along the south-east margin of the White Limestone outcrop is difficulty encountered in defining the upper limit of the Bladon Beds and White

Limestone upon this basis. It is only in this region that Arkell (op. cit.), Richardson (op. cit.), McKerrow et al. (op. cit.) and other authors record the presence of Epithyris and Coral/Epithyris beds (see Fig. 1.31).

In the present author's opinion, all of these Epithyris and Coral/Epithyris beds belong to the Bladon Beds, occurring above the A. ardleyensis beds and below the A. bladonensis bed, and hence are of White Limestone age. The presence of A. bladonensis above these brachiopod horizons has been confirmed by the present author at Bunkers Hill, Enslow Bridge and Ardley Fields Quarry (see Fig. 1.22 and sections in Figs. 1.15, 1.16 and 1.18). Arkell (1933, p. 180) reported a similar situation in the old White House Quarry at Bladon, close to the type locality of Aphanoptyxis bladonensis.

Apparently there is a thick wedge of sediment along the south-east margin of the White Limestone outcrop. Stratigraphically, it occurs between the A. ardleyensis beds and the A. bladonensis bed and thins rapidly north-westwards. This wedge of sediment consists of much finer lithologies than the rest of the White Limestone. The limestones are fine-grained (variously described as micritic, sublithographic and 'cream cheese' limestones) frequently containing Epithyris oxonica, Modiolus imbricatus, oysters and corals. Furthermore, marls and clays constitute a much greater proportion of the lithologies than in the typical White Limestone. The clays frequently contain Eomiodon (Astarte) fimbriatus and Bakevellia (Gervillia) waltoni. Mckerrow et al. (op. cit.) interpret the Epithyris and coral/Epithyris limestones at Kirtlington and adjacent

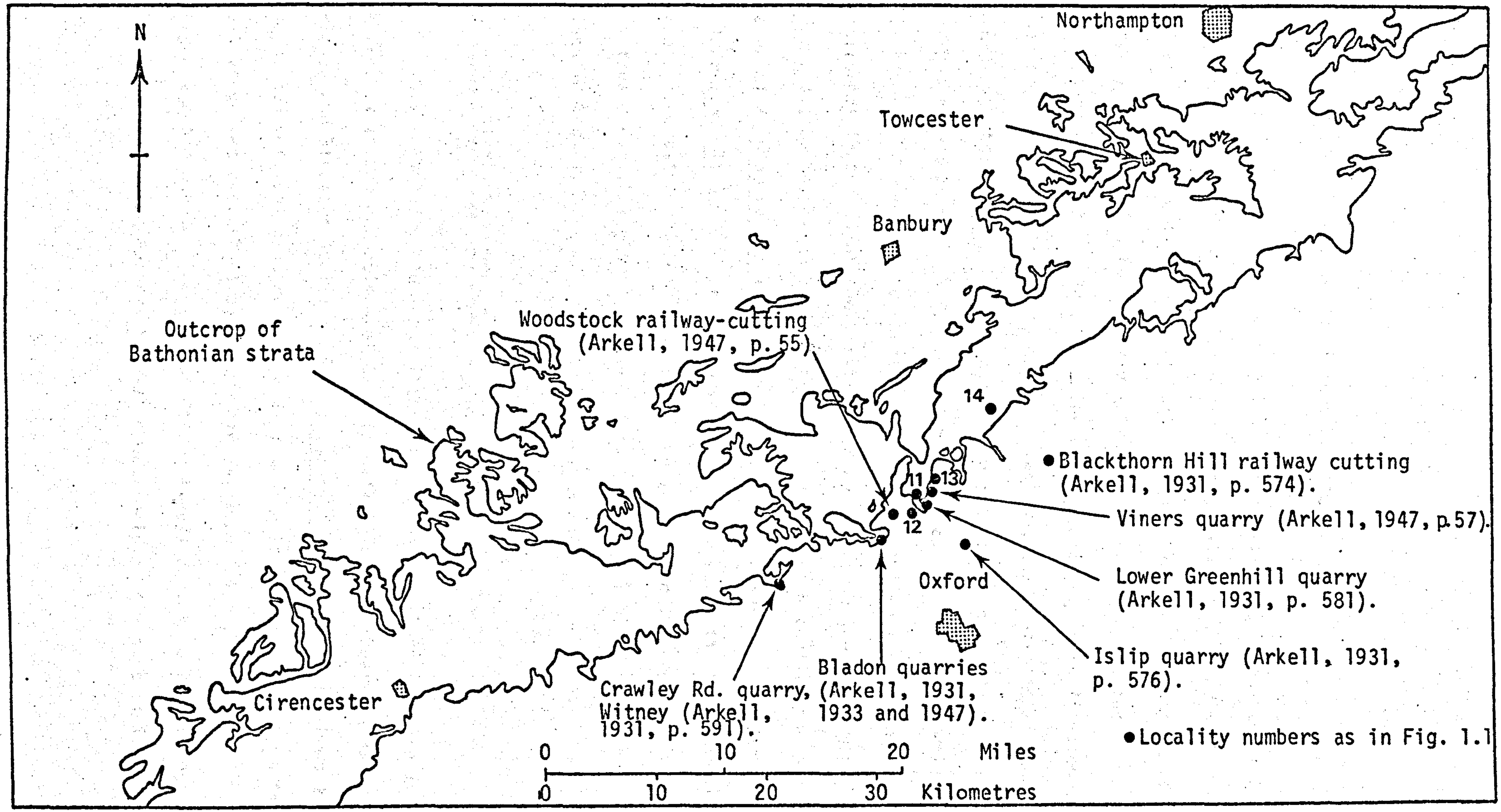


Fig. 1.31. The distribution of Coral/Epithyris limestone horizons in the White Limestone.

areas as channel deposits cut into tidal flats.

As this wedge of sediment thins north-westwards, it passes into soft fine-grained marls and limestones (as at Slape Hill) and white unfossiliferous 'oolites' (as at North Leigh). To the east exposures are scarce but at Elm Farm Quarry (Stratton Audley) the lateral equivalent would appear to be a thick white sublithographic limestone, the upper part of which contains algal laminae, dessication cracks and birds-eye structures. These suggest a supratidal origin. Palmer (1973) and Palmer and Jenkyns (1975) regard this bed as the top of the White Limestone. However, the present author has identified the high-spired gastropods in bed 10 of the Stratton Audley section given by Palmer (*op. cit.*, p. 54) as *A. bladonensis* but was unable to confirm the presence of *A. bladonensis* lower down in bed 2 of the White Limestone of Palmer (*op. cit.*). The present author therefore suggests that the White Limetone/Forest Marble boundary is at the top of bed 10, approximately 2 metres above that given by Palmer (*op. cit.*). A revised section is given in Fig. 1.20.

The *Aphanoptyxis bladonensis* bed

This remarkable bed is unmistakable in most sections in which it occurs. With the exceptions of Bunkers Hill, Gibraltar Quarry (Enslow Bridge) and Stratton Audley, the *A. bladonensis* bed invariably shows a pronounced vertical grading from a very coarse intrasparite at the base to a very fine micritic-sublithographic limestone at the top; the original Cream Cheese limestone of Barrow (1907) and, in part, Odling (1913). The grading appears to have a dual origin. In part it is due to progressive, increasing micritisation from the base to the top of the bed. In spite of extensive micritisation the clast structure can still be discerned under the microscope, albeit faintly, although their identification is difficult. There is also a progressive vertical decrease in the grain-size and variation in clast composition within the bed suggesting that the grading is, in part, primary in origin. At Worsham and Minster Lovell (2 km. apart) the A. bladonensis bed is particularly well exposed and rock specimens were taken from the bed at 0.05 metre intervals and thin sections prepared for modal analysis. The results, based upon 800 points per section, are shown in Figures 1.32 - 1.37. The vertical variation in clast composition is very similar at both localities, reflecting a progressive decrease in depositional energy as the bed was deposited. There is a marked vertical decrease in true ooliths, superficial ooliths, accretions, intraclasts and sparry calcite cement with a corresponding increase in the amount of micritised skeletal debris and micritic matrix. The structural 'oöids'/lumps are difficult to classify. They may be in part pelletal and in part intraclastic in origin. Only clasts with a definite intraclast structure have been classified as such.

At Croughton, Ardley Fields Quarry, Stratton Audley and Slape Hill the top of the A. bladonensis bed shows signs of algal laminae, dessication cracks and birds-eye structures; features typically associated with supratidal conditions and periods of emergence in modern environments (Shinn, 1968; Palmer and Jenkyns, 1975). Palmer and Jenkyns (op. cit.) suggest that the top of this bed formed a supratidal island in this region and the present author substantially agrees with their conclusions.

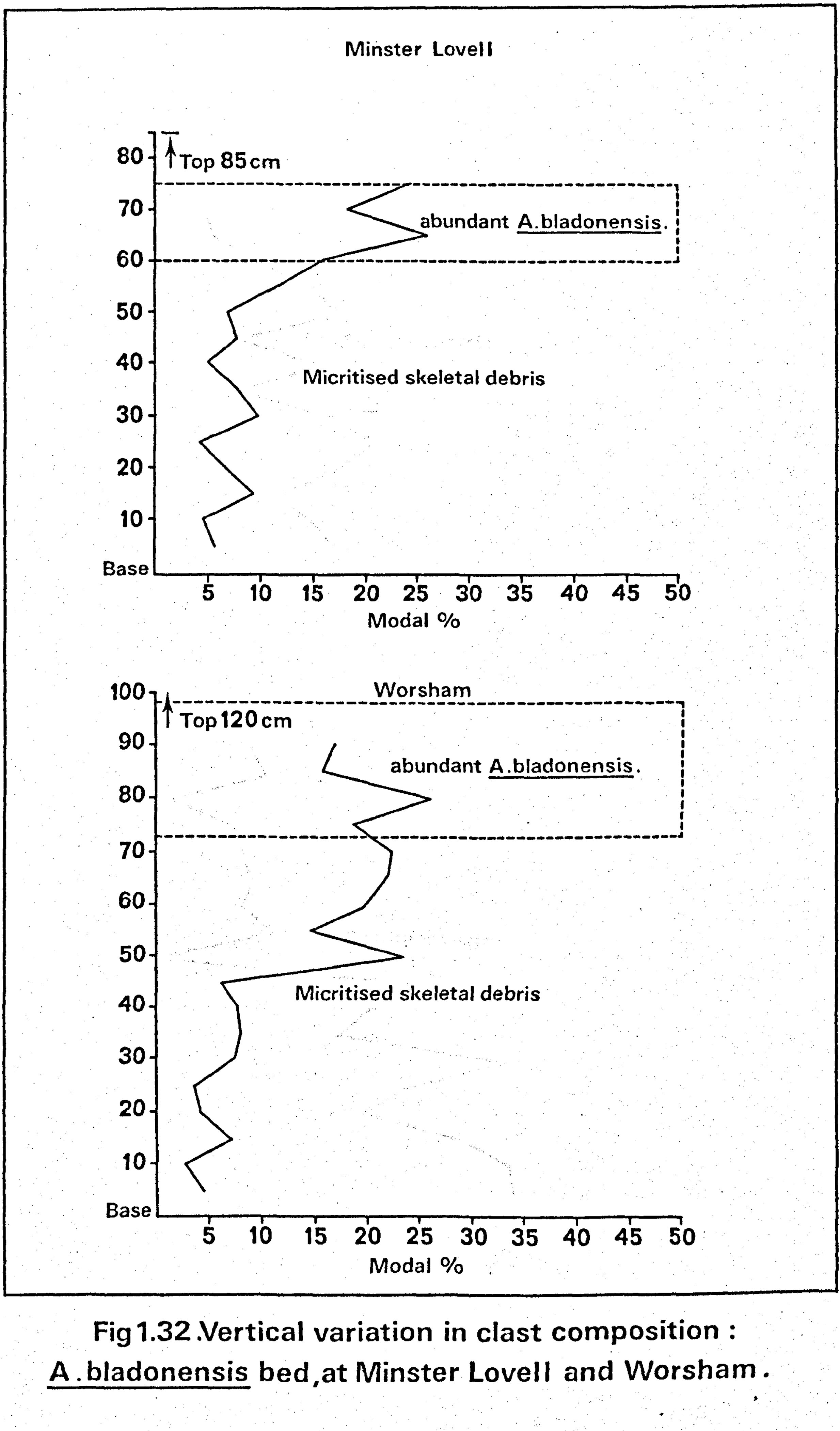


Fig 1.32 Vertical variation in clast composition : *A. bladonensis* bed, at Minster Lovell and Worsham.

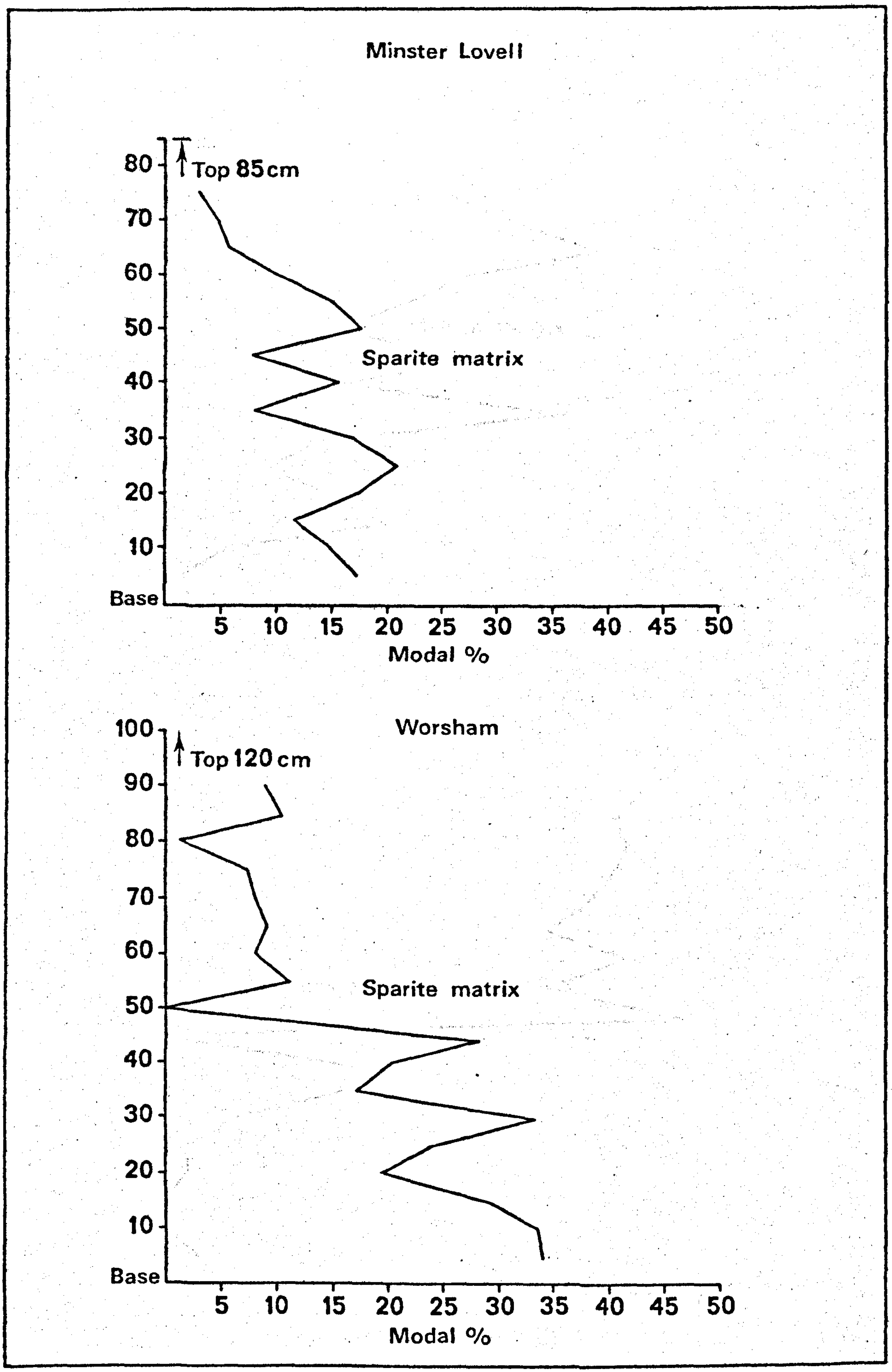


Fig1.33.Vertical variation in clast composition : A.bladonensis bed,at Minster Lovell and Worsham.

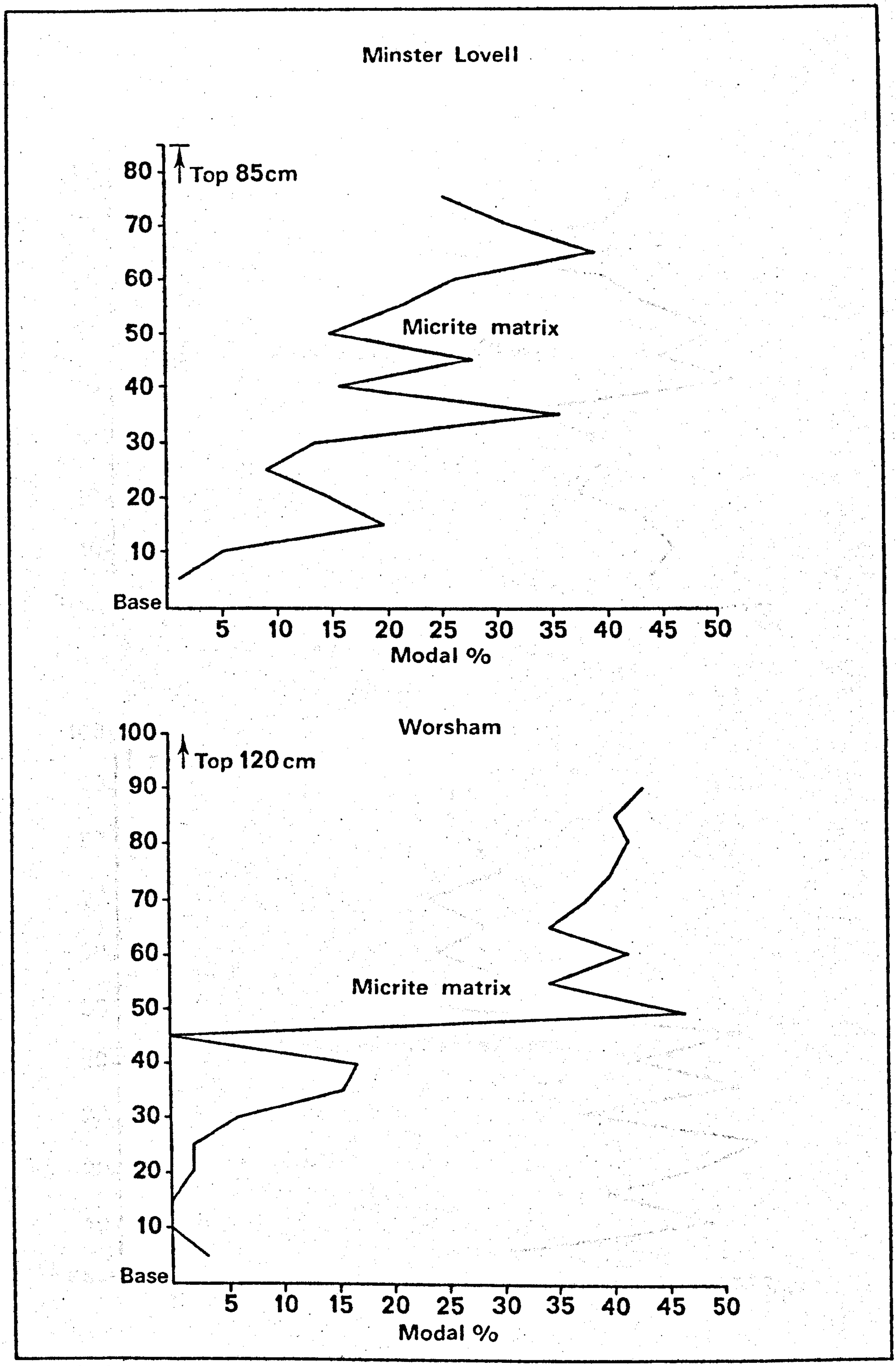


Fig1.34.Vertical variation in clast composition: A.bladonensis bed, at Minster Lovell and Worsham.

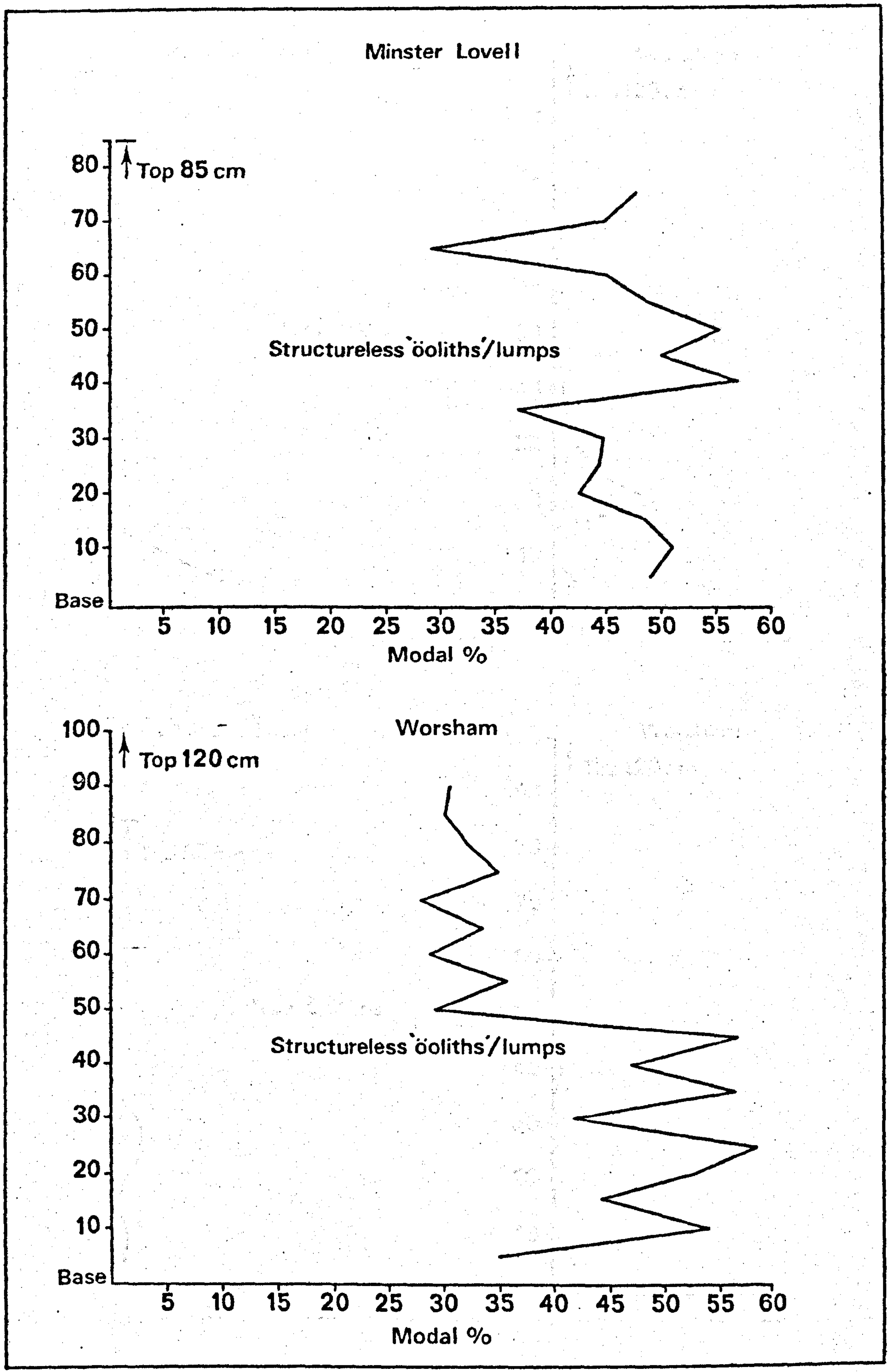


Fig1.35.Vertical variation in clast composition : <u>A.bladonensis</u> bed, at Minster Lovell and Worsham.

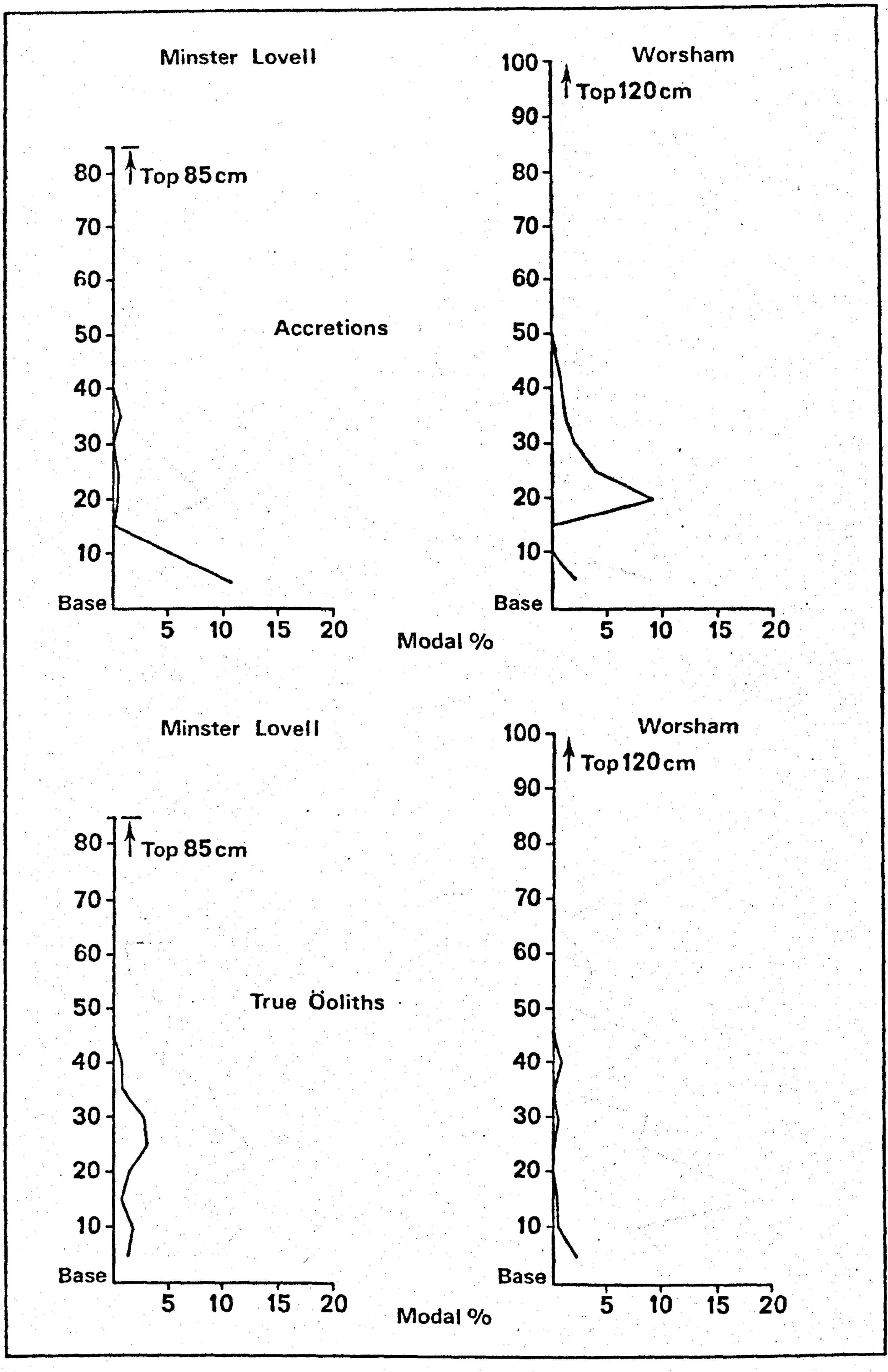


Fig 1.36.Vertical variation in clast composition : A.bladonensis bed, at Minster Lovell and Worsham.

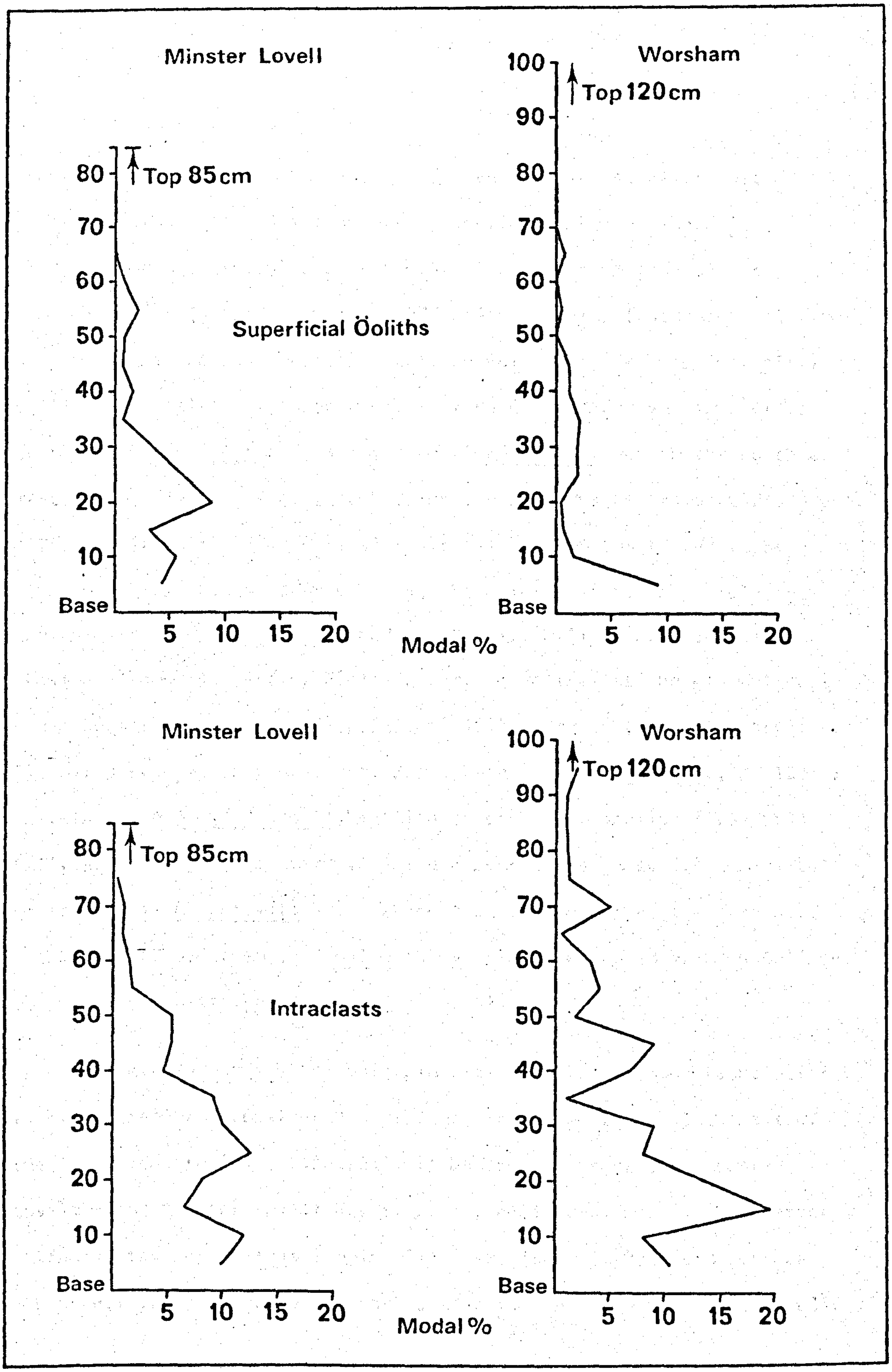


Fig1.37 Vertical variation in clast composition: A. bladonensis bed, at Minster Lovell and Worsham .

However, the present author does not agree with the stratigraphic interpretation of the Stratton Audley section by Palmer (*op. cit.*, see previous discussion) but as the *A. bladonensis* horizon of the present author (bed 10 of Palmer 1973) also contains features suggestive of emergence, the conclusions reached by Palmer and Jenkyns (*op. cit.*) still appear valid. The correlation by Palmer and Jenkyns (*op. cit.*) of the *A. bladonensis* bed with the Coral-*Epithyris* beds to the south at Kirtlington, Bunkers Hill (the Shipton Cement works of Palmer and Jenkyns, 1975) and Gibraltar Quarry (Enslow Bridge) is also considered to be erroneous. As discussed previously, the occurrence of the *A. bladonensis* bed *above* the Coral/*Epithyris* beds at Bunkers Hill, Gibraltar Quarry (Enslow Bridge) and Ardley Fields Quarry as well as at the Old White House Quarry, Bladon (Arkell, 1933, p. 180) suggests that this correlation is unlikely. To the south-west, Palmer and Jenkyns (*op. cit.*, p. 128-9) correlate the *A. bladonensis* bed with cross-bedded oopelsparites at Shilton and Sturt Farm Quarry. These cross-bedded units lie immediately on top of the *A. excavata* bed. As mentioned previously, the present author has traced them from *below* the *A. bladonensis* bed at Eton College, Worsham and Minster Lovell (see Fig. 1.29).

The *A. bladonensis* bed maintains its lithological and faunal distinctiveness for a considerable distance to the west and south-west of the supratidal region. Eventually it becomes a hardground; poorly developed at Minster Lovell but extremely well developed (with adherent epifauna) further west at Temple Mills (see Arkell, 1933) and further south-west in the Wiggold railway cutting (see Richardson, 1933, p. 62).

The fauna of the bed is dominated by the Nerineid Aphanoptyxis bladonensis Arkell, 1931. Associated species commonly include: Modiolus imbricatus J. Sow; Eomiodon (Astarte) fimbriatus (Lycett); Bakevellia (Gervillia) waltoni (Lycett); Corbula hulliana Morris; Protocardia lycetti (Rollier) and P. stricklandi (Morris and Lycett). Occasionally, the fauna is sparse, as at Slape Hill. In the Wiggold railway cutting, A. bladonensis is apparently absent but the unique lithological nature of this bed and the associated fauna leaves no doubt as to its identity (Richardson, 1933, p. 62).

An extreme, isolated occurrence of the A. bladonensis bed was recorded by Arkell (1931, p. 603) from Fairleigh, Somerset. The reliable occurrences of A. bladonensis known to the present author are shown in Fig. 1.38.

As with the Roach Bed at Ardley, the fauna of the A. bladonensis bed is not evenly distributed throughout the bed. It is invariably found in the upper one third of the bed although it is usually absent at the very top. The conclusion reached by the present author is that a close relationship existed between the fauna and the sediment. Unlike the Roach Bed (see Chapter 6), the depositional energy decreases vertically up the A. bladonensis bed and only when the hydrodynamic regime was sufficiently reduced and the substrate relatively stable could an abundant fauna be supported.

At Bunkers Hill and Stratton Audley the A. bladonensis bed is not fully developed. The fauna occurs in a micritic limestone, as at other localities, but the coarse-grained lower portion and the grading are

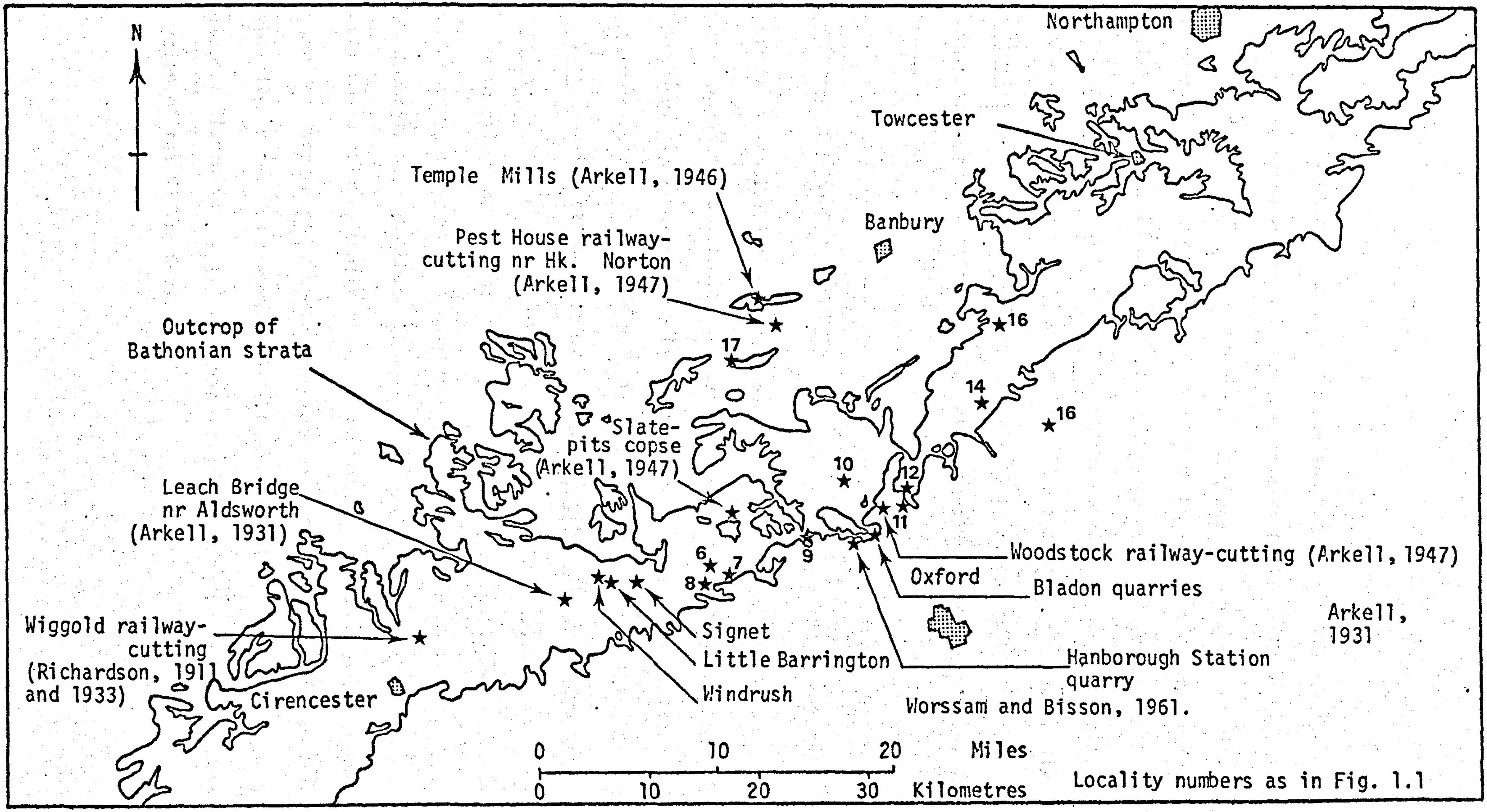


Fig. 1.38. The geographical distribution of A. bladonensis.

absent. The lithology and preservation suggest that transportation was minimal. However, this is not the case at Enslow Bridge where it would appear that the top of the A. bladonensis bed has been reworked, the gastropods are extensively damaged and the sediment is very coarse. Possibly, the unusual nature of the A. bladonensis bed at these localities is due to a continuation of the earlier intertidal regime with associated channelling, which deposited the Epithyris and Coral/ Epithyris limestones below (see McKerrow et al. 1969). This region would pass laterally into the adjacent supra-tidal island of Palmer and Jenkyns (op. cit.).

The strata above the Bladon Beds

The essential lithological relationships between the White Limestone and the succeeding strata have been described by Worssam and Bisson (op. cit.). The White Limestone is succeeded by marls frequently containing E. fimbriatus and B. waltoni or limestones containing drifted E. oxonica valves at the base with Lima (P.) subcardiiformis and Praeexogyra hebridica higher up. The limestones are fine-grained oolites, white-yellow in colour and rather flaggy. They have a discontinuous outcrop and according to Worssam and Bisson (op. cit.), they are slightly unconformable upon the White Limestone below. Although the present author was unable to confirm this relationship, a well developed hard-ground does separate the White Limestone from the succeeding strata especially in the south-west. These beds were called the Signet Beds by Worssam & Bisson (op. cit.) and they considered them to be a lower sub-division of the Kemble Beds.

Subsequently the Signet Beds were eroded and channelled with later deposition of coarsely-shelly, false-bedded, flaggy limestones (the upper subdivision of the Kemble Beds of Worssam and Bisson (op. cit.). These channels have been mapped by Worssam & Bisson (op. cit., p. 98-99). The present author considers the upper subdivision of the Kemble Beds (Worssam & Bisson op. cit.) to be the true Forest Marble. The unconformable and channelled relationship between the Forest Marble and the underlying strata can also be seen in the Wiggold railway cutting and at Bunkers Hill where the Forest Marble cuts through the A. bladonensis bed. The discordance between the Forest Marble and the underlying strata has been reported by several authors: Woodward (1894, p. 269, 289, 299); Odling (1913, p. 485, 489); Richardson (1933, p. 48, 73) and Worssam & Bisson (1961, p. 102).

The Signet Beds of Worssam & Bisson (op. cit.) are the lateral equivalent of the Kemble Beds of Great Oolite facies (Richardson, 1933) and together these pass south-westwards into the true Kemble Beds of Woodward (1894, p. 272-5; see discussion previously). Woodward (op. cit., p. 285) stated that; "The Kemble Beds evidently thin when traced from Kemble to Cirencester". The thicknesses given are 9.14 metres (30 feet) at Kemble and 3.04 metres (10 feet) at Cirencester. The maximum thickness of Kemble Beds observed by the present author is 2.42 metres at North Leigh (see Fig. 1.14). It is impossible to ascertain to what extent the north-easterly thinning of the Kemble Beds represents a true depositional thinning or how much is due to erosion associated with the overlying high-energy Forest Marble deposits.

Both the Kemble Beds and the Forest Marble become finer-grained and contain more clay bands towards the north-east, presumably due to a greater influx of terrigenous clastic material on approaching the London-Ardennes land-mass. Eventually the Forest Marble (and probably the Kemble Beds) pass north-eastwards into the Blisworth Clay.

Correlations to the south and west of the White Limestone Outcrop

The Minchinhampton Gastropod faunas

Much of our early knowledge of British Bathonian Mollusca was based upon the work of Dr. John Lycett in the neighbourhood of Minchinhampton. With Professor John Morris as geological collaborator, the results of his work were finally published as Palaeontographical Society Monographs (Morris and Lycett, 1851-55 and Lycett 1863). Almost one hundred years later a long overdue taxonomic revision of the British Great Oolite Molluscan faunas through a synoptic supplement for these works by Cox and Arkell (1948-50) became available. The history of Lycett's work has been briefly documented by Cox and Arkell (op. cit., 1948-50).

The interpretation of the Minchinhampton faunas and stratigraphy has caused considerable difficulty for a number of years (Woodward, 1894; Cox and Arkell, 1948-50; Arkell and Donovan, 1952). Apart from Simmonds quarry at Burleigh (Channon, 1950), no sections are now accessible on Minchinhampton common. The original account of the stratigraphy is obscure and confusing (Morris and Lycett, 1851-55). However, Lycett did publish a clearer description of the largest quarry at Minchinhampton (Lycett, 1857) and although no bed by bed correlation is possible, Woodward's section (1894, p. 278-9) substantially agrees with Lycett's section. Unfortunately the exact horizons from which Lycett obtained his fossils are, at best, only vaguely recorded but more often completely unknown. The beds evidently exhibited considerable lateral variation. Morris and Lycett (op. cit., 1851-55, p. 2) when describing the Weatherstones state; "The variety of mineral character is so great, that no two quarries, or beds of the same quarry, or even distant parts of the same bed, are alike in structure, aspect, hardness, durability, or in abundance of their included organic relics; ....". Lycett (op. cit., p. 93) describes how "the uppermost or planking bed changes its condition very materially between the two extreme ends of the section, losing all testacea towards its southern extension". Normally detailed mapping would provide a considerable amount of information about the stratigraphic relationships between the Minchinhampton area and the surrounding districts but Arkell and Donovan (op. cit., p. 243) state; "Round the Minchinhampton plateau, where the valleys are 600 feet deep and extremely steep, there has been so much slipping and cambering that detailed mapping is impracticable". Cambering is also well developed in Simmonds quarry at Burleigh (Channon, 1950).

The gastropod fauna of Minchinhampton constitutes part of a facies fauna which is unique in the British Bathonian. The Great Ponton Beds of the Upper Lincolnshire Limestone (Bajocian) are very similar in lithology and fauna, the gastropods having been described by Hudleston (1887-96). Examination of the British Museum (Natural History) and the Institute of Geological Sciences collections, combined with the limited information on species abundance given by Morris and Lycett (op. cit.) reveals the unique character of the Minchinhampton gastropod fauna.

Of the Nerineid gastropods, Fibuloptyxis witchelli (Cox and Arkell) and Melanioptyxis altararis (Cossmann) are by far the most abundant in the Museum collections. Both species were recorded by Morris and Lycett (op. cit.) as N. voltzii Eudes - Deslongchamps (see Chapter 2 for taxonomic details and geographic distribution). The highly distinctive Eparciella dufrenoyi (d'Archiac) was also abundant and apart from one recorded occurrence in the Sevenhampton Rhynchonella Bed (Richardson, 1929, p. 106), this gastropod was apparently restricted to the Minchinhampton facies. The type specimens of Eunerinea eudesii (Morris and Lycett) come from Minchinhampton (Lectotype GSM 8288; Paratypes and Topotypes GSM 49428-9: Institute of Geological Sciences Museum Registration numbers). The present author has not recorded Eu. eudesii in the field and is of the opinion that this species, like F. witchelli was one that was largely confined to the Minchinhampton facies (see Chapter 2). The most common species of Nerinella at Minchinhampton was N. scalaris (d'Orbigny) not N. cf. acicula (d'Archiac) or N. cf. pseudocylindrica (d'Orb.) as in the White Limestone to the east. However, Bactroptyxis implicata (d'Orbigny) and Cossmannea bathonica (Cossmann) were apparently reasonably common but, as far as it is possible to ascertain, Rigauxia varicosa (Rigaux et Sauvage) and Endiaplocus munieri (Rigaux et Sauvage) did not occur at Minchinhampton. Similarly,no records of Aphanoptyxis ardleyensis Arkell or A. excavata sp. nov. from this area are known to the present author. Cox and Arkell (op. cit.) doubtfully record specimens of A. eulimoides (Lycett) in the British Museum (Natural History) collection from Minchinhampton. These are probably specimens G. 66726-7; 66730-1 and G. 8243 which the present author would only identify as ?*Aphanoptyxis* sp. due to their poor preservation.

The species identified as *Cerithium Roissii* (d'Archiac) by Morris and Lycett (*op. cit.*) was later re-assigned as *Endiaplocus roissyi* by Cox and Arkell (*op. cit.*). However, because of the absence of an umbilicus, this species cannot be an *Endiaplocus* (see Morris and Lycett *op. cit.* pl. 7, Fig. 14a and Chapter 2 for further discussion of the genus *Endiaplocus*). The only Bathonian species known to the present author which it resembles is *Aphanoptyxis bladonensis*. The known specimens of *C. Roissii* from Minchinhampton (GSM. 8213; 84350; 84354 and 4541: Institute of Geological Sciences Registration numbers) are poorly preserved. The apical angle of specimen GSM. 8213 (the only one measurable) is 30°, which is somewhat large for *A. bladonensis*. However, amongst Arkell's topotype material in the Oxford University Museum, one specimen (J. 13035, an undoubted *A. bladonensis*) has an apical angle of 32° (see Chapter 2). Furthermore, the British Museum (Natural History) collections contain three specimens (collectively numbered G 10592), identified as *Cerithium Roissii*, from Great Rollright, which on comparison with the topotypes of *A. bladonensis* (both Arkell's original topotypes and those collected by the present author) can be shown to be misidentified specimens of *A. bladonensis*. The Hudleston collection (Sedgewick Museum, Cambridge) also contains specimens identified as *E. roissyi* (J. 31643-6) from Gibraltar Quarry and again these probably represent gerontic *A. bladonensis* with rather large apical angles. If, as the present author believes, the specimens variously identified as *C. roissyi* and *E. roissyi* represent gerontic *A. bladonensis*, then the occurrence of *A. bladonensis* in the Minchinhampton faunas would provide a valuable stratigraphic datum in the correlation with surrounding areas.

The British Museum (Natural History) Bathonian gastropod collection contains two Nerineid gastropods, BM 15074 and BM 51086, recorded from Minchinhampton but of doubtful authenticity. The complex folding of the internal body chamber and the presence of an umbilicus indicate a Pygmatis sp. It probably belongs to the P. pseudobruntrutana "group". The described species of this group P. pseudobruntrutana (Gemmellaro); P. tornata (Gemm.); P. meneghini (Gemm.); P. carpathica (Zeuschner); P. mandelsolhi (Bronn); P. curmentensis (de Loriol) and P. salomoniana (Cotteau) probably represent a single geographically widespread and morphologically variable species (with a variation similar to that of B. implicata - see Chapter 2) and will require further work in order to elucidate their inter-relationships. These species are all of Upper Oxfordian - Tithonian age. If specimens BM 15074 and BM 51086 are definitely from the Minchinhampton Great Oolite then a) they would be the first recorded occurrence of Ptygmatis in this country and b) the stratigraphical range of the genus Ptygmatis would be considerably extended downwards(2). Specimens BM 15074 and 51086 are part of the

---

Footnote(2)

Delpy (1948) described the Mesozoic (ranging from Upper Lias to Campanian) gastropod faunas of Madagascar. Amongst the "Bathonian" gastropods she recorded were Nerinella cf. bacillus, Nerinea bathonica and a new species Nerinella ampandrabensis (Delpy, 1948). The figure of Nerinella ampandrabensis shows a complex, multi-folded body chamber and a distinct umbilicus (Delpy, 1948, pl.II, Fig. 8). Although poorly drawn, nevertheless it appears to belong to the P. pseudobruntrutana group. This is the only other recorded occurrence of a Bathonian Ptygmatis known to the present author. However, Delpy's identification of Nerinea bathonica (i.e. Cossmannea bathonica), which she describes as having three folds and an umbilicus (see Chapter 2), must be erroneous. Of Nerinella cf. bacillus (i.e. Bactroptyxis cf. implicata) she writes (p. 12), "Il est impossible d'observer la section de l'enchantillon malgache trop mal conservé". Therefore, the present author is of the opinion that the Bathonian age of this gastropod fauna, in the absence of confirmatory evidence, must be regarded with caution and the occurrence of Ptygmatis in known Bathonian strata as yet unproven.

J. Morris collection of English invertebrates which was subsequently acquired and dispersed by a continental dealer, Dr. Kranz. In 1863 the British Museum purchased some of the Morris collection from Kranz, including the above specimens. It seems probable that these specimens may have been erroneously included in the Morris collection. They are probably from a stratigraphically higher horizon of Upper Oxfordian - Tithonian age with a facies similar to that of Minchinhampton. Possible examples could be the Stramberger limestone (Upper Tithonian of the north-west Carpathians - see Zittel, 1873) or the Astartian - Kimmeridgian limestones, south of Warsaw, Poland (Karczewski, 1960). The non-Nerineid gastropods from Minchinhampton are also distinctive and are briefly documented below.

Purpuroidea spp. According to Morris and Lycett (op. cit.) this genus is found only in and above the Planking at Minchinhampton where it was common in small areas (see Morris and Lycett, op. cit., p. 25-6). The only recorded occurrence of this genus in Bathonian strata other than in the Minchinhampton facies is at Sturt Farm in strongly current-bedded shelly oolites above the Excavata bed (Worssam & Bisson op. cit., p. 94). Specimens from Minchinhampton are frequently heavily encrusted with epifauna and apparently preferred high-energy environments.

Dicroloma spp. The British Museum (Natural History) and Institute of Geological Sciences Museum contain numerous, well-developed specimens from Minchinhampton. According to Morris and Lycett (op. cit.) the genus is not particularly common but apparently it is considerably more abundant at Minchinhampton than in the White Limestone where its occurrence is sporadic.

Ceritella acuta and *C. actaeoniformis*: "Numerous in all the shelly beds" (Morris and Lycett, *op. cit.*, p. 37) but uncommon elsewhere in the White Limestone.

Naticidae: Globularia, Ampullospira and *Naricopsina*. As in the White Limestone species belonging to these genera occur only in small numbers at Minchinhampton but the specific diversity appears to be higher, although this may be due to differences in sampling.

Actaeonidae. Ten species of the genus *Cylindrites* are recorded from Minchinhampton of which *C. acutus* was described as "one of the most common univalves in the Great Oolite at Minchinhampton" (Morris and Lycett, *op. cit.*, p. 98). Apart from the common occurrence of *C. angulatus* in the *Bactroptyxis* bed at Dagham Downs (see Fig. 1.6) few specimens have been found elsewhere in the White Limestone.

Pseudomelania spp. Five species; *P. communis*, *lonsdalei*, *subglobosa*, *leymeriei* and *conica* are recorded from Minchinhampton and according to Morris and Lycett (*op. cit.*, p. 48), *P. communis* is "decidedly the most common univalve in the Great Oolite". Species of this genus are not uncommon in the White Limestone although their abundance apparently decreases to the north-east.

Procerithidae. A difficult family to deal with unless the specimens are well preserved. Sixteen species belonging to this family are recorded from the Minchinhampton facies of which *Procerithium minchinhamptonense*; *P. (Cosmocerithium) betulae* and *P. (Rhabdocolpus) variable* are abundant. Members of this family are sporadically distributed in the White Limestone in other areas.

Amberleya bathonica. Only five specimens are recorded from Minchinhampton whereas this species occurs very commonly in the White Limestone (see Figs. 1.5 - 1.21).

Neritidae. Further research is necessary in order to adequately distinguish (or otherwise) the numerous recorded species of *Neritoma* (*Neridomus*) (see Fischer, 1969, pp. 135-8). All specimens of this subgenus found by the present author have here been recorded as *N.* (*N.*) cf. *cooksonii* (Deslongchamps) pending further research. Specimens frequently exhibit excellent colour banding and occur commonly both at Minchinhampton and throughout the White Limestone. Morris and Lycett (*op. cit.*) record the neritid genera *Lissochilus* and *Pileolus* from Minchinhampton but these have not been recorded from the White Limestone elsewhere as far as the present author is aware.

The most noticable feature of the Minchinhampton gastropod faunas is the occurrence of nine species of Patellacean gastropods, of which *Symmetrocapulus tessoni* and *Scurria bathiensis* are abundant. Their distribution appears to be related to the high-energy facies at Minchinhampton. The highly specialised, distinctive morphology of these cap-shaped limpet gastropods suggests that their ecological requirements were also specialised.

Recent representatives of the class Gastropoda which possess this range of shell morphologies do indeed occupy a specialised environment, namely the rocky intertidal zone and there can be little doubt that the fossil analogues at Minchinhampton occupied a similar niché in Bathonian times.

General observation of modern rocky intertidal environments suggests that limpets are not subject to large-scale post-mortem transport. Also transportation is very quickly reflected in abrasion and damage to the shell. The fossil limpet faunas at Minchinhampton are usually extremely abundant and well-preserved, often with no evident signs of abrasion or damage.

Thus the occurrence, abundance and state of preservation of the patelliform gastropod genera at Minchinhampton clearly suggest that the Minchinhampton facies was deposited in close proximity to a rocky shoreline, probably to the north or north-west.

To the knowledge of the present author, no patelliform gastropod has been found or recorded from the White Limestone elsewhere.

Evidently the gastropods of Minchinhampton represent a relatively local fauna which was adapted to the high-energy depositional environments which existed in this region.

The stratigraphy of the Minchinhampton strata

The stratigraphic range of the Minchinhampton beds is difficult to ascertain with any certainty. The only existing exposure, Simmonds quarry at Burleigh, has not yielded any ammonites and those ammonites recorded by Morris and Lycett (*op. cit.*) are unlocated. Although not common, several years of collecting by Lycett accumulated a large Bathonian ammonite fauna. These largely consist of several *Morrisiceras* spp., *Lycetticeras* spp. and *Tulites* spp. These included the holotypes of

Morrisiceras morrisi (Oppel) and Lycetticeras lycetti Arkell as well as the lectotype of Tulites subcontractus (S.S. Buckman) (see Arkell, 1951-9; Arkell and Donovan, 1952 and Torrens, 1969 for details). Arkell (1951-59) placed the whole of the Minchinhampton beds in one zone, the Subcontractus zone. However, the more detailed revised Bathonian zonal stratigraphy of Torrens (1967a; 1969) clearly demonstrates the existence of at least two zones at Minchinhampton, the Subcontractus zone and the overlying Morrisi zone. A number of other ammonite genera have been recorded from Minchinhampton. These have been reviewed by Torrens (1969, pp. 68-9 and p. 71) who stated (p. 71); "The other ammonites, chiefly the Perisphinctids, suggest that other zones may be represented amongst these faunas". The Perisphinctids are Wagnericeras pseudosubtile (Lissajous), W. suspensum (S.S. Buckman) and a Procerites sp. from the 'Scroff' bed found in situ by P. Channon and recorded by Cox and Arkell (op. cit., p. XVII). As noted by Torrens (1967a) the basal part of the Retrocostatum zone (i.e. the zone above the Morrisi zone) in the south of England is overwhelmingly characterised by Perisphinctids especially species of Procerites. However, Torrens (1967a) stresses the uncertain nature of these ammonite faunas and concludes (p. 71), "unless new exposures become available nothing can be said".

Examination of the Minchinhampton gastropod faunas suggests it may be possible to confirm the presence of the Retrocostatum zone at Minchinhampton. The holotype of Fibuloptyxis witchelli (Cox and Arkell) came from Tiltups End only 4 kilometres (2.5 miles) south of Minchinhampton Common. The abundant Nerineid fauna, which included Bactroptyxis implicata (d'Orbigny), was recorded by Witchell (1886). The quarry also yielded *Bullatimorphites bullatimorphus* S.S. Buckman, a reliable index of the Retrocostatum zone. *All* occurrences of *F. witchelli* and all Bathonian occurrences of *B. implicata* which the present author has been able to place in the revised zonal stratigraphy of the White Limestone are of Retrocostatum age and invariably in the upper part of the zone. The common occurrence of *F. witchelli* and *B. implicata* in the Minchinhampton faunas is consistent with the meagre ammonite evidence in indicating the presence of the Retrocostatum zone. In this context the possible occurrence at Minchinhampton of *Aphanoptyxis bladonensis* Arkell (a subzonal gastropod index, the occurrence of which marks the upper boundary of the Retrocostatum zone and the White Limestone) would lend additional support to this hypothesis if the identification of *C. roissyi* as *A. bladonensis* could be confirmed.

As noted by Torrens (1969, p. 68) a higher zone, the Aspidoides zone, may be represented in the Minchinhampton beds by *Oppelia* (*Oxycerites*) *aspidoides* (Oppel)(Sedgwick Museum registration number SMB. 3785) and *Wagnericeras* (*Suspensites*) *arbustigerum* (d'Orbigny) (British Museum (Natural History) registration number BM C. 10047: see also Arkell, 1951-59, p. 64 and p. 208). This would considerably extend the zonal range of the Minchinhampton beds. Moreover, since the Retrocostatum zone is obviously well developed at Tiltups End immediately adjacent to the Minchinhampton sections, the present author believes this latter zonal range over portions of four zones is not unreasonable.

Arkell and Donovan (*op. cit.*) considered that the ammonites collected at Minchinhampton came from the 'Scroff' and 'Planking' and not the 'Shelly Beds' and 'Weatherstones' as previous authors had assumed. As noted by Arkell and Donovan (op. cit.) it is probable that the holotype of Morrisiceras morrisi (Oppel) as well as a specimen of M. fornicatum (S.S. Buckman) came from the compact, fine-grained White Limestone facies exposed in a road cutting at Pinfarthing on the western edge of Minchinhampton Common. This horizon corresponds to the limestones containing Morrisiceras at Woodchester Park Farm quarry (4 kilometres (2.5 miles) west of Minchinhampton Common: see Torrens, 1969). Because the Morrisiceras limestones at Woodchester Park Farm overlie flaggy oolites similar to the upper part of the Minchinhampton beds and because fine-grained White Limestone facies limestones have not been recorded in the Minchinhampton beds, Arkell and Donovan (op. cit.) inferred the Morrisiceras limestones lay above the Minchinhampton beds. This interpretation would mean that no zones higher than the Morrisi zone could be present on the Minchinhampton plateau. Because the Pinfarthing beds lie at a level corresponding to the lower beds on Minchinhampton Common, Arkell and Donovan (op. cit.) believed them faulted down or otherwise lowered to their present position. The record of Procerites from the 'Scroff' (approximately halfway up the Minchinhampton strata) is not consistent with their interpretation. Furthermore this interpretation would make the Morrisi and Subcontractus zones very much thicker than in any other recorded English section.

The present author believes that the apparent absence of a well developed White Limestone facies at Minchinhampton is probably due to the persistence of a small area of shallow-water high-energy conditions for a considerable length of time (M. - U. Bathonian) in the Minchinhampton region. The fine-grained White Limestones at the margins attenuate and pass into coarser false-bedded shelly oolites.

In terms of the prevailing Bathonian palaeogeography, the Minchinhampton area may be envisaged as a high-energy shelly oolite shoal with some proximity to a rocky shore-line. In this region, it effectively separated the finer-grained, deeper water deposits to the south-west (represented by the Upper Fullers Earth Clay and Hawksbury Clay) from the more restricted ?lagoonal subtidal carbonate substrates to the north-east (represented by intrapelmicrites and sparites of the White Limestone). The White Limestone shows marked faunal and sedimentary gradients as one passes north-eastwards from the Minchinhampton facies. Gradually the sediments become finer-grained and pass into inter-tidal (in places supra-tidal) micrites and clays in close proximity to the low-lying London - Ardennes landmass. The changes in the molluscan fauna correspond closely with changes in the substrate composition/texture and also probable changes in salinity. The geographical limitsof the White Limestone Formation as used in the present work extends from Bisley (SO 905060) in the south-west to Stratton Audley (SP 601255) in the north-east.

Evidently a small area of White Limestone facies existed to the south-west of the Minchinhampton facies during the Upper Retrocostatum zone (i.e. the 'White Limestone' and associated Nerineid fauna of Tiltups End). However, this quickly passed laterally into the finer-grained, deeper water carbonate deposits now represented by the Tresham Rock to the south-west.

Green and Donovan (1969, p. 24) suggest that the carbonate facies of Bath and the South Cotswolds deposited during the Aspidoides zone (the Coombe Down Oolite, Twinhoe Beds and Bath Oolite) accumulated in a north-west to south-east belt at the junction between the Cotswold Shelf (see Martin, 1967) and a basinal area to the south-west. The present author considers that at an earlier age (Subcontractus to Retrocostatum zones) the high-energy facies of Minchinhampton may have represented this junction. It is not yet possible to ascertain whether this high-energy marginal facies is continuous beneath the marginal younger rocks to the south-east.

A proposed correlation of the Minchinhampton area with the strata to the south and with the White Limestone of the Cirencester area to the north-east is shown in Fig. 1.39. The sections used are based upon the published data of Green and Donovan, 1969; Torrens, 1968; Arkell and Donovan, 1952 and Witchell, 1886. The locations of the sections are shown in Fig. 1.40.

Correlations to the north-east of the White Limestone outcrop

The White Limestone passes, in part, into the Blisworth (= Great Oolite) Limestone of the Midlands. The stratigraphy and palaeontology of the Blisworth Limestone has been well documented by Torrens (1967b). As noted by Torrens (in Sylvester-Bradley and Ford, 1968, p. 239) the critical area in which to establish an exact correlation between the White Limestone of Oxfordshire and the Blisworth Limestone of the Midlands, is one in which complete sections are rare. However, the

FIG 1.39 A PROPOSED CORRELATION OF THE WHITE LIMESTONE WITH SECTIONS TO THE SOUTH AND WEST

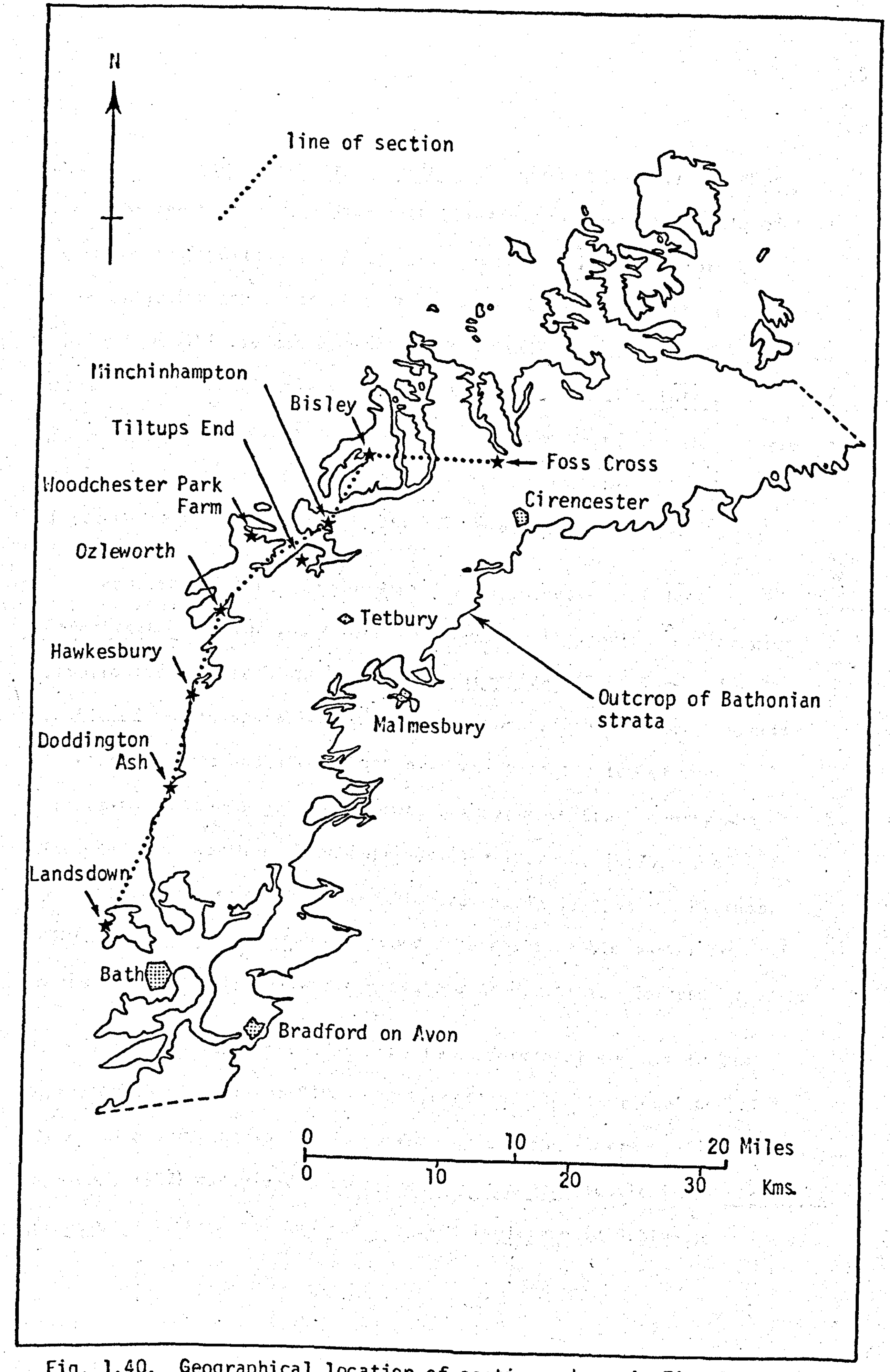


Fig. 1.40. Geographical location of sections shown in Fig. 1.39.

occurrence of *Procerites* cf. *quercinus* (Terquem et Jourdy) and *Choffatia* spp. near the base of the Blisworth Limestone suggests the whole of this formation falls within the Retrocostatum zone and is therefore to be correlated with the upper part of the White Limestone to the south-west. A second possibility has been suggested: that the distribution of these Bathonian ammonite faunas may be facies controlled with *Tulites* spp. and *Morrisiceras* spp. occurring in the fine-grained White Limestone facies and *Procerites* spp. occurring coevally but in a different, Blisworth Limestone facies to the north-east (Torrens, 1967b, p. 85).

However, support for the empirical hypothesis of a later, *Retrocostatum* age for the Blisworth Limestone is provided by the distribution of the brachiopod *Digonella digonoides* (S.S. Buckman). This brachiopod occurs sporadically in the south-western part of the White Limestone outcrop and always within strata near the top of the Retrocostatum zone e.g. Dagham Downs quarry, Foss Cross quarry and the Aldgrove - Chedworth railway cuttings (see Torrens, 1967b, p. 85-6 for localities and discussion; also Richardson, 1911, 1933 and Pittham, 1970). *Digonella digonoides* is found as a correlatable marker horizon in the middle of the Blisworth Limestone of Northants (Torrens, 1967b).

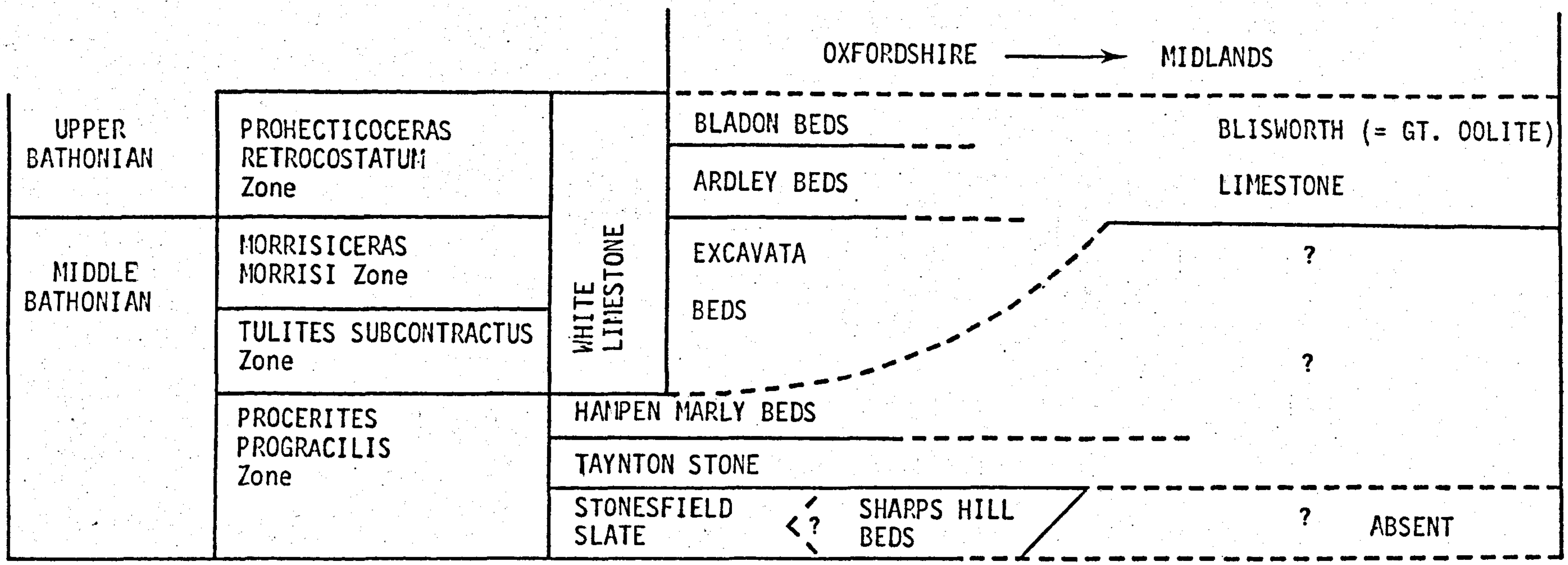
The Nerineid gastropod faunas lend additional support to the Retrocostatum age of the Blisworth Limestone. The 'Nerinea' bed at Blisworth quarry and in the Roade railway cutting (Torrens, 1967b; Thompson, 1927) has yielded *Eunerinea arduennensis* (Buvignier), *Nerinella* cf. *acicula* (d'Archiac) and *Bactroptyxis implicata* (d'Orbigny).

Eunerinea arduennensis is uncommon below the Ardley Beds and the latter two gastropods have been found by the present author only in the Ardley and Bladon Beds (i.e. the Retrocostatum zone). The present author also possesses a number of internal moulds of Aphanoptyxis bladonensis collected by P. Pittham from the Blisworth Limestone at Wellingborough No. 6 pit (SP 915795). Unfortunately, this quarry is now completely infilled and it is not yet possible to ascertain from which bed in the section recorded by Pittham (1970, pp. 52-53) the specimens were collected.

No specimens of A. ardleyensis from the Blisworth Limestone are known to the present author.

Although no bed by bed correlation with the White Limestone appears possible, the palaeontological evidence is overwhelmingly in favour of a Retrocostatum zone age for the Blisworth Limestone and it is to be correlated with the Ardley and Bladon Beds to the south-west.

A revised correlation diagram based on Torrens (1967b) is shown in Figure 1.41.



Modified from Torrens, 1967.

Fig. 1.41. Correlation of White Limestone and Blisworth Limestone.

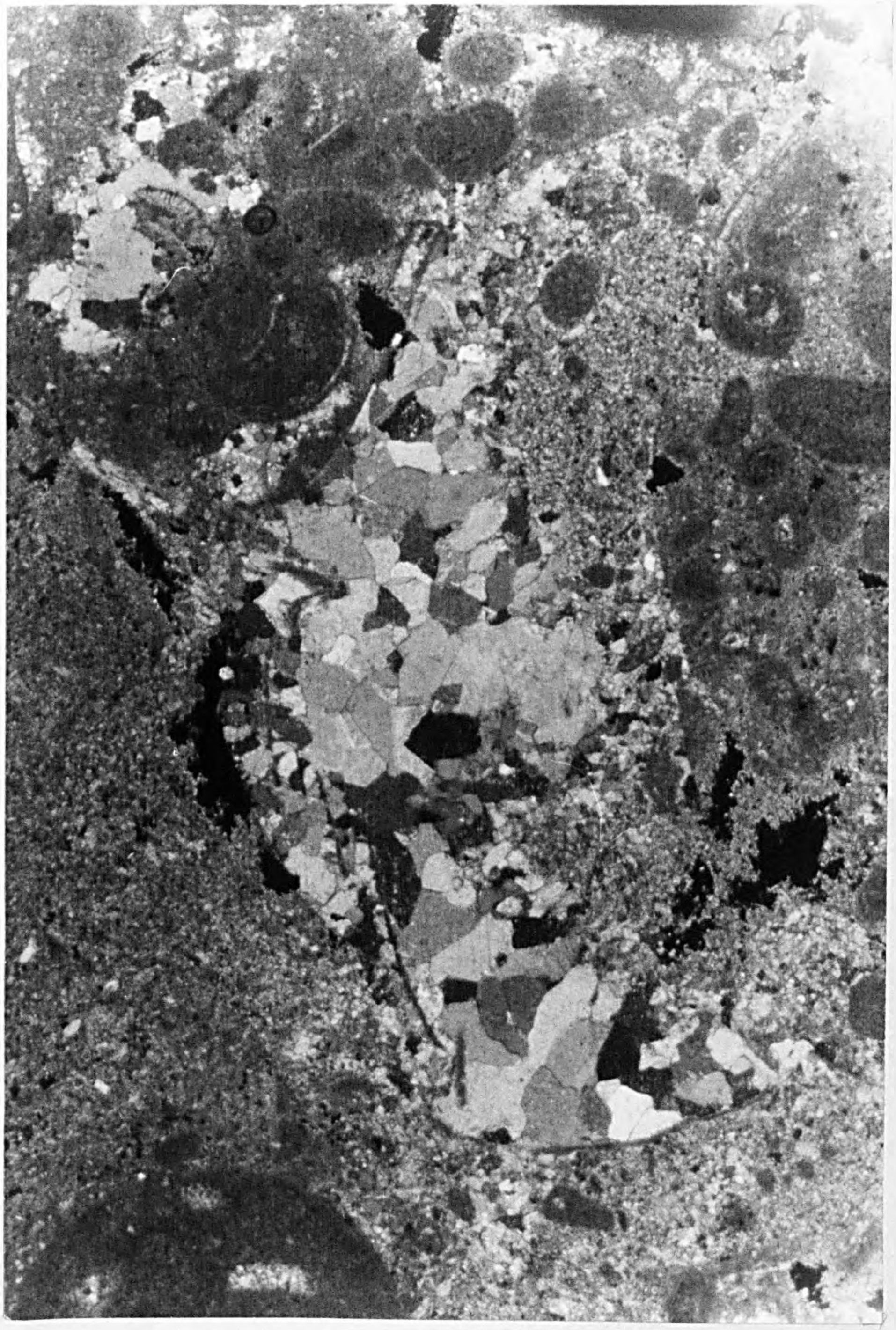
The lithology of the *A. excavata* Bed.

Worsham, bed 6, 0.05 m from top

Thin section, crossed polars, x50.

Slide W6/5 - M.J.B. collection.

Plate 1.A.



Chapter 2

A TAXONOMIC REVISION OF ENGLISH BATHONIAN NERINEACEAN GASTROPODS (INCLUDING A NON-NERINEACEAN HOMEOMORPH)

'Don't take action because of a name! A name is an uncertain thing, you can't count on it!'

Bertolt Brecht, A Man's a Man, 1927.

Introduction

The Nerineacea comprise a large superfamily of gastropods which are exclusively Mesozoic in age. All members have two distinctive features:

1) they possess a slit in the aperture next to the suture. This is secondarily infilled to produce a selenizone or slitband, as in Pleurotomaria, but in the Nerineacea the selenizone is adjacent to the suture and not in the middle of the outer lip (see plate 2.I.).

2) the aperture is terminated by a distinct apertural canal or notch (see plate 2.J.).

The external morphology of these gastropods is rather variable. British Jurassic representatives are, in general, high-spired with flat or slightly concave whorls and little ornamentation. Elsewhere, genera are found which are squat, ovate or globose although they still retain the two characteristic Nerineacean features outlined previously.

However, the best known feature of these remarkable gastropods is the restriction of the internal whorl cavity in many genera by a number of secondarily emplaced calcareous lamellae called 'folds' (see Chapters 4 and 5). A few genera do not possess these folds, e.g. the well known Aptyxiella portlandica (the 'Portland Screw'). This species is the only representative of this superfamily recorded from the Tithonian-Volgian strata of Britain. Apart from A. portlandica, Nerineacean gastropods are both abundant and diverse in other British Jurassic carbonate facies namely in the U. Oxfordian (Corallian), the Bajocian (particularly the Upper and Lower Lincolnshire Limestone) and especially in the Bathonian White Limestone - the subject of this study.

Western European workers recognise three families within the Nerineacea; the Nerineidae, the Itieriidae and the Ceritellidae, although representatives of the Itieriidae have not been reported from British Jurassic strata. The characteristics of these families together with problems of further subdivision and the affinities of these gastropods are more fully dealt with in Chapter 7.

The object of this Chapter is to evaluate the various morphological characteristics of the Nerineacean shell and apply consistent taxobases to those genera and species found in the Bathonian White Limestone. The evaluation of the shell morphology is based upon the data presented in Chapters 3, 4 and 5. Considerable attention has been paid to relevant French literature since many of the species found are common to the Bathonian of both France and England. However, until the important collections of d'Orbigny and Cossmann can be studied and can be combined with extensive fieldwork in France, some of the problems concerning the total stratigraphic range, wider geographical distribution (and even identity) of some species must remain, at this stage, only partially resolved. In other cases, such as the genus Bactroptyxis, Bajocian representatives were also studied and for Bactroptyxis in particular, the more extensive data available enabled a comprehensive taxonomic revision of the described species to be presented. Where necessary, problems concerning the scope of a genus or its interpretation have been reviewed and hopefully resolved. In the discussions of individual species, previous authors' synonymies have been referred to where no additional information was necessary or no re-interpretation of the species was proposed. For each of the species found, the morphologic and diagnostic features are summarised and data are presented on their known stratigraphic and geographic distribution in the Bathonian White Limestone Formation of England.

Contents

B Family Nerineidae

C Family Ceritellidae

A The species concept and its application to Nerineid gastropods.

The differences between the neontological and palaeontological species concepts have been conclusively discussed in recent years and only a very brief summary is presented below. Most palaeontologists now accept the fact that terms such as gene-flow, reproductive isolation, allopatric speciation, sibling species and other aspects of population genetics, which are pertinent to the modern biological species concept, were also pertinent, and indeed can be recognised, though rarely, in fossil species. Conversely, most biologists are aware of the data loss associated with fossilisation together with the problems introduced by that unique perspective of palaeontology: time.

In practise, the two species concepts are not so very different. The biological species definition: "species are groups of interbreeding natural populations that are reproductively isolated from other such groups", so eloquently advocated by Mayr (1963, 1970), is a genetic concept which is not normally rigorously applied even in neontological species recognition. In practise, because the genetic variation of a species is expressed in phenotypic variation, most species in biology are also recognised on morphological criteria. As noted by McAlester (1962, p. 1378) "consistent morphological differences can be demonstrated to exist in the vast majority of living genetically differentiated species and this criterion will probably always provide the most useful means of recognising species." Effectively therefore there is little difference in the practical taxonomic procedures of the biologist and palaeontologist. The position was summarised by Thomas (in Sylvester-Bradley, 1956, p. 20) who stated, "Palaeontologists depend on the assumption that morphological differences or discontinuities coupled with a degree of isolation in space or time of populations statistically demonstrated to be homogeneous, usually express genetic differences and discontinuities".

The phenotypic variability of modern species is distributed in discrete interbreeding local populations each of which may be characterised by slight differences in morphology when compared with adjacent populations of the same species. These differences reflect the interaction of the smaller genetic variability in a local population with local environmental modifications. Sampling and subsequent statistical analysis of these populations can extrapolate the variation in the morphology of a relatively few specimens into a more generalised morphological variation for the whole species. Despite the data loss in fossils this procedure can be applied to fossil species and the use of biometrics and biostatistics has been discussed by several authors, particularly Newell (in Sylvester-Bradley, 1956, pp. 63-82) and Imbrie (1956). However, palaeontologists must also appreciate that a morphologically distinctive fossil species must inevitably represent an over-simplification, in that much of the anatomical, behavioural and environmental information used by biologists is not preserved in the fossil record.

This approach to the species problem must also take cognizance of two important factors: a) the stratigraphic utility of fossils and b) the existence of phyletic lineages. The fiercely pragmatic approach of Arkell (in Sylvester-Bradley, 1956, pp. 97-99) emphasised the artificial nature of a fossil species and suggested that (p. 97) "the only logical criterion for the size and definition of a taxon in palaeontology is its usefulness." This utilatarian position was, at that time, a justifiable reaction against the unnecessary, theoretically motivated, splitting of species by some earlier workers, notably Buckmann (1886-1907) and Spath (1924). To follow the example of Arkell (op. cit.) would be to subdivide fossils into as many morphologically distinct, specimens or groups of specimens provided that they were of stratigraphic value and eventually the species concept in palaeontology would have no biological basis. However, this subdivision into discrete morphological groups is precisely the problem encountered in a phyletic lineage such as the Micraster populations in the Chalk of southern England.

Both of these palaeontological problems can be adequately encompassed in a biological species concept. Of course it is desirable that stratigraphically useful forms should have their potential fully exploited and the present author considers that the terms 'variety' and 'form' as defined by the International Code of Zoological Nomenclature (1964, article 45e) could be used for this purpose. Furthermore, evolutionary lineages could be subdivided using the arbitary 'species interval' of McAlester (op. cit., p. 1380). The application of both these solutions to the difficult taxonomic problems of ammonite faunas has been clearly discussed by Howarth (1958, pp. xxii-xxiv and 1973, pp. 246-249), but these techniques have not as yet been widely adopted.

In both living and fossil organisms the basic factors which separate species are genetic. The problems of species recognition in palaeontology are best resolved not by divorcing palaeontology from recent systematic studies but by modifying and assimilating modern biological concepts.

The application of the above principles to the Nerineacea is not without problems for as noted by Arkell (in Sylvester-Bradley, 1956, p. 98) "The more featureless a genus, the fewer will be the recognised species, and the longer the stratigraphic range." In the case of several closely related Nerineid species, differentiation must be based upon adequate samples and be statistically evaluated, especially when dealing with morphologically rather simple fossils such as gastropods where differences in skeletal morphology are subtle and need quantification in order to achieve some objectivity and consistency in species discrimination. However, as noted by Thomas (in Sylvester-Bradley, 1956, p. 22), "It must be appreciated that while fossil populations may differ statistically, the taxonomic significance of such differences must be a separate evaluation, preferably guided by neontological analogies." In the taxonomic revisions below, the present author initially attempted to ascertain the morphological variation within a gastropod population from a sample obtained at a single locality and horizon. This variation was then compared with other similar gastropod populations in the White Limestone. If a considerable amount of morphological overlap existed between the Nerineid populations and there was no stratigraphic value in their separation, they were grouped into a single variable species. Where a population was clearly outside the range of continuously variable morphologies exhibited by species A, it was considered to be an interbreeding population of individuals belonging to another separate species B.

Clearly this species concept assumes that members of an unbiased sample from a single locality and horizons were genetically related and are fossil representatives of a homogeneous population. This assumption cannot be made unless two conditions are fulfilled; firstly, that post-mortem geological processes i.e. transportation of shells, mixing of several populations, etc., have not significantly biased the sample and secondly, that specimens within a relatively thin stratum are likely to be genetically related both horizontally and vertically.

A number of lines of evidence suggest that the faunas of most gastropod-bearing horizons within the White Limestone are essentially non-drifted.

1) In many cases, a large proportion of the gastropod fauna is represented by an infaunal species and analyses of the relationships between the various species present and their modes of life suggest that these gastropod-bearing horizons were ecologically balanced and viable (see Chapter 5).

2) The relationship between the surrounding matrix and the sedimentary infill of the gastropod body-chamber provides evidence for exhumation where this has occurred. Abrasion associated with shell movement, together with epibiontic colonisation of the shell are readily apparent in those specimens which have lain at the sediment - water interface for long periods of time (see Chapter 6). In most Nerineacean-bearing strata in the White Limestone, taphonomic studies indicate that exhumation and transportation of infaunal species have been minimal.

3) The preservation of the gastropods in well-indurated limestones precludes the possibility of contructing detailed size-frequency analyses. However, the use of X ray-radiography allows a qualitative assessment of

size-variation to be made and preliminary results show that in most horizons juvenile gastropods are present and all growth-stages appear to be represented.

4) The biometric data do not contain inconsistencies or inhomogeneities which might result from the mixing of several populations.

5) There is no sedimentological evidence to suggest that the White Limestone gastropod faunas are in any way 'condensed' in the sense of the Bajocian strata and faunas of Dorset. The sediments of the gastropod beds are for the most part fine-grained biointramicrites and biointrasparites and lithological discontinuities (including cross-bedding) *within* a bed are uncommon. Furthermore the usual sedimentary indicators of condensed and transported horizons, such as iron and manganese concentrations, limonitic algal pisolites and 'snuff-boxes', conglomerates etc. (as are found for example in the Red Conglomerate - Bajocian, Romani - Polygyralis Subzones, Burton Bradstock, Dorset) are absent in the gastropod horizons from the White Limestone.

When considered from the above points of view, those gastropod bearing strata in which the fauna has been subject to transportation, abrasion and colonisation are readily apparent (e.g. bed 10, Worsham quarry, see fig. 1.12 and Chapter 6). However, in the absence of contrary evidence, the present author concludes that *post-mortem* processes have not significantly modified the original population structure in most of the Nerineid horizons studied.

None of the gastropod samples were collected from horizons more than 0.50 metres in thickness and it is not unreasonable to assume that amongst representatives of the population sampled, genetic continuity and contact was maintained both in time and space. In a horizontal sense, all members of the population would be theoretically capable of interbreeding and contributing to the 'gene-pool' whereas genetic contact in a vertical sense (i.e. through time) would be operative via ancestor-descendant inter-relationships.

The taxonomic significance of slight variations in Nerineid fold morphology was also considered in the light of new palaeobiological interpretations presented here (see Chapter 5). Clearly subtle differences in fold strength and development are more evident in Nerineids possessing a complex fold pattern (such as Bactroptyxis spp.) than in the simpler Nerineids with few folds (such as Nerinella spp.) and the importance of these variations should not be over-emphasised.

Biometrical techniques and their application to White Limestone Nerineid populations are discussed in Chapter 3. In those synonymies presented in this Chapter, the signs in front of the year are intended to supply additional information relevant to the present author's interpretation of the particular species. The symbols used are modified from those proposed by Richter (1948) and are reviewed by Matthews (1973).

B1 Genus Zenoplocus gen. nov.

Name from Zeno, a Greek philosopher and plocus, Greek, meaning curl.

Type (and only) species Zenoplocus microplicatus sp. nov.; from the Middle Jurassic (Bathonian - at least the Morrisi zone) between Woodchester Park Farm Quarry (SO 811011) and Grickstone Farm (ST 775833).

Description

Highly acicular, turretted Nerineid gastropod with a small spiral angle (4° in the type-species). Early whorls slightly concave becoming very slightly convex in the middle of later whorls. Ornamentation consists of fine spiral lirae. Whorls noticeably rather high in relation to the whorl width. Suture slightly elevated with no overlap of the whorls and the selenizone narrow. The adapertural periphery of the whorls is angular; clearly defined with the whorl bases noticeably concave. The details of the aperture are not known.

A single median labral fold is present (fold diagnosis - 0010) but is not developed until some four or five whorls from the aperture. This fold development is unusual, if not unique, in Nerineid gastropods and is the most distinctive feature of this genus.

B1/1 Zenoplocus microplicatus sp. nov. Plates 2.A and 2.B

Name micro plicatus - small fold.

Description

Slender, elongate Nerineid gastropod with a spiral angle of 3 - 4 degrees. No complete specimens are known and therefore details of aperture and apex are not at present available. Maximum observed length

7.5 cms. Whorls high in relation to their width (mean whorl width/height ratio - 1.34; range 1.00 - 1.59; N = 16). The usual ontogenetic change in whorl shape found in Nerineids is also found in this species, the early whorls (up to 20) being slightly concave, gradually becoming slightly convex in more mature specimens. The whorl sides are ornamented with fine subequal spiral lirae (usually eight). The suture is slightly elevated on a carina formed by the angular adapertural periphery of the upper whorl and the narrow adapical juxtasutural ramp (the selenizone) of the lower whorl. The flat juxtasutural ramp forming the selenizone is clearly visible in longitudinal sections (Plate 2.B). The whorls do not overlap. The basal wall of the whorls (and therefore the base of the shell) is markedly concave and is clearly separated from the labral wall by an angular periphery.

Longitudinal sections reveal the presence of a single, small, rather angular, median labral fold. A distinctive feature of this species,is the absence of this fold in the lower four or five whorls (Plate 2.B). In other fold-bearing Nerineid species, only the last 1-1½ whorls lack folds. The cross-sectional shape of the body-chamber is also distinctive. The columellar and labral walls are almost parallel. The labral wall is sharply differentiated from both the parietal and basal walls. The parietal wall is convex and the basal wall is concave and both merge asymptotically with the columellar wall.

Discussion

The median fold and juxtasutural selenizone clearly suggest that this species belongs to the Nerineacea.

In the past, it has been variously named: Aphanoptyxis cf. langrunensis (HIC 4566 , Institute of Geological Sciences Museum, Ivimey-Cook - Butler Collection); Aphanoptyxis ardleyensis (CV 398, Institute of Geological Sciences Museum, Cave Collection); Nerinella striata (Zn 3837-9, Institute of Geological Sciences Museum, Mellville Collection) and Nerinea (GG 5538, Institute of Geological Sciences Museum, Donovan Collection). It was almost certainly recorded as Nerinea from Bed 5 in Woodchester Park Farm Quarry by Channon (1950, p. 259) and as ?Bactroptyxis from the same locality in Cox and Arkell (1948-50, p. 5). Dr. H. S. Torrens (Keele University) kindly donated specimens collected in situ from Bed 5 of Channon's description here at Woodchester Park Farm Quarry where elongate Nerineids occur in somewhat sparsely distributed 'shelly' lenses. Upon sectioning they proved to be the present species and are at present temporarily housed in the personal collection of the author (Registration Number WPF5/1 - WPF5/14).

The presence of a single labral fold in this species clearly indicates that it cannot be a species of Aphanoptyxis (no folds), Nerinea (three folds), Nerinella (three folds) or Bactroptyxis (multiple folds). Indeed, as far as the present author is aware, the only supra-specific Nerineid taxonomic category possessing this extremely unusual fold configuration (0010), is the monotypic Bajocian (Murchisonae Zone, Bradfordensis subzone) subgenus Nerinella (Nailsworthia) from the Cotswolds of England. The type, and only, species is N. (N.) lycetti (Cossmann, 1901) = Chemnitzia gracilis Lycett 1853 non Zekeli 1852 (the Holotype, G.S.M. 8083, is from the Oolite Marl horizon at Nailsworth Hill - see also Cox, 1954, p. 94). However, the broadly convex, rounded periphery; robust fold; normal (as distinct from delayed) fold development, combined with an external appearance resembling Pseudomelania, clearly indicates that the Bathonian species now under discussion cannot be placed in this subgenus.

The morphology of Zenoplocus gen. nov. clearly suggests that it is related to the genus Aptyxiella Fischer 1885, from which it is separated by the presence of a single labral fold.

Occurrences

All specimens unless otherwise stated are those of the Institute of Geological Sciences Museum.

The known material of Zenoplocus microplicatus gen. nov. et sp. nov. examined by the present author is as follows:

a) HIC 4566 (2 specimens) from a quarry 500 yards S 80° W of St. Margarets Church, Yatton Keynell and 1 mile 300 yards N 50° W of Sparrow Farm, Chippenham Without, Wiltshire (G.R. - ST 862763). See plate 2.A.

b) GG 5538 from an old quarry in angle of Hall Lane and A46, 1 mile south-east of Horton, Gloucestershire. See plate 2.B.

c) CV 100, 400 yards north-west of Grickstone Farm (G.R. - ST 775833). Specimens have also been reported from several other localities in the immediate vicinity (pers. comm. - H. S. Torrens). See plate 2.B.

d) CV 397 and CV 398, Brash, 330 yards north-west of Grickstone Farm and 1470 yards south-east of Horton Rectory Farm, Horton, Gloucestershire (G.R. - ST 775833).

e) Borehole material.

i) Ba 3183 and Ba 8188a. Dr. I. E. Penn (pers. comm., April, 1971) states that these specimens came out of the Shipton Moyne borehole from the 'Passage Beds' at 151 feet (Ba 3183) and 152 feet 6 inches (Ba 3188a) from the surface. It was implied that the borehole was the Shipton Moyne No. 3, described by Richardson (1919), although the sequence in this borehole was apparently very similar to that encountered in the earlier Shipton Moyne boreholes described by Richardson (1915) - see also Richardson (1919, p. 151 and p. 155).

ii) Ba 451a is a specimen of Z. microplicatus from the Tetbury borehole at a depth of 168 feet below the surface. From the same borehole a specimen of F. witchelli (Ba 405) was obtained from a depth of 80 feet below the surface. It is not at the present time certain as to whether this Tetbury borehole is the one described by Pringle (1929), known as the Tetbury No. 4 borehole from which Nerinella gracilis (Lycett) ? = Z. microplicatus was recorded (Pringle, op. cit., p. 187), or the Tetbury Waterworks borehole described earlier by Richardson (1915). The stratigraphic implications of these occurrences are discussed later.

f) Zn 3837-9 from a natural scar, 2/3rds mile north north-west of Kingscote Church and approximately 300 yards west of Binley Farm, Gloucestershire.

g) WPF5/1 - WPF5/14 (personal collection of the author) from Woodchester Park Farm Quarry (G.R. - SO 811011), Bed 5 of Channon (1950). Channon (op. cit.) recorded Nerinea sp. from this bed but the material has not yet been located.

Probable records of this new genus and species include the following,

1) Nerinea (Nerinella) cf. pseudocylindrica from Tolldown by Richardson (1935, pp. 281-2) but the location of this material is currently unknown.

2) *Ptygmatis* sp. nov. from a shallow excavation for a pylon (No. W.66), north of north-east corner of Middle Hill Wood and north of footpath from Hartley Cottages to Hartley Bottom. The horizon was given as the Sevenhampton *Rhynchonella* Bed by Channon (1946, pp. 119-120).

Stratigraphic distribution

The occurrence of *Zenoplocus microplicatus* gen. nov. et sp. nov. at Woodchester Park Farm Quarry is of some importance. It is the most northerly locality where this genus is so far known to occur. Furthermore, the bed in which it was found (Bed 5 of Channon, 1950) can be dated (Morrisi zone - Middle Bathonian) and has yielded several fine specimens of *Morrisiceras morrisi* (see Torrens, 1969, p. 70 and Torrens, 1970 for synonymy). This is the only locality where the occurrence of *Z. microplicatus* can be unequivocally and accurately dated. Some specimens contain remnants of the original duct systems in what was the digestive gland/gonad of the gastropod (see Chapter 5).

The precise zonal age of all other occurrences noted above must at this stage be regarded as indeterminate. Some specimens, e.g. Zn 3837-3829 (f above) are recorded as coming from the Cross Hands Rock whereas others, e.g. CV 100, CV 397-98 (c and d above) are recorded from the Tresham Rock. These latter specimens from around Grickstone Farm are from an area containing pre-Triassic faulting although some of the faults may be much younger. This together with the poor exposure suggests that any formational boundaries proposed in this region are conjectural. Furthermore, whilst the lithologies of the specimens are comparable with those of the Tresham Rock (U. Retrocostatum zone), they are also comparable with the stratigraphically lower Doddington Ash Rock (U. Morrisi zone).

The borehole specimens also present difficulties. Specimens Ba 3183 and Ba 3188a would be from the Great Oolite/'Passage Beds' junction in the borehole section given by Richardson (1919, p. 158) and with the Acuminata Beds occurring approximately 120 feet lower down the borehole, this suggests a Retrocostatum zone age. Specimen Ba 415a indicates a similar horizon near the top of the 'Passage Beds' if it came from the Tetbury No. 4 borehole. However, if this specimen came from the Tetbury Waterworks borehole described by Richardson (1915), this depth below the surface would be at the base of the 'Passage Beds' and approximately equivalent to the Morrisi zone because this borehole started some 50 feet lower in the Forest Marble succession. The occurrence of F. witchelli (Ba 405) 80 feet below the surface is more consistent with the latter interpretation, based upon known distribution of F. witchelli in the White Limestone.

In the section at Tolldown, the absence of L. acuminata and M. echinata suggests that Richardson (1936) misidentified the Inferior oolite horizon. The presence of Terebratula and Rhynchonella in this section (Richardson, op. cit., p. 282) is suggestive of the Ornithella Beds and the record of Nerinea (Nerinella) cf. pseudocylindrica would be of basal Retrocostatum zone age. It is noticeable that the lithological description of the lowest bed in the Tolldown section recalls that of the Doddington Ash Rock (U. Morrisi zone - see Torrens, 1968).

Clearly more research will be necessary in order to establish the age range of this species more accurately. At present the little evidence available suggests that Z. microplicatus occurs within and just above the M. morrisi zone.

The best preserved material of *Z. microplicatus* at present known to the author is figured in plates 2.A and 2.B. It is unfortunate that the exact stratigraphic horizons from which these specimens came are as yet unknown. Consequently since

a) taxonomic descriptions in unpublished theses have no official validity and

b) *Recommendation 73C (10) of the International Code of* Zoological Nomenclature states that the holotype of a new species should have its geological age and stratigraphical position stated, if possible, in metres above or below a well-established plane,

no holotype of *Zenoplocus microplicatus* has yet been designated. When better preserved material of *Z. microplicatus* from known stratigraphic horizons become available or when the stratigraphy of the localities noted above is more clearly and unequivocally established then a holotype will be designated.

Zenoplocus *microplicatus* gen. et sp. nov.

HIC 4566 Institute of Geological Sciences Museum

The scales used in all plates are in mm.

Plate 2.A.


HIC4566
mm
1
2
3
4

Zenoplocus *microplicatus* gen. et sp. nov.

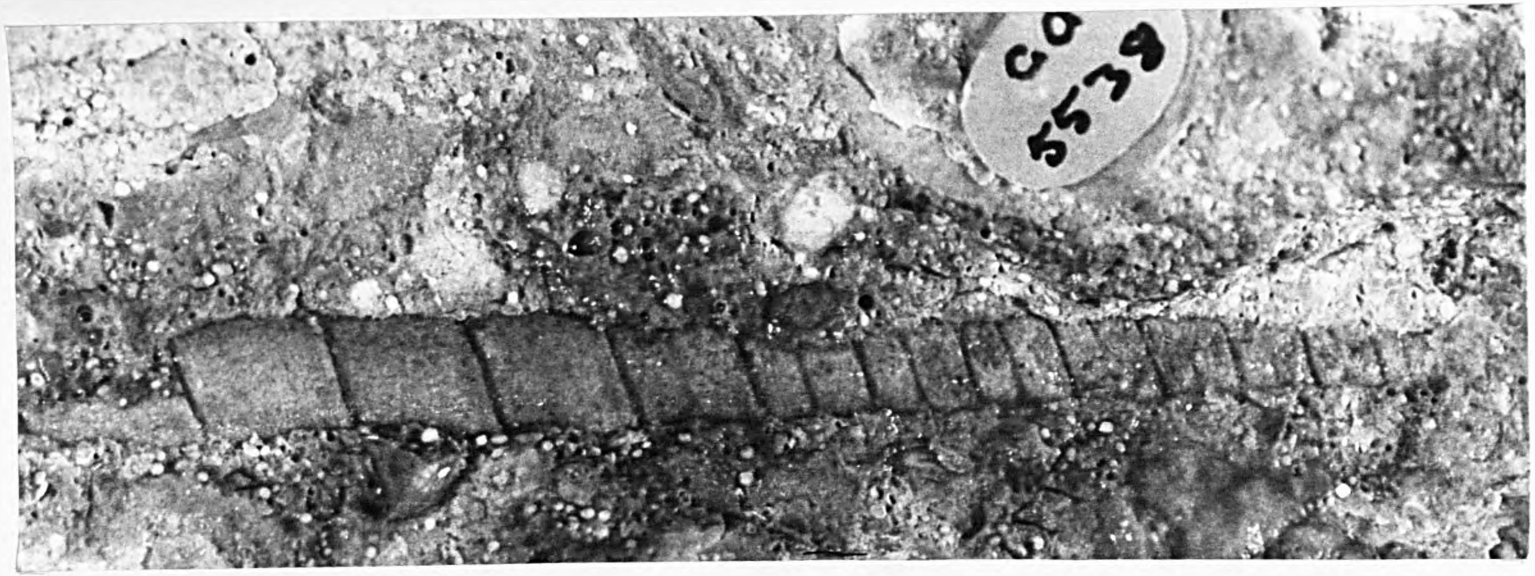
GG 5538 CV 100

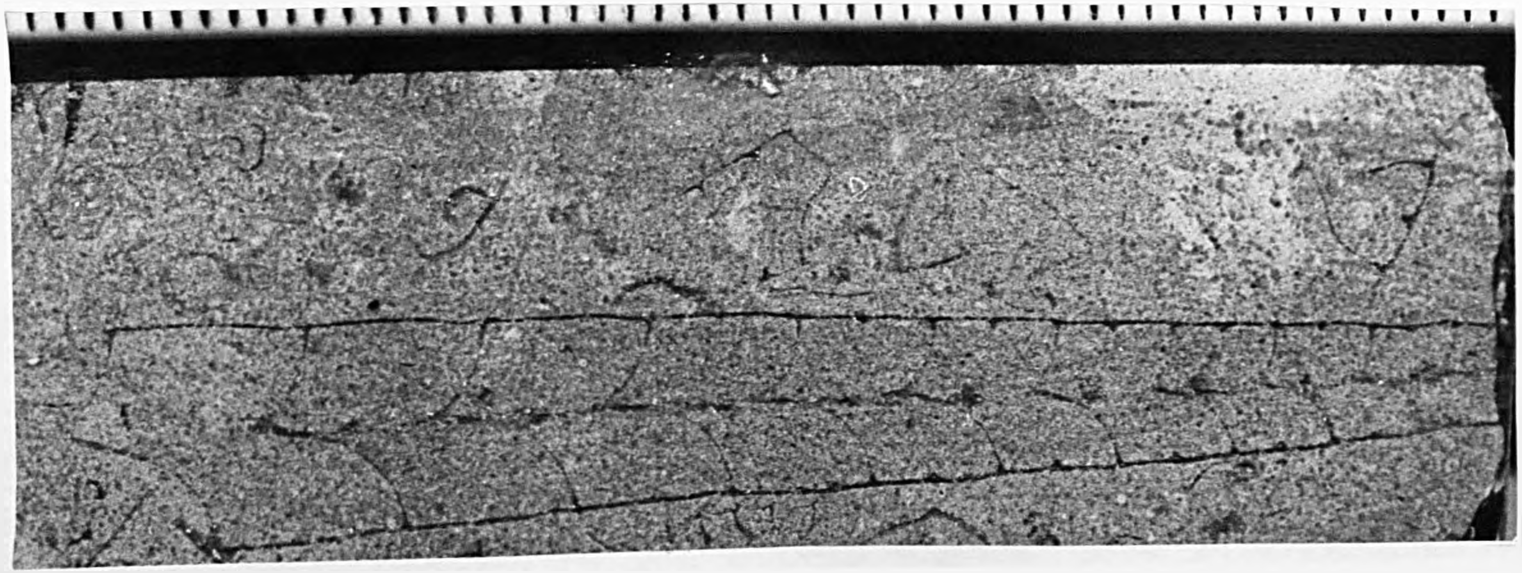
Institute of Geological Sciences Museum

same scale for both photographs

CV 100 is a median axial section coated with a glycerine film to enhance contrast.

Plate 2.B.


CO
5538



B2 Genus APHANOPTYXIS Cossmann, 1896.

Type-species Aphanoptyxis langrunensis (d'Orbigny)
Bathonian - France.

Discussion

Although this genus is stratigraphically widely distributed, its known geographical distribution is rather restricted (mainly to England, France and Germany). It ranges with certainty from the Lower Bathonian to the Upper Volgian.

However, according to Pchelintsev (1965, p. 52), Aptyxiella subconica Hudleston (Hudleston, 1887-1896, p. 191-2, pl. XII, figs. 10 and 11) should be placed in the genus Aphanoptyxis and Hudleston when describing the species remarked (op. cit., p. 192), "one would suspect its relationship to Cerithium defrancii Deslongchamps". (= A. langrunensis). This would therefore increase the stratigraphic range of the genus Aphanoptyxis and its first occurrence would then be in the Parkinsoni zone (Upper Bajocian) of the Cotswolds. When Cossmann referred to A. subconica, he stated (1898, p. 174) "ce n'est pas un Aptyxiella" and questionably assigned the species to Aphanoptyxis; a situation reiterated by Dietrich (1925, p. 27). Cox (M.S. notes, ca. 1960) placed subconica in Aptyxiella and gives the stratigraphic range of Aphanoptyxis as Bathonian to Portlandian. One should note that Hudleston in his description of A. subconica states (op. cit., p. 191) "the available specimens are much worn" but nevertheless, the very flat base and acicular form of the specimens figured by Hudleston suggest to the present author that this species is more likely to belong to Aptyxiella; although confirmation is needed.

Recently, Fischer (1969, p. 181) has placed the genus *Endiaplocus* (Cossmann, 1896, p. 45-46) in *Aphanoptyxis*, considering that both genera possessed an umbilicus. In the original diagnosis of *Aphanoptyxis*, Cossmann (1896, p. 35) clearly states "dont la perforation ombilicale est entièrement rècouverte par le bord columellaire." This statement implies that the umbilicus is secondarily closed by the coiling of the columellar edge of the apertural canal. However, the examination of many median sections of various *Aphanoptyxis* spp. by the present author has failed to reveal an umbilicus which was open at any stage in the animals growth. Clearly the growth of siphonostomatous genera with small whorl expansion rates, such as *Aphanoptyxis*, results in a solid columella. Certain Recent Naticid genera such as *Polinices* and *Lunatia* exhibit a secondarily closed umbilicus. Since Cossmann (*op. cit.*) no subsequent author (apart from Fischer, *op. cit.*) has suggested that *Aphanoptyxis* was phaneromphalous and the present author therefore sees no valid reason for uniting the non-umbilicate *Aphanoptyxis* with the umbilicate *Endiaplocus*.

The following non-Bathonian forms are considered by the present author to be valid species of *Aphanoptyxis* (see Dietrich, 1925, p. 67).

a) *A. variabilis* Favre
Horizon Volgian (Upper Purbeck - Marine facies)
Locality Petit Salève and Grand Salève.

b) *A. atalanta* (d'Orbigny)
Horizon Kimmeridgian
Locality Ahlem (Hannover).

c) A. polyspira (Quenstedt)
Horizon Rauracean - Upper Oxfordian
Region Württemberg (Germany).

d) A. substriata (d'Orbigny)
Horizon Astartian - Rauracean - Upper Oxfordian
Locality St. Mihiel (Meuse) also Sulejow (Poland) (see Barczyk, 1961).

The acme of Aphanoptyxis seems to have been in the Bathonian stage of England and France where four valid species have already been described (A. eulimoides, bladonensis, ardleyensis and langrunensis and a further two new species are described below (A. excavata and compressa).

B2/1 Aphanoptyxis eulimoides (Lycett 1863). Plate 2.C.
Synonymy see Cox and Arkell, 1948-50, p. 79.
Holotype Arkell, 1931, pl. 50, fig. 16; Oxford University Museum, Specimen Number J. 845.

Discussion

As noted by Arkell (op. cit., p. 619) this species is easily distinguished from A. bladonensis and other Aphanoptyxis spp. by its more swollen, rounded base and the lack of any spiral ornament. The rounded whorl base produces a markedly concave parietal region in the succeeding whorl (see plate 2.C), thus giving a distinctive cross-sectional shape to the body chamber.

The species is somewhat variable in its morphology and although Arkell (op. cit., p. 619) describes the whorls as being flat; in many specimens the whorls are in fact noticeably concave. The relative development of the two carinas bordering the suture also varies considerably. More frequently the lower, adapertural carina (which in Nerineids carries the selenizone) projects beyond the upper carina but occasionally the reverse is true; less commonly the sutures are impressed.

A large collection of A. eulimoides from the Sharps Hill Beds (Bed 4a) of Snowshill Hill, Glos. was made by the present author (for details of section, see Barker and Torrens, in Torrens, 1969) but apart from the measurement of the apical angle, they proved unsuitable for biometric analysis, because of abrasion. However, a number of specimens from the Charlbury railway cutting in the J. Parker collection at the Oxford University Museum (Registration Numbers J 23536, J 23538-40, J 25542-3) together with the holotype (J 845) and the paratypes (J 844 and J 846) were reasonably well preserved and were instead measured for whorl width-height values. The results are shown below.

Apical angle Oxford University Museum specimens + Snowshill Hill specimens.

Mean	-	18.5^{o}
Standard Deviation	-	2.4^{o}
Observed Range	-	14.0^{o}-25.0^{o}
N	-	58

Whorl-width-height ratios Oxford University Museum specimens only.

Mean - 2.09

Standard Deviation - 0.20

Observed Range - 1.75-2.62

N - 43

Reduced Major Axis Y = MX + C

Height - 0.424 Width + 1.207

Correlation Coefficient - 0.979

The results are graphically summarised in Fig. 2.1.

Distribution

Apart from those localities given by Arkell (*op. cit.*, p. 619) and Cox and Arkell (*op. cit.*, p. 79), this species has also been found by the present author in the Sharps Hill Formation above the Chipping Norton Formation in the Ditchley Road Quarry, Charlbury (G.R. - SP 365198 - see McKerrow and Kennedy, 1973, p. 12-13). The associated suite of fossils at this locality was virtually identical to that given by Barker and Torrens (*op. cit.*) for the Snowshill Hill section.

It therefore seems that *A. eulimoides* was restricted in its distribution to the Sharps Hill Beds and the Sevenhampton *Rhynchonella* bed, no specimens having been reported from other horizons (as already noted by Cox and Arkell, *op. cit.*, p. 79, Minchinhampton specimens in the British Museum are of unrecorded history and doubtful authenticity). The range of this species (Upper Zigzag zone to Lower Progracilis zone) was sufficiently restricted for Arkell (1947, p. 34) to suggest its use as a local sub-zonal index species in Oxfordshire.

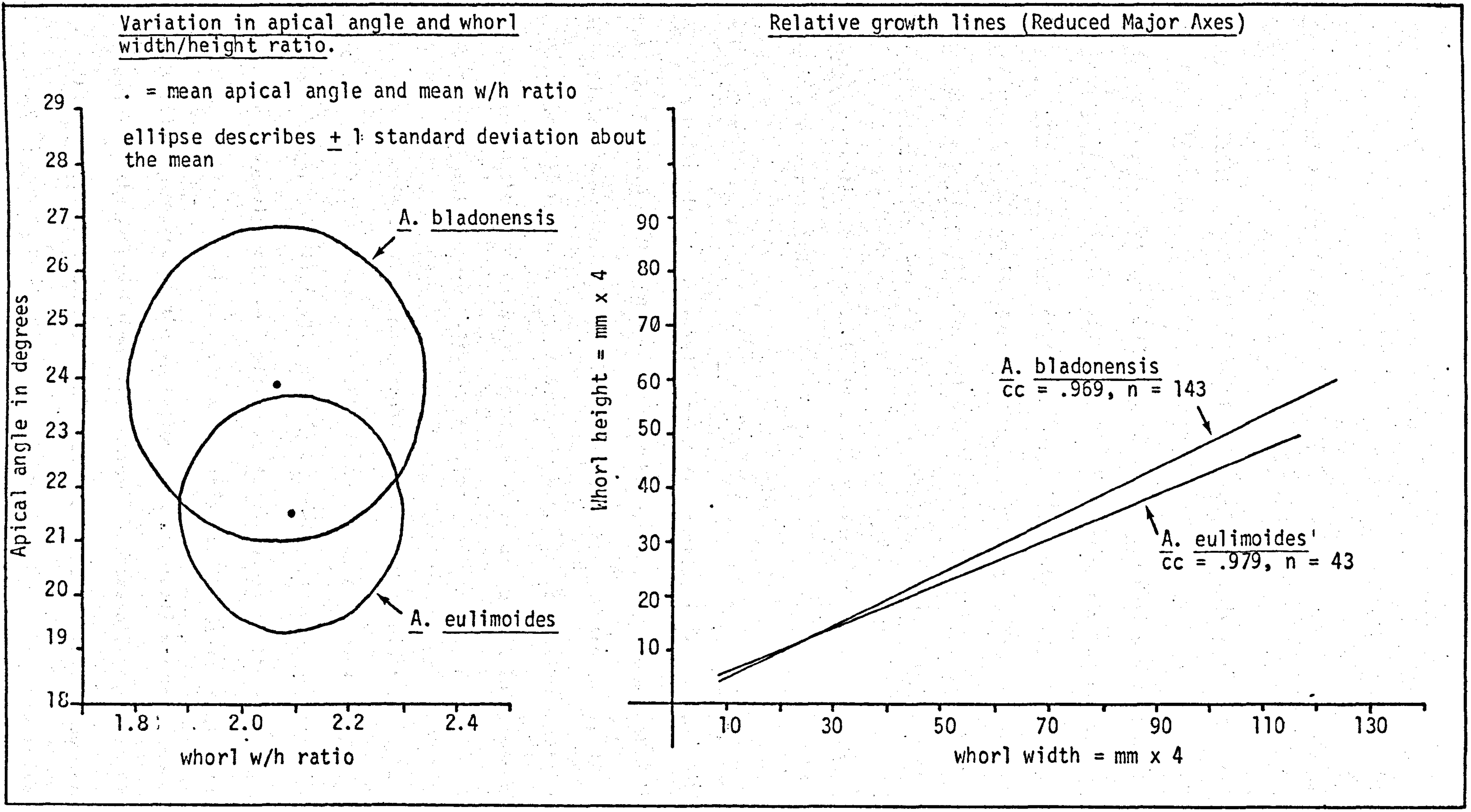


Fig. 2.1. The morphological variation and growth of *A. bladonensis* and *A. eulimoides*.

B2/2 A. bladonensis Arkell, 1931. Plates 2.D and 2.E.

Synonymy See Cox and Arkell, 1948-50, p. 79.

Cerithium roissii Morris and Lycett, 1851, p. 32, pl. VII, figs. 14, 14a (non d'Archiac).

Nerinaea eudesii Odling, 1913, pp. 489, 497 (non Morris and Lycett).

Nerinea eudesii Pringle, 1926, pp. 18, 23 (non Morris and Lycett).

Aphanoptyxis bladonensis Arkell, 1931, p. 618, pl. 50, figs. 8-14.

Aphanoptyxis bladonensis Arkell, 1947, p. 43, fig. 5, no. 3.

Aphanoptyxis bladonensis Cox and Arkell, 1948-50, p. 79.

Endiaplocus roissyi Cox and Arkell, 1948-50, p. 80 (non d'Archiac).

Holotype Arkell, 1931, pl. 50, fig. 11; Oxford University Museum, Specimen Number J. 840.

Discussion

The material used by Arkell (1931) to describe this species came from the Orchard Quarry in Bladon, near Woodstock, Oxfordshire (G.R. - SP 449151). Arkell (1933, p. 177) noted that the Orchard Quarry was - "a very small opening, long abandoned" but, with a little excavation the present author has obtained topotype material (albeit indifferently preserved) from this much overgrown section.

This species shows a considerable amount of morphological variation, particularly in the amount of whorl concavity and the development of the sutural carina. Arkell (1931, p. 618) was evidently aware of this variation (comparing the variability of A. bladonensis with that described for C. bathonica by Cossmann, 1885, p. 184-5) and Plates 2D and 2E illustrate some of the variation amongst Arkell's type material now housed in the Oxford University Museum. In general, the preservation of A. bladonensis is inadequate for detailed biometrical study as almost invariably the occurrence of this species is accompanied by extreme micritisation which affects both specimens and matrix. Furthermore the transformation of the original aragonite shell into calcite frequently entails the loss of finer morphological details. However, the large numbers of *A. bladonensis* which Arkell collected from the Orchard Quarry at Bladon are somewhat better preserved than is usual and were therefore measured. The results are shown below.

Apical angle Oxford University Museum.
Type specimens of Arkell (1931).
Mean - 24.0°
Standard Deviation -- 2.9°
Observed Range - 18.0° - 32.0°
N - 65

Whorl width-height ratios
Mean - 2.06
Standard Deviation - 0.26
Observed Range - 1.33 - 2.80
N - 276

Reduced Major Axis, $Y = MX + C$
Height - 0.481 Width + 0.492
Correlation Coefficient - 0.969
These results are graphically summarised in Fig. 2.1.

In the opinion of the present author a number of specimens from Minchinhampton (Lycett collection) identified as *Endiaplocus roissyi* are incorrectly named. The best preserved specimen is that figured by

Morris and Lycett (1851, pl. VII, figs. 14, 14a) and is now housed in the Geological Survey Museum (Registration number G.S.M. 8213). The absence of an umbilicus in these specimens (apart from G.S.M. 84356 which is probably a worn specimen of F. witchelli) clearly indicates that they do not belong to the genus Endiaplocus. Cossmann (1898, p. 164) evidently agreed and stated - "Je ne suis pas très sûr que la coquille de Minchinhampton soit bien E. Roissyi: la figure de l'ouvrage de Morris and Lycett n'indique pas d'ombilic, la forme et l'ornamentation des tours parassent diffèrents", whilst Hudleston and Wilson (1892, p. 72) also had doubts about assigning the name roissyi to these specimens. As mentioned above, amongst the specimens from Minchinhampton identified as E. roissyi, G.S.M. 84356 is probably F. witchelli and another specimen, G.S.M. 84355 can probably be assigned to M. altararis, although exact confirmation cannot be made without sectioning. When compared with the type specimens of A. bladonensis and Topotype material collected by the present author, the remaining specimens, G.S.M. 8213 (figured by Morris and Lycett, op. cit., pl. VII, fig. 14, 14a), G.S.M. 84354 and GSa 4541, appear to be rather large, very worn A. bladonensis. G.S.M. 8213 is shown in Plate 2.E and can be compared with the type specimens of A. bladonensis shown in Plate 2.D.

Furthermore, three undoubted specimens of A. bladonensis (British Museum, Natural History, Collective Registration Number G 10592) from Great Rollright (see Fig. 1.21) a locality where A. bladonensis is abundant (Arkell, 1947, pp. 62-64) were also mis-identified as Cerithium roissyi.

Distribution

The stratigraphic and geographic distribution of A. bladonensis is discussed in Chapter 1 (see especially Figs. 1.22 and 1.38). As far as the present author is aware, A. bladonensis is confined to the Bladonensis Bed and as such forms a valuable marker horizon at the top of the White Limestone (M. Jurassic, U. Bathonian). The identification of this species from the Minchinhampton locality is interesting in that their occurrence probably represents a few drifted examples from the quieter subtidal carbonate substrates to the east. An extreme isolated occurrence of A. bladonensis, together with a Bivalve fauna typical of the Bladonensis Bed, has been reported from Farleigh, Somerset by Arkell (1931, pp. 603-4).

The present author considers that the A. bladonensis bed probably represents the top of the Retrocostatum zone (M. Jurassic, U. Bathonian - see Torrens, 1969, p. 66 and Chapter 1).

B2/3 Aphanoptyxis ardleyensis Arkell 1931, Plates 2.F and 2.G

Synonymy - see Cox and Arkell, 1948-50, pp. 78-80.

Type-material

The following type-material was designated by Arkell (1931, p. 626).

a) Two syntypes (O.U.M. - J 828 and J 829)
Ardleyensis Bed, Ardley-Fritwell railway cutting, M. Odling collection.

b) Paratype, Topotype (O.U.M. - J 830)
Ardleyensis Bed, Ardley-Fritwell railway cutting, M. Odling collection.

c) Paratype (O.U.M. - J 885)
Ardleyensis Bed, Kirtlington Cement Works, Arkell collection.

The rules of the International Code of Zoological Nomenclature clearly indicate that the type-series of a species should consist of either a series of syntypes (Article 73c) or, more preferably, a holotype and several paratypes (Article 73a, Recommendation 73a and 73d). Clearly Arkell has failed to satisfy these requirements with respect to the type series of A. ardleyensis. However, since Arkell clearly designated two paratypes, it is reasonable to suppose that he regarded one of the two syntypes (J 828 and J 829) as a holotype. Therefore, under the provision of Article 74a, the present author proposes that one of Arkell's syntypes of A. ardleyensis - J 829 should be designated the lectotype and that all remaining specimens in the type-series (J 828, J 830 and J 885) should be regarded as paratypes.

Discussion

This small, rather elegant Nerineid gastropod is noticeably more 'angular''than A. eulimoides or A. bladonensis; the sutural carinae being sharper and well defined. The figured syntypes of Arkell (1931) possess flat whorls (see plate 2.F) but as noted by Arkell (op. cit., p. 619), "The carinae.... vary greatly amongst associated individuals". This usually results in concave whorls where the sutural carinae are prominent and convex whorls where the sutures are impressed (see plate 2.G). The base of the shell is smooth, without ornamentation other than growth striae and noticeably flatter than the bases of A. eulimoides or A. bladonensis.

The type-specimens of A. ardleyensis (see previously) clearly represent a very small sample of the species. Therefore, a sample of A. ardleyensis was taken from Ardley Fields Quarry (G.R. - SP 543263), bed 41 in Fig. 1.18, Upper Ardley Beds, Retrocostatum zone between 1 and 2.5 km. from the type locality of *A. ardleyensis* which is the adjacent, now overgrown Ardley-Fritwell railway cutting (Odling, 1913, pp. 585-589; Arkell, Richardson and Pringle, 1933, pp. 340-343). Details of the Ardley Fields section are given in Chapter 1. Measurements of the type specimens of *A. ardleyensis* and those collected from Ardley Fields Quarry were analysed and the results shown below.

Apical Angle

	Oxford University Museum Type Specimens	Ardley Fields Quarry *A. ardleyensis* bed No. 41
Mean	12.8	16.3
Standard Deviation	2.4	1.5
Observed Range	11.0 - 15.5	14.0 - 18.5
N	3	14

Whorl width-height ratio

	Oxford University Museum Type Specimens	Ardley Fields Quarry *A. ardleyensis* bed No. 41
Mean	1.65	1.91
Standard Deviation	0.18	0.11
Observed Range	1.38 - 2.09	1.69 - 2.15
N	21	58

Reduced Major Axis - Isometry Y = MX + C

Height = M Width + C

	Oxford University Museum Type Specimens	Ardley Fields Quarry *A. ardleyensis* bed No. 41
	Mt = 0.61W - 0.056	Mt = 0.52W + 0.133
Correlation Coefficient	0.976	0.984

These results are graphically summarised in Figs. 3.5 and 3.10

The differences between the two groups of A. ardleyensis are statistically significant and their interpretation is discussed in Chapter 3.

Clearly more research and larger samples are needed from both the Upper and Lower Ardleyensis bed in order to establish whether biologically as well as statistically significant differences exist between the specimens from these two horizons. The present author considers that the Upper Ardleyensis bed and adjacent Lower Ardleyensis bed contain a single species Aphanoptyxis ardleyensis. The taxonomic implications are that A. ardleyensis must have been sufficiently variable in its morphology to include specimens with apical angles, as large as 18.5° and whorl width-height ratios as large as 2.15.

Other populations of Aphanoptyxis sp. occur within the White Limestone and show some morphological overlap with A. ardleyensis (see Fig. 3.10). However besides being statistically separable from A. ardleyensis, these populations were stratigraphically separated from A. ardleyensis. Bearing in mind that these other Aphanoptyxis populations (particularly Eton College, bed 14, Worsham, bed 8 and North Leigh, bed 17; see Chapter 1).also form a stratigraphically useful marker horizon in the White Limestone, the present author considers that they should be regarded as a separate species.

Distribution

A. ardleyensis has been used as a sub-zonal index species (Bathonian, White Limestone-- Retrocostatum zone) by various authors, particularly Arkell (1931 and 1947). The geographic distribution of this species is shown in Fig. 1.30 and the stratigraphic distribution is shown in Fig. 1.22. The restricted stratigraphic range led Arkell (1947, p. 42) to define the top of the Ardley Beds by means of the A. ardleyensis bed. In the present work, the top of the Ardley Beds is taken as the top of the Upper A. ardleyensis bed as Arkell (op. cit.) did not distinguish a Lower and Upper A. ardleyensis bed.

B2/4 Aphanoptyxis langrunensis (d'Orbigny 1850) Plate 2.H

Synonymy - see Fischer, 1969, p. 181.

Discussion

Apart from those species given above, the only other recorded species of Aphanoptyxis from British Bathonian strata is the common French species A. langrunensis. In France it is found in the Middle Bathonian of Eparcy, Bucilly and Martigny and lower Upper Bathonian of Rumigny and Langrune (Cossmann, 1885, p. 217; 1898, p. 87; Fischer, op. cit., p. 181).

The occurrence of this species in Britain is based upon five specimens in the Hudleston collection, one of which was figured by Blake (1905, pl. XVII, fig. 19, p. 74). These specimens were also considered to be distinct from other White Limestone species of Aphanoptyxis by Cox and Arkell (1948-50, p. 80) who, based on published descriptions and figures of various French specimens, named tham A. langrunensis. According to Blake (op. cit., p. 74) the British specimens came from the Cornbrash or underlying beds in the Woodstock railway cutting near Shipton-on-Cherwell. The Woodstock section formerly exposed almost the whole thickness of the White Limestone and was first described by Woodward (1894, p. 320) with subsequent minor revision by Arkell (1947, p. 55). Only the A. bladonensis bed at the top of the White Limestone can be positively identified from the published descriptions of the now overgrown cutting. The nearest section at present visible is the Oxford Portland Cement Company's quarry at Bunkers Hill (see Fig. 1.15) 1.5 km. (1 mile) east north-east of the Woodstock cutting. The Bunkers Hill section shows the lowest of the Aphanoptyxis horizons in the Ardley Beds but not the highest (the A. ardleyensis bed). The A. ardleyensis may be obscured by quarry talus but the present author is of the opinion that it is not present in this section. It is therefore possible that the Hudleston specimens identified by Cox and Arkell (op. cit.) as A. langrunensis may have come from the same horizon as the Aphanoptyxis sp. at the base of the Ardley Beds in the nearby Bunkers Hill section.

Dr. J. C. Fischer (Muséum National d'Histoire Naturelle, Paris) kindly made available four specimens of A. langrunensis from the Georges Le Mesle collection from the Bathonian of Hydrequent (Pas de Calais). These were photographed (see plate 2.H), measured and the results plotted on Fig. 3.10. In general, the Le Mesle specimens and the published descriptions and figures of A. langrunensis compare well with the morphology of Aphanoptyxis sp. at the base of the Ardley Beds. All possess fine spiral ornament on the shell base (see crennulate junction of the whorls in Plate 2.H), a feature not found in A. ardleyensis. The higher whorl width/height ratios of the Le Mesle specimens is not statistically significant ($P > 0.05$) and is probably only a reflection of the very small sample size (four specimens).

However, differences appear to exist in the form of the base of the shell. The figures of A. langrunensis in Eudes-Deslongchamps (1842, pl. VIII, figs. 35 and 36), d'Orbigny (1851, pl. 238, fig. 8) and Cossmann (1885, pl. 1, figs. 1-6 and pl. XI, fig. 7) together with the Le Mesle specimens all possess an angular, more acute whorl periphery passing into a base which is less convex adjacent to the periphery i.e. the base is flatter, than in the British specimens of *Aphanoptyxis* from the base of the Ardley Beds. Evidently some variation exists in the French species in that the photograph of *A. langrunensis* in Cossmann (1896, pl. 11, fig. 6 and also 1898, pl. VII, fig. 17) shows a base with the slightly more rounded form typical of the British *Aphanoptyxis* sp.

The taxonomic implications of these differences cannot be fully assessed until it is established whether the flatter base is a widespread feature in the French species or not. Furthermore, the stratigraphic distribution of *A. langrunensis* in the French Bathonian is very poorly understood. Fischer (1969) has recently revised the fauna of the Bathonian strata south-west of the Ardennes platform. The geological situation in this region is comparable to that of the White Limestone adjacent to the London platform. Arkell (1956, p. 61) described the French strata in this region as being typical White Limestone and they were also named 'Calcaire blancs' by d'Archiac (1843), Piette (1855) and Bonte (1941). Unfortunately, although many of the fossil species are common to both countries, the stratigraphy of the French 'White Limestone' and distribution of the fossils within it have not been as extensively studied as their British counterparts. The present author hopes to rectify this situation in the future. Until then, the *Aphanoptyxis* at the base of the Ardley Beds is provisionally identified as *Aphanoptyxis* cf. *langrunensis*.

The morphological variability of three samples of *Aphanoptyxis* cf. *langrunensis* from the base of the Ardley Beds (White Limestone) are shown in Fig.3.10 and discussed in Chapter 3.

Distribution

Bathonian, White Limestone, near the base of the Ardley Beds (i.e. the basal Retrocostatum zone) at Eton College, bed 14; Worsham, bed 8; North Leigh, bed 17 and Bunkers Hill, bed 11 (see Chapter 1 for details of sections and locations). The stratigraphic distribution of this species is sufficiently restricted for it to be used as a reliable sub-zonal gastropod index species comparable with A. ardleyensis and A. bladonensis although the geographic distribution in Britain is not as extensive when compared with the latter two species.

B2/5 Aphanoptyxis excavata sp. nov. Plates 2.I and 2.J.

Holotype Oxford University Museum Registration Number J 29500 Plate 2.I.

Paratypes Oxford University Museum Registration Numbers J 29501-J 29523 Plates 2.I and 2.J.

Type-Locality Sturt Farm Quarry (G.R. SP 271109), Bed 5 (the A. excavata bed) at the top of the Excavata Beds; Upper part of the Morrisi zone, White Limestone (Bathonian) England. (see Chapter 1; fig. 1.10 for details of section). Extremely abundant.

Description

Nerineid gastropod with a moderately large spiral angle. Whorls relatively wide and concave; maximum concavity being slightly adapertural relative to the centre of the whorl. Suture on prominent raised carinae, of which the adapical carina (i.e. the juxtasutural selenizone) is usually more prominent, wider and bears crescentic lunulae. Occasionally the whorls are ornamented with three or four spiral lirae but more usually the whorls are not ornamented. Growth lirae are frequently visible. Periphery angular and carinate, frequently beaded when the growth lirae are well developed. Base convex and ornamented with between six and eight prominent spiral cords, also beaded when traversed by prominent growth-lines. Aperture quadrate with columellar-parietal junction rounded. The siphonal canal is short and the juxtasutural slit is deep (approximately one sixth of a whorl). Small amounts of inductura are present on the columellar lip of the aperture.

Discussion

Aphanoptyxis excavata sp. nov. has the largest mean apical angle (24.8°) of all known species of *Aphanoptyxis*. It is a moderately sized gastropod, maximum observed axial length 38 mm and has a rather squat, wide-based appearance. The whorls are noticeably rather low and wide and the mean whorl width-height (2.29) is greater than in any other British *Aphanoptyxis* species. Furthermore the presence of spiral cords on the base, much smaller size and angulated periphery readily serve to distinguish this species from *A. bladonensis* with which there is some morphological overlap with respect to the apical angle and whorl width/height ratio (see Chapter 3). The species is rather variable in morphology depending largely upon the development of the sutural carinae. When the sutures are prominent, the whorls are markedly concave (see plate 2.J. for extreme example); more rarely, the sutures, and hence the whorls, are flat (see plate 2.J).

The whorl sides are usually unornamented apart from growth lirae. A few specimens show three or four faint spiral lirae, usually beaded, with the second adapertural lira (approximately one third of the whorl height from the adapertural carina) being slightly more prominent.

Variation in the strength of the growth lirae also affects other aspects of the shell morphology. The sutural carinae, carinate periphery and spiral cords on the base may all become beaded when the growth lirae are pronounced.

A sample of *A. excavata* sp. nov. was collected from the type locality and measured. The results are shown below.

Apical angle

Mean - 24.8°

Standard Deviation - 3.3°

Observed Range - 19.0° - 31.0°

N - 27

Whorl width/height ratios

Mean - 2.29

Standard Deviation - 0.22

Observed Range - 1.68 - 2.81

N - 80

Reduced Major Axis $Y = Mx + C$

Height = 0.456 width - 0.01

Correlation Coefficient - 0.881

The results are graphically summarised in Fig. 3.10.

Distribution

Foss Cross, bed 2; Sturt Farm, bed 5; Eton College, bed 10; Worsham, bed 6; Slape Hill, bed 3; Bunkers Hill, bed 7 and Ardley Fields, bed 30 (see Chapter 1 for details of the sections). This gastropod species is the most widely distributed of the *Aphanoptyxis* species in the White Limestone. Not only does the *Aphanoptyxis excavata* bed form a valuable marker horizon in the White Limestone, the associated fauna of this, and the lower beds, is significantly distinct from the rest of the White Limestone above to warrant the creation of a new stratigraphic unit, the Excavata Beds. In most places the Excavata Beds (with the *A. excavata* bed at the top) are terminated by a marked hardground. The sporadic ammonites found in the Excavata Beds (*Morrisiceras* spp., see Torrens 1970, *Bull. Soc. Pal. Ital.*) suggest that *A. excavata* sp. nov. can be used as a reliable sub-zonal species occurring at the top of the Morrisi zone (see Chapter 1 for fuller discussion).

Remarks

The systematic change in the morphology of three progressively younger species of *Aphanoptyxis* (*A. excavata*, *A.* cf. *langrunensis* and *A. ardleyensis*) and their relationship to the stratigraphy of the White Limestone have been discussed in Chapter 3 and are summarised in Fig. 3.10. Other features show similar systematic trends. The spiral cords on the base of *A. excavata* are less pronounced in *A.* cf. *langrunensis* (see plate 2.H) and are absent in *A. ardleyensis*. Spiral ornament on the sides of the whorl are normally absent in *A. excavata*, variably developed in *A.* cf. *langrunensis* and readily apparent in *A. ardleyensis*. In the present author's opinion, these related changes indicate a short evolutionary lineage. As one might expect, *A. ardleyensis* and *A.* cf. *langrunensis* show some morphological overlap. The complete morphological separation of A. excavata from A. cf. langrunensis is perhaps due to a period of non-deposition represented by the hardground at the top of the Excavata Beds and consequently no intermediate forms are preserved. This evolutionary lineage is apparently the first to be described in Nerineid gastropods. McKerrow et. al. (1969, p. 57-8) claimed an evolutionary relationship between A. ardleyensis and A. bladonensis. However, no supporting evidence was offered and the present author is of the opinion that no such relationship exists.

B2/6 Aphanoptyxis compressa sp. nov. Plate 2.K.

Holotype. Oxford University Museum, Registration Number J 29524 Plate 2.K.

Paratypes Oxford University Museum, Registration Numbers J 29525-J 29532 Plate 2.K.

Localities The Holotype (J 29524) and Paratypes (J 29525-J 29529) came from Sturt Farm Quarry (G.R. - SP 271109), Bed 5 (the A. excavata bed) at the top of the Excavata Beds; Upper part of the Morrisi zone, White Limestone. Paratypes (J 29530-J 29532) came from Slape Hill Quarry (G.R. - SP 425196), Bed 3 (the A. excavata bed: See Chapter 1, Figs. 1.10 and 1.5 for details of sections). This species is not uncommon at these localities.

Description

A small Nerineid gastropod (maximum length approximately 20 mm). Apical angle between 20.5°-25.5°. Whorls extremely low relative to their width and markedly concave (maximum concavity in the centre of the whorl sides). Sutures raised on particularly prominent carinae of equal development. Ornamentation consists of very faint spiral riblets and growth-lirae.

In section the body-cavity is almost square with the columellar-parietal angle rounded and the labral wall concave. The columella is solid, without an umbilicus and folds are not present. The details of the aperture are unknown.

Discussion

The pronounced sutural carinae, concave whorls and 'compressed' appearance (hence the specific name) readily distinguish this species from all other *Aphanoptyxis* spp. Examples of this species are never common and hence some difficulty has been encountered in obtaining specimens suitable for measurement (especially the apical angle).

The mean whorl width/height ratio is 2.51 (range 2.18-2.85; N = 12).

Distribution

A. compressa has been found in the *A. excavata* bed at the top of the Excavata Beds in Foss Cross Quarry bed 2; Sturt Farm, bed 5 (the type locality); Eton College, bed 10; Worsham, bed 6 and Slape Hill, bed 5, (see Chapter 1 for details of sections).

This species was used as one of the faunal elements whose restricted distribution led to the designation of the Excavata Beds (see Chapter 1). However, it has been found in the basal horizon of the overlying Ardley Beds at Slape Hill (bed 5) where two specimens (numbers Sl.H.Ox. 28 and 33 - personal collection of author) were found by the present author. Otherwise, the species is unknown outside the Excavata Beds.

Aphanoptyxis eulimoides (Lycett)

J 846 - Paratype

J 845 - Holotype

Oxford University Museum.

Plate 2.C.


MM


MM

Aphanoptyxis bladonensis Arkell

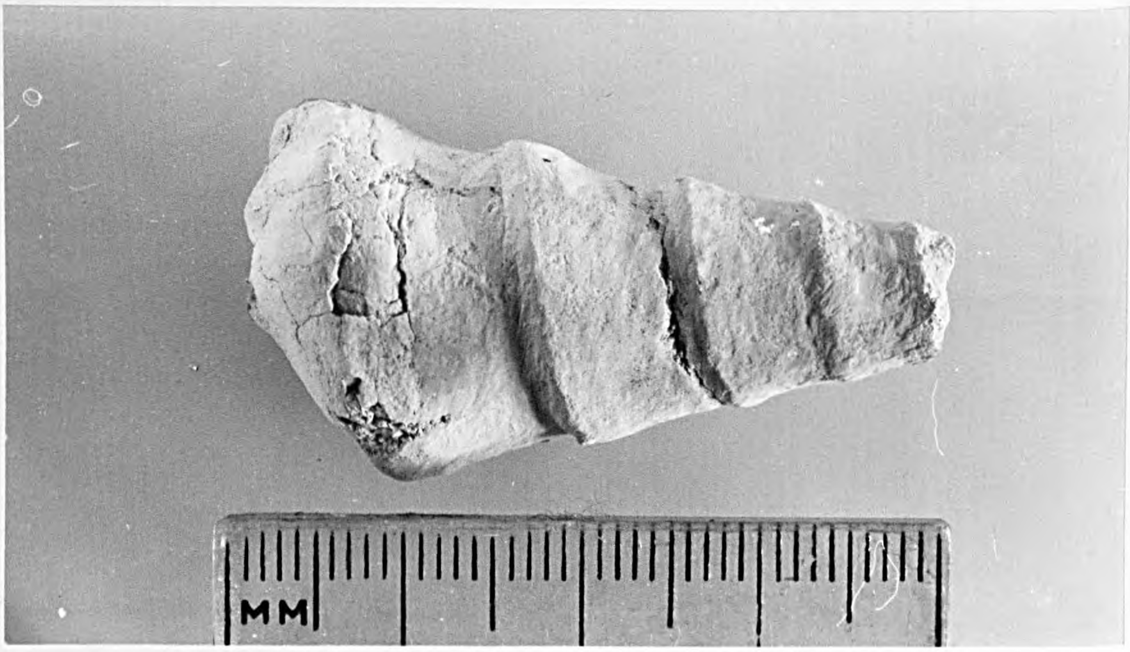
Holotype	Paratype	Paratype
J 840	J 841	J 837

Oxford University Museum.

All specimens coated with NH_4Cl.

Plate 2.D.


MM
1
2
3
4


MM


MM

'*Endiaplocus roissyi*'

GSM 8213

Geological Survey Museum

Aphanoptyxis bladonensis Arkell

Paratype

J 13035

Paratype

J 13021

Oxford University Museum

All specimens coated with NH_4Cl.

Plate 2.E.


MM


MM

Aphanoptyxis ardleyensis Arkell

Paratype
J 830

Lectotype
J 829

Paratype
J 828

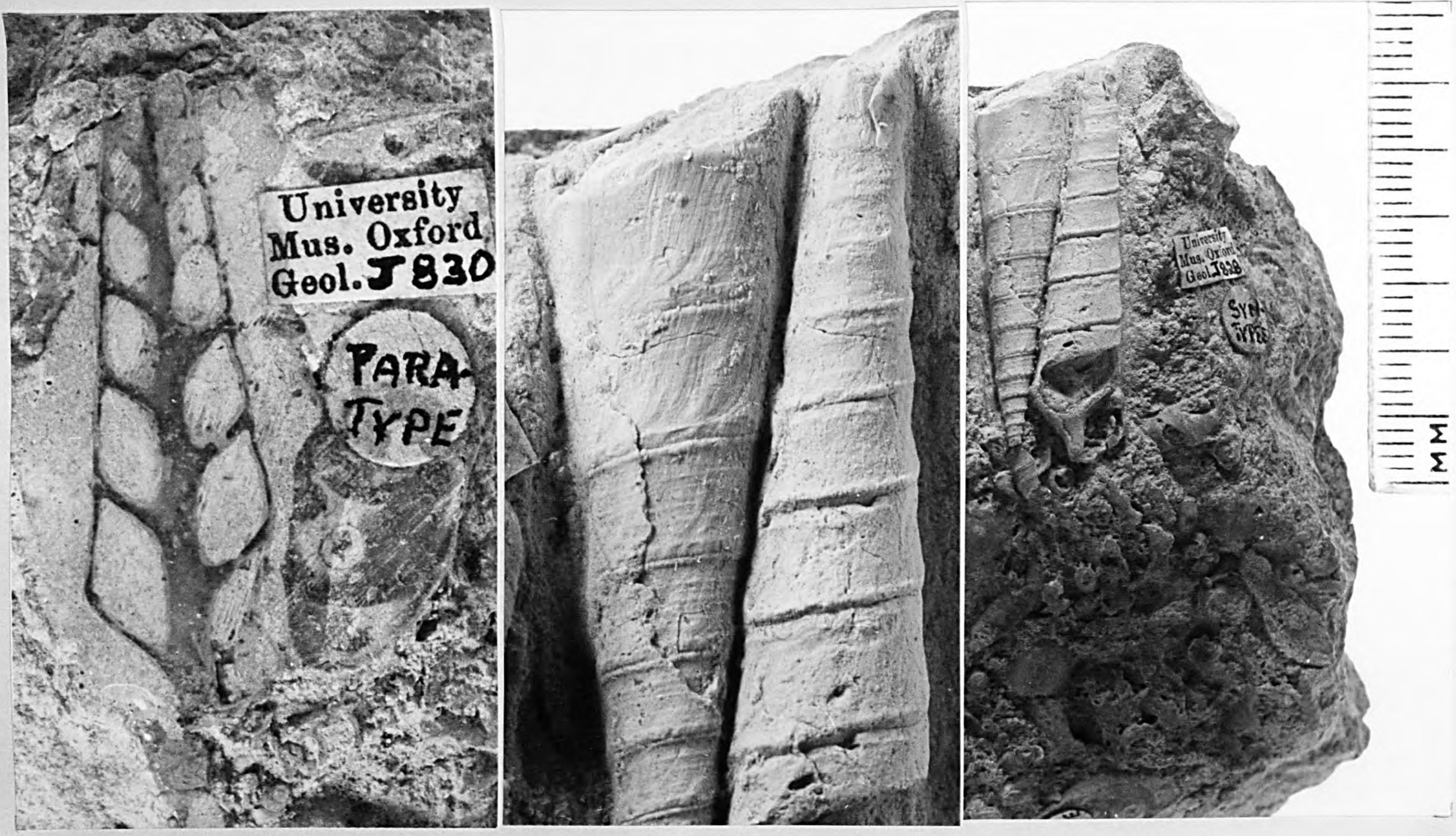
Enlargement:
note well preserved growth striae

Lectotype
J 829
Left hand specimen

Paratype
J 828
Right hand specimen

Oxford University Museum: Specimens J 828 and J 829 coated with NH_4Cl.

Plate 2.F.


University
Mus. Oxford
Geol. J 830
PARA-
TYPE
University
Mus. Oxford
Geol. J838
SYN-
TYPES
MM

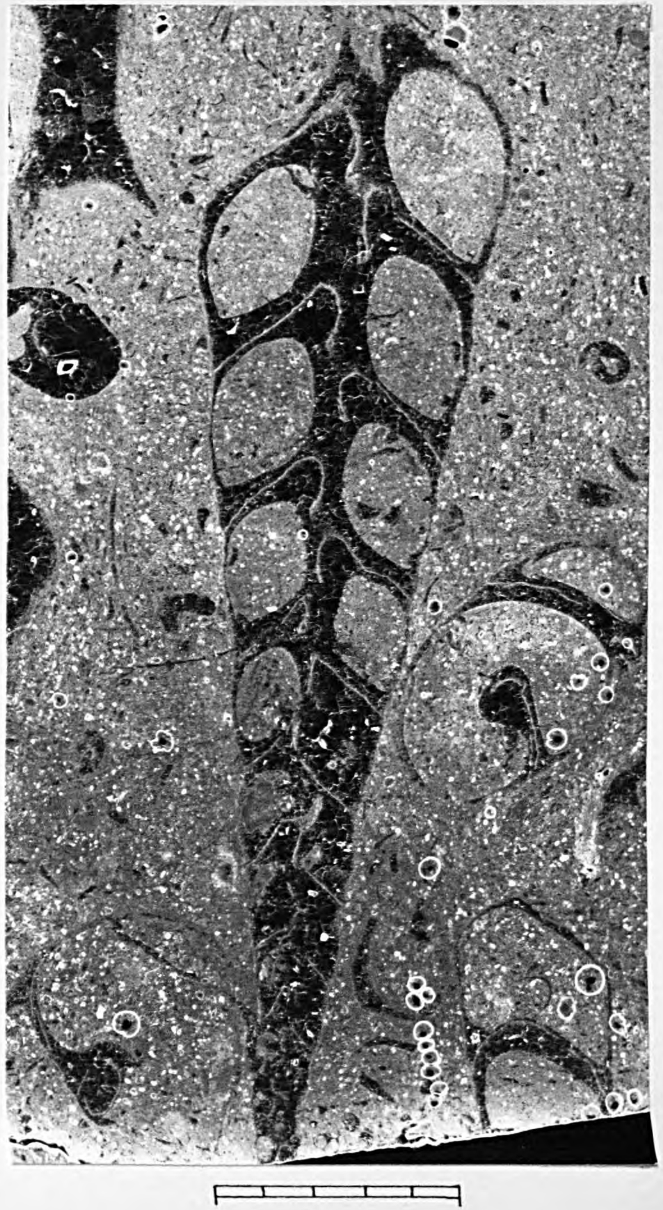
Variation in whorl concavity in Aphanoptyxis ardleyensis Arkell

AF 41/22 AF 41/16 AF 41/33

Ardley Fields Quarry, Bed 41 - the Lr. Ardleyensis Bed

All acetate peels. M.J.B. colln.

Plate 2.G.



Aphanoptyxis langrunensis (d'Orb.)

G. le Mesle colln.

Bathonian, Hydrequent (Pas de Calais).

Specimen coated with MgO.

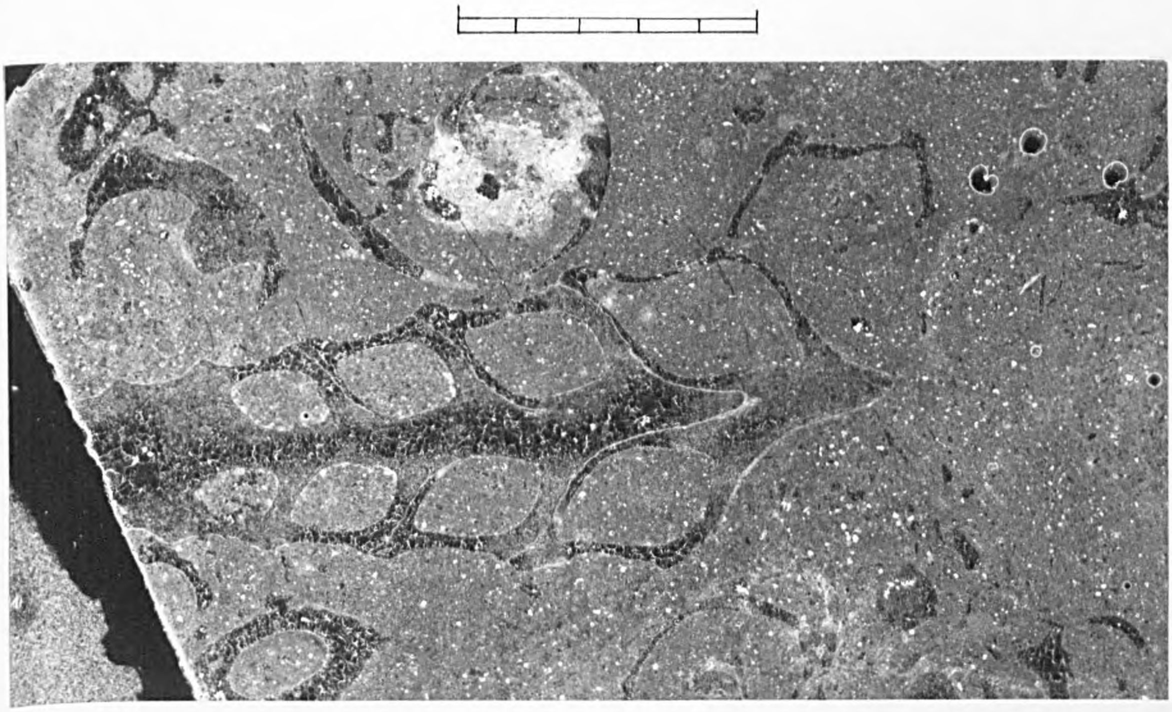
Aphanoptyxis cf. *langrunensis*

Specimen EC 45.

Eton College Quarry, Bed 14.

Acetate peel.   M.J.B. colln.

Plate 2.H.



Aphanoptyxis excavata sp. nov.

Holotype

J 29500.

Paratype

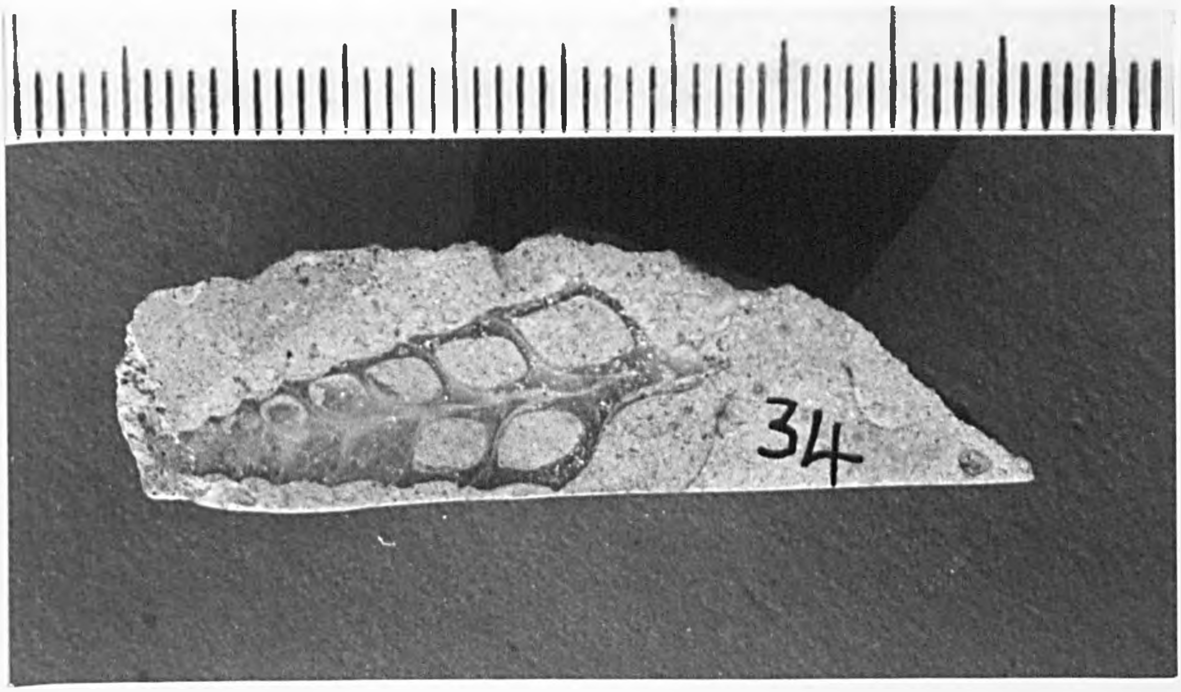
J 29501.

Oxford University Museum.

Specimen coated with MgO.

Median axial section.

Plate 2.1.


34

Variation in Aphanoptyxis excavata sp. nov.

Paratype

J 29502.

Paratype

J 29503.

Paratype

J 29504.

(note growth striae)

(note ornamentation)

Paratype

J 29505.

(the larger specimen)

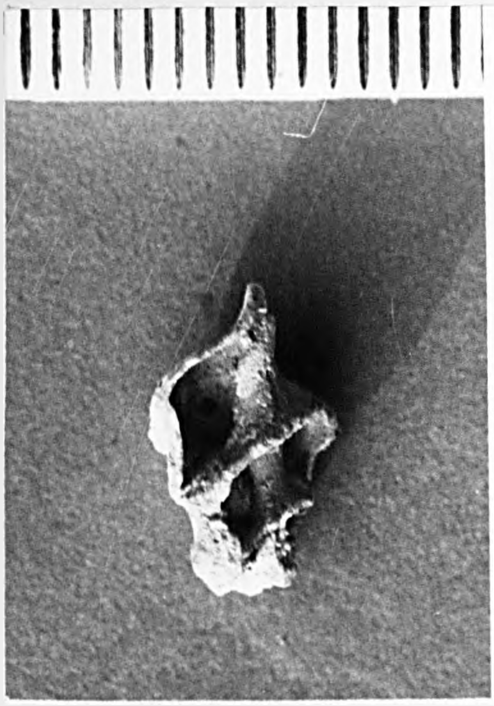
Paratype

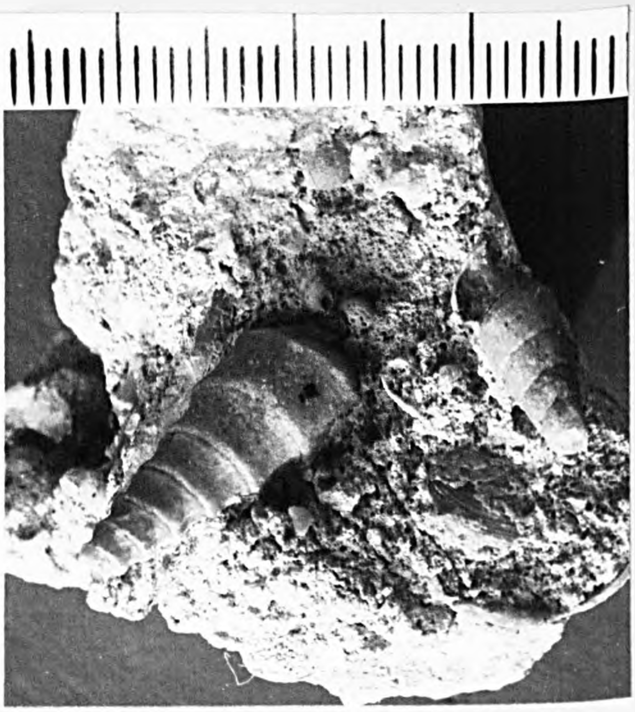
J 29506.

(note siphonal canal)

All specimens uncoated.

Plate 2.J.





Aphanoptyxis compressa sp. nov.

Paratype

J 29530.

Acetate peel.

Slape Hill, Bed 3 (the *A. excavata* bed)

Holotype

J 29524.

Left hand photograph
external morphology

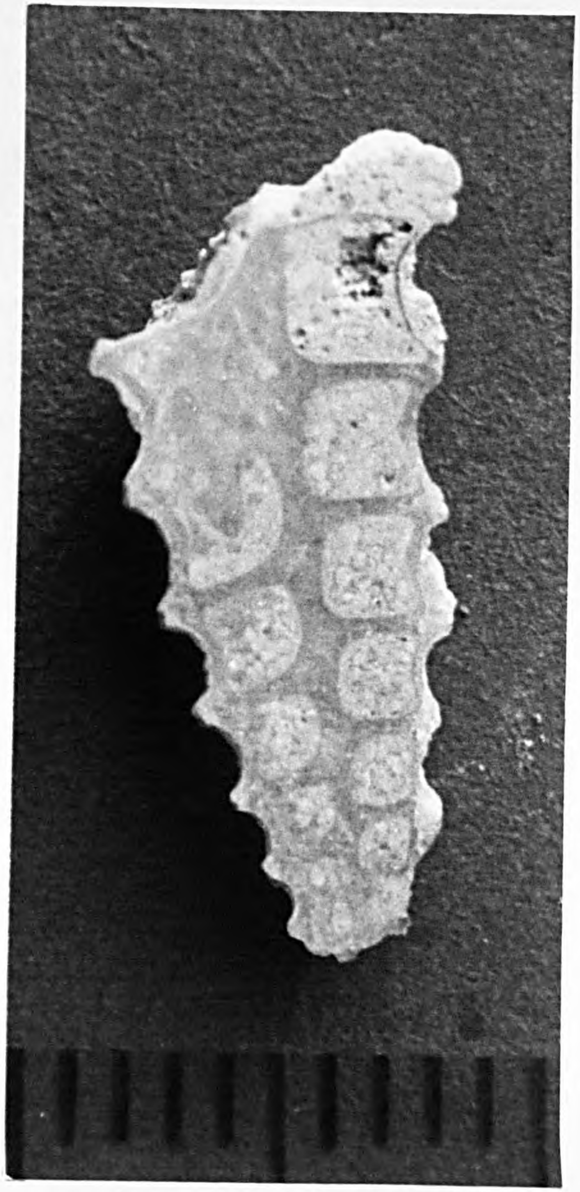
Right hand photograph
median axial section

specimen uncoated.

Sturt Farm, Bed 5 (the *A. excavata* bed)

Oxford University Museum.

Plate 2.K.



Cossmannea, Eunerinea and Nerinella

General discussion

Representatives of these genera are widely distributed throughout Jurassic and Cretaceous strata, the Bathonian White Limestone of England being no exception.

The difficulties encountered in distinguishing between various Nerineid gastropods at the specific level because of the subjective nature of many species are also present, although less so, at the generic level. As remarked by Cox (Treatise manuscript notes, ca. 1960-1965, housed in the British Museum, Natural History) "-- in the case of species with concave whorls and a bulging sutural region, it is not always easy to decide where to draw the limit between *Nerinella* and *Cossmannea*".

The taxonomic history of *Nerinella* is rather complicated. The gastropod genus *Nerinella* was originally designated and described as a subgenus of *Nerinea* by Sharpe (1850, p. 103) in what was the first attempt to subdivide the Nerineacea. Subsequent discussion by Cossmann (1896, p. 35-39) elevated Nerinella to full generic status; selected a valid type species for the first time and provided a much better diagnosis to replace the rather imprecise one of Sharpe (*op. cit.*). Furthermore, Cossmann (*op. cit.*) appended *Bactroptyxis* Cossmann 1896; *Aptyxiella* Fischer 1885 and *Endiatrachelus* Cossmann 1896 as subgenera of *Nerinella*. Most subsequent authors have accepted the amended diagnosis of *Nerinella* given by Cossmann (*op. cit.*) but the relationship of *Nerinella* to other Nerineid ~~genera~~/subgenera claimed by Cossmann (*op. cit.*) has not been so readily accepted.

Pchelintsev (1927, pp. 3-20) removed *Endiatrachelus* from *Nerinella* and placed it as a subgenus of '*Nerinea*' (*sensu* Cossmann) and added *Polyptyxis* Pchelintsev 1924; *Triptyxis* Pchelintsev 1924 and *Aptyxis* Zittel 1873 - all as subgenera of *Nerinella*. However, Wenz (1938-44, p. 824) did not apparently approve of this arrangement and proposed that *Aptyxiella* Fischer 1885 be given full generic status. Wenz (*op. cit.*) further claimed that *Nerinella* Sharpe 1850 was an invalid junior homonym of *Nerinella* Nardo 1847 (Vermes) and proposed a new replacement name *Nerinoides* for *Nerinella* Sharpe which he regarded as a subgenus of *Aptyxiella*. The validity of *Nerinella* Sharpe 1850 was upheld after Cox (1951, pp. 299-300) had applied to the International Commission on Zoological Nomenclature for a ruling that the 'Prodromo' of S. A. Renier and the "Prospetto della classe dei Vermi" (dated 1804) were not published within the meaning of Article 25 of the I.C.Z.N.

The genus *Nerinella* Nardo was based by monotypy upon the 'species' '*Amphione chermesina*' Renier. Opinion 316 (Opinions and Declarations rendered by the I.C.Z.N., vol. 9, pt. 5, 91-106, December 1954) states:

OPINION 316

REJECTION FOR NOMENCLATORIAL PURPOSES OF THE "TAVOLA ALFABETICA DELLE CONCHIGLEI ADRIATICHE" AND "PROSPETTO DELLA CLASSE DEI VERMI" OF S.A. RENIER COMMONLY ATTRIBUTED TO THE YEAR 1804

RULING: - (1) It is hereby ruled that neither (a) the *Tavola alfabetica delle Conchiglei Adriatiche* of Renier (S.A.) nor (b) that author's *Prospetto della Classe dei Vermi*, each of which is commonly attributed to the year 1804, was duly published within the meaning of Article 25 of the Règles and therefore that no name acquired the status of availability by reason of appearing in either of the foregoing works.

(2) The two works rejected for nomenclatorial purposes under (1) above are hereby placed in the Official Index of Rejected and Invalid Works in Zoological Nomenclature as Works Nos. 24 and 25 respectively.

(3) The under-mentioned generic name is hereby placed on the Official List of Generic Names in Zoology as Name No. 761: Nerinella Sharpe, 1850 (gender: feminine)(type species, by selection by Cossmann (1896): Nerinea dupiniana d'Orbigny, 1843).

(4) The under-mentioned generic names are hereby placed on the Official Index of Rejected and Invalid Generic Names in Zoology as Name Nos. 170 and 171: - (a) Nerinella Nardo, 1847 (a name published without an "indication"); (b) Nerinoides Wenz, 1940 (a junior objective synonym of Nerinella Sharpe, 1850).

(5) The under-mentioned name is hereby placed on the Official List of Specific Names in Zoology as Name No. 194: - dupiniana d'Orbigny, 1843, as published in the combination Nerinea dupiniana (specific name of type species of Nerinella Sharpe, 1850).

(6) The under-mentioned specific names or reputed specific names are hereby placed on the Official Index of Rejected and Invalid Specific Names in Zoology as Names Nos. 88 and 89 respectively: - (a) chermesina Renier (erroneously alleged to have appeared in 1804 in the combination Amphinome chermesina in a work rejected, under (1) above, for nomenclatorial purposes) (a cheironym); (b) coccinea Renier (included in the combination Amphinome coccinea in a work reputed to have been prepared in 1804, rejected, under (1) above, for nomenclatorial purposes).

The work 'Tavola alfabetica delle Conchiglei Adriatiche' by Renier is referred to by Cox (1951) as the 'Prodromo' - a much larger projected work by Renier of which the 'Tavola alfabetica delle Conchiglei Adriatiche' was only a fragment. Further references to the nomenclatorial status of works by S. A. Renier may be found in Opinions and Declarations rendered by the I.C.Z.N. - Opinion 427, vol. 14, pt. 11, 281-310, Oct. 1956 and Opinion 436, vol. 15, pt. 1, 1-24, Jan. 1957.

Along with *Nerinella* = obj. syn. *Nerinoides* and *Bactroptyxis* Cossmann 1896, Wenz (*op. cit.*) once again reinstated *Endiatrachelus* Cossmann 1896 to a group of high-spired subgenera belonging not to *Nerinella* but to the genus *Aptyxiella* Fischer 1885. *Triptyxis* Pchelintsev 1924 and *Polyptyxis* Pchelintsev 1924 (subgenera of *Nerinella* according to Pchelintsev, 1927) were now included by Wenz in the subgenus *Ptygmatis* Sharpe 1850 which Wenz (*op. cit.*) placed in the genus '*Nerinea*' (*sensu* Cossmann). *Aptyxis* Zittel 1873 (also a subgenus of *Nerinella*'Sharpe 1850 according to Pchelintsev, 1927) was now established as an objective synonym of *Aptyxiella* Fischer 1885 by Wenz (*op. cit.*).

Pchelintsev in a series of publications (1927, 1931, 1954, 1960 - in Orlov and 1965) clearly did not accept any of the revisions proposed by Wenz (*op. cit.*). Several new genera were created by Pchelintsev in 1954 followed by the creation of a new family the Nerinellidae in 1960 (to contain the 1954 genera together with the 1927 subgenera which had subsequently been given generic status in 1931). His later publication (Pchelintsev, 1965) continued the earlier trend of taxonomic elevation and proposed a new gastropod order, the Murchisoniata (largely composed of the Nerineacea). A new superfamily the Nerinellacea containing the families Nerinellidae, Elatiorellidae, Bactroptyxisidae, Elegantellidae, Auroraellidae, Upellidae, Polyptyxisidae and Triptyxisidae was established. This unnecessary taxonomic splitting of Pchelintsev (1965), on the basis of reasons which can only be described as inadequate, resulted in the creation of 15 new families, 19 new genera, 1 new subgenus and 18 new species amongst the Nerineid gastropods. In the short space of twenty-five years, Nerinella has been inflated from a subgenus of Aptyxiella to become the type-genus of a superfamily with a large number of included genera.

In preparation for the projected Treatise on Invertebrate Palaeontology (Gastropoda exc. Archaeogastropoda) Cox (M.S., ca. 1960-1965) did not attempt a supra-generic classification of those Nerineid genera and subgenera that he considered valid. The genus Nerinella was placed by Cox (op. cit.) in an informal group of "Nerineids with 1-3 internal folds, with the umbilicus absent or narrow". Three subgenera were recognised by Cox (op. cit.); Nerinella (Nerinella), Nerinella (Endiatrachelus) and Nerinella (Nailsworthia). Although the higher taxonomic affinities remain uncertain, the genus Nerinella Sharpe 1850; with subsequent type-species designation by Cossmann, 1896, seems to constitute a distinct morphological group of species. The problems of achieving a satisfactory phylogenetic classification of Nerineid gastropods is discussed in Chapter 7.

The taxonomic positions of Cossmannea Pchelintsev 1927 and Eunerinea Cox 1949 are equally complex and are closely connected with the problem of the type-species of Nerinea. The gastropod genus Nerinea was first mentioned by Defrance (1824) who used only the vernacular name 'Nériné'. (N.B. At an earlier date, C. S. Rafinesque - Analyse, 1815, p. 316, used a nomen nudum Nerinea for a polychaete worm). The internal cast of a species called 'Nériné tuberculeuse' was illustrated by Defrance (1825) and subsequently adopted by most authors, in the invalidly modified form of Nerinea tuberculosa, as the type-species of Nerinea. The Latin binomial N. tuberculosa was first used by Roemer (1839) to describe a species from Hanover which according to Cossmann (1896, pp. 26-27) was, by a remarkable coincidence, identical with the species previously described by Defrance (op. cit.) as 'Nériné tuberculeuse'.

Cox (1949, p. 249) clearly demonstrated that 'Nériné tuberculeuse' is an invalid name, because French vernacular names cannot be accepted as equivalent to the Latin names under the International Rules on Zoological Nomenclature and furthermore (Cox, op. cit., p. 249) "... there is an element of doubt in the identification of Defrance's 'Nériné tuberculeuse'". The factors which constitute that 'element of doubt' include;

a) the fact that the illustration of 'Nériné tuberculeuse' by Defrance (1825) clearly shows the presence of two columellar folds, one parietal fold and one labral fold (fold diagnosis; 2.1.1.0): whereas Cossmann states (1896, p. 26) "sur tous les examplaire de N. tuberculosa on ne constale, en réalité, que l'existance d'un pli à la columelle et d'un pli parietal" which together with the labral fold gives a fold diagnosis of 1.1.1.0. Cossmann dismissed this difference by remarking (1896, p. 26) "il est probable que Defrance, abusé par l'état défecteux de conservation de son échantellon".

b) the fact that the type-specimen of 'Nériné tuberculeuse' was presumed lost in a fire which destroyed the Deslongchamps collection at Caen in 1944.

c) the fact that the proposed neotype of *N. tuberculosa* Defrance which Cossmann (1898, pp. 33-35, pl. III, fig. 5) selected from the Cotteau collection (U. Oxfordian at Yonne) was probably misidentified and according to Levasseur (1934, p. 282) belongs to *Cossmannea desvoidyi* (d'Orb.).

The first valid publication of the generic name *Nerinea* was by Deshayes (1827) who described only one species, *Nerinea mosae*, with a subsequent illustration in 1831. This species, as noted by Cox (*op. cit.*), is therefore the type-species of the genus *Nerinea*. Although the validity of *N. mosae* as the first described Nerineid species was accepted by Pchelintsev (1965) and Wieczorek (1975), neither author was prepared to accept the consequent changes in Nerineid taxonomy. Pchelintsev (1965) continued to use *N. tuberculosa* Defrance as the type-species of *Nerinea* and Wieczorek (1975, p. 158) stated "... the systematics proposed by Pchelintsev (1965) would seem more soundly grounded whereas the suggestions of Cox .... are hardly acceptable".

N. mosae is a rather large, conical gastropod with a broadly rounded base. It is heavily ornamented with sutural nodes, transverse ribs and spiral lirae. The aperture is roundly quadrate and a narrow umbilicus is present. There are two columellar folds, one parietal fold, one labral fold and a very small basal fold near the basal-labral junction (fold diagnosis 2:1:1:1). This is a rather unusual morphology and consequently authors have experienced considerable difficulty in the interpretation of this species.

N. mosae was placed in the genus *Iteria* by Zittel (1873) and de Loriol (1886-1888, 1889-1892), a position which cannot be accepted because of the absence of whorl overlap and the more complex fold development in *N. mosae*. Cossmann (1898) assigned *N. mosae* to the genus *Ptygmatis* and subsequent authors (Dietrich, 1925; Pchelintsev, 1931; Levasseur, 1934 and Karczewski, 1960) concurred, although some of them (e.g. Karczweski, 1960, p. 37) expressed reservations about this. Cox (1949) accepted Cossmann's (1898) interpretation that *N. mosae* belonged to *Ptygmatis* Sharpe 1850 and consequently declared that *Ptygmatis* Sharpe 1850 and *Nerinea* Deshayes 1827 were subjectively synonymous with *Nerinea* taking priority.

However, the doubts of authors such as Karczweski (*op. cit.*) would seem to be well-founded. Pchelintsev (1965) decided that the differences in both external shell morphology and internal fold development between *N. mosae* and typical representatives of *Ptygmatis* (e.g. the type-species *P. bruntrutana* (Thurmann) and *P. meneghini* Gemmellaro, U. Oxfordian) were so great that *N. mosae* could not satisfactorily be placed in the genus *Ptygmatis*. The heavy rounded base, strong ornamentation and greater apical angle of *N. mosae* together with the more pronounced fold development of *Ptygmatis* spp. support the view (albeit erroneous) of Pchelintsev (*op. cit.*). In his final revision of the Nerineacea, Pchelintsev (*op. cit.*) created a new genus *Fibuloptygmatis* for *N. mosae* (the type-species) and a related species *N. costulata* Etallon, to be included in the family Ptygmatisidae Pchelintsev, 1965. Wieczorek (1975) and also the present author consider that *Fibuloptygmatis* shows much greater affinity with *Phaneroptyxis* Cossmann, 1896, being distinguished from the latter genus by the presence of more folds (at least one columellar fold and in some cases one basal fold more than in

Phaneroptyxis). Externally the morphologies of the two genera are very similar but *Fibuloptygmatis* shows less whorl overlap.

It follows that as *N. mosae* is the type-species of both *Fibuloptygmatis* Pchelintsev and *Nerinea* Deshayes, 1827 then *Fibuloptygmatis* Pschelintsev, 1965 is an objective junior synonym of *Nerinea*. The known species here assigned to *Nerinea* are; *N. mosae* Deshayes and *N. costulata* Etallon (both M. Oxfordian - L. Kimmeridgian) together with *N. diozoptygmatis* Delpy, *N. schiosensis* Pirona, *N. nobilis* Münster and *N. requienei* d'Orb. (all Cenomanian - Turonian).

The remaining problem concerns those Nerineid species which Cossmann (1896, pp. 25-29) included in his subgenus *Nerinea* (*Nerinea*) *sensu-stricto* founded with the invalid [redacted] type-species *N. tuberculosa* Defrance. The sub-genus was later regarded as a distinct genus *Nerinea* by Cossmann (1898), Dietrich (1925) and Pchelintsev (1965) - see previously. The generic name *Nerinea* is no longer available for this group which according to Cossmann (1896) contains amongst other species, *N. desvoidyi* d"Orb.; *N. bathonica* Rigaux et Sauvage; *N. castor* d'Orb.; *N. esparyensis* Piette and *N. eudesi* Morris and Lycett. Cossmann (1898, p. 25) in his diagnosis of this group noted that "Il n'y a jamais plus de trois pli". However, Pchelintsev (1927) noted that two distinct morphological groups of species were united in *Nerinea* by Cossmann (*op. cit.*). One group of 'Nerineas' (*sensu* Cossmann) possessed three folds (1.1.1.0) whereas the other group possessed two folds (one columellar and one labral: 1.0.1.0). Pchelintsev (*op. cit.*) named the latter group *Cossmannea* (type-species *N. desvoidyi* d'Orb.). The diagnosis of *Cossmannea* given by Pchelintsev (1965, p. 29) is as follows:-

"Large, turreted shells, often semicylindrical in the terminal part, consisting of concave, smooth or slightly sculptured whorls. Umbilicus absent or narrow, closed. Aperture high, rhombic, with two folds, one on the columella and the other on the outer lip".

The remaining 'Nerineas' (*sensu* Cossmann) were given the subgeneric name *Eunerinea* (with type-species *N. castor* d'Orb.) by Cox (1949, p. 250) with the following diagnosis:-

"Shell of medium acuteness, with strongly concave whorls and a convex, projecting sutural region. Aperture rhomboidal, not greatly extended anteriorily, where it ends in a short canal; with three internal folds - one on the labrum, one on the columella and one on the parietal wall".

Because Pchelintsev (1965) did not consider *N. tuberculosa* Defrance an invalid name, be continued to use *Nerinea* in the sense of Cossmann (1896 and 1898) and therefore regarded *Eunerinea* Cox, 1949 as a junior [redacted] synonym of *Nerinea*.

In his Treatise manuscript (*ca*. 1960-1965) Cox suggested that *Eunerinea* was "probably not worth separating as a distinct subgenus" and that *Cossmannea* Pchelintsev 1931 should be used for all species of the genus *Nerinea* (*sensu* Cossmann).

The present author does not agree that *Cossmannea* and *Eunerinea* should be combined. Not only are the fold developments completely different, the whorls in *Cossmannea* spp. are always much higher relative to the whorl width than in *Eunerinea* spp. and constitute a very distinctive and diagnostic feature (see Fig. 3.6). Consequently, the present author considers that *Cossmannea* and *Eunerinea* are morphologically distinct, easily separable and should be regarded as separate valid genera.

The following species of *Cossmannea* are known to the present author: *C. desvoidyi* (d'Orb.) - the type-species, *C. bathonica* (Rigaux et Sauvage), *C. impressa* (Quenstedt), *C. nautuacensis* (d'Orb.), *C. imlayi* Sohl, *C. kanabensis* Sohl, *C. turbatrix* (de Loriol), *C. subdesvoidyi* Pchelintsev and *C. kokkozensis* Pchelintsev.

Rabbi (1960, pp. 185-194) described a subgenus of *Nerinea* (*sensu* Cossmann) with two folds and high whorls; called *Gortania*, with the type-species *Nerinea bathonica* Rigaux et Sauvage. He was evidently unaware of the work of Pchelintsev (*op. cit.*) and *Gortania* Rabbi, 1960 must be regarded as a junior subjective synonym of *Cossmannea* Pchelintsev, 1931.

Species of *Eunerinea* are much more numerous than species of *Cossmannea*. The type-species of *Eunerinea* is *N. castor* d'Orb. and Bathonian representatives include *Eu. eudesi* (Morris and Lycett), *Eu. esparcyensis* (Cossmann ex. Piette), *Eu. multistriata* (Cossmann ex. Piette) and *Eu. arduennensis* (Buvignier).

B3 Genus Nerinella Sharpe, 1850; Subsequent Description Cossmann, 1896.

Cox (Treatise manuscript, ca. 1960-65) remarked that it is not always easy to decide where to draw the limit between Nerinella and Cossmannea (inc. Eunerinea). The essential differences were outlined by Cossmann (1896, p. 37) who stated, "Les Nerinella se distinquent des Nerinea principalement par leur aspect baculiforme ou aciculé, par leurs tours plus nombreux et surtout plus éléves, ...". On this basis, the two species of Nerinella recognised by the present author in the White Limestone can easily be distinguished from coeval Cossmannea and Eunerinea species by means of their small apical angle and relatively high whorls (see Fig. 3.9). Furthermore, although the early whorls of Nerinella spp. may be noticeably concave, the later whorls are always flatter than in Cossmannea/Eunerinea spp. where the whorls remain markedly concave throughout their ontogeny. In addition to the points mentioned above, Cossmann (1898, p. 88) considered that Nerinella was "... surtout s'en distinque par la position de la suture sur une arête saillante chez Nerinella, au lieu qu'elle est rainurée sous un bourrelet ou entre des bourrelets chez Nerinea" and "... au lieu de tubercles suturaux et de filets spiraux, l'ornamentation de Nerinella comporte de cordons granuleux qui donnent à la coquille un aspect tout différent de celui de Nerinea". N.B. Nerinea (sensu Cossmann) comprises Cossmannea and Eunerinea as used by the present author.

The latter two points of difference, namely the suture and ornamentation were also considered by Geiger (1901, p. 306) who stated, "Vor diesen 5 Unterschiedungsmerkmalen sind nur 2 (the suture) and 5 (the ornament) von grösserer Bedeutung." However, subsequently Geiger admitted that (*op*. *cit*., p. 307), "Die Zahl derjenigen Nerinellen , die im Hinsicht der Suturlage ganz anderer Verhältnisse aufweist, ab sie Cossmann als ein für die Nerinellen wesentliches Merkmal aufstellt, übersteigt die mit typischer Nachtlage"., and that, "Auch die Verzierung des Nahtrandes is bei *Nerinea* *sensu* *stricto* nicht wesentlich von der bei *Nerinella* verschieden".

The present author has also experienced considerable difficulty in the use of shell ornament and sutural development in the discrimination of Nerineids. The development of the sutural carinae is extremely variable in almost all Nerineid species (see, for example, *A*. *excavata* sp. nov, plate 2.J) and cannot be reliably used at the generic level. In *Nerinella*, *Cossmannea* and *Eunerinea* the ornament is never pronounced and whether a spiral lira is beaded or not depends upon the relative strength of the growth lines as does the development of tubercles on the sutural carinae. Furthermore, it is usually impossible to obtain enough specimens with the ornamentation well preserved for detailed analysis.

However, within the White Limestone, the present author has found that the use of the apical angle and whorl width/height ratios satisfactorily distinguishes *Nerinella* from other Nerineid genera and believes that these parameters should be used as the primary taxobases to distinguish this genus.

B3/1 *Nerinella* cf. *pseudocylindrica* (d'Orbigny 1851) Plate 2.L.

Synonymy

Nerinea *cylindrica*, Deslongchamps, 1842, p. 187, pl. VIII, fig. 33 (*non* Voltz).

Nerinea pseudocylindrica, d'Orbigny, 1849, p. 298, no. 39.
Nerinea pseudocylindrica, d'Orbigny, 1851, p. 86, pl. CCLII, figs. 11-13.
Nerinea clavis, Terquem et Jourdy, 1871, p. 48 (non Deslongchamps).
Nerinea pseudocylindrica, Cossmann, 1885, p. 204, no. 264.
Nerinella pseudocylindrica, Cossmann, 1898, p. 98, pl. VIII, fig. 14.
Nerinella pseudocylindrica, Dietrich, 1925, p. 34.

Discussion

Of the nine species of Nerinella listed by Cox and Arkell (1948-50, pp. 78-79) in their revision of the British Great Oolite Mollusca, two are considered by those authors as being indeterminate and two (N. granulata and N. stricklandi) are based on very few specimens with the holotypes having been lost. Three of the remaining species (N. scalaris, N. dufrenoyi and N. calcarea) are found only at or very close to Minchinhampton, whilst N. striata is found in the Sevenhampton Rhynchonella Bed and N. dimidata found in the Lower Cornbrash. Where possible, specimens of all these species from the British Museum (Natural History), Institute of Geological Sciences Museum and the Oxford University Museum have been compared with the two species of Nerinella found by the present author in the White Limestone but neither specimens nor published figures and descriptions agree with the morphologies of the White Limestone species which have evidently not previously been described from British Bathonian strata.

The Nerinella sp. from Eton College (Fig. 1.11, bed 14) and Bunkers Hill (Fig. 1.15, bed 11) has a very distinctive morphology. Specimens are particularly acute, with a very small apical angle (see Chapter 3) and appear almost cylindrical. The adapertural sutural carina is pronounced whilst the adapical sutural carina (i.e. the selenizone) is rather rounder; the result being a concavo-convex whorl shape with the adapical half of the whorl convex and the adapertural half being concave - the maximum concavity just above the adapertural carina (see pl. 2.L). The base of the shell is noticeably concave. Growth lines are frequently visible but spiral ornament is virtually absent.

An extensive search of relevant literature revealed only one previously described Nerinella species with this distinctive whorl shape - the French Upper Bathonian Nerinella pseudocylindrica (d'Orb.). This species was described by Cossmann (1898, pp. 98-99) who remarked "surface lisse, un peu excavée vers les deux tiers de la hauteux du côté antérieur, avec un renflement peu saillant et émoussé sous la suture, et une partie légerement convexe du côté postérieur. Dernier tour élevé, caréné a la périphérie de la base qui est évidée". Also the figures of d'Orbigny (1851, pl. CCLII, figs. 11-13) agree very well with the specimens collected by the present author.

Until it is possible to examine the collections of d'Orbigny and Cossmann in the Muséum National d'Histoire Naturelle and Laboratoire de Géologie de la Sorbonne in Paris and also collect some French specimens for sectioning, this White Limestone species is provisionally identified as Nerinella cf. pseudocylindrica.

Distribution

English Nerinella cf. pseudocylindrica are found in the lower part of the Ardley Beds (basal Retrocostatum zone, Upper Bathonian, White Limestone) at Eton College and Bunkers Hill (see previously). It is very abundant at these two localities. French localities according to

Cossmann (1898, p. 99) include Luc, Langrune, Buisson and Meurthe et Moselle (all Upper Bathonian).

B3/2 Nerinella cf. acicula (d'Archiac 1843) Plate 2.M.

Synonymy see Fischer, 1969, p. 172.

Discussion

This common French species is evidently rather variable in morphology for as noted by Cossmann (1898, p. 104) "..., il n'y a aucun motif pour séparer N. tumentisutura de l'espèce de d'Archiac, qui est d'ailleurs variable...". Although Nerinella lineifera Piette was regarded by Cossmann (op. cit.) as a separate species, he added (op. cit., p. 105), "... que N. acicula est une espèce très variable, il est probable que N. lineifera n'en est qu'une variété;...". This was later confirmed by Fischer (1969, p. 172) who wrote, "... il ne peut être décelé aucune différence spécifique constant entre N. lineifera et N. acicula ..." and "on reconnait l'espèce (N. acicula) à son angle apical très aigu et à son ornamentation composée de 4 ou 5 filets spiraux entièrement lisses sur chaque tour ainsi que sur la base".

The very abundant Nerinella sp. from the basal horizon of the Ardley Beds (White Limestone) at Slape Hill (Fig. 1.5, bed 5) and Ardley Fields (Fig. 1.18, bed 32a) corresponds remarkably well with the published figures and descriptions of N. acicula (see particularly Cossmann, 1898, pl. VIII, figs. 22-25; 32-34). The detailed ornamentation of four or five spiral striae on the whorl sides with striations also present on the base of the shell support the identification. Therefore, the species is provisionally named Nerinella cf. acicula until such time as the identification can be substantiated.

Distribution

Nerinella cf. *acicula* is found in the basal Retrocostatum zone (Lower Ardley Beds) of the White Limestone at Slape Hill (fig. 1.5, bed 5) and Ardley Fields (fig. 1.18, bed 32a, the Roach-stone of Arkell *et*. *al*., 1933).

French localities are given by Cossmann (1898, p. 105) and Fischer (1969, p. 172). According to Fischer (*op*. *cit*.), *N*. *acicula* is found in the Calcaire pseudo-oolithiques supérieur (M. Bathonian) and the Calcaire marno-crayeux inférieurs (transition zone between the M. and U. Bathonian). He further states (*op*. *cit*., p. 18) that the Calcaire pseudo-oolithique (inférieur et supérieur) "représentent les Stonesfield Slates et la Great Oolite d'Angleterre (zones à Progracilis et à Subcontractus)". Presumably the stratigraphically higher Calcaire marneux-crayeux inférieur could range into the succeeding Morrisi and Retrocostatum zones but no further details are given. Since the detailed zonal stratigraphy of the French White Limestone is at present so poorly known, one can only conclude that the occurrence of *N*. *acicula* in French strata range from the Subcontractus zone possibly into the Retrocostatum zone and therefore may be in part equivalent in age to the British occurrences of *N*. cf. *acicula* (see above).

Nerinella cf. *pseudocylindrica* (d'Orb.)

Specimen EC 53

External morphology

Specimen coated with MgO.

Specimen EC 9

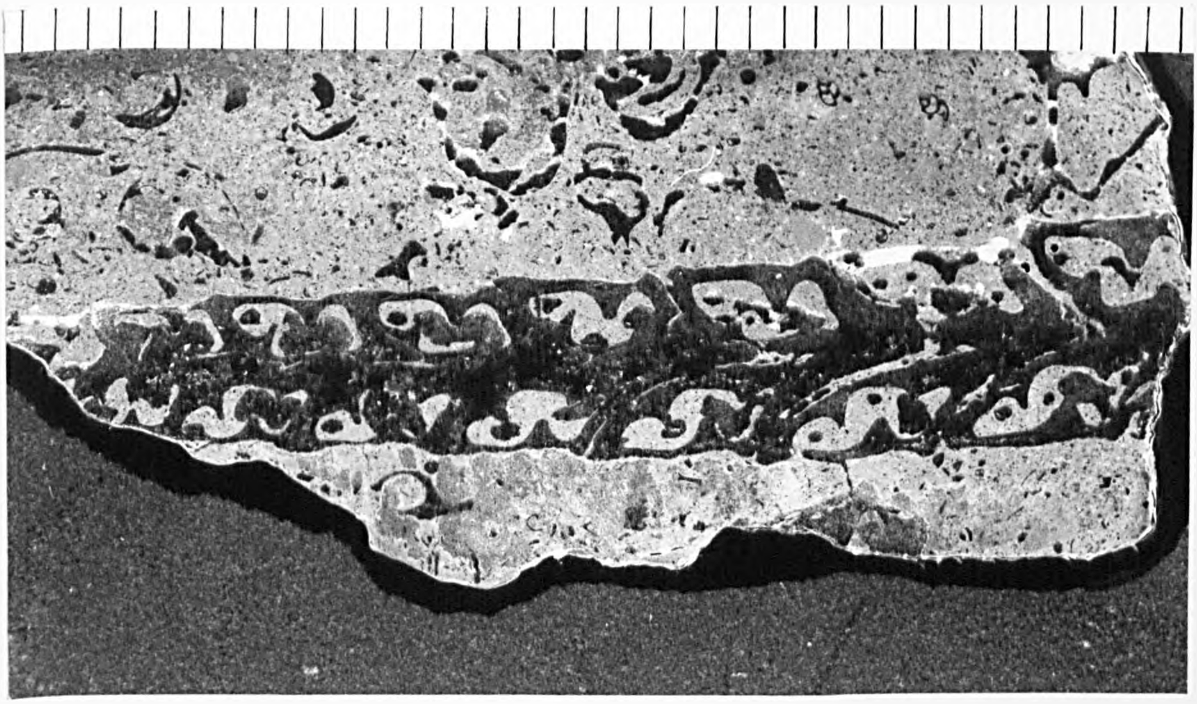
Median axial section

Acetate peel.

Eton College Quarry, Bed 14.

Both specimens M.J.B. colln.

Plate 2.L.



Nerinella cf. acicula

Specimen Sl.H.Ox. 5/29a

External morphology

Specimen coated with MgO.

Specimen Sl.H.Ox. 5/15

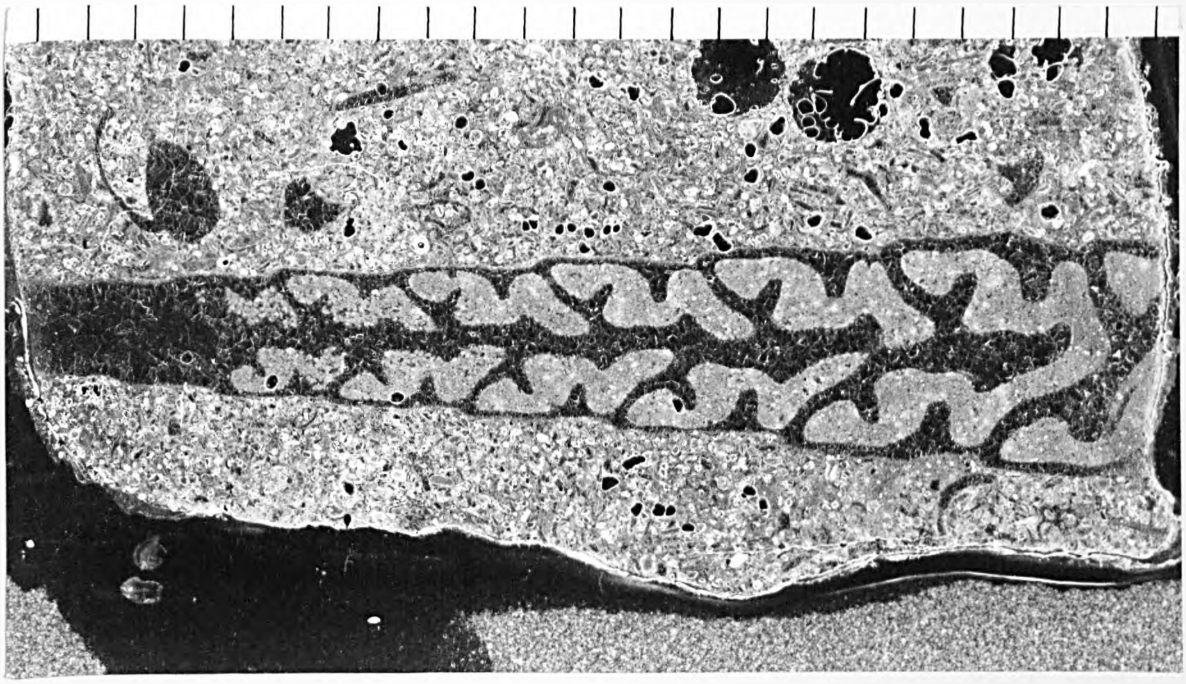
Median axial section

Acetate peel.

Slape Hill Quarry, Bed 5.

Both specimens M.J.B. colln.

Plate 2.M.



B4/1 Eunerinea eudesii (Morris and Lycett) Plates 2.N and 2.0, (= subjective synonym Eu. ashfordensis Arkell).

Synonymy see Cox and Arkell (1948-50, p. 76).

Type-material The available type-series for Eu. eudesii consists of three specimens housed in the Institute of Geological Sciences Museum (G.S.M. 8288, G.S.M. 49428 and G.S.M. 49429). Of these, only one, G.S.M. 8288, was figured by Morris and Lycett (1851, plate 7, fig. 6, 6a) in their original description of this species but no types were cited. Subsequently Arkell (1931) figured all three specimens (G.S.M. 8288 in plate L, fig. 5: G.S.M. 49428 in plate L, fig. 1 and G.S.M. 49429 in plate L, fig. 6) and designated G.S.M. 8288 (the figured specimen of Morris and Lycett) the holotype with the remaining two specimens paratypes. It is evident from Articles 73 and 74 of the International Code of Zoological Nomenclature, that a holotype can only be designated by the original author. Consequently specimen G.S.M. 8288 must be regarded as the lectotype of Eunerinea eudesii (Morris and Lycett) designated in error as a holotype by Arkell (1931).

Discussion

The distribution of Eu. eudesii outside the Minchinhampton facies was first discussed by Arkell (1931, pp. 615-617). The doubts expressed by Morris and Lycett (1851, p.34) about the internal configuration of N. eudesii were resolved by Arkell (op. cit.) by the sectioning of a paratype from the Lycett collection (Institute of Geological Sciences Museum, G.S.M. 49429, see Arkell op. cit., plate L, fig. 6 and plate 2.N. Although Arkell (op. cit., p. 616) states that the "triplicate section (of the Lycett paratype G.S.M. 49429) has been clearly revealed identical with that of the specimens from the Oxford district", the only cross-section of this species he figured (other than the paratype) is that of a specimen from the N. eudesii bed in the Ashford Mill railway cutting shown in plate L, fig. 4. This specimen (Oxford University Museum Number J 835) together with another sectioned gastropod (J 13077) from the same horizon and locality but not previously published are shown in plate 2.0. There can be no doubt that the Ashford Mill specimens collected by Arkell (op. cit.) are the same species as the specimens recorded as N. eudesii by Morris and Lycett (op. cit.).

However, the shell parameters of the type-specimens of Eu. eudesii together with those of the Oxford University Museum specimens from the Ashford Mill railway cutting are statistically very significantly different from the Eunerinea sp. populations present in the White Limestone (see Chapter 3 and Fig. 3.9). The large number of specimens of Eunerinea sp. from the White Limestone collected by the present author are taken to represent a single morphologically rather variable species (see later) but their range of morphologies does not encompass those exhibited by Eu. eudesii. The very considerable differences in morphology backed up by their statistical significance must mean that two separate biological species existed; Eu. eudesii and the White Limestone Eunerinea sp. Indeed, the present author has not collected or identified any specimen of Eu. eudesii from the White Limestone.

Externally, Eu. eudesii differs from the White Limestone Eunerinea sp. in that the apical angle is larger and the whorls are generally less high relative to the whorl width (see Fig. 3.9). The internal cross-section of the body cavity of Eu. eudesii is very distinctive in that the columellar and labral folds are almost opposite each other producing a cross-section which appears 'pinched' in the middle. The labral fold is also narrower and less deeply incised in *Eu. eudesii* than in the White Limestone *Eunerinea* sp. (see Fig. 2.2.).

In spite of these differences, not only did Arkell (*op. cit.*) and subsequent authors (e.g. Richardson, in Richardson, Arkell and Dines, 1946 and McKerrow *et. al.*, 1969) unite *Eu. eudesii* and the White Limestone *Eunerinea* sp., other nerineid gastropods with three internal folds (particularly *Melanioptyxis altararis*) were misidentified as *Eu. eudesii* (e.g. J. 13080 in the Arkell collection, Oxford University Museum).

The single specimen and holotype of *Eunerinea ashfordensis* (Arkell, 1931) from the Ashford Mill railway-cutting was considered by Arkell (*op. cit.*, p. 612, pl. L, fig. 7) to be a separate species allied to *Eu. eudesii* and from the same bed. An interal section taken from the holotype is shown in Fig. 2.2. Although Arkell (*op. cit.*) considered that the whorls of *Eu. ashfordensis* were shorter and more concave than *Eu. eudesii* and that the apical angle was larger, the present author believes that the comparison that Arkell made was not with *Eu. eudesii* but with the White Limestone *Eunerinea* sp. and that the differences between *Eu. eudesii* and *Eu. ashfordensis* are insufficient to warrant the creation of a separate species (see Fig. 2.2).

Distribution

Apart from the type-specimens from Minchinhampton, the occurrences of *Eu. eudesii* known to the present author are all from the Sharps Hill Formation; namely the Ashford Mill railway cutting (Arkell, *op. cit.*, p. 615, bed 2) and Sharps Hill quarry (Arkell, 1947, p. 63, bed 12 and

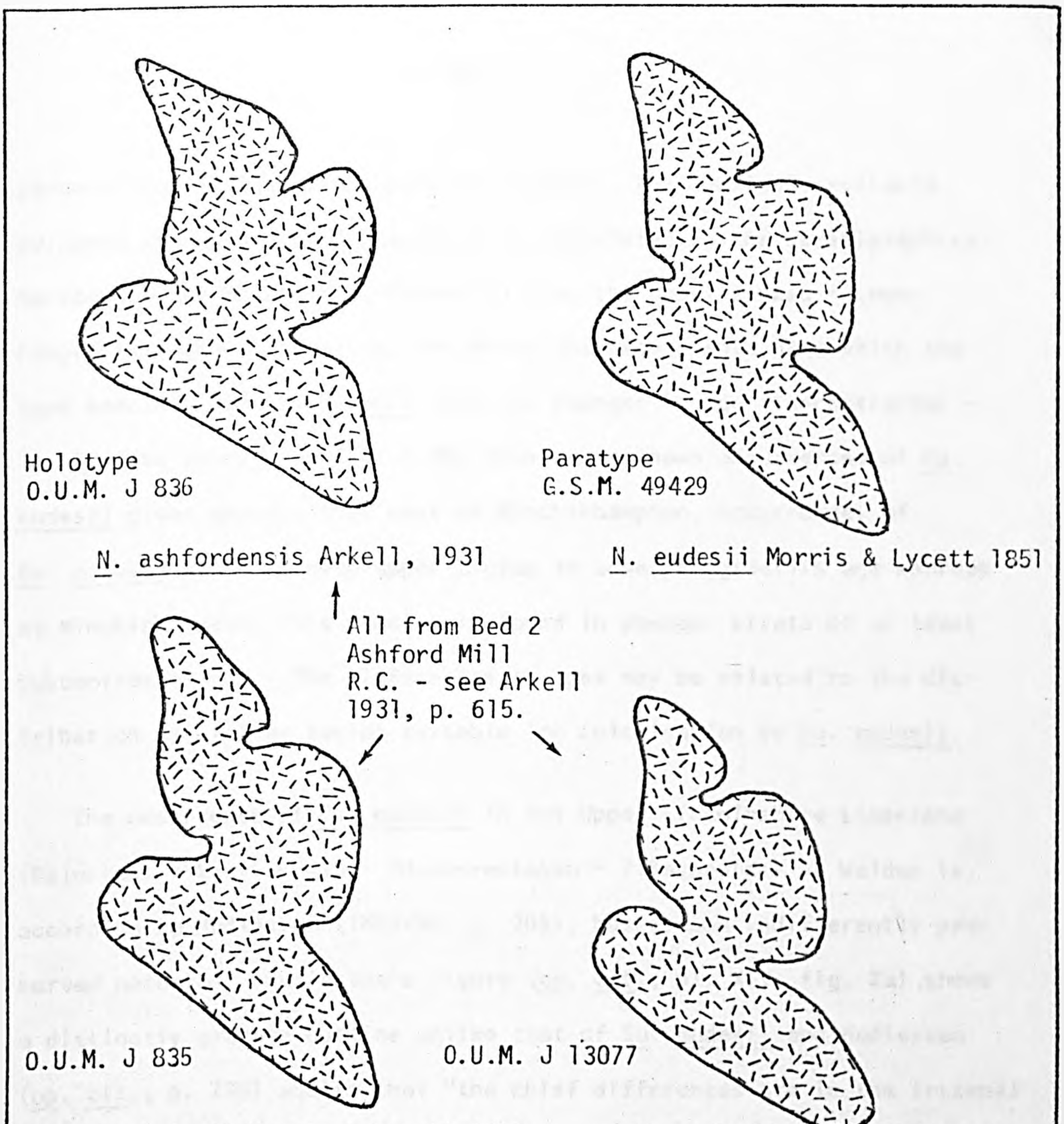


Fig. 2.2. The fold morphologies of Eu. eudesii (= Eu. ashfordensis) and Eu. cf. arduennensis.

personal collection of the present author). The available reliable evidence suggests that *Eu. eudesii* is restricted to the stratigraphical horizon of the Sharps Hill Formation i.e. the Upper Zigzag - Lower Progracilis zones. However, the Minchinhampton strata from which the type specimens of *Eu. eudesii* came are younger in age (Subcontractus - ?Aspidoides zones, see Fig. 1.39) than other known occurrences of *Eu. eudesii* given above. Thus east of Minchinhampton, occurrences of *Eu. eudesii* are of proven Upper Zigzag to Lower Progracilis age whereas at Minchinhampton, this species is found in younger strata of at least Subcontractus age. The differences in ages may be related to the distribution of similar facies suitable for colonisation by *Eu. eudesii*.

The occurrence of *Eu. eudesii* in the Upper Lincolnshire Limestone (Bajocian: - Laeviuscula - ?Humphresianum - ??Bathonian) at Weldon is, according to Hudleston (1887-96, p. 205), based upon indifferently preserved material. Hudleston's figure (*op. cit.*, pl. XIV, fig. 2a) shows a distinctly gradate outline unlike that of *Eu. eudesii* and Hudleston (*op. cit.*, p. 205) admits that "the chief differences are in the internal section". The fauna of the Upper Lincolnshire Limestone urgently needs revision, particularly in view of the uncertain stratigraphic range of these strata and the present author is currently pursuing this topic. Certainly none of the Nerineids collected by the present author from the Upper Lincolnshire Limestone resemble *Eu. eudesii*.

B4/2 *Eunerinea arduennensis* (Buvignier 1852) plates 2.P and 2.Q.

Synonymy

Nerinea arduennensis, Buvignier, 1852, p. 34, pl. XXXII, figs. 17, 18.

Nerinea buvignieri, Piette, 1855, p. 1105 (insuff. characterisé).

Nerinea bulsoni, Piette, 1855, p. 1105 (insuff. characterisé).

Nerinea buvignieri, Cossmann (ex. Piette), 1885, p. 209, pl. XVIII, figs. 11-14.

Nerinea bulsonensis, Cossmann (ex. Piette), 1885, p. 208, pl. XVIII, figs. 15-17.

Nerinella buvignieri, Cossmann, 1898, p. 95, pl. VIII, figs. 6-9.

Nerinella bulsonensis, Cossmann, 1898, p. 94, pl. VIII, figs. 4-5.

Nerinella elegantula, Cossmann, 1905, p. 832, pl. XLVI, fig. 10-14, (*non* d'Orbigny).

Nerinella arduennensis, Fischer, 1969, p. 174, pl. XVII, figs. 46-49.

Nerinella arduennensis var. *bulsonensis*, Fischer, 1969, p. 174.

Discussion

The location and biometric parameters of the various samples of *Eunerinea* sp. from the White Limestone are given in Chapter 3. Examination of Fig. 3.9 shows that there is a considerable amount of morphological overlap between the samples. Within this overlap, no evident geographic distribution or stratigraphic trend is discernable and the present author concludes that the samples were drawn from several populations separated in time and space but belonging to a single, rather variable species.

The whorl sides of the White Limestone *Eunerinea* sp. are evenly, slightly to moderately, concave and the suture is bordered by small, rather bulging, subequal carinae. The ornamentation of the whorls is most pronounced in the juvenile forms and consists of three evenly-spaced spiral, beaded lirae interspaced with much finer smooth spiral striae.

This ornamentation gradually fades and, in the more mature parts of the shell, the whorl sides appear unornamented except occasionally in those specimens where the growth-lines are well developed. Strong development of growth-lines can produce tuberculate carinae, a feature which is often accentuated by weathering. The spiral ornamentation also continues onto the base of the shell.

The descriptions of *Nerinella buvignieri* (= *Eu. arduennensis*) by Cossmann (1898, p. 95) and *Nerinella arduennensis* by Fischer (1969, p. 174) agree very well with the *Eunerinea* sp. from the English White Limestone - especially in the detailed ontogenetic development of the ornamentation. Cossmann (*op. cit.*, p. 95) remarked about *N. buvignieri* that "surface d'abord ornée de trois filets subgranuleux, - celui du milieu un peu plus proéminent, - qui s'effaient sur les derniers tours;" and that "mais les dernier tours des individus adultes sont totalement lisses". Fischer (*op. cit.*, p. 174) considers that *N. arduennensis* "présente un important polymorphisome qu'il est nécessaire de préciser: l'angle apical, compris entre 15° et 27° selon les individus....". Not only is *Eu. arduennensis* a rather variable species but according to Fischer (*op. cit.*, p. 174) the specimens from the French 'White Limestone' at Any-Martin-Rieux identified by Bonte (1941, p. 100) as *Nerinea eudesii* are really *Eu. arduennensis*!

Dr. J.-C. Fischer (Muséum National d'Histoire Naturelle) kindly made seven specimens of *Eunerinea arduennensis* from the Piette collection (locality: Bulson - Ardennes, ?M. Bathonian) available to the present author. Of these, five were suitable for measurement and the results are shown in Fig. 3.9 (see also plate 2.Q).

Considering that

a) the samples of *Eunerinea* sp. from the White Limestone are taken to represent a single variable species,

b) the French species *Eu. arduennensis* is also variable in its morphology (*teste* Fischer, *op. cit.*),

c) the morphologies of the *Eunerinea* sp. samples and the small French sample of *Eu. arduennensis* overlap considerably (see Fig. 3.9), and

d) the ontogenetic development of the ornamentation is the same,

the present author considers that the White Limestone *Eunerinea* sp. is the same as the French *Eunerinea arduennensis*.

The regularly concave whorls; the high values of the whorl width/height ratios and moderately large apical angle of *Eu. arduennensis* clearly suggest to the present author that the authors who have assigned *arduennensis* to the genus *Nerinella* are mistaken. As mentioned previously, *Nerinella* spp. can easily be distinguished from *Eunerinea*/*Cossmannea* spp. on the basis of the smaller apical angle and smaller whorl width/height ratios. Examination of Fig. 3.9 and the comparison of plates 2.L and 2.M with plates 2.N and 2.Q indicate that the generic affinity of *arduennensis* lies with *Eunerinea* rather than *Nerinella*.

Distribution

Eu. arduennensis is particularly abundant in the White Limestone of England where it occurs in several correlatable horizons. It is found sporadically throughout the Excavata Beds (Morrisi zone) but is particularly associated with Ardley Beds (Lower Retrocostatum zone), north-east of Worsham, where it is found as part of the *Nerinea eudesii* bed (*sensu* Arkell, 1931) and in the basal horizon of the Ardley Beds (the roach-stone of Arkell *et. al.*, 1933 and lateral equivalents). South-west of Worsham, *Eu. arduennensis* is still very abundant but as the *A. ardleyensis* beds are absent in this region it is possible that *Eu. arduennensis* may also be present in the basal Bladon Beds (Upper Retrocostatum zone). For details of the distribution in the White Limestone, see Chapter 1.

No specimens of *Eu. arduennensis* have been positively identified from the Minchinhampton facies inspite of the large collections of fossils from that area housed in the British Museum (Natural History), Institute of Geological Sciences Museum and Oxford University Museum.

The occurrences of *Eu. arduennensis* in the French 'White Limestone' are given by Cossmann (1898, p. 95) and Fischer (1969, p. 174). Once again the precise age of the French occurrences of this species is difficult to ascertain. *Eu. arduennensis* is known to occur in the Calcaire pseudo-oolithique (inférieur et supérieur) of Fischer (*op. cit.*) which he considers to be Middle Bathonian (Progracilis - Subcontractus) in age. However, Bonte (1941) has correlated these strata with the Hampen Marly Beds and White Limestone of England.

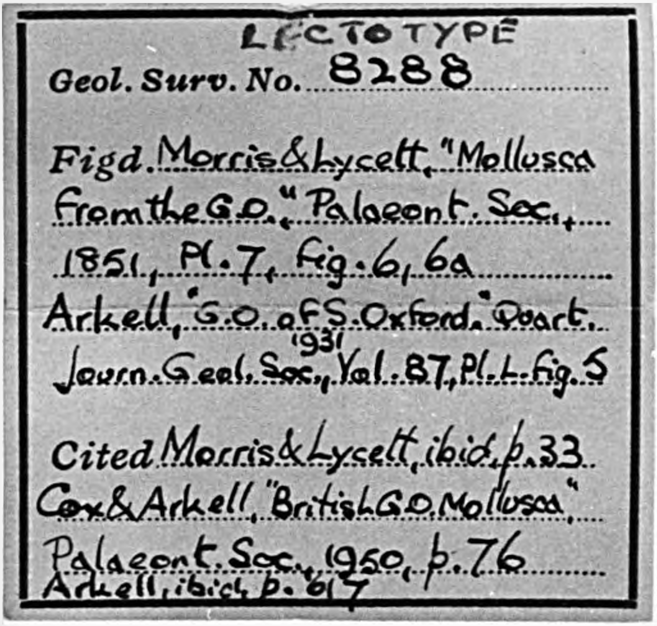
Eunerinea eudesii (Morris and Lycett)

Lectotype	Paratype
GSM 8288	GSM 49429

Specimen coated with NH_4Cl.

Institute of Geological Sciences Museum

Plate 2.N.

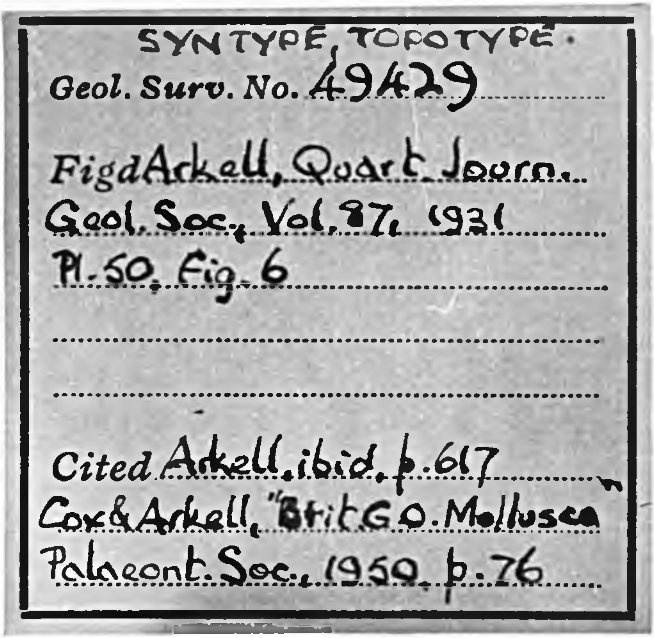


LECTOTYPE

Geol. Surv. No. 8288

Figd. Morris & Lycett, "Mollusca
from the G.O.", Palaeont. Soc.,
1851, Pl. 7, fig. 6, 6a
Arkell, "G.O. of S. Oxford." Quart.
Journ. Geol. Soc., 1931, Vol. 87, Pl. L. fig. 5

Cited Morris & Lycett, ibid. p. 33
Cox & Arkell, "British G.O. Mollusca",
Palaeont. Soc., 1950, p. 76
Arkell, ibid. p. 617



SYNTYPE, TOPOTYPE.

Geol. Surv. No. 49429

Figd Arkell, Quart. Journ.
Geol. Soc., Vol. 87, 1931
Pl. 50, Fig. 6

Cited Arkell, ibid. p. 617
Cox & Arkell, "Brit. G.O. Mollusca"
Palaeont. Soc., 1950, p. 76

Eunerinea eudesii from the Ashford Mill railway-cutting

J 835

median axial section

J 13077

median axial section

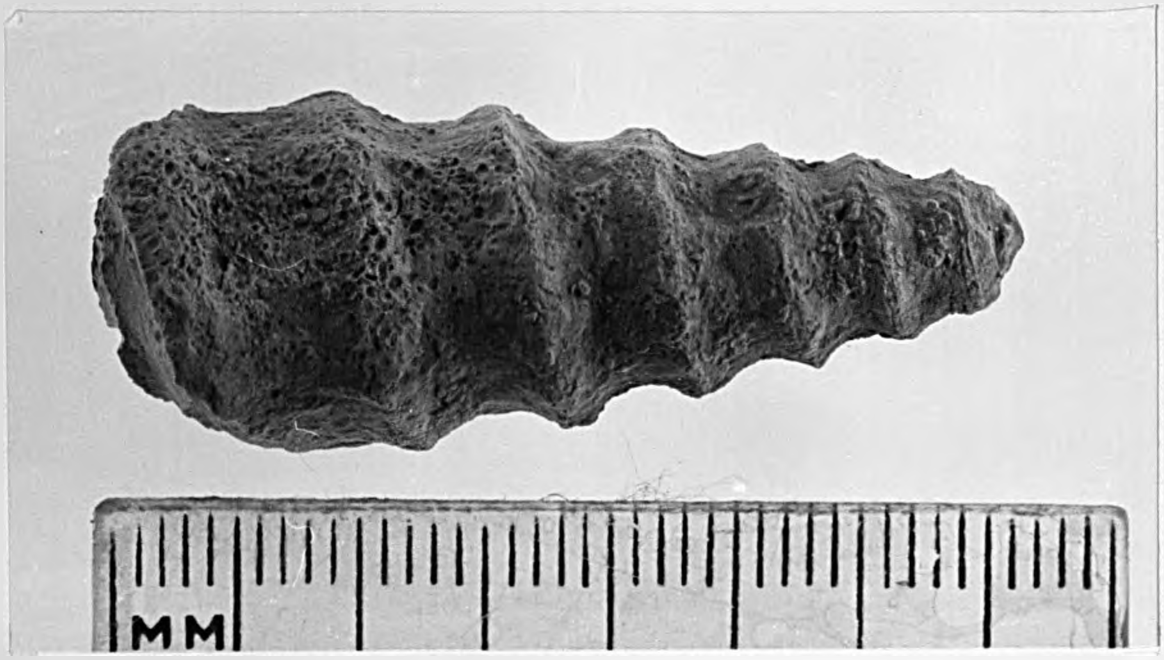
external morphology

Oxford University Museum.

Plate 2.0.


MM


MM


MM

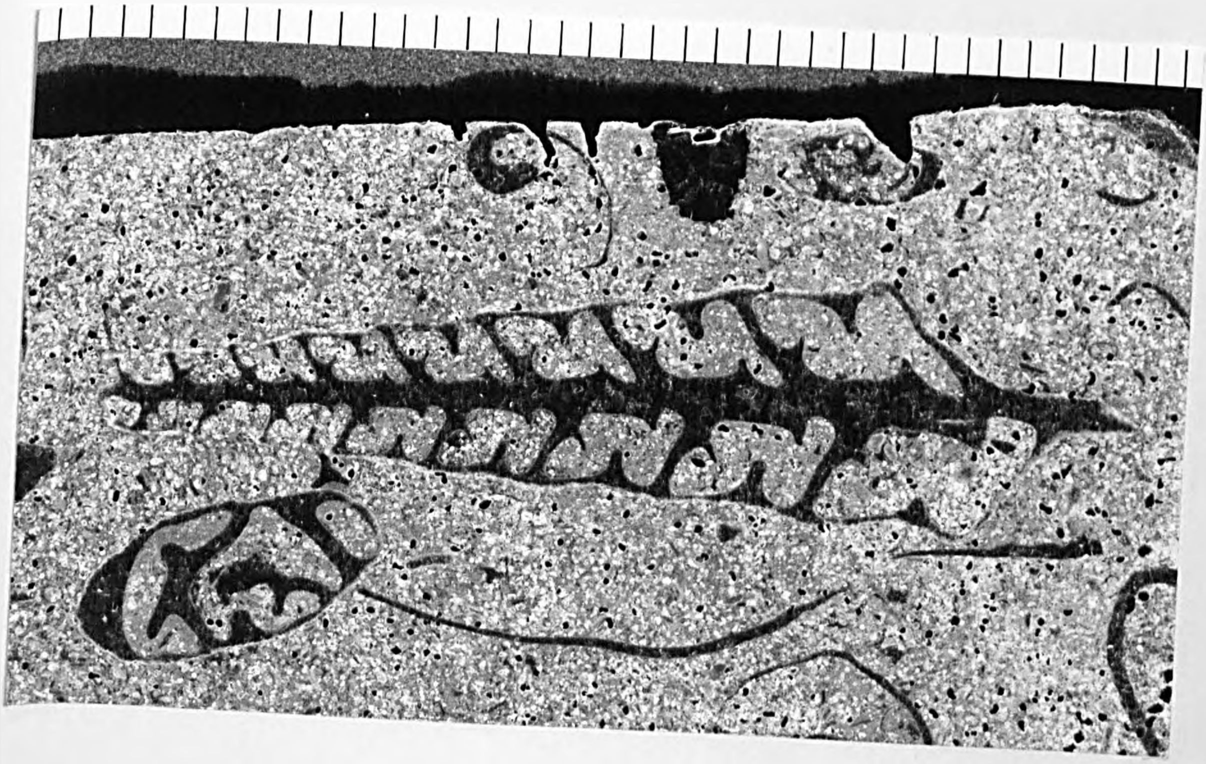
Eunerinea arduennensis (Buv.) - Internal morphology

Specimen Sl.H.Ox. 5/23	Specimen CR 10/11
Slape Hill Quarry, Bed 5.	Croughton Quarry, Bed 10.

Median axial sections; Acetate peels.

Both specimens M.J.B. colln.

Plate 2.P.



Eunerinea arduennensis (Buv.) - External morphology

Specimen 4P

Piette collection

?M. Bathonian; Bulson, Ardennes.

Specimen Sl.H.Ox. 5/296

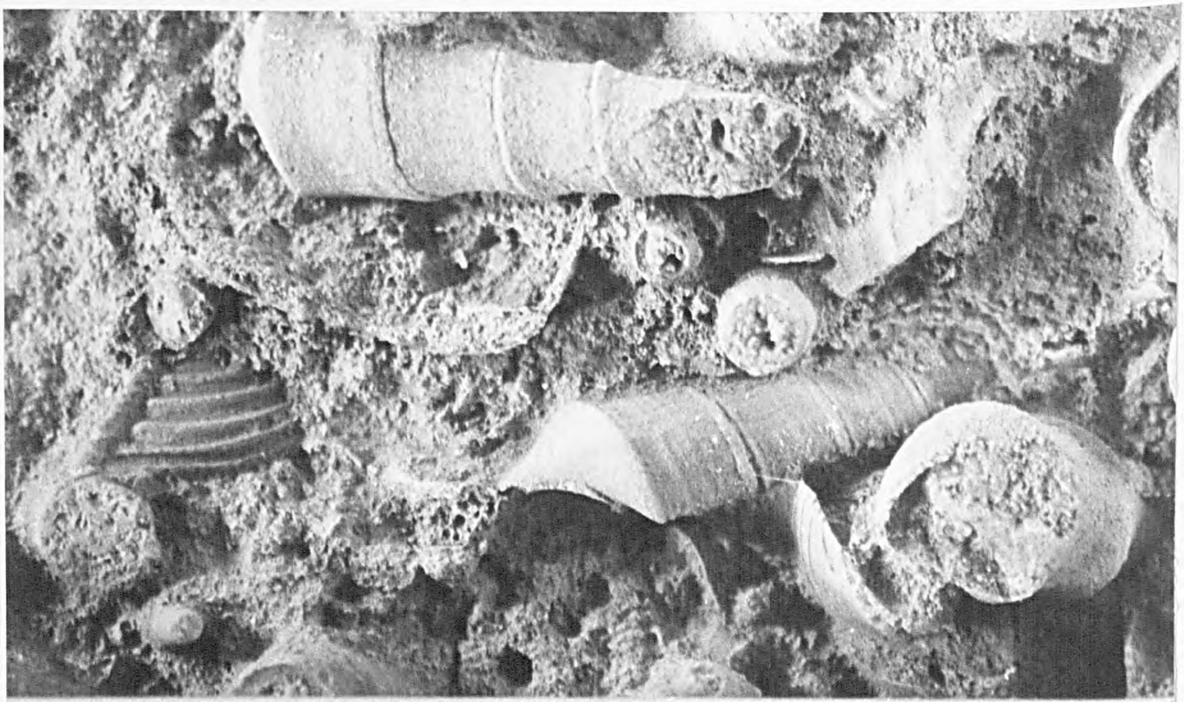
(left hand specimen)

note specimen of *N.* cf. *acicula* in centre of photograph.

Slape Hill Quarry, Bed 5.
M.J.B. colln.

Both specimens coated with MgO.

Plate 2.Q.



B5/I Cossmannea bathonica (Rigaux et Sauvage 1868).

Synonymy see Fischer, 1969, p. 70. Plate 2.R.

Discussion

According to Arkell (1931, p. 616) this species, which is common in the French Bathonian, is known in England only rarely - a few specimens from Minchinhampton in the Sedgwick Museum, Cambridge and the specimens recorded from the Lower Cornbrash by Blake (1905, p. 72, pl. VII, fig. 17) and Douglas and Arkell (1928, p. 139).

The essential differences between C. bathonica and Eu. eudesii were also noted by Arkell (op. cit., p. 616) ... "The whorls of N. bathonica, however, are distinctly higher, ..., while in section N. eudesii is triplicate, N. bathonica being only biplicate, ...". Using these criteria the separation of the two species is a simple matter (see Fig. 3.6 and compare plate 2.R with 2.N and 2.0). In spite of this, specimens are frequently misidentified. A fine specimen of C. bathonica in the Oxford University Museum (O.U.M. J 23521 - see plate 2.R) from North Leigh (unlocated) was misidentified by Arkell as C. eudesii. Several specimens of C. bathonica in the British Musum (Natural History) were similarly misidentified (e.g. G 16404 from Tiltups End - Witchell collection - identified as C. cf. eudesii and G 80082 from east of Hillsome Farm, Tetbury - Channon collection - identified as Nerinea sp.). The specimens recorded from the Cornbrash (see previously) are also misidentified; the figure of the internal whorl section by Blake (op. cit., pl. VII, fig. 17b) showing three folds instead of the two in C. bathonica. Indeed, the morphology of C. bathonica is so distinctive that specimens can be identified using X-radiography. In a preliminary study to evaluate the use of X-radiography in the identification of Nerineids, particularly type-specimens where sectioning would be impossible, Cossmannea bathonica was identified in slabs of limestone (from Foss Cross, bed 7) in which its presence was previously unknown. Plate 2.R shows a photographic print of the X-radiograph and also the specimen of C. bathonica which was later obtained by sectioning. Further details on radiographic techniques may be found in Kummel and Raup (1965, pp. 303-326).

C. bathonica has a much wider distribution in the White Limestone than has previously been suspected. Besides occurring at Minchinhampton, it has previously been recorded from only three White Limestone localities namely Tiltups End, nr. Nailsworth; Rodmarton and Tangley, Gloucestershire (see Cox and Arkell, op. cit., p. 77). The present author has found C. bathonica at Dagham Downs (Fig. 1.6, bed 7), Foss Cross (Fig. 1.7, beds 7 and 10), Ardley Fields (Fig. 1.18, bed 34), Croughton (Fig. 1.19, bed 7), Stratton Audley (Fig. 1.20, bed 4) and Woodeaton (see Palmer, 1973, pp. 58-59 for section). Museum specimens reliably confirm the presence of C. bathonica at New Barn Quarry, North Leach (Channon collection, British Museum (Natural History) - G 80126) and North Leigh (see previously).

The species is also widely distributed in the French Bathonian (see Cossmann, 1898, pp. 26-27 and Fischer, 1969, p. 70 for details). C. bathonica has also been reported from the Bathonian of Sardinia (Deninger, 1907), North Madagascar (Lemoine, 1906 and Douvillé, 1904), South Peru (Jaworski, 1914) and North Chile (Bayle et Coquand, 1851) but some of these records may be suspect in view of the misidentifications noted above.

All specimens of C. bathonica collected by the present author have been found in the Ardley Beds of the White Limestone and records of this gastropod in other British localities such as Tiltups End, North Leigh, etc. are consistent with this stratigraphic range. Although never abundant, it is nevertheless a fairly common species in those horizons where it occurs.

Cossmannea bathonica (Rigaux et Sauvage)

J 23521

Oxford University Museum

Specimen coated with NH_4Cl.

FXFB 35

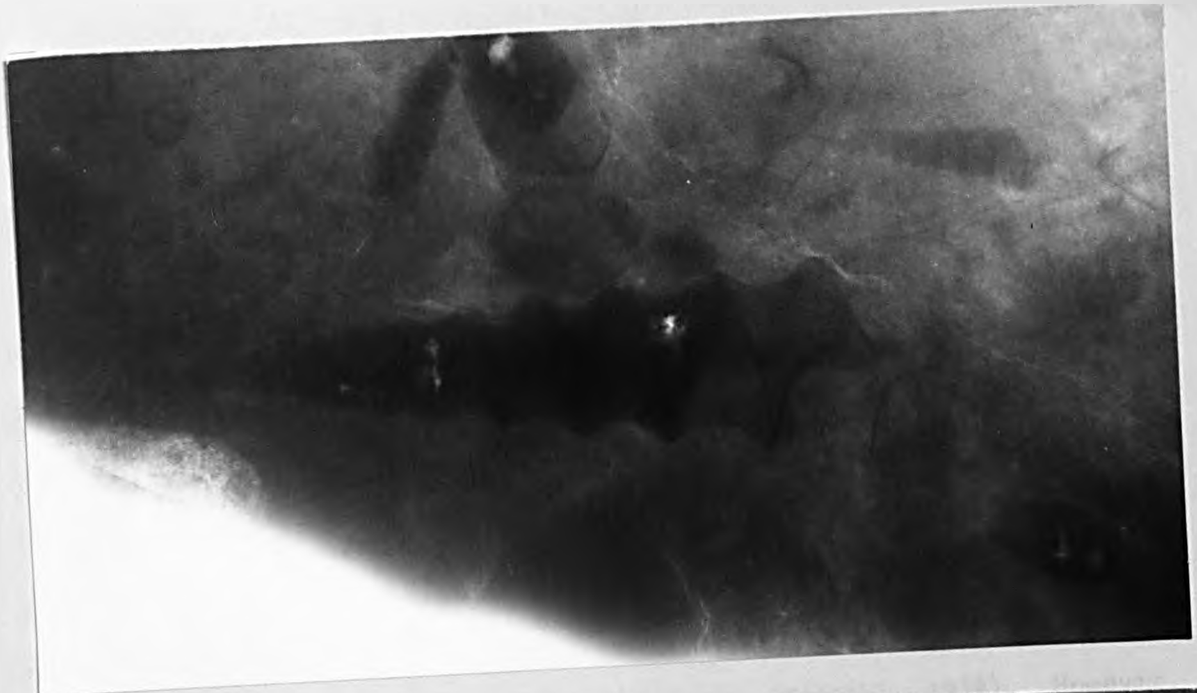
median axial section

specimen coated with glycerine
to enhance contrast

print from
X-radiograph

Foss Cross Quarry, *Fibuloptyxis* bed, bed 7.
M.J.B. colln.

Plate 2.R.




FXFB35
130
140
150
160
170
180
190
200
210
2


MM

B6 Genus BACTROPTYXIS Cossmann 1896.

Type-species *Bactroptyxis implicata* (d'Orbigny 1854).

Age Bathonian of France.

Discussion

Representatives of this genus are widely distributed both stratigraphically (Bajocian - Kimmeridgian) and geographically (mainly Western Europe but also reported from Kuban, U.S.S.R. - north of the Black Sea, Pchelintsev, 1927, and North Peru, Jaworski, 1914). However, *Bactroptyxis* is particularly well represented in the Middle Jurassic strata (Bajocian, inc. Aalenian - Bathonian) of England and France.

Bactroptyxis is a very distinctive genus which is characterised above all by possessing the most complicated internal folding of the whorl cavity to be found in Nerineid gastropods. This feature, combined with the acicular spire and solid columella, enables representatives of this genus to be readily distinguished.

Only one species (*B. bacillus* (d'Orb.) = subjective synonym *N. complicata* Witchell) has been described from British Bathonian strata (Witchell, 1886, p. 272; Arkell, 1931, p. 620; Cox and Arkell, 1948-50, p. 79). This contrasts markedly with the large number of *Bactroptyxis* "spp". described from coeval strata in France (Cossmann, 1885, 1896; Fischer, 1969) and Bajocian strata in England (Witchell, 1887; Hudleston, 1890-96). Those described species known to the present author are listed below.

Bajocian (including Aalenian)

B. bacillus (d'Orbigny).

B. bacillus var. *cervicula* (Hudleston).

B. bacillus var. *carnicotensis* (Hudleston).

B. bacillus var. *crassicincta* (Hudleston).

B. brevivoluta (Hudleston).

B. campana (Hudleston).

B. conica (Witchell).

B. consobrina (Witchell).

B. cotteswoldiae (Lycett).

B. guisei (Witchell).

B. jonesii (Lycett).

B. lebruni (d'Orbigny).

B. oppelensis (Lycett).

B. pisolitica (Witchell).

B. producta (Witchell).

B. santonis (Hudleston).

B. stroudiensis (Witchell).

B. subbrevivoluta (Hudleston).

B. velox (Witchell).

B. xenos (Hudleston).

Bathonian

B. axonensis (d'Orbigny).

B. bacillus (d'Orbigny).

B. bacillus var. *simonis* Dietrich ex. Piette.

B. bacillus var. *michaleti* Cossmann.

B. barrandeana (Cossmann ex. Piette).

B. complicata (Witchell).

B. cossmanni Fischer.

B. implicata (d'Orbigny).

B. rayana (d'Orbigny).

B. subbruntrutana (d'Orbigny).

B. sulcifera (Cossmann).

B. trachaea (Deslongchamps).

During this study, many of these species proved difficult to recognise or were unrecognisable. Bearing in mind that many of the original descriptions and identifications of the above species are of considerable antiquity, the present author considered that a taxonomic revision of these species was long overdue and that a satisfactory basis for this revision would best be achieved by variation studies on selected *Bactroptyxis* populations.

The intra-specific variation in fold morphology in several *Bactroptyxis* samples is shown in the following figures;

Fig. 2.3a and b Foss Cross, *Fibuloptyxis* Bed, bed 7 in Fig. 1.7.

Fig. 2.4 Foss Cross, *Solenopora* Bed, bed 10 in Fig. 1.7.

Fig. 2.5 Dagham Downs, *Bactroptyxis* Bed, bed 12 in Fig. 1.6.

Fig. 2.6 Stony Furlong railway cutting, *Bactroptyxis* Bed, bed 13c of Richardson, 1911, p. 110 and Fig. 1.8.

Fig. 2.7 Clypeus Grit, Golden Valley road cutting (SO 902922) 0.40m. below the prominent *Stiphrothyris* marl (bed 2 of Channon, 1951, p. 174).

In all these diagrams, only the complete, mature fold development is shown and none of the sections are taken from the early ontogenetic growth stages or the apertural region (the ontogenetic fold variation and development is described in Chapter 4).

Specimen numbers refer to personal collection of the author.

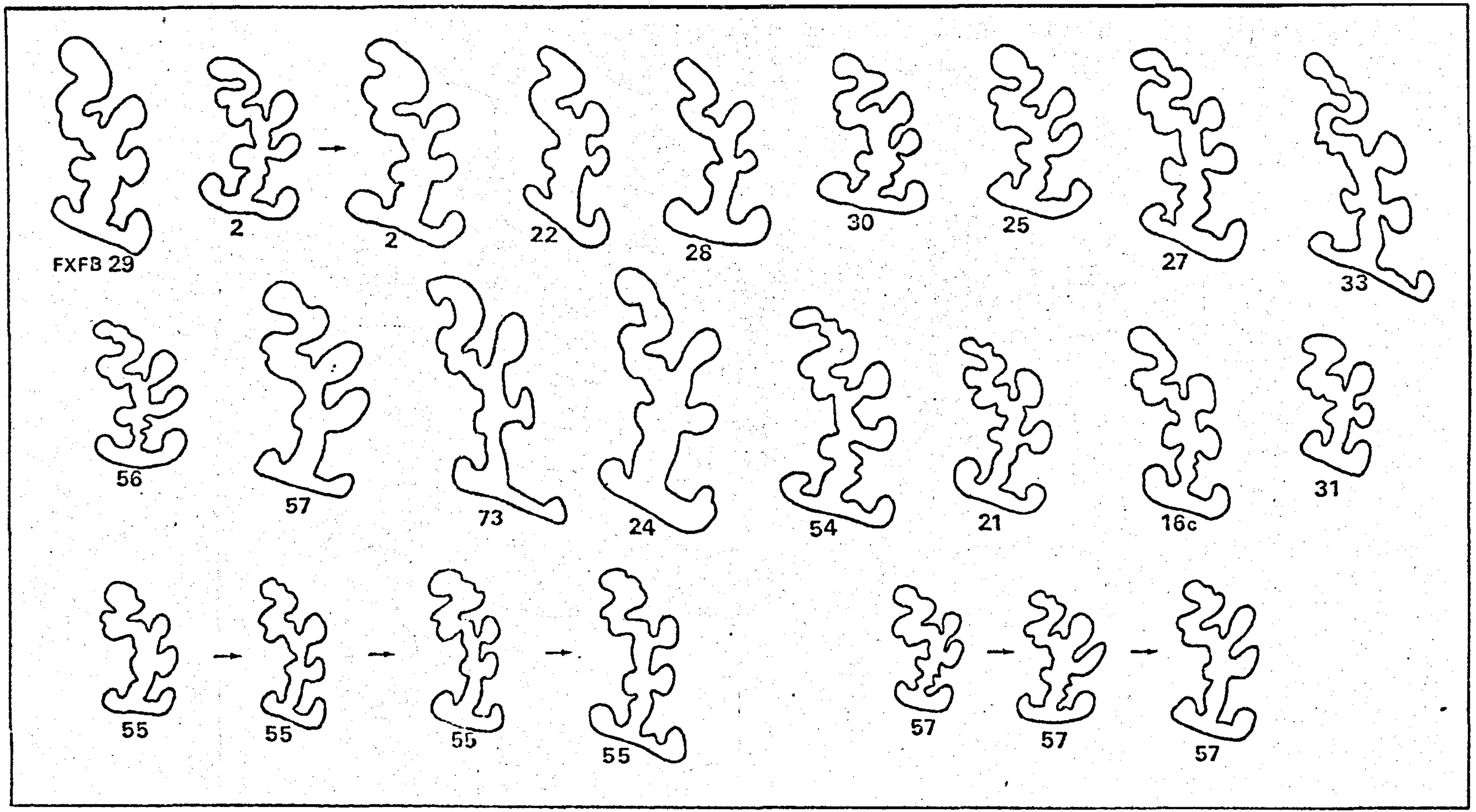


Fig. 3a. Variation in fold morphology. B. implicata Foss Cross Fibuloptyxis bed (7).

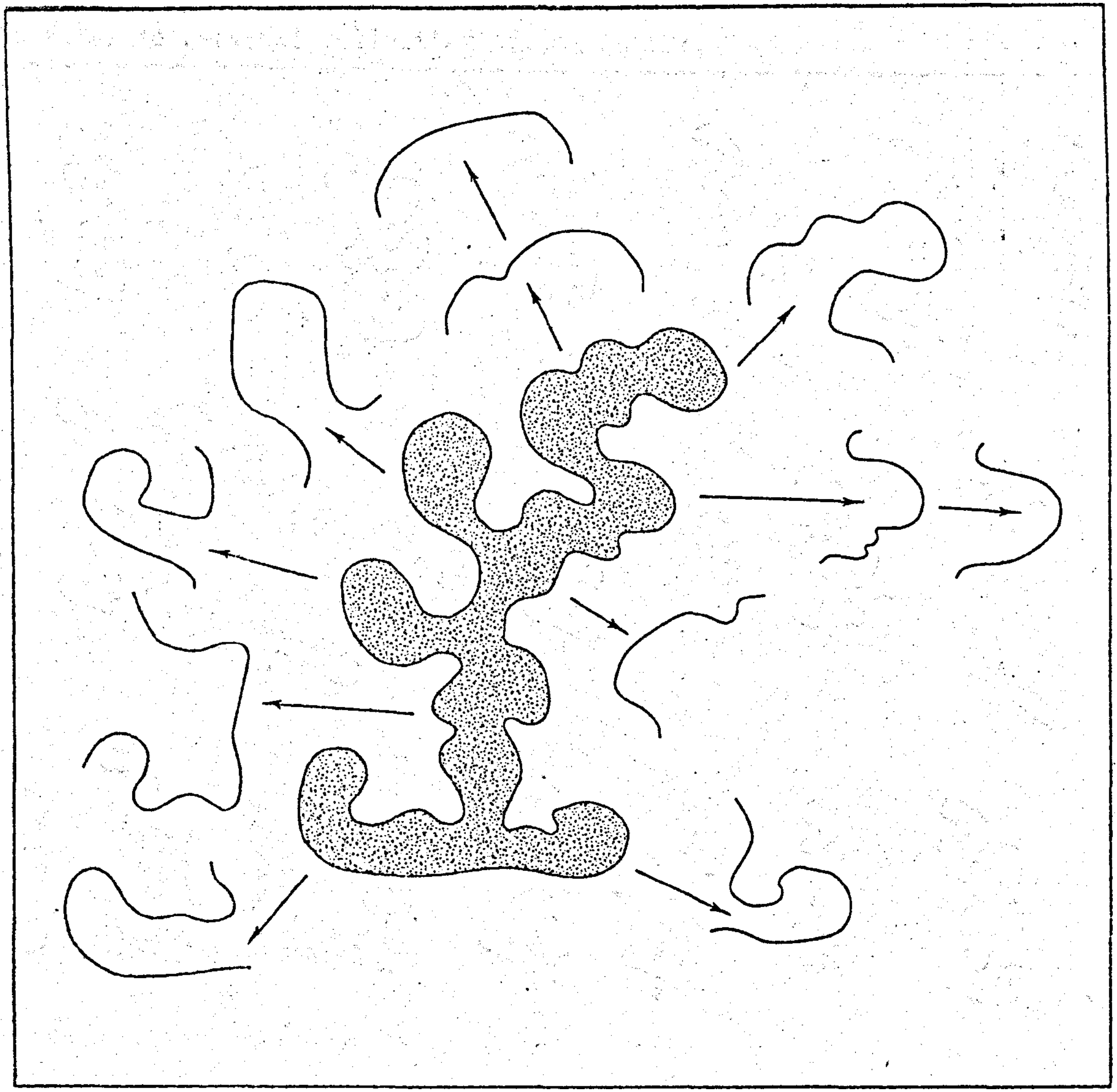


Fig.3b. Variation in fold morphology.
B. implicata ; Foss Cross *Fibuloptyxis* bed (7)

Specimen numbers refer to personal collection of the author.

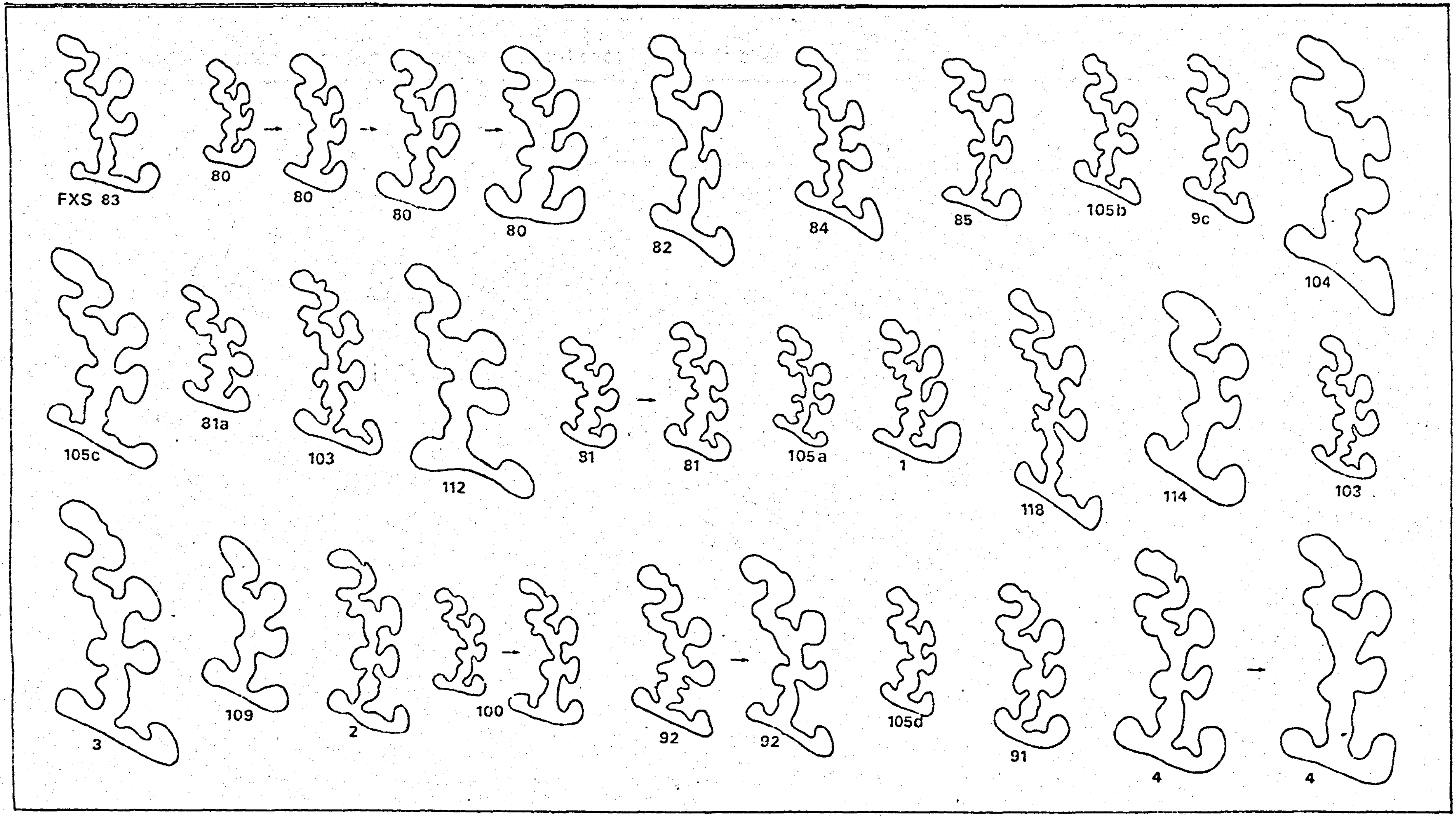


Fig. 2.4. Variation in fold morphology. *B. implicata* Foss Cross *Solenopora* bed (10).

Specimen numbers refer to personal collection of the author.

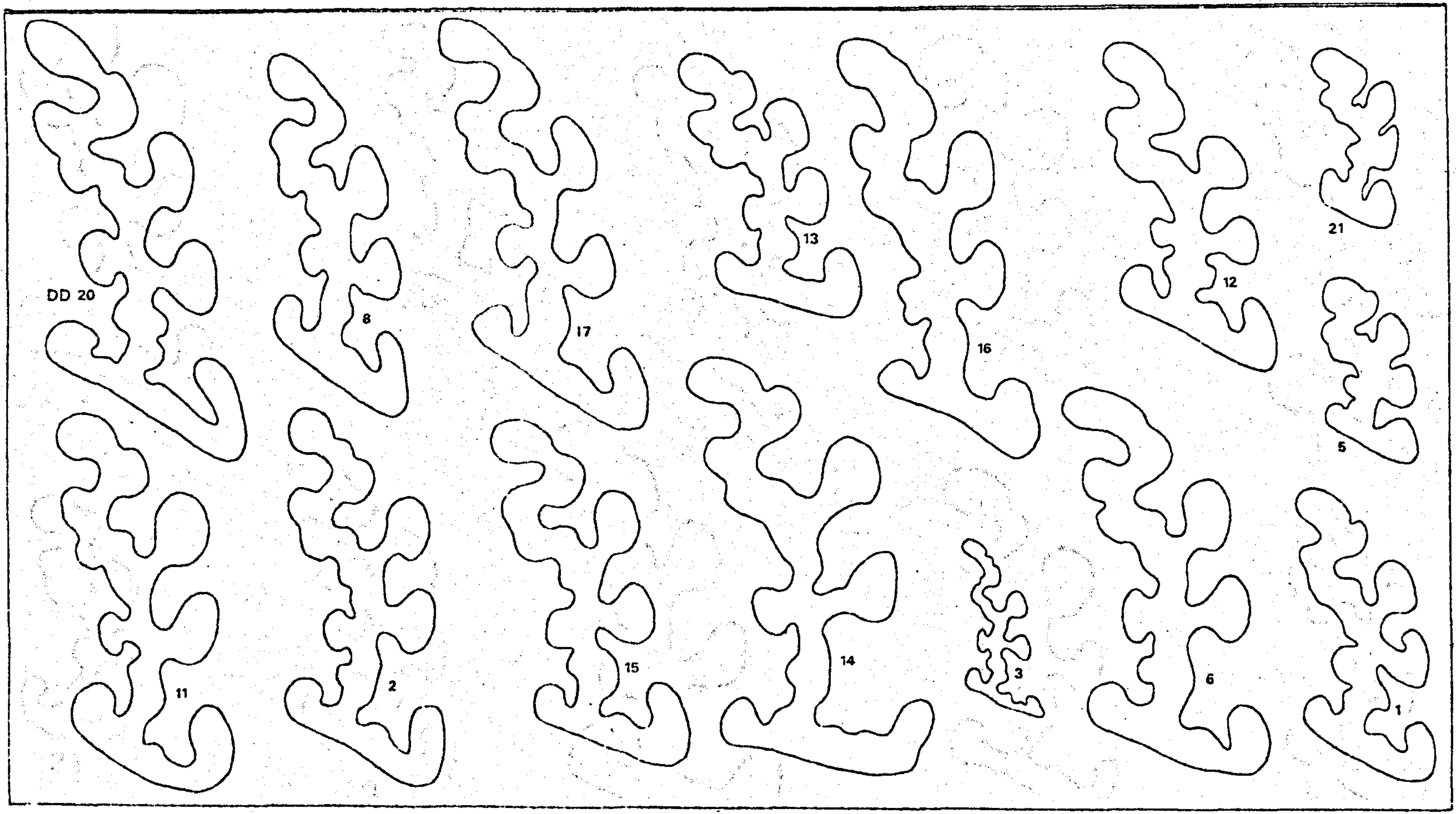


Fig. 2.5. Variation in fold morphology. *B. implicata* Dagham Downs, bed 12.

Specimen numbers refer to personal collection of the author.

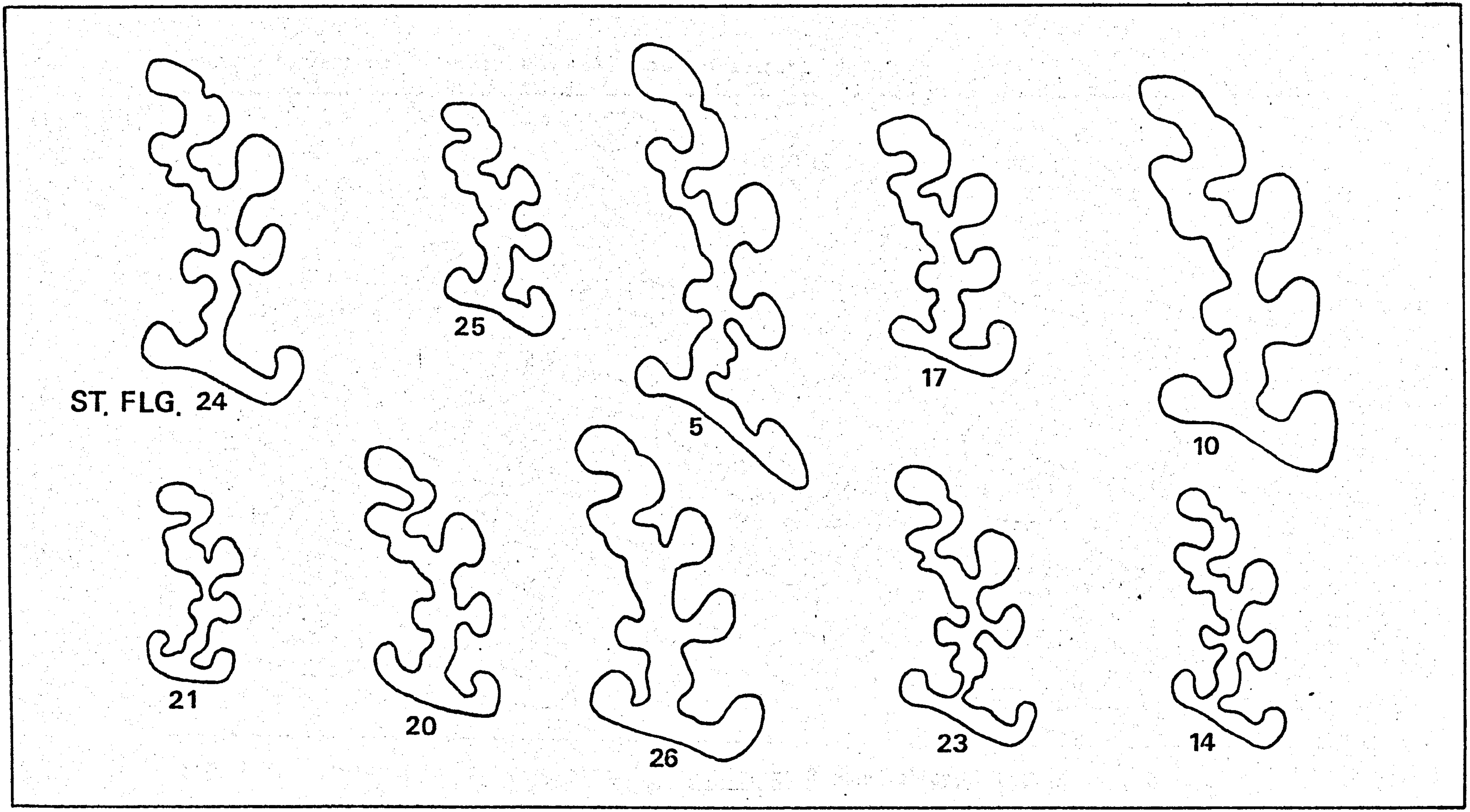


Fig. 2.6. Variation in fold morphology. *B. implicata* Stony Furlong, bed 13c.

Specimen numbers refer to personal collection of author.

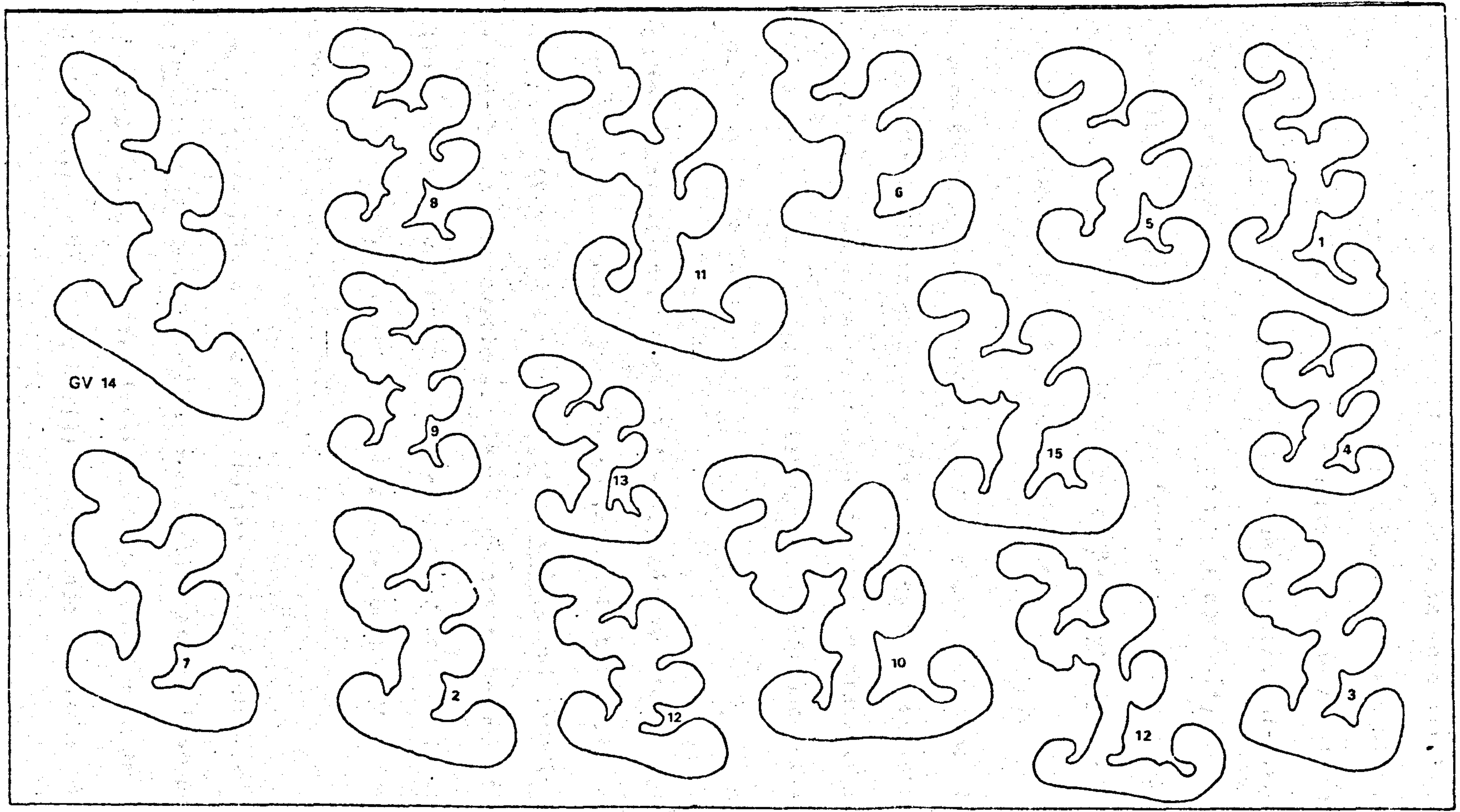


Fig. 2.7. Variation in fold morphology. *B. implicata* Golden Valley, bed 2.

The variation in external shell morphology is more difficult to illustrate. Median sections of the gastropods enable a qualitative assessment of the whorl concavity to be made. In general, the whorls of most Bactroptyxis spp. are slightly concave to straight-sided and the variation is such that this amount of whorl concavity does not seem to constitute a reliable basis for further taxonomic subdivision. The significance of those representatives of Bactroptyxis with extremely concave whorls will be discussed later.

The very faint spiral ornament found in these gastropods is normally very difficult to observe. The vagaries of preservation and data loss consequent upon post-mortem abrasion where present, combine to effectively negate any practical taxonomic significance of shell ornamentation in these forms.

From the examination of Figs. 2.3 - 2.7 and many other specimens, the present author considers that the variation in both fold morphology and whorl concavity within a single Bactroptyxis population is as great as that between populations. There appears to be no satisfactory basis within the species concept outlined earlier upon which to subdivide any of the Bactroptyxis sp. populations found in the course of this study.

Such type-materials as are known to the present author of the various Bactroptyxis spp. described from British strata have been examined and Dr. J.-C. Fischer (Institut de Paléontologie, Muséum National d'Histoire Naturelle, Paris) kindly made available some material of the following French species;

1. *Bactroptyxis trachaea* (Desl.) Hydrequent, Bathonian inférieur, coll. le Mesle.
2. *Bactroptyxis trachaea* (Desl.) Les Pichottes, Bathonian supérieur, coll. le Mesle.
3. *Bactroptyxis trachaea* (Desl.) Rumigny, Bathonian supérieur, coll. Fischer.
4. *Bactroptyxis trachaea* (Desl.) Poix, Bathonian supérieur, coll. Peron.
5. *Bactroptyxis axonensis* (d'Orb.) Rumigny, Bathonian supérieur, coll. Fischer.
6. *Nerinea bacillus* d'Orb., Marquise, Bathonian, coll. d'Orbigny, collective number 2622.
7. *Nerinea implicata* d'Orb., Marquise, Bathonian, coll. d'Orbigny, collective number 2618.

Considering the degree of overlapping morphological variation shown to be present in the White Limestone (M. Bathonian) populations and 1 Clypeus Grit (U. Bajocian) population, the present author believes that the genus *Bactroptyxis* has been extensively and erroneously 'oversplit'. Nevertheless, using the criteria of distinctive internal folding and/or distinctive external morphology, several 'species' categories can be readily identified which are retained here and these are briefly summarised below.

B6/ 1. *Bactroptyxis cotteswoldiae* (Lycett 1857) = subjective synonym *Nerinea conica* Witchell 1887.

Internal cross-section of whorl cavity is unmistakeable in having three columellar folds. Fold diagnosis 3.1.2.0. See Figure 2.8. Age; Bajocian, mainly Murchisonae Zone; abundant in the Pea Grit and Oolite Marl of the Cotswolds and especially throughout the Lower Lincolnshire Limestone.

Bb/2. Bactroptyxis xenos (Hudleston 1890).

Whorls very high in relation to width; spire extremely acicular. Internal section very elongate with folds simple. Fold diagnosis 2.1.2.0. See Figure 2.8. Age; Bajocian, base of Murchisonae Zone; - Haugi Subzone; uncommon, from the shell bed below the Lower Limestone at Cleeve Hill (Hudleston, op. cit., p. 216).

Bb/3. Bactroptyxis guisei (Witchell 1880).

A very distinctive species in which the whorls are extremely concave with bulging, rounded sutures. Whorls very high in relation to width. The figures of Hudleston (op. cit., pl. XV, fig. 1a - c) are reasonably accurate. The internal section has the fold diagnosis 2.1.2.0. but the folds, especially the columellar ones are very poorly developed. See Figure 2.8. Age; recorded from the Upper Bajocian - mainly confined to the Clypeus Grit (see Hudleston, op. cit., for localities) although the present author has collected this species from the Lower Lincolnshire Limestone (Discites Zone) at Castle Bytham (SK 9918) - bed 3 of Kent, in Sylvester-Bradley and Ford, 1968, p. 223.

Bb/4. Bactroptyxis campana (Hudleston 1890).

This species has the appearance of a compressed guisei, the whorls being much shorter with respect to their width. The internal section given by Hudleston (1890-96, pl. XV, fig. 2b) is certainly inaccurate. The type-specimens (J 7829-32: Sedgwick Museum, Cambridge) show no clear internal section. However, the very distinctive external morphology serves to distinguish this species. Age; Bajocian - Lower Lincolnshire Limestone at Blemisthorpe ?Discites Zone.

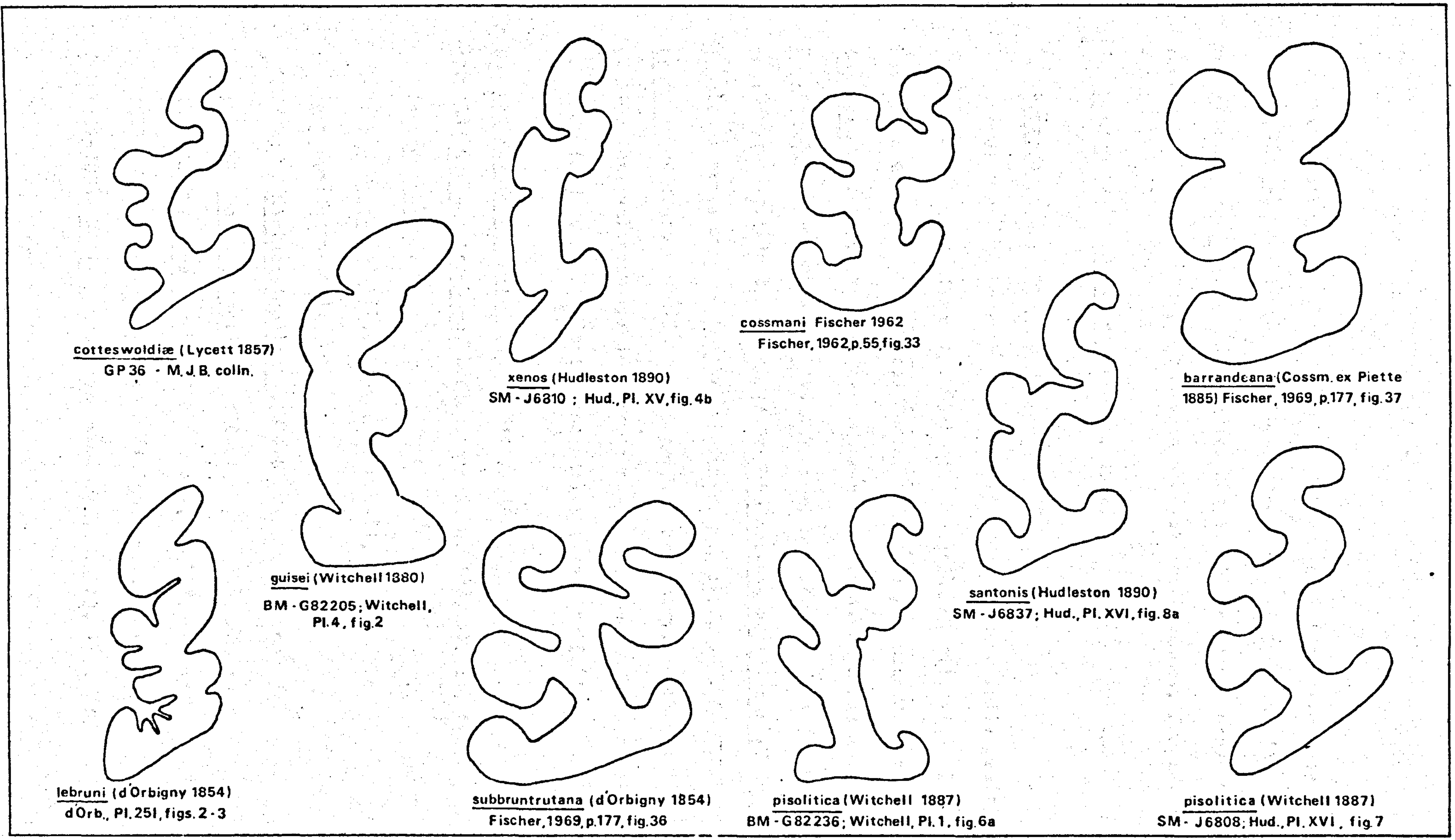
Bb/5. Bactroptyxis lebruni (d'Orbigny, 1854).

The holotype of this French Upper Bajocian species came from Crépey S.W. of Nancy, Moselle and, according to both Cossmann (1898, p. 140) and Dietrich (1925, p. 38), the type has been lost. Consequently, Cossmann (*op. cit.*, p. 140) designated a very poorly preserved neotype (*op. cit.*, pl. X, fig. 16) from Frouard (Gaiffe collection). Externally the neotype of Bactroptyxis lebruni is apparently indistinguishable from many other Bactroptyxis spp. in that the spire is acicular with numerous smooth, almost flat whorls. The only figured internal section known to the present author is that of d'Orbigny (1851-60, pl. 251, figs. 2-3) which appears very distinct and on this basis B. lebruni is provisionally regarded as a valid species (see Figure 2.8).

Bb/6. Bactroptyxis barrandeana (Cossmann ex. Piette, 1885).

1885 Nerinea barrandeana, Piette, p. 1113 (insuffisament caractérisé).
1885 Nerinaea barrandeana, Cossmann ex. Piette, p. 205, pl. XVII, fig. 48.
1898 Nerinella barrandei, Cossmann, p. 96, pl. VIII, fig. 41.
1969 Bactroptyxis barrandeana Fischer, p. 178, fig. 37, pl. XVIII, figs. 6-8.

The true generic affinities of this species remained unknown until Fischer (*op. cit.*) sectioned a number of specimens which showed a typical Bactroptyxis internal structure. The fold diagnosis is 2.1.2.0; the folds being either simple or bi-angular producing an internal structure unlike that of any other described Bactroptyxis sp. (see Figure 2.8).



cotteswoldiæ (Lycett 1857)
GP 36 - M.J.B. colln.

guisei (Witchell 1880)
BM - G82205; Witchell, Pl. 4, fig. 2

xenos (Hudleston 1890)
SM - J6810 ; Hud., Pl. XV, fig. 4b

cossmani Fischer 1962
Fischer, 1962, p. 55, fig. 33

barrandeana (Cossm. ex Piette 1885) Fischer, 1969, p. 177, fig. 37

santonis (Hudleston 1890)
SM - J6837; Hud., Pl. XVI, fig. 8a

lebruni (d'Orbigny 1854)
d'Orb., Pl. 251, figs. 2-3

subbruntrutana (d'Orbigny 1854)
Fischer, 1969, p. 177, fig. 36

pisolitica (Witchell 1887)
BM - G82236; Witchell, Pl. 1, fig. 6a

pisolitica (Witchell 1887)
SM - J6808; Hud., Pl. XVI, fig. 7

Fig. 2.8. Fold morphology of 'valid' Bajocian and Bathonian species of Bactroptyxis.

Externally, the apical angle is rather large (approximately 10°) and the concave whorls are very low. According to Cossmann (*op. cit.*) and Fischer (*op. cit.*), this species has a well developed ornament of four spiral lirae. Age; Upper Bathonian of the Ardennes, France.

Bb/7. *Bactroptyxis cossmanni* Fischer, 1962.

Bb/8. *Bactroptyxis subbruntrutana* (d'Orbigny, 1854).

The distinction between these two species has been fully dealt with elsewhere (Fischer, 1964, pp. 55-6, figs. 33-34, pl. II, figs. 23-29). Both species have large apical angles (12°-15°) and according to Fischer (*op. cit.*, p. 55), they are distinguished by their external morphologies. *B. cossmanni* has convex whorls, a rounded periphery and is "exterieurement très difficile à distinquer de *Fibuloptyxis bucillyensis*" (= subjective synonym of *F. witchelli*) (Fischer, *op. cit.*, p. 55). *B. subbruntrutana* has concave whorls and an angular periphery. Both species have similar internal sections in which the very pronounced bi-angular parietal fold is particularly distinctive (see Fig. 2.8).

Bb/9. *Bactroptyxis implicata* (d'Orbigny, 1854).

(?) 1842 *Nerinea trachaea*, Deslongchamps, p. 188, pl. 11, figs. 3-4, (*nomen dubium*).

1843 *Nerinea voltzii*, d'Archiac, p. 381, pl. 30, fig. 5, (*non* Deslongchamps).

1849/50 *Nerinea implicata*, d'Orbigny, p. 298, no. 35.

1849-50 *Nerinea bacillus*, d'Orbigny, p. 298, no. 36.

1849/50 *Nerinea trachaea*, d'Orbigny, p. 298, no. 40.

1849/50 *Nerinea axonensis*, d'Orbigny, p. 299, no. 45.

(?) 1851-1856 *Nerinea trachaea*, Woodward, p. 129, fig. 79.

*V. 1854 *Nerinea implicata*, d'Orbigny, p. 82, pl. 251, figs. 4-7.

V. 1854 *Nerinea bacillus*, d'Orbigny, p. 84, pl. 252, figs. 3-6.

1854 *Nerinea trachaea*, d'Orbigny, p. 89, pl. 253, figs. 7-8.

. 1854 *Nerinea axonensis*, d'Orbigny, p. 92, pl. 253, figs. 12-15.

1854 *Nerinea rayana*, Cotteau, p. 20.

. 1855 *Nerinea axonensis*, Piette, p. 1098, and p. 1118.

1855 *Nerinea Simonis*, Piette, p. 1114.

V*. 1857 *Nerinea Jonesii*, Lycett, p. 124, pl. 2, fig. 4.

V*. 1857 *Nerinea Oppelensis*, Lycett, p. 123, pl. 2, fig. 6.

1867 *Nerinea bacillus*, Laube, p. 21.

1885 *Nerinea* (*Ptygmatis*) *implicata*, Cossmann, p. 196, pl. 1, fig. 23-24.

1885 *Nerinea* (*Ptygmatis*) *bacillus*, Cossmann, p. 196, pl. 1, figs. 25-26 and pl. XI, fig. 18.

. 1885 *Nerinea* (*Ptygmatis*) *axonensis*, Cossmann, p. 198, pl. 9, figs. 1-2.

1885 *Nerinea* (*Ptygmatis*) *trachaea*, Cossmann, p. 199.

V*. 1886 *Nerinaea complicata*, Witchell, p. 272-3, pl. 4, fig. 2.

1886 *Nerinella* (*Bactroptyxis*) *implicata*, Cossmann, p. 39-40, pl. III, figs. 13-14.

. 1886 *Nerinella* (*Bactroptyxis*) *Jonesii*, Cossmann, p. 40.

. 1886 *Nerinella* (*Bactroptyxis*) *producta*, Cossmann, p. 40.

. 1886 *Nerinella* (*Bactroptyxis*) *Oppelensis*, Cossmann, p. 40.

1886 *Nerinella* (*Bactroptyxis*) *bacillus*, Cossmann, p. 40.

1886 *Nerinella* (*Bactroptyxis*) *trachaea*, Cossmann, p. 40.

. 1886 *Nerinella* (*Bactroptyxis*) *axonensis*, Cossmann, p. 40.

. 1886 *Nerinella* (*Bactroptyxis*) *complicata*, Cossmann, p. 40.

V. 1887 *Nerinaea Oppelensis*, Witchell, p. 31, pl. I, fig. 5.

V*. 1887 _Nerinaea_ _stroudiensis_, Witchell, p. 33, pl. I, fig. 9.

V*. 1887 _Nerinaea_ _consobrina_, Witchell, p. 33, pl. I, fig. 10.

V*. 1887 _Nerinaea_ _producta_, Witchell, p. 34, pl. I, fig. 13.

V*. 1887 _Nerinaea_ _velox_, Witchell, p. 34, pl. II, fig. 3.

. 1887 _Nerinaea_ _Jonesii_, Witchell, p. 25.

1888 _Ptygmatis_ _axonensis_, Schlippe, p. 190.

V. 1890 _Nerinaea_ (_Ptygmatis_) _bacillus_, Hudleston, pp. 217-8, pl. XV, figs. 5-7, pl. XVI, fig. 12.

V. 1890 _Nerinaea_ (_Ptygmatis_) _bacillus_ var. _carnicotensis_, pl. XV, fig. 5a and b.

V. 1890 _Nerinaea_ (_Ptygmatis_) _bacillus_ var. _cervicula_ (_pars_.), pl. XV, fig. 6a - c.

V. 1890 _Nerinaea_ (_Ptygmatis_) _bacillus_ var. _crassicincta_, pl. XV, fig. 7a.

V. 1890 _Nerinaea_ (_Ptygmatis_) _Jonesii_, Hudleston, pp. 218-9, pl. XV, fig. 9.

V. 1890 _Nerinaea_ (_Ptygmatis_) _Oppelensis_, Hudleston, pp. 219-20, pl. XV, fig. 11.

V. 1890 _Nerinaea_ (_Ptygmatis_) _producta_, Hudleston, pp. 220-21, pl. XV, fig. 10.

. 1890 _Nerinaea_ (_Ptygmatis_) _consobrina_, Hudleston, p. 221.

V. 1890 _Nerinaea_ (_Ptygmatis_) _velox_, Hudleston, p. 221, pl. XVI, fig. 1.

V. 1890 _Nerinaea_ (_Ptygmatis_) _stroudiensis_, Hudleston, p. 222, pl. XVI, fig. 2.

V*. 1890 _Nerinaea_ (_Ptygmatis_) _brevivoluta_, Hudleston, pp. 225-6, pl. XVI, figs. 9-10.

V*. 1890 _Nerinaea_ (_Ptygmatis_) _subbrevivoluta_, Hudleston, p. 226, pl. XVI, fig. 11.

. 1898 *Bactroptyxis jonesii*, Cossmann, p. 141, pl. X, figs. 23-24.

1898 *Bactroptyxis bacillus*, Cossmann, pp. 141-2, pl. X, figs. 19-21.

1898 *Bactroptyxis bacillus* var. *michaleti*, Cossmann, pp. 141-2, pl. X, fig. 22.

1898 *Bactroptyxis implicata*, Cossmann, pp. 142-3, pl. X, figs. 25-28.

. 1898 *Bactroptyxis axonensis*, Cossmann, pp. 143-4, pl. XI, figs. 1-2.

1898 *Bactroptyxis trachaea*, Cossmann, p. 145.

. 1898 *Bactroptyxis brevivoluta*, Cossmann, p. 168.

. 1898 *Bactroptyxis complicata*, Cossmann, p. 168.

. 1898 *Bactroptyxis consobrina*, Cossmann, p. 168.

. 1898 *Bactroptyxis oppelensis*, Cossmann, p. 172.

. 1898 *Bactroptyxis producta*, Cossmann, p. 174.

. 1898 *Bactroptyxis subbrevivoluta*, Cossmann, p. 174.

. 1898 *Bactroptyxis stroudiensis*, Cossmann, p. 174.

. 1898 *Bactroptyxis velox*, Cossmann, p. 175.

. 1925 *Bactroptyxis axonensis*, Dietrich, p. 36.

1925 *Bactroptyxis bacillus*, Dietrich, p. 36.

. . 1925 *Bactroptyxis brevivoluta*, Dietrich, p. 36.

. 1925 *Bactroptyxis complicata*, Dietrich, p. 37.

. 1925 *Bactroptyxis consobrina*, Dietrich, p. 37.

1925 *Bactroptyxis implicata*, Dietrich, p. 37.

. 1925 *Bactroptyxis jonesii*, Dietrich, p. 38.

. 1925 *Bactroptyxis oppelensis*, Dietrich, p. 38.

. 1925 *Bactroptyxis producta*, Dietrich, p. 38.

1925 *Bactroptyxis simonis*, Dietrich, p. 39.

. 1925 *Bactroptyxis stroudiensis*, Dietrich, p. 39.

. 1925 *Bactroptyxis subbrevivoluta*, Dietrich, p. 39.
1925 *Bactroptyxis trachaea*, Dietrich, p. 40.
. 1925 *Bactroptyxis velox*, Dietrich, p. 40.
V. 1931 *Ptygmatis (Bactroptyxis) bacillus*, Arkell, p. 620, pl. XLIX, fig. 13.
V. 1947 *Ptygmatis (Bactroptyxis) bacillus*, Arkell, p. 43, fig. 5, no. 2.
V. 1950 *Bactroptyxis bacillus*, Cox and Arkell, p. 79.
V. 1969 *Bactroptyxis axonensis*, Fischer, pp. 177-8, fig. 38.
V. 1969 *Bactroptyxis trachaea*, Fischer, pp. 178-9, fig. 39.

Discussion

In view of the rather drastic changes in taxonomy proposed by re-defining *B. implicata*, a more or less complete synonymy has been given for this species.

French examples

The earliest available name for this species as defined by the present author, is apparently *N. trachaea*, Deslongchamps, 1842. However, the original description of Deslongchamps (1842, p. 185) was too generalised for subsequent use and the figures of *N. trachaea* (Deslongchamps, 1842, pl. XI, figs. 3-4: not pl. IX, figs. 2-3 as given in the text, p. 188) are poorly drawn fragments of an internal mould. Furthermore, the cross-section is not comparable with that of any other figured *Bactroptyxis* sp. Evidently Cossmann (1898) agreed that *N. trachaea* Deslongchamps was inadequately diagnosed and remarks (p. 145) "Si réellement il s'agit bien de la mème espèce, - et je suis teuté de la croire, - il est impossible de substituer *trachaea* à *implicata*, quoique ce soit une dénomination antérieure, attendu qu'elle est trop imparfaitement caractérisée pour remplacer une diagnose aussi précise que celle de N. implicata d'Orb." Furthermore, as noted by Cossmann (op. cit., p. 145) the only other figure of N. trachaea is that given by Woodward (1851-1856, p. 129, fig. 79) which is also poorly drawn and quite unsatisfactory.

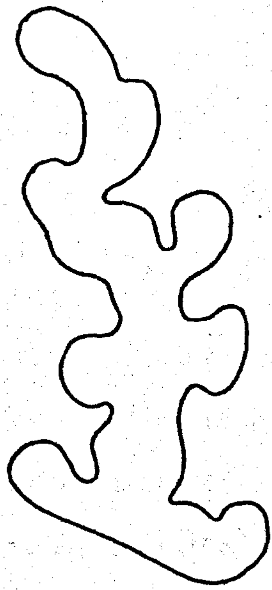
The holotype, and only specimen according to Delongchamps (op. cit.), is now presumed to be lost along with most of the Deslongchamps collection (Cossmann, 1896, p. 26) and no other specimen is available from the same locality to act as a neotype (see Cossmann, 1898, p. 145). Consequently the present author considers that as

a) the holotype of N. trachaea is unavailable for study
b) no neotype has been designated
c) the original descriptions and figures of Deslongchamps (op. cit.) are inadequate, N. trachaea should be regarded as a nomen dubium.

The next available and interpretable name (N. implicata d'Orb.) should therefore be used for this taxon. Presumably, Cossmann's doubts about the identity of N. trachaea were at least partially responsible for his designation of N. implicata as the type-species of Bactroptyxis (Cossmann, 1896, p. 39). However, subsequently the species name trachaea has been retained by Fischer, (1969, p. 178).

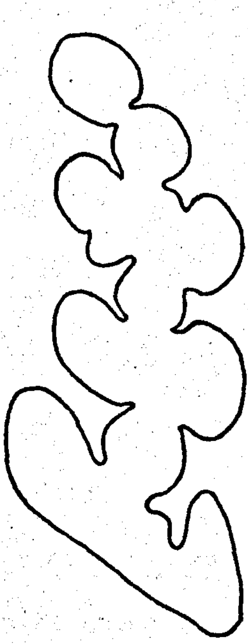
In his revision of the fauna from the Bathonian strata south-west of the Ardennes, Fischer (op. cit.) proposed that B. implicata (d'Orb.) and B. bacillus (d'Orb.) are subjective synonyms on the basis that (p.178) "...l'examen de nombreux lots montre que l'évidement des tours peut subir des variations graduelles chez une même population et par fois sur un même individu,..." and that "... la valeur de l'angle sutural peut varier indifférement de 13° à 18°, sans aucune relation constante avec l'évidement des tours." Fischer concluded that (op. cit., p. 178), "Il n'y a donc pas lieu de distinguer deux espèces et il serait même abusif de les considérer au rang de variétés." These conclusions were based upon external shell morphology. Evidently Fischer (op. cit.) did not examine the variation in fold morphologies, although he did consider that (p. 178) "chacun de ces plis peut êntre bi- ou tri-anguleux;". On the basis of the d'Orbigny material made available to the present author (see previously) and the variation studies outlined earlier, the unification of B. implicata and B. bacillus seems to be justified.

The present author believes that the range of variation found in B. implicata is sufficiently large to also encompass those specimens described by d'Orbigny and subsequent authors as B. axonensis. Cossmann (1898, pp. 143-4, pl. XI, figs. 1-2) and Fischer (1969, pp. 177-8, fig. 38) have both described various aspects of B. axonensis. Cossmann (op. cit.) only considered the external shell morphology and concluded that B. axonensis could be distinguished from B. bacillus only on the basis of the slightly larger apical angle of the former. A neotype was designated by Cossmann (op. cit., pl. XI, fig. 2) presumably because the holotype was unavailable, but neither the neotype nor the associated specimen of B. axonensis figured by Cossmann (pl. XI, fig. 1) have apical angles outside the range observed in the B. implicata samples examined by the present author (see previously). Indeed, the variation in external shell morphology of those specimens identified and collected by Fischer as B. axonensis from the Bathonian of Rumigny, France, can be



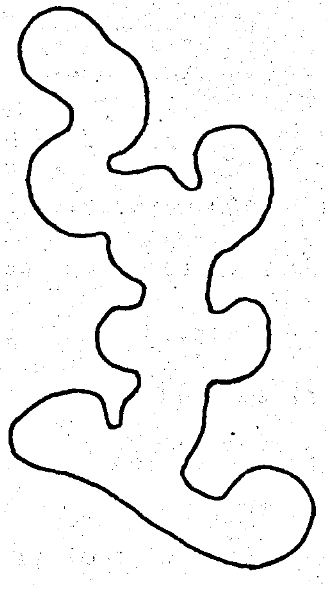
bacillus d'Orb. 1854

Spec. 2622 d'Orbigny colln.
Bath. sup., Marquise.



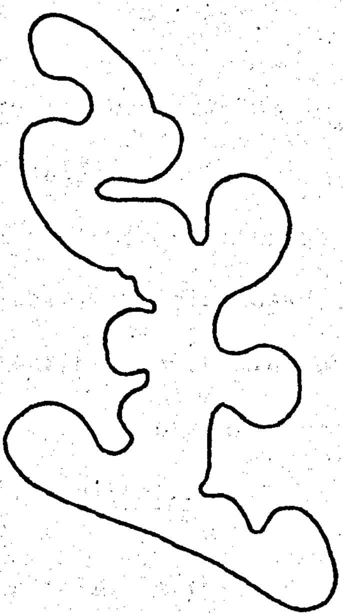
implicata d'Orb. 1854

figd. d'Orbigny, 1854, pl. 251,
fig. 7.



trachaea Desl. 1843

Spec. 5K, Peron colln.
Bath. sup., Poix, Ardennes.



axoniensis d'Orb. 1854

Spec. 1Q, J.-C. Fischer colln.
Bath. sup., Rumigny, Ardennes.

Fig. 2.9. Fold morphologies of French subjective synonyms of *B. implicata*.

matched amongst specimens identified (and in part collected) by Fischer as *B. implicata* (le Mesle collection, Pas de Calais and Fischer collection, Rumigny) (See Plates 2.S and 2.T).

As noted by Fischer (*op. cit.*, p. 177) "Il est nécessaire de figuer à nouveau line coupe longitudinale, la seule publiée jusqu'alors, par d'Archiac, étaut trop schématique," and the section given (fig. 38) shows that the internal fold morphology of *B. axonensis* is encompassed within the range of the British samples shown in Figs. 2.3 to 2.7. This was confirmed by the examination of specimens of *B. axonensis* sent to the present author by Fischer (see previously). The internal fold morphology of the several French *Bactroptyxis* spp. examined by the present author and considered subjective synonyms of *B. implicata* are shown in Figure 2.9.

British examples

The numerous Bajocian species of *Bactroptyxis* were originally described by Lycett (1857), Witchell (1886 and 1887) and Hudleston (1890). Having examined as much type-material of these species as could be located, the present author considers that they were diagnosed on the basis of inadequate samples ans that no practical taxonomic subdivision of these species is possible or needed. They are all therefore here regarded as subjective synonyms of *B. implicata*.

The various internal configurations of the folds in these British Bajocian *Bactroptyxis* 'species' are shown in Figure 2.10. Where possible, the internal sections have been drawn from the original type-material, as described below.

oppelensis Lycett 1857.

Of the two Lycett syntypes from Selsey Hill, one (G.S.M. 112690) is not sectioned and in the other (G.S.M. 112691) the section is not axial. Therefore a cross-section of the whorl cavity from specimen G 16304 (Topotype from Selsey, Witchell collection; British Museum, Natural History) which was figured by Witchell (1887, pl. 1, fig. 3a) is shown in Figure 2.10.

jonesii Lycett 1857.

Neither the holotype, G.S.M. 8089, nor the paratype, G.S.M. 41447, of this Lycett species have been sectioned. At present, no sectioned specimen appears available for comparison. The type-material was obtained from the Lr. Freestone (Murchisonae Subzone) at Nailsworth.

consobrina Witchell 1887.

A section of the whorl cavity from the figured syntype of Witchell (B.M.N.H. - G. 16301; 1887, pl. 1, fig. 10a) is shown in Figure 2.10 together with another example, from the Witchell collection, B.M.N.H. - G. 82229. The type-specimens were collected from the Pisolite (? = Pea Grit) at Longfords nr. Nailsworth.

complicata Witchell 1886.

Witchell's syntype (B.M.N.H. - G. 16250; 1886, pl. IV, fig. 2a) was collected at Tiltups End (Retrocostatum Zone - Bathonian) and is shown in Figure 2.10.

velox Witchell 1887.

The type-specimens on which Witchell based this species were borrowed from Hudleston who collected them from the Oolite Marl (Bradfordensis Subzone) at Swifts Hill and Longridge. Figure 2.10 shows an internal section of the whorl cavity from the specimen figured by Hudleston (1890, pl. XVI, fig. 1) as Ptygmatis velox. (S.M. - J 6826).

stroudiensis Witchell 1887.

Witchell (1887, p. 33, pl. 1, fig. 9) did not figure a section of this species. However, the Witchell collection contains a sectioned specimen (? a para type; B.M.N.H. - G 82244).which is shown in Figure 2.10. This species is recorded by Witchell (op. cit.) from the 'marly limestone' (? = Oolite Marl) of Swifts Hill.

producta Witchell 1887.

The internal section shown in Figure 2.10 is that of Witchell's syntype, B.M.N.H. - G 822113 (Witchell, 1887, p. 34, fig. 13a). Another example from the Hudleston collection (figured in Hudleston, op. cit., pl. XV, fig. 10a) is also shown (S.M. - J 6824). The known specimens are from the Pea Grit (Murchisonae Subzone) at Longfords, nr. Nailsworth.

brevivoluta Hudleston 1890.

Three internal sections are shown in Figure 2.10; the figured specimen of Hudleston (1890, pl. XVI, fig. 9b; S.M. J 6839) together with specimens S.M. J 7924 and J 7921) Hudleston collection, Sedgwick Museum, Cambridge).

Comparison of Figure 2.10 with Figures 2.4 - 2.8 and 2.9 suggests that no practical subdivision based upon internal fold morphology is possible. Evidently Hudleston (op. cit.) at least partially agreed for in several statements he concludes;

(p. 222) "Internally all three (i.e. *oppelensis*, *velox* and *stroudiensis* are closely related and some might be disposed to regard them as varieties of one species".

(p. 221) "He (Witchell) says that it (i.e. *consobrina*) differs very little in its internal structure from *N. oppelensis*,".

and (p. 220) "The section of *Ptyg. oppelensis* differs in no material respect from the sections of *Ptyg. bacillus*".

In those museum specimens which are both well-preserved and *complete*, it is noticeable that the shells of specimens identified as *oppelensis*, *jonesii*, *consobrina*, *velox* and *stroudiensis* are dimorphic. The whorls of the apical part of the shell have concave walls, but the concavity disappears aperturally and the lower whorls of these shells are flat or only slightly concave, thus being *totally indistinguisable* from *implicata*, *bacillus*, *producta*, etc. which do not exhibit this dimorphism. The taxonomic significance of this feature is difficult to assess. Since the vast majority of *Bactroptyxis* specimens are incomplete and lack the apical part of the shell, this feature is unlikely to be of any practical value. In the light of the studies undertaken so far, it would probably be best to regard those specimens of *B. implicata* with markedly concave apical whorls as a subspecies - *oppelensis*.

Until further specimens are available it is also suggested that the larger apical angles (12^{o}-14^{o}) of *brevivoluta* Hudleston (inc. *subbrevivoluta*) sufficiently distinguish these specimens to warrant a subspecific name - *brevivoluta*. They are otherwise indistinguishable

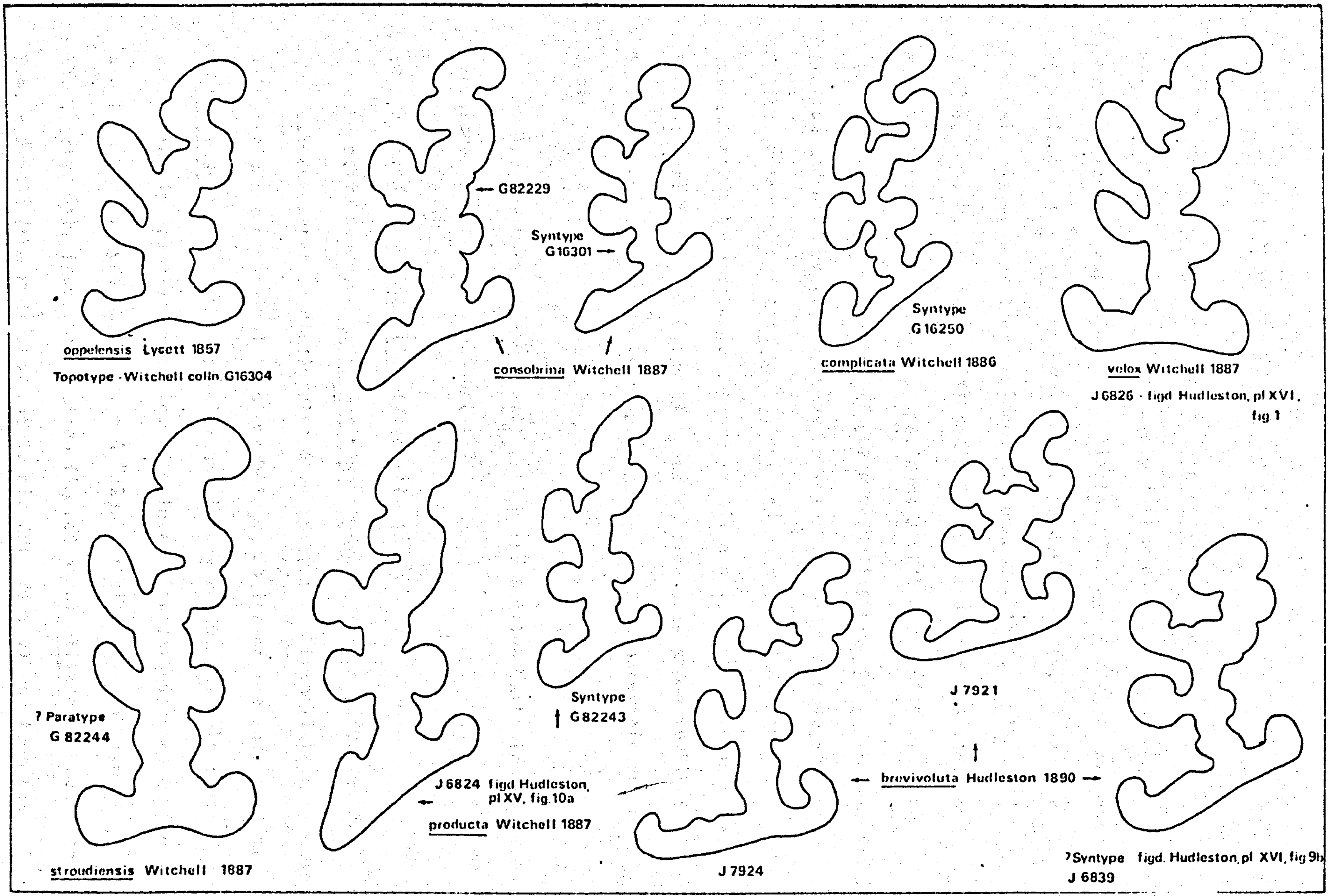


Fig. 2.10. The fold morphologies of British subjective synonyms of *B. implicata*.

from other members of the B. implicata group.

The B. bacillus varieties carnicotensis (Hudleston) and crassicincta (Hudleston) undoubtedly fall within the range of morphological variation of B. implicata. The other variety proposed by Hudleston (op. cit.) B. bacillus var. cervicula is, in part, rather unusual. Several of the specimens are undoubtedly B. implicata (e.g. J 6816, J 7848; Crickley Hill and J 7849; Birdlip - all Sedgwick Museum, Cambridge). However, specimens J 6814 and J 6815 from the Upper Lincolnshire Limestone (figured by Hudleston, op. cit., pl. XV, fig. 6a and b respectively) show an internal fold morphology intermediate between implicata and guisei and an external morphology characterised by extremely concave whorls and very acicular spires. The internal fold morphology of these specimens is shown in Figure 2.11. Their taxonomic position is at present regarded as uncertain and must await further study of Bajocian forms.

The distribution of B. implicata in the British Bathonian White Limestone is discussed in Chapter 1.

36/10. Bactroptyxis pisolitica (Witchell 1887).

(= subjective synonym Ptygmatis santonis Hudleston 1890, p. 224). Two features serve to distinguish this species. The shell is remarkably acicular and the internal fold morphology, whilst of the same plan as B. implicata, never shows complex ancilliary folds, the main folds always remain relatively simple. The internal sections shown in Fig.2.8 are from the syntype, B.M.N.H. - G 82236, of pisolitica (Witchell, 1887, pl. 1, fig. 6a), from the specimen figured as pisolitica by Hudleston, S.M. - J 6808 (see Hudleston, 1890, pl. XVI, fig. 7) and from the figured syntype of santonis S.M. - J 6837 (Hudleston, 1890, pl. XVI, fig. 8a).

Age: Lower Bajocian, Murchisonae Zone (Oolite Marl and Pea Grit).

The stratigraphic distribution of B. implicata in the White Limestone has been discussed in Chapter 1. Within the area studied, this species is confined to the Retrocostatum Zone. However to the south-west of the White Limestone, B. implicata evidently ranges into the stratigraphically higher Aspidoides Zone since Green and Donovan (1969, pp. 32-33) reliably record this species from the Upper Rags of the Great Oolite in the Corsham railway cutting.

Variation in external morphology of specimens identified

as *B. axonensis* by J.-C. Fischer

Specimen 1f

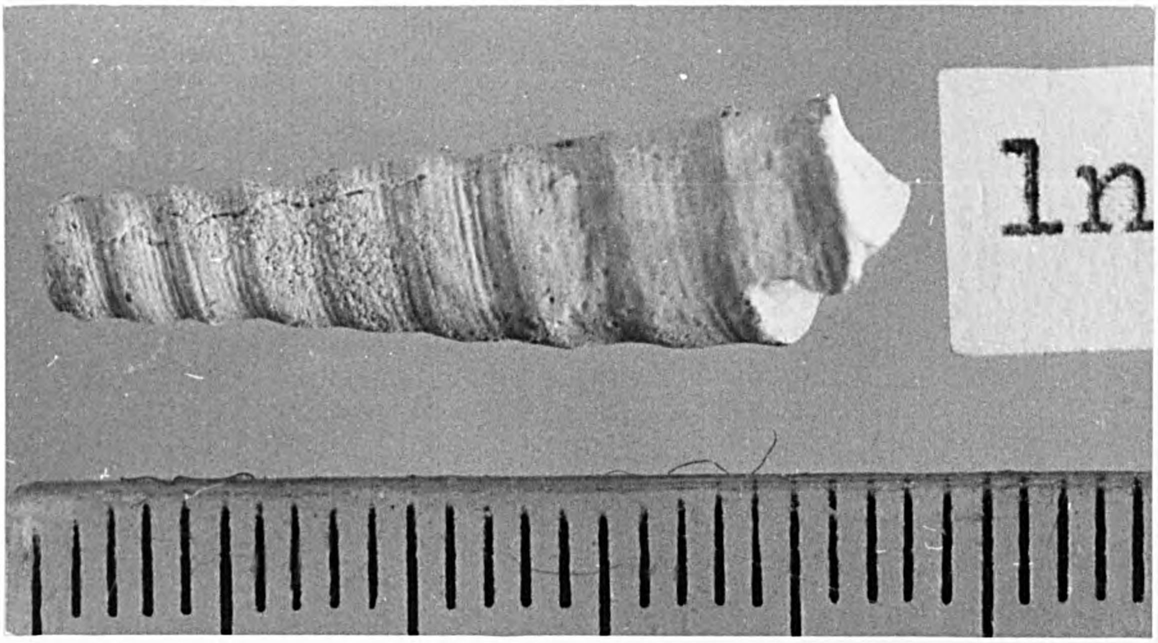
Specimen 1c

Specimen 1n

J.-C. Fischer colln., Bathonian, Rumigny, France.

All specimens coated with NH_4Cl.

Plate 2.S.


1n


MM

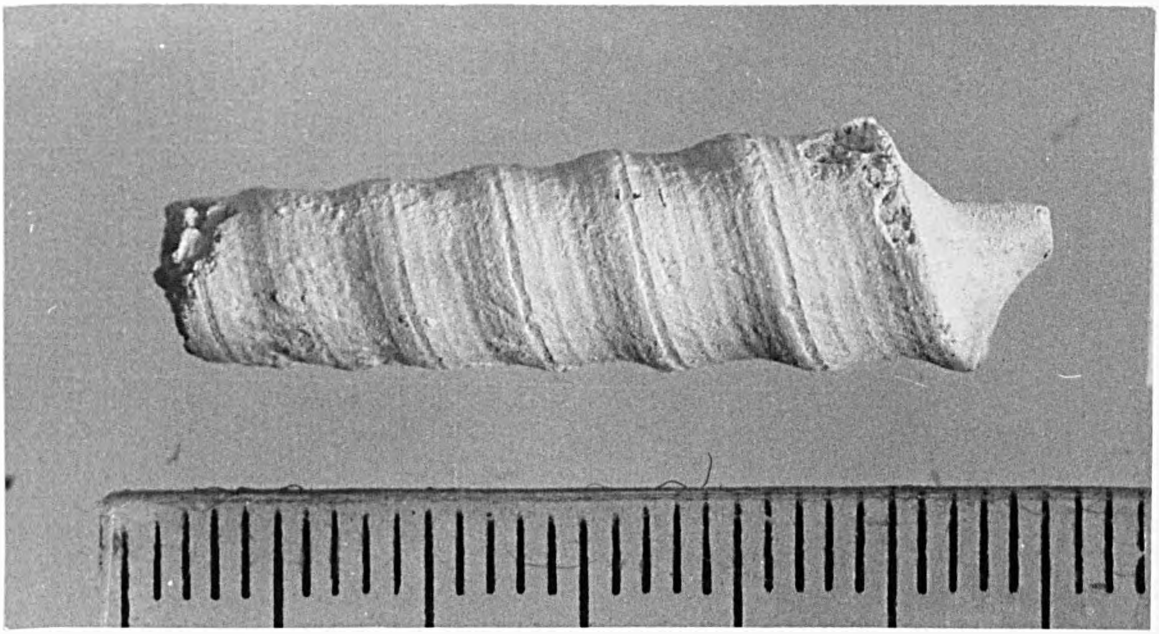

MM

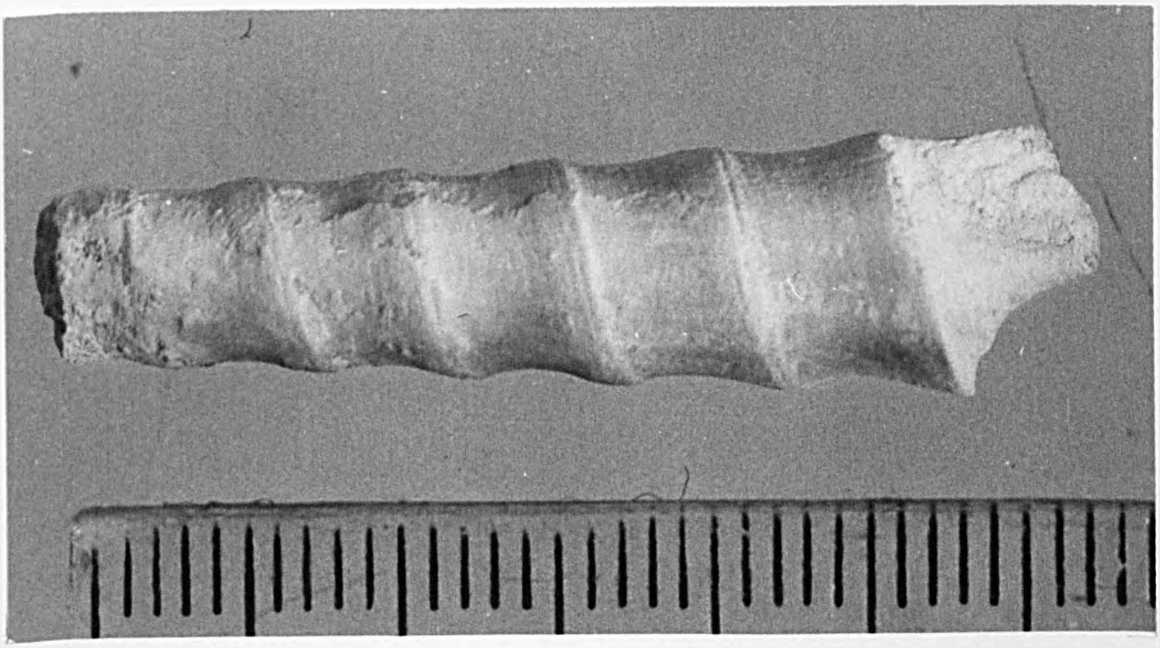
Variation in external morphology of specimens identified as *B. implicata*

Specimen 3a	Specimen 4b	Specimen 3b
Bath. sup.	Bath. sup.	Bath. sup.
Talus de la Gimpette Rumigny, Ardennes	Les Pichottes, Pas de Calais	Talus de la Gimpette Rumigny, Ardennes
J.-C. Fischer colln.	G. le Mesle colln.	J.-C. Fischer colln.

All specimens coated with NH_4Cl.

Plate 2.T.





B7 Genus *Fibuloptyxis* Cossmann 1898

Type-species *Fibuloptyxis umbicilifera* (Piette 1855)

Discussion

Apart from a brief mention by the present author in the International Field Symposium on the British Jurassic,1969 - Excursion Guides, Excursions from London (ed. Torrens, 1969), this is the first discussion of the genus *Fibuloptyxis* in England.

The type-species *'N'*. *umbicilifera* Piette (1855) together with *N*. *voltzii* Deslongchamps (1842) were placed by Cossmann (1898, pp. 66-67) in his 'section' *Melanioptyxis*, although the presence of an umbilicus in these two species led him to observe (*op*. *cit*., p. 66), "Cette espèce, ainsi que la suivanle forment évidemment un groupe à part; mais l'état de conservation des individues que j'en connais n'est pas assez satisfaisant pour qu'on piusse les prendre comme types d'une section nouvelle, à laquelle on pourrait peut-èntre ulterieurement attribeur le nom - *Fibuloptyxis* Cossm., 1898."

Both *Melanioptyxis* and *Fibuloptyxis* were designated 'sections' by Cossmann (*op*. *cit*.) and were considered infra-subgeneric in their taxonomic status, both being placed in the subgenus *Nerinea* (*Nerinea*). Wenz (1940) ranked *Fibuloptyxis* (along with *Melanioptyxis*, *Diozoptyxis*, *Ptygmatis*, etc.) as a subgenus of *Nerinea* and gave the first formal diagnosis (Wenz, *op*. *cit*., p. 821). Later, Fischer (1960, 1964, 1969) described three new species of *Fibuloptyxis* (which he then gave full generic status) and gave their distribution in the Bathonian of France. Pchelintsev (1965) in discussing his new order, the Murchisoniata, had also created a new family, the Fibuloptyxisidae, belonging to the superfamily Nerineacea. Pchelintsev (*op. cit.*) included a familial diagnosis and placed only two genera, *Fibuloptyxis* and *Melanioptyxis* in the family, regarding them both as highly primitive; retaining most of the ancestral characters and having an external morphology characteristic of the superfamily Tubiferacea but with a Nerineacean internal morphology.'

However in the progressive taxonomic elevation of *Fibuloptyxis*, neither Fischer (*op. cit.*) nor Pchelintsev (*op. cit.*) gave a generic diagnosis for *Fibuloptyxis*. The lack of any diagnosis was previously recognised by Cox (Treatise M.S. ca. 1960-65) and in preparation for the projected Treatise on Invertebrate Palaeontology (vol. Gastropoda exc. Archaeogastropoda) he gave a diagnosis for the genus *Fibuloptyxis* in order to rectify the omission.

Prior to the preparation of his Treatise manuscript, Cox (1954) had created a new genus *Pseudotrochalia* (with *N. patella* Piette 1855, from the Bathonian of France as the type-species) and then believing *Fibuloptyxis* and *Pseudotrochalia* to be separate genera, included both in his Treatise manuscript.

The close similarity existing between *Fibuloptyxis* and *Pseudotrochalia* was first noticed by Fischer (1960, p. 209) who stated "A l'examen simultané de *Pseudotrochalia* et de *Fibuloptyxis*, il est permis de penser que ces deux genres sont assez voisins:". Fischer later concluded (1969, p. 179: - after the preparation of Cox's Treatise manuscript) that the two genera are subjectively synonymous, a decision with which the present author agrees. Therefore an emended generic diagnosis for *Fibuloptyxis* and a list of the known species is given below.

Genus *Fibuloptyxis* Cossmann 1898 (= subjective synonym *Pseudotrochalia* Cox 1954)

Type-species *Nerinea umbicilifera* Piette 1855.

Emended diagnosis herein

Rather stoutly conical to trochiform. Slightly cyrtoconoid in conical species to slightly coeloconoid in trochiform representatives. Whorls low, almost flat or feebly convex, smooth, the last evenly convex at periphery. Aperture rounded with indistinct siphonal outlet. Conspicuous umbilicus, often variably developed but always present. Folds 1, 0-1, 1, 0; the columellar and parietal folds frequently very weak.

Distribution Probably Upper Bathonian only in France and England.

Known species *F. umbicilifera* (Piette 1855)
F. quadrata (Fischer 1960)
F. elegans Fischer 1960
F. archiaciana (d'Orbigny 1850)
F. patella (Piette 1855)
F. excavata Fischer 1964
F. witchelli (Cox and Arkell 1950)

B7/1 *Fibuloptyxis witchelli* (Cox and Arkell 1950)

Synonymy

Vp *Nerinea voltzii*, Morris and Lycett, 1851, p. 32 (*partim*), pl. VII, Figs. 11, 11a (*non*. figs. 7, 7a) (*non* Deslongchamps).

V. *Nerinea voltzii*, Witchell, 1886, p. 275, pl. V, fig. 3, (*non* Deslongchamps).

Melanioptyxis altararis, Cossmann, 1900a, p. 546, pl. XV, figs. 6-8, (*non* Cossmann, 1885).

? *Nerinella fibula*, Cossmann, 1900a, p. 547, pl. XIV, figs. 2-3, (*non* Deslongchamps).

? *Nerinella* cf. *scalaris*, Cossmann, 1900a, p. 548, pl. XIV, fig. 9, (*non* d'Orbigny).

V* *Melanioptyxis witchelli*, Cox and Arkell, 1950, p. 77.

V. *Fibuloptyxis bucillyensis*, J.-C. Fischer, 1960, p. 206, figs. 21-25.

. *Fibuloptyxis bucillyensis*, J.-C. Fischer, 1964, p. 70, figs. 27-28.

. *Fibuloptyxis bucillyensis*, J.-C. Fischer, 1969, p. 180.

. *Fibuloptyxis* sp., Torrens (ed.), 1969, p. 12.

Of the seven recorded species of *Fibuloptyxis*, only *F. witchelli* has been found in England. Upon first finding this species the author sent a sectioned specimen to Dr. J.-C. Fischer (Institut de Paléontologie, Muséum National d'Histoire Naturelle, Paris) who replied (*pers. comm.* Nov. 1970), "J'ai comparé votre spécimen de *Fibuloptyxis* à ceux de ma collection, et je vous confirme qu'il s'agit bien d'un *F. bucillyensis* parfaitement typique". Subsequently examination of type material in the British Museum (Natural History) showed *Melanoptyxis witchelli* Cox and Arkell to be subjectively synonymous with *F. bucillyensis* Fischer. The mistake of Cox and Arkell (*op. cit.*) in placing this species in *Melanioptyxis* instead of *Fibuloptyxis* is understandable. Their work was based solely upon Museum collections and, for this species, mainly upon the Witchell collection. The specimens in the Witchell collection are frequently badly developed, often appearing 'hand-carved' and the representatives of this species are no exception. The only unequivocal criterion to distinguish *Melanioptyxis* from *Fibuloptyxis* is the presence or absence of an umbilicus as seen in a median longitudinal axial section. Within the Witchell collection, only one specimen (G 16403, labelled *N. voltzii* Deslongchamps, Gt. Oolite, Near Cirencester) has been sectioned. This specimen has, unfortunately, been overground and the section is not therefore a median axial section. No umbilicus is visible and this led Cox and Arkell (*op. cit.*) to consider the species imperforate and hence name it *Melanioptyxis witchelli*. After the examination and preparation of many specimens of this species in the present author's collection (collected from localities near to that from which the type-specimens came), there can be no doubt that the specimen (G 16403) originally possessed an umbilicus and that the species *M. witchelli* is exactly the same as that described by Fischer (*op. cit.*) as *F. bucillyensis*. The earlier name *witchelli* must therefore take precedence.

Fischer (1964) noted the variability in development of the umbilicus in his specimens of *F. witchelli* from the Bathonian of the Vallée de la Creuse (Indre). A similar variability from a very conspicuous umbilicus to one hardly visible is found in the specimens from the *Fibuloptyxis* bed, Foss Cross Quarry (Fig. 1.7, bed 7) - see plate 2.U. However, the umbilicus is *always* present and the differences between specimens are caused by variation in the amount of inductura (callus) deposited in the region of the inner-lip during growth. If this is slight, the umbilicus is conspicuous but excessive production of calcareous material can partially occlude the umbilicus and make it seem variable in size. A similar variation can be found in the modern gastropods *Gibbula umbilicalis*, *G. cineraria*, and *Monodonta lineata* (Prof. A. Graham, *pers. comm.*, Sept., 1971).

The British Museum (Natural History) and the Institute of Geological Sciences Museum contain large numbers of both *F. witchelli* and *M. altararis*, predominantly from the Minchinhampton quarries. Prior to the present author's examination, these specimens were either uncurated or all confused as *M. altararis*. The following criteria serve to distinguish the two distinct species;

1. Internal features seen in median axial sections,
   a) *F. witchelli* is always umbilicate.
   M. altararis never shows an umbilicus.
   b) The columellar and parietal folds are much fainter in *F. witchelli* than in *M. altararis*.
   c) The columellar fold is much lower (in an adapertural direction) on the whorl cavity section in *M. altararis* than in *F. witchelli*.

2. External featres,
   a) The base of *F. witchelli* appears swollen and heavier than in *M. altararis*.
   b) The last whorl in *F. witchelli* is broadly and evenly convex with no demarcation between the whorl sides and base, whereas *M. altararis* has a marked angulation between the whorl sides and the base of the shell. Consequently *M. altararis* has a more rhomboidal aperture than *F. witchelli*.

Morris and Lycett (1851, pp. 32-33) clearly failed to distinguish two species, naming both *N. voltzii* Deslongchamps. Of their two figures (pl. VII, figs. 11 and 11a), figure 11 is probably an external view of *M. altararis* and Figure 11a is a section of *F. witchelli* but, strangely, without the umbilicus which is readily apparent in the actual specimen (Institute of Geological Sciences Museum, No. - G.S.M. 8289).

Distribution

F. witchelli is abundant in the south-western part of the White Limestone outcrop and, to judge from Museum collections, it was formerly very abundant in the now largely inaccessible Minchinhampton facies.

Besides occurring at Minchinhampton, F. witchelli has also been found at Tiltups End near Nailsworth (Witchell, 1886, p. 275, pl. 5, fig. 3 - specimen G 16295; the holotype, and also G 16403; a topotype -both in the British Museum). The present author has also recorded the presence of this species at Foss Cross (Fig. 1.7, beds 7 and 10), Dagham Downs (Fig. 1.6, bed 7) and in the road-cutting at Jackaments Bottom, along the A433, near Rodmarton (G.R. - ST 965975). F. witchelli has also been found in the No. 4 borehole at Tetbury watermarks, 80 feet below the surface (Institute of Geological Sciences Museum, specimen Ba 405 - see also Richardson, 1919 and Pringle, 1929).

French localities are given by Fischer (1964, p. 52; 1969, p. 180).

The occurrence of F. witchelli at Tiltups End can be dated with some certainty (U. Bathonian, Retrocostatum Zone) since the holotype (G.S.M. 25620) of Bullatimorphites bullatimorphus S. Buckmann came from this small quarry section (Arkell and Donovan, 1952, p. 241; Arkell, 1951-58, p. 110 and Torrens, 1969, p. 64 and p. 67). A similar age can also be established for F. witchelli at Dagham Downs and Foss Cross where it occurs in the Upper Ardley Beds - Lower Bladon Beds (see Chapter 1). A specimen of Procerties subcongenor (Lissajous) was obtained from the Tetbury borehole at a depth of 255 feet from the surface (Arkell, 1951-58, p. 197). This possibly represents the Progracilis zone since the top of the Bajocian was recorded at 261' (Arkell, op. cit., p. 197) and the occurrence of F. witchelli 175 feet higher in the succession could easily be in the Retrocostatum zone.

Thus all available evidence indicates that in the White Limestone, F. witchelli is found only in the Retrocostatum Zone and apparently constitutes a reliable stratigraphic index species. However, it is of only limited application in England due to its restricted geographical distribution, being confined to the Minchinhampton facies and peripheral White Limestone to the south and east of this.

As with most other gastropods, the stratigraphic value of this species in the French Bathonian has not yet been ascertained.

B8/1 Melanioptyxis altararis (Cossmann 1885) Plate 2.V.

Synonymy see Cox and Arkell (1950, p. 77).

Discussion

The widespread previous confusion of F. witchelli with M. altararis has been discussed in the previous section dealing with F. witchelli.

Distribution

This species was abundant in the former Minchinhampton Quarries but has not otherwise been recorded from the White Limestone or any other horizon. Outside of Minchinhampton, its occurrence is sporadic, seemingly not conforming to the faunal gradients and facies control seen in the geographical distribution of F. witchelli, B. implicata, Aphanoptyxis spp. and other organisms.

M. altararis has been found in the Hampen Marly Beds at Danes Hill (wrongly recorded as C. eudesii - by Torrens, in Sylvester-Bradley and

Ford, 1968, p. 254, bed 10). The present author has also found this species at Dagham Downs (Fig. 1.6, bed 12), Foss Cross (Fig. 1.7, beds 7 and 10) and Ardley Fields (Fig. 1.18, bed 34). The stratigraphic range is Progracilis Zone (Hampen Marly Beds) to Retrocostatum zone (Upper Ardley Beds and Lower Bladon Beds, of the White Limestone). For further details see Chaper 1.

Variation in umbilical diameter in *F. witchelli*

Specimen FXFB/37d

Acetate peel

note ectoproct colonisation

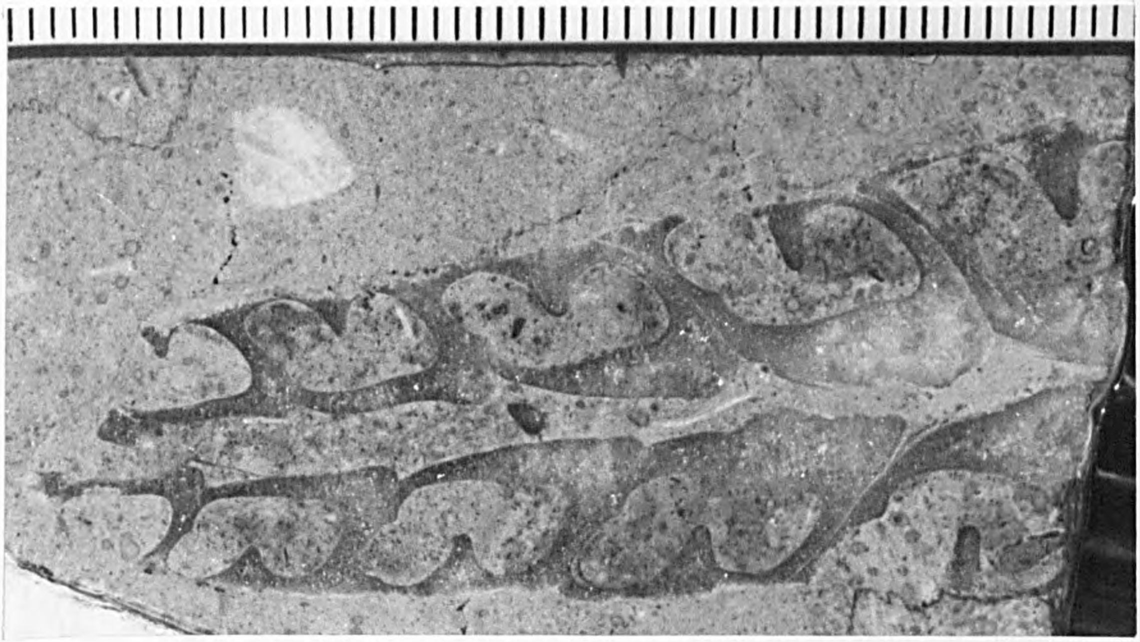
Specimen FXFB/53a

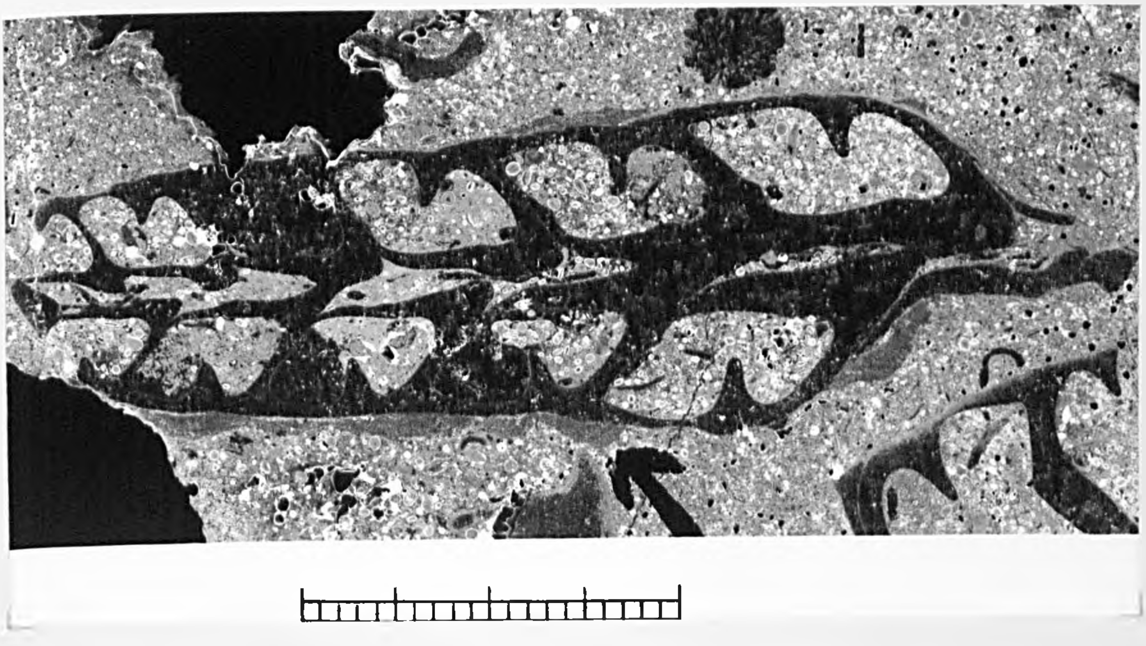
Median section coated with
glycerine to enhance contrast

Foss Cross Quarry, Bed 7.

Both specimens M.J.B. colln.

Plate 2.U.





Melanioptyxis altararis

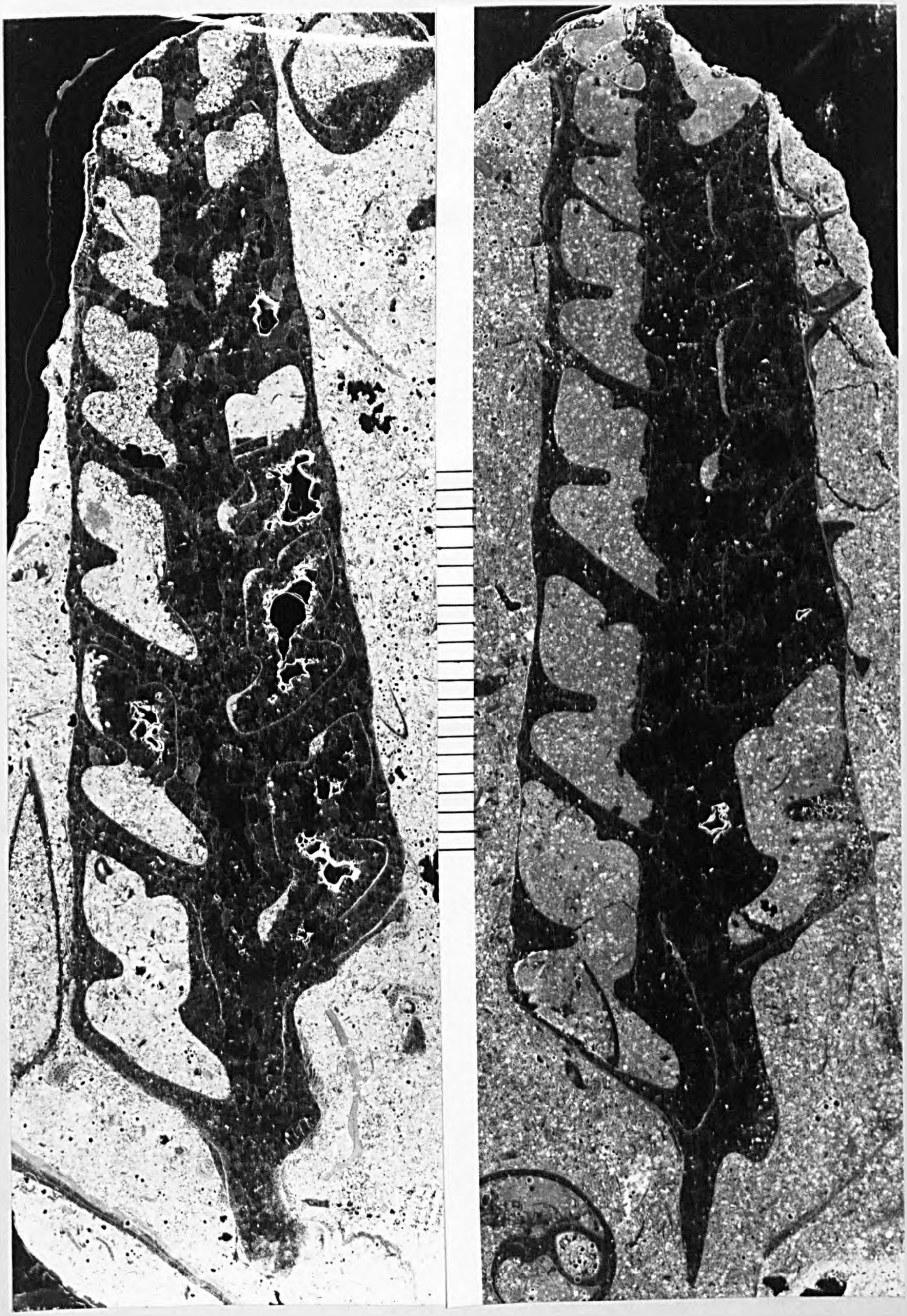
Specimen AR 34/11 Specimen AR 34/15

Both specimens from Ardley Fields Quarry, Bed 34.

Acetate peels. M.J.B. colln.

note epifauna in both specimens.

Plate 2.V.



B9/1 Endiaplocus munieri (Rigaux et Sauvage) Plate 2.W.

Synonymy see Fischer (1969, pp. 181-2).

Discussion

The present author has previously discussed the reasons for disagreeing with Fischer (op. cit.) who regards Endiaplocus as a subjective synonym of Aphanoptyxis.

The distinctive Nerineid species E. munieri is widely distributed in the White Limestone but has not yet been described from this country. The large apical angle, straight or slightly coeloconoid shape, square whorl section, absence of folds and large umbilicus makes this species unmistakable. The ornamentation consits of numerous fine spiral lirae on the whorl sides and base.

Distribution

This species forms a small but nevertheless distinctive component of the fauna in the A. excavata bed (Excavata Beds, White Limestone, Morrisi Zone: see Fig. 1.25). The specimens are usually small in size (maximum height up to 2.0 cms.) and have been found at Foss Cross (Fig. 1.7, bed 2), Sturt Farm (Fig. 1.10, bed 5), Slape Hill (Fig. 1.5, bed 3) and Ardley Fields (Fig. 1.18, bed 30). Endiaplocus munieri is also found near the base of the overlying Ardley Beds (White Limestone, Lower Retrocostatum Zone). Here, E. munieri is commonly found as part of the fauna in a correlatable horizon dominated by Eu. arduennensis at Bunkers Hill (Fig. 1.15, bed 11), Ardley Fields (Fig. 1.18, bed 34), Croughton (Fig. 1.19, bed 7) and Stratton Audley (Fig. 1.20, beds 4 and 5). Specimens in this horizon are much larger (up to 6.0 cms. in height) than specimens in the underlying A. excavata bed. Further details are given in Chapter 1.

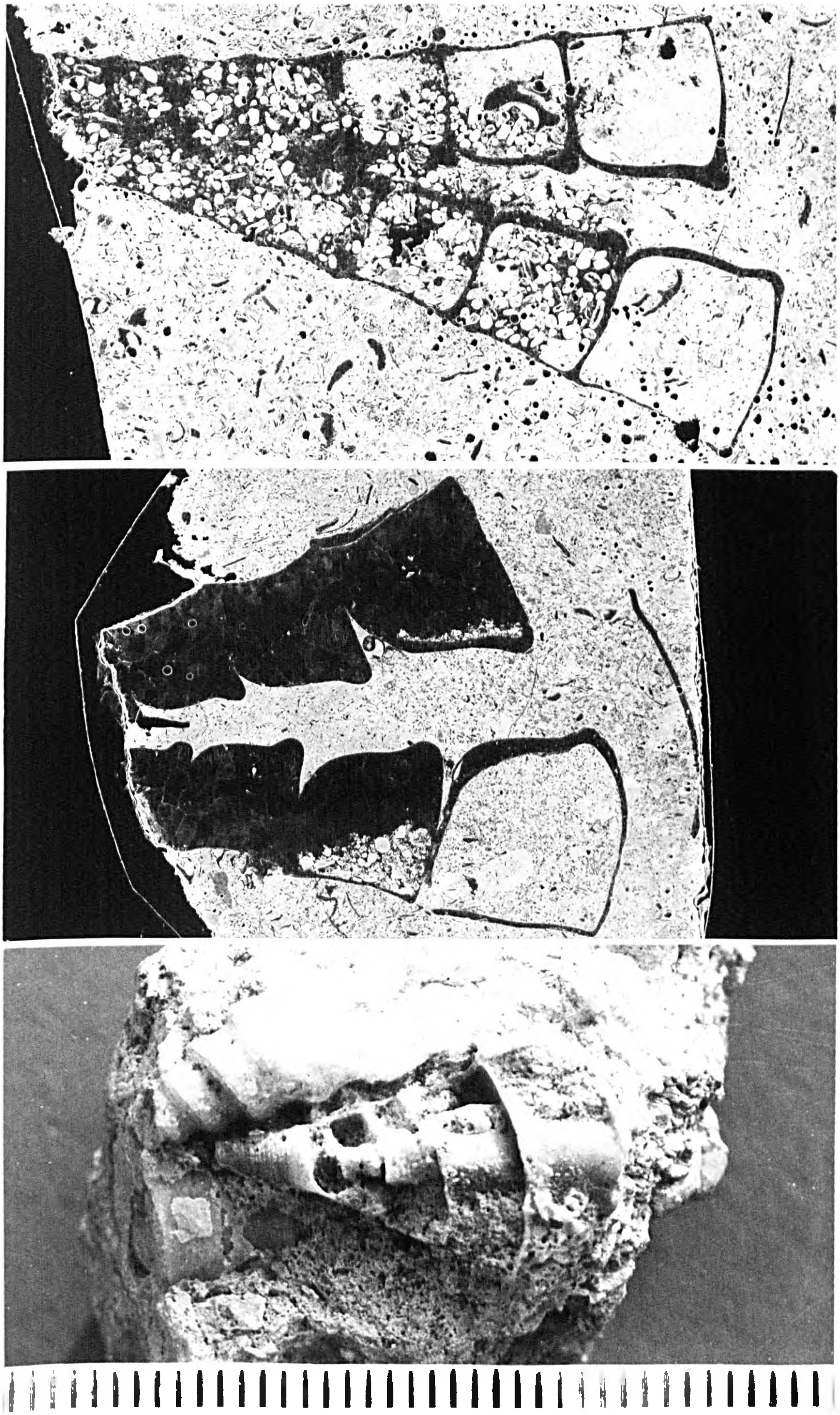
French occurrences of this species may be found in Cossmann (1898, p. 165) and Fischer (1969, p. 182).

Endiaplocus munieri

Specimen SF5/38	Specimen CR 10/30	Specimen CR 10/24
Sturt Farm, Bed 5	Croughton, Bed 10	
specimen uncoated	Acetate peels	

All specimens M.J.B. colln.

Plate 2.W.



Cl/1 *Fibula reticulata* sp. nov. Plate 2.Y.

Name referring to reticulate ornament.

Holotype Oxford University Museum No. J 29533 (Plate 2.X)

Paratypes Oxford University Museum No. J 29534 (Plate 2.X), No. J 29535 (Plate 2.X) and Nos. J 29536 - J 29545.

Locality of type-specimens

Sturt Farm (G.R. SP 271109) bed 5 (see Fig. 1.10), the *A. excavata* bed, Upper Excavata Beds, White Limestone, Morrisi Zone.

Description

A small, turreted Nerineacean gastropod. The maximum observed height of the shell is 2.1 cms. and the projected height, based upon fragmented specimens, is up to 3.0 cms. Apical angle varies between 18° and 23°. with the sides of the shell straight. Whorls relatively low, either flat or slightly convex sides. Suture usually slightly impressed and grooved with no sutural carinae. Juxtasutural selenizone wide and conspicuous. Growth-lines numerous and well developed, orthocline becoming markedly opisthocline near the selenizone. Whorl sides and base ornamented with spiral lirae which together with the growth-lines produce a marked reticulate ornament. There are usually seven spiral lirae on the whorl sides; the two near the selenizone being faint, the next three in the middle of the whorl are more prominent, the sixth one is faint and the seventh one adjacent to the adapertural suture is prominent. The latter lira marks the junction between the whorl sides and base which although not angulated and sharply defined is nevertheless distinguished by this rather prominent lira. The base of the shell is roundly convex with approximately 7-9 fine, subequal spiral lirae. Length of slit at least ¼ that of last whorl. Details of apex, aperture and siphonal outlet unknown. Internal section of whorl cavity is ovoid without folds.

The ornamentation of the whorls bears a remarkable resemblance to *Turritella communis* Risso but this recent gastropod does not possess the Nerineacean selenizone and slit.

Discussion

Representatives of the genus *Fibula* are never very abundant in the White Limestone. *F. phasianoides* (Morris and Lycett) and *F. undans* (Piette)(see plate 2.Z) have been recorded by Cox and Arkell (1950, p. 76) and two additional species, *F. undulosa* (Piette) and *F. lavillei* Cossmann have been described by Cossmann (1895, pp. 112-116) from the Bathonian 'White Limestone' of France.

It is not uncommon to find occasional (usually indeterminate) specimens of either *F. phasianoides* or *F. undans* throughout the White Limestone, especially at Eton College (Fig. 1.11, bed 14) where they were mistaken for *A. bladonensis* by Arkell (1931); Kirtlington (McKerrow *et al.*, 1969, Profile 3, bed j, p. 63) and throughout the higher levels of Enslow Bridge Quarry (Fig. 1.16).

It is noticeable that these rather large *Fibula* spp. are more associated with higher-energy carbonate sediments than other coeval Nerineacea.

The new species described above has the general shape and form of a small *Fibula* although the ornamentation is somewhat unusual in possessing a strong spiral element. The ornamentation is so distinctive that the present author considers this gastropod to be a new species. Plate 2.Z shows a specimen of *F. undans* and *T. communis* for comparison.

Distribution

F. reticulata sp. nov. occurs in small numbers in the south-western part of the *A. excavata* bed (Upper Excavata Beds, White Limestone, Morrisi Zone) at Foss Cross, Sturt Farm and Worsham where it forms part of the diagnostic fauna of this horizon (see Chapter 1 and Fig. 1.25).

Fibula reticulata sp. nov.

Holotype

J 29533.

note juxtasutural slit

Paratype

J 29534.

Both specimens coated with MgO

Paratypes

J 29535.

J 29536.

Median axial sections coated
with glycerine to enhance contrast

Sturt Farm, Bed 5, (*A. excavata* Bed)

Oxford University Museum.

Plate 2.Y.

Fibula undans and Turritella communis

F. undans (2 views)

Foss Cross Quarry
(unlocated)

note growth-lines and
selenizone

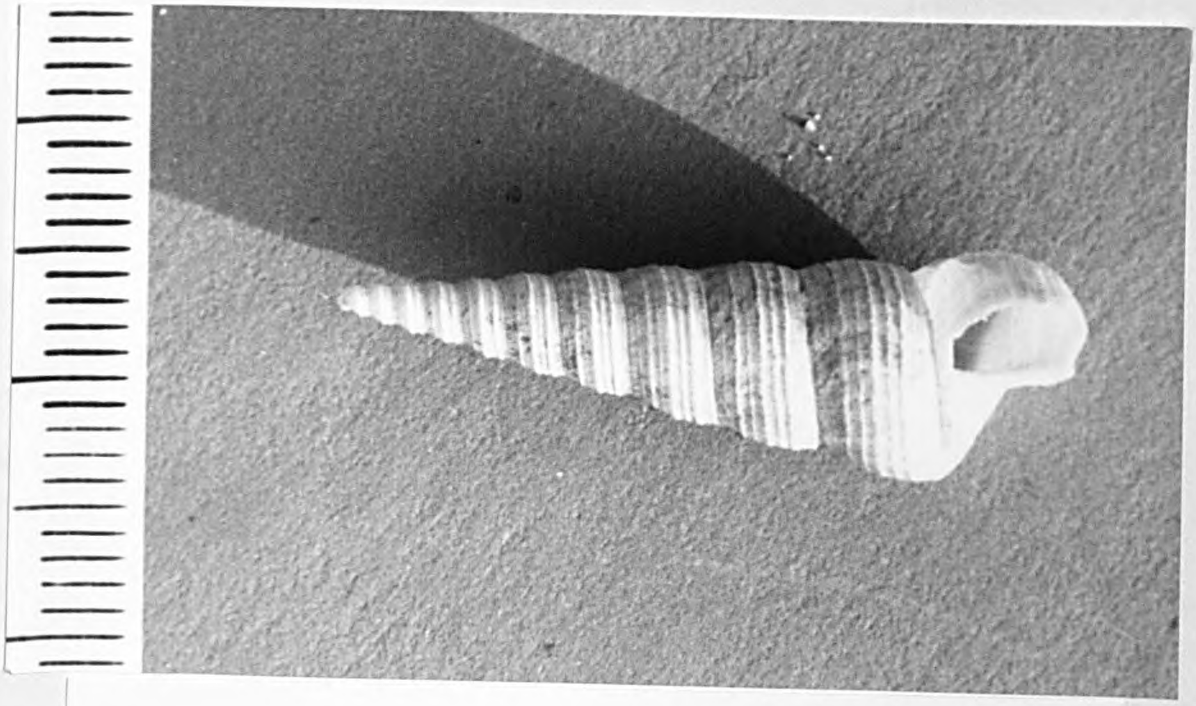
M.J.B. colln.

T. communis

Recent

Millport, Isle of Cumbrae, Scotland

Plate 2.Z.




MM

D| Genus *Rigauxia* Cossmann 1885.

Type-species *Rigauxia caniculata* (Rigaux et Sauvage 1868).

This is another example of a genus widely distributed in both the French and English Bathonian but not previously recorded from British strata.

Externally *Rigauxia* has a certain resemblance to *Nerinella* in that it is elongate, with high whorls and a small apical angle. However, in some species the suture is impressed (e.g. *R. caniculata*), in others the whorls are markedly gradate (e.g. *R. gradata*) and some possess strong longitudinal ornamentation (e.g. *R. varicosa*). Internally *Rigauxia* is one of the few non-Nerineid genera to possess spiral folds. Only a labral fold is present and, as in the Nerineacea, the fold disappears in the terminal whorl of the shell.

The taxonomic position of *Rigauxia* was considered by Cossmann (1885, p. 166) when he created the genus and initially regarded its position as *incertae sedis*. However, subsequently Cossmann (1913, p. 207) placed *Rigauxia* in the family Zygopleuridae (order Mesogastropoda, superfamily Loxonematacea).

The original exclusion of *Rigauxia* from the Nerineacea by Cossmann (1885, p. 166) is certainly well-founded and based upon the total absence of a juxtasutural slit and selenizone in this genus.

The adoption of an otherwise essentially Nerineid morphology by a non-Nerineid gastropod genus as *Rigauxia* is almost certainly a case of adaptive homeomorphy in order that *Rigauxia* could also utilise the resources that were being exploited by the Nerineacea. The basic adaptive strategy to cope with the ingestion of carbonate sediment and an infaunal mode of life (namely the development of internal folds) was apparently arrived at independently in both. To judge by their abundance and specific diversity, the solution that was developed by the Nerineacea was far more efficient than that of Rigauxia which shows less diversity.

Details of the seven known species of Rigauxia and their distribution are given by Cossmann (1885, pp. 167-169; 1913, pp. 207-210) and Fischer (1969, pp. 151-152). Only R. varicosa, the sole species presently known from British strata, is described here.

DI/1. Rigauxia varicosa (Rigaux et Sauvage). Plate 2.X.

Synonymy see Fischer (1969, p. 152).

Discussion

Apart from the small apical angle (ca. 5^{o}-10^{o}) and relatively high whorls, the presence of straight, rather rounded longitudinal costae and the concavo-convex whorl shape are particularly distinctive external features of this species. The maximum convexity of the whorls occurs just below the adapical suture and in mature specimens this produces a roundly gradate aspect. The growth-lines are straight and slightly prosocline. Faint spiral lirae are sometimes visible on the whorl sides.

The internal cross-section of R. varicosa is also unmistakable. The ovoid whorl section (cf. the rhomboid whorl section of most Nerineids) is modified by a sharp median labral fold and the concave parietal region is sharply differentiated from the columellar and labral walls. The maximum observed length is ca. 6.0 cms.

Distribution

R. varicosa is widely distributed in the *A. excavata* bed (Excavata Beds, White Limestone, Morrisi Zone) where, like *E. munieri*, this species forms a distinctive component of the fauna. It is abundant at this horizon at Foss Cross Quarry (Fig. 1.7, bed 2) and in the Stony Furlong railway cutting (Richardson, 1911, p. 111, beds 18 and 19). Elsewhere *R. varicosa* occurs less commonly in the *A. excavata* bed at Worsham (Fig. 1.12, bed 6), Sturt Farm (Fig. 1.10, bed 5), Slape Hill (Fig. 1.5, bed 3) and Ardley Fields (Fig. 1.18, bed 18). It is also found (uncommonly) in the lower horizons of the Excavata Beds at North Leigh (Fig. 1.14, bed 11). The only definite occurrence of *R. varicosa* above the Excavata Beds is at Dagham Downs where it occurs uncommonly in bed 7 (Fig. 1.6), which is probably near the top of the Ardley Beds or base of the Bladon Beds (see Chapter 1).

As far as the present author is aware, *R. varicosa* did not occur in the Minchinhampton facies.

The distribution of this species in the French Bathonian is given by Cossmann (1885, pp. 166-169 and 1913, pp. 207-210) and Fischer (1969, pp. 151-152).

Rigauxia varicosa

FXEB 14

External morphology

specimen uncoated

FXEB 22

Internal morphology

median section coated with
glycerine to enhance contrast

Foss Cross Quarry, Bed 2, (*A. excavata* Bed).

Both specimens M.J.B. colln.

Plate 2.X.


MM