# ASPECTS OF THE STRATIGRAPHY AND AMMONITE FAUNAS OF THE AALENIAN - BAJOCIAN STAGES IN GREAT BRITAIN

BY

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"Additions to fauna decrease the imperfection of the zoological, but increase that of any local geological record : the gaps caused by destruction stand revealed more plainly"

S.S.BUCKMAN,
'Type Ammonites' Vol.III

"It is one of the greatest misfortunes for Jurassic geology that when increasing age and fraility prevented Buckman from continuing active field-work, he lost sight of the distinction between results obtained with hammer, collecting bag and field notebook, and those arrived at by speculation and deduction from matrices at home. The extent of the calamity is magnified by the fact that this loss of grasp of the importance of keeping surmise distinct from fact came when his reputation was at its highest, and the two kinds of results are almost inextricably interwoven in his later published works"

W.J.ARKELL,
'The Jurassic System in
Great Britain' p.36.

d'Orbigny's Bajocian : Les Hachettes, St.Honorine -des-Pertes, Normandy,France.

ABSTRACT : A detailed stratigraphic revision of parts of the Aalenian-Bajocian Stages is undertaken. The status of the Sowerbyi zone is discussed and reasons given for its rejection and replacement by the Discites and Laeviuscula Zones. The Sauzei Zone is redefined. The detailed stratigraphy of the Humphriesianum/Subfurcatum Zone rocks of Southern England is described, its correlation discussed and a detailed analysis of their ammonite faunas given. The litho- and bio-stratigraphy of the Garantiana/Parkinsoni Zone rocks of the Sherborne area are revised. Formations and Members of the Cotswold Inferior Oolite Group are re-defined, and their Bajocian Ammonite faunas listed. The litho- and biostratigraphy of the Aalenian-Bajocian rocks of Dundry Hill, Bristol, are revised and the type horizons of Buckman's and Sowerbys' ammonite species located. The ammonite faunas of the Scarborough Formation of N.E.Yorkshire are revised and its lithostratigraphy described.

Two new Bajocian, microconch Otoitid species are described and their phylogenetic and stratigraphic significance discussed. A detailed systematic revision of the Sphaeroceratinae is given. Its constituent genera are re-defined and six species and subspecies of Sphaeroceras (S.), eight of Chondroceras (C.) ;including one new; and two subspecies of Labyrinthoceras are described. The evolution of the subfamily is discussed, its problems of sexual dimorphism summarised, and the stratigraphic distribution and significance of its members detailed.

Finally a summary of the stratigraphic part of this work is given in a discussion of the Bajocian standard zonal scheme.

# CONTENTS

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iv. The stratigraphy of the Stony Head Cutting. Proc.Dorset Nat.Hist.Arch.Soc. 1975.

v. Ammonite evidence for dating some Inferior Oolite sections in the North Cotswolds. Proc.Geol. Ass. 1976.

# INTRODUCTION

The rocks assigned to the Aalenian-Bajocian Stages in southern England, and in particular north Dorset, are some of the most highly fossiliferous beds in the world (Arkell, 1933,p.193). Over the years these beds have yielded a wealth of ammonites, which on one hand have provided the type material for numerous new genera and species (Smith,1817; J.&J.de C.Sowerby,1812-46; Buckman,1909-30),and on the other they have provided the stratigraphic basis for much of the present standard zonal scheme. The original aim of this work was to have been a taxonomic revision of the ammonite Superfamily Stephanoceratacea, which forms an important part of these abundant Dorset faunas. At an early stage it became evident that before this primary aim could be accomplished, the stratigraphy of the Bajocian rocks of southern England would have to be revised. It was initially assumed that the standard zonal scheme for the Aalenian-Bajocian, as adopted by Spath (1936) and Arkell (1956), was a fair reflection of the stratigraphic distribution of the ammonite faunas. However, my research confirmed some already prevalent suspicions (Torrens,1969,p.302),that the Spath/Arkell scheme, based as it was on S.S.Buckman's scheme of hemerae (Buckman, 1893,1910,1909-30), was full of inconsistencies and in some cases outright errors. A high proportion of this thesis is thus taken up with stratigraphic problems, in first revising certain parts of the standard zonal scheme, and secondly in applying this scheme to some specific areas of English Bajocian rocks.

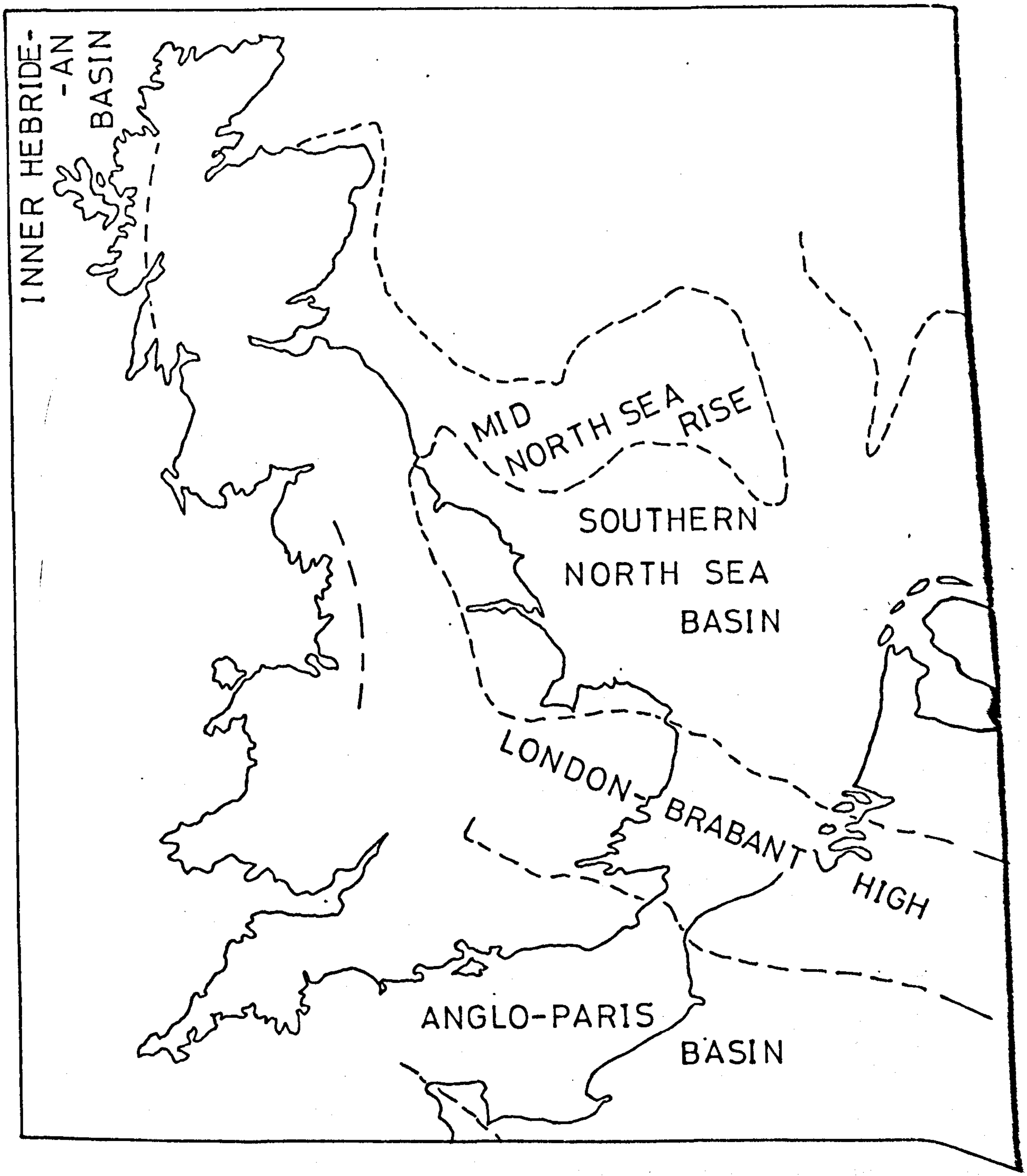


Figure 1

The main structural features controlling the deposition and subsequent preservation of the Middle Jurassic of the British Isles.

# 1. LITHOSTRATIGRAPHY

The original deposition, and to a certain extent the subsequent preservation of the British Middle Jurassic rocks has been controlled by important deep seated structural features. This has resulted in the thickest sequences being deposited in the centres of 'negative areas' or 'basins' , whilst on the'positive areas' or 'highs', only much attenuated or incomplete successions are preserved - see Figure 1 & Table 1. The most well known and frequently used lithostratigraphic term spanning the Aalenian-Bajocian, is the Inferior Oolite Group or 'series' . As originally defined (Townsend,1813), the use of this name should be restricted to those rocks on the western periphery of the Anglo-Paris Basin.

## (a) The Anglo-Paris Basin

Whilst thick sequences of Aalenian-Bajocian rocks are preserved at the subsurface, towards the centre of this basin (e.g. Ashdown,No.2 borehole , see Gatrall,Jenkyns & Parsons, 1972,fig.8), only the surface outcrops,with their relatively common ammonites,are of any real value for detailed stratigraphic work. These latter beds, which have long been known as the Inferior Oolite, are exposed in the area between Bridport on the English Channel and Hook Norton in north Oxfordshire. The Inferior Oolite, and in particular the middle and lower Inferior Oolite (Aalenian & Lower Bajocian), is preserved in two distinct facies, which are broadly separated by the present Mendip Hills, which appear to have acted as a 'positive area' throughout much of the Lower and Middle Jurassic. The upper Inferior Oolite, which is represented by oolitic and bioclastic limestones, is relatively uniform in character across the whole outcrop. On the other hand, the lower and middle Inferior Oolite are largely represented by condensed

| | NORTH-WESTERN PERIPHERY OF THE ANGLO-PARIS BASIN | | | | WESTERN PERIPHERY OF THE SOUTH NORTH SEA BASIN | | | INNER HEBRIDEAN BASIN |
|---|---|---|---|---|---|---|---|---|
| | Dorset/Somers. | MENDIPS | Cotswolds | "OXFORD SHALLOWS" | East Midlands | MARKET WEIGHTON 'STRUCTURE' | Yorkshire | |
| BAJOCIAN | Upper Inferior Oolite<br>fossiliferous oolitic lsts.<br>31m. | | Upper Inferior Oolite<br>pisolitic & bioclastic lsts.<br>14m | | Upper Estuarine 'series'<br>(?mainly Bathonian) | | Ravenscar Group<br>dominantly non-marine<br>ssts. with thin marine intercalations, 200m | Great Estuarine 'series' |
| | Middle Inferior Oolite<br>highly fossiliferous 'iron-shot' lsts.<br>0.0-5.0m | | Middle Inferior Oolite<br>bioclastic lsts.<br>0.0-21m | | Lincolnshire Limestone Formation<br>massive oolitic lst. 30m. | | | Bearreraig Sandstone Formation<br>massive ssts<br>208m |
| AALENIAN | Lower Inferior Oolite<br>highly fossiliferous 'iron-shot' lsts.<br>0.0-6.0m | | Lower Inferior Oolite<br>pisolitic & oolitic lsts. & marls<br>50m | | Grantham Formation<br>non-marine silts<br>0.0-5.0m | | | |
| | | | | | Northampton Formation<br>10m | | Dogger<br>ferrug. sst.<br>0.0-12m | |

Table 1.

The main lithostratigraphic units of the British Aalenian-Bajocian, and their interelationship.

'iron-shot' and ferruginous limestones to the south of the Mendips, whilst to the north there is an expanded sequence dominated by bioclastic limestones in the middle, and by pisolitic limestones and marls in the lower Inferior Oolite, - see Table 1. These differences in lithology are mirrored by similar distinctions in the faunal characters of these beds,with marked differences in the brachiopod and bivalve populations,reflecting their different depositional environments. Perhaps the most marked faunal difference between these two areas, is to be seen in their ammonite distributions. In the southern area the ammonites are abundant and well preserved, with intact fragile spines and lappets, whilst to the north they become increasingly rare and more badly preserved, with a generally worn and broken appearance,reflecting their allochthonous nature. It is thus hardly surprising that it is the southern area, which has in the past provided most of the figured and type ammonites.

(b) The south North Sea Basin

The advent of exploration for gas in the south North Sea, has produced a wealth of information relating to the subsurface Middle Jurassic. Unfortunately very few, if any of the boreholes drilled through this part of the sequence have been cored, hence our knowledge of these beds is mainly based on 'chippings' and various geophysical logging techniques.Based on this evidence, the Middle Jurassic ,West Sole Group (Rhys, 1974), appears to be very similar to the equivalent horizons at the western periphery of the basin, where they are exposed in the east Midlands and in Yorkshire. These beds consist of dominantly non-marine,clastic horizons, interbedded with marine limestones and ferruginous sandstones. In the east Midlands there is a rough balance between the non-marine silts and the marine elements : the Northampton Sand

Formation & the Lincolnshire Limestone Formation. However, towards the north there is an increase in the relative amount of clastic material,with a subsequent thickening of the non-marine elements. In north-east Yorkshire non-marine, deltaic sandstones dominate the Ravenscar Group (Hemingway & Knox,1973), whilst the marine horizons (Eller Beck,Millepore and Scarborough beds),are relatively thin and of less significance.

(c) The Hebridean Basin

In the Inner Hebrides isolated patches of Jurassic sediments are preserved beneath the plateau basalts and cut by Tertiary dykes and sills. The Aalenian-Bajocian is represented by the Bearreraig Sandstone Formation (Morton,1976),which is dominated by cross-bedded sandstones. Ammonites are not uncommon, and these beds appear to be wholly marine,although drifted wood and plant fragments are not uncommon at some horizons (Morton,1965). There are rapid lateral facies changes in these beds, with massive, relatively unfossiliferous sandstones, such as the Druim an Fhurain sandstones of Strathaird (Skye), which pass laterally into thinner bedded highly fossiliferous units, such as the Rigg sandstones of Trotternish (N.Skye).

(d) Other,offshore areas

The increasing momentum of the search for hydocarbons in the north-west european continental shelf is producing an immense quantity of information related to the distribution and nature of the off-shore Jurassic. Much of this data is still secret and commercial requirements will for some time militate against its general release. However, a broad overall picture is appearing, and it would seem that to the north of the Anglo-Paris Basin, the Aalenian Bajocian period is mainly represented by clastic and sandstone facies. Thus in both the north North Sea (e.g. the Brent oil-field, Bowen, 1974), and in Cardigan Bay (Penn & Evans, 1976), there are thick, relatively unfossiliferous sandstone deposits. It is self-evident that sequences such as these are going to add little to our detailed biostratigraphic knowledge of this period. To the south, the English Channel has yielded sufficient information to suggest that the subsurface Inferior Oolite is very similar to the coastal exposures. Thus boreholes in Lyme Bay have revealed thicker, although otherwise very similar ammonite rich beds, to those of south Dorset. Detailed examination of this area could thus add considerably to the existing biostratigraphic picture.

## 2. BIOSTRATIGRAPHY

The Aalenian/Bajocian rocks, with their abundant and diverse ammonite faunas, have figured prominently in the development of both biostratigraphic methods and terminology (viz, d'Orbigny, 1850, who was the author of the Bajocian Stage; Oppel, 1856-8, who erected many of the Bajocian zones). The detailed stratigraphy of this period is closely linked with the study of the north Dorset successions. Many of the type specimens of the existing zonal and subzonal indices originate from this area, whilst the germinal work carried out by S.S.Buckman (1893), in the Sherborne district, forms the basis for much of the present subzonal scheme. However, whilst the existing biostratigraphic framework is apparently well founded and has had a long historical usage, it contains some inherent weaknesses. On one hand this has led to prolonged arguments and discussions concerning the interpretation and definition of the Bajocian Stage, whilst on the other hand doubts have emerged concerning the validity of parts of the standard zonal scheme.

Many of these problems have arisen because of the peculiar nature of the mode of preservation of the Dorset Inferior Oolite, which has an extremely thin and attenuated sequence. The latter has strongly influenced the British view point on the status of the Aalenian Stage (see pp.501-4,below),and has helped to introduce errors into the interpretation of the faunal sequences, which consequently became incorporated in the standard zonal scheme. It is perhaps significant in this context to compare a section such as South Main-road quarry (Dundry Hill,Avon),where the _discites_,_laeviuscula_ and _sauzei_ Zone beds are less than 1.7m thick, with Lokut Hill (Bakony Mountains,Hungary), where equivalent horizons in an 'ammonitico rosso' facies are over 4.0m thick (Galacz,1976,p.179). The Dundry beds are thus less than half the thickness of equivalent horizons, in what is commonly thought of as one of the most 'condensed' Jurassic facies. If the British Bajocian ammonite faunas, their stratigraphic distribution and rates of evolution are to be appreciated in comparison with those found in more expanded sequences, such as the Lias, then they must be compared in equivalent facies. The shales and mudstones of the Scarborough Formation (N.E.Yorkshire),are very similar to much of the Lias. Here at Hundale Point,Cloughton, the _romani_ Subzone beds alone are 12m thick (compared to 0.30m,Oborne,Dorset),whilst the _humphriesianum_ Zone as a whole is more than 20m thick (0.70-0.80m,Oborne).

The highly attenuated Dorset sequence also creates problems in the interpretation and recognition of biostratigraphic units. The ammonite faunas tend to occur in highly 'condensed', extremely fossiliferous 'fossil-beds' . Although very accurate collection can some times give the appearance of discrete stratigraphic ranges within these beds (e.g. fig.3,p.39; figs. 5-6,pp.113-6), in most cases the faunas are homogeneous in any one particular layer or bed. Thus most of the faunas collected can only be assigned to 'fauni-zones' in their broadest sense (Holland et al.,1978,p.13), as an assemblage biozone. The interpretation of these zones or subzones in terms of accurate,relative stratigraphic ranges and first appearances (concurrent-range, partial-range biozones etc.), can only be done with reference to thicker,more expanded sequences. Although most of the British Lower Bajocian faunas in this light, are of limited international significance, their very abundance and diversity have given them a crucial importance in the interpretation of the systematics of various ammonite groups. The real value thus comes, when the material obtained from these beds can be combined in a synthesis with the stratigraphic information from thicker sequences elsewhere.

(a) Development of the Standard Zonal Scheme

The backbone of the present zonal scheme for the Aalenian and Bajocian Stages is made up of the four Zones erected by Oppel (1856-8): that is the parkinsoni,humphriesianum,sauzei and murchisonae Zones. The majority of the other Zones have been added in a more piecemeal fashion (e.g. subfurcatum Zone, Terquem & Jourdy,1869; laeviuscula Zone,Haug,1894), and Buckman's work (1893,1895,1896,1910), marks one of the first attempts, subsequent to Oppel, to produce a detailed and comprehensive Bajocian stratigraphy.

In his early work, Buckman (1881 ,1891 ) used, with some modifications Oppel's Zones. However, in 1893, he introduced a new unit, the hemera , based on the acme of a particular ammonite species or genus. As originally defined (Buckman,1893,p.482), the hemera was a theoretically based, chronological unit, which was not intended as a replacement for the Zone. Most of Buckman's contemporaries did not understand the intrinsic difference between chronological and stratigraphic units, and tended to treat hemerae as nothing more than stratigraphic subdivisions of a slightly lower order than the Zone. Indeed Buckman in his later works also seems to have lost sight of the distinction between the two, since Zones and hemerae are interchanged in his later zonal tables (Buckman,1913 in 1909-30;1915).

Buckman readily appreciated the highly condensed nature of the Inferior Oolite,which led him to greater refinements of his polyhemeral scheme. He argued (Buckman,1893,p.482), that if the acme of any one species was characteristic of a particular unit of time (a hemera ), then in condensed sequences, it would be logical to find several different hemeral indices together in one bed, whilst in thicker sequences they would have distinct stratigraphic ranges. Taking this methodology to extreme lengths, in condensed horizons,virtually every ammonite could be assigned to a different hemera . Whilst there is some logic to the above argument, in his later works, such as Type Ammonites (Buckman,1909-30),Buckman went to absurd lengths in the creation of new hemerae, many of which were based on poorly localised material, or apparently in some cases, no ammonites at all . This led to the production of numerous totally artificial hemerae ,which either were defined as containing several different ammonite species, which can now be shown to occupy different horizons, or which were duplicated, with several hemerae being applied to the same bed. In the case of some Lower Bajocian hemerae, it is evident that there is an inextricable mixture of these two faults (see Parsons, 1974, Table 1).

With the recognition of the dubious nature of Buckman's later polyhemeral schemes, there came a reaction against all his work. This is unfortunate, since much of his detailed research carried out prior to 1910, is of outstanding value. Later workers (Spath, 1936) were forced to go back to earlier zonal concepts, and Oppel's Zones were re-instated, often with Buckman's earlier hemerae as subzones (e.g. the 'Sowerbyi' Zone). Arkell (1956) merely used a modification of Spath's scheme, it hence contained the inherent weaknesses carried over with Buckman's hemerae.

There has recently been a resurgence of interest in the problems of Bajocian stratigraphy, with some important studies in thick, uncondensed sequences (e.g. Pavia & Sturani, 1968). This would suggest that we are gradually approaching the situation, where a consensus can be reached on a Bajocian stratigraphic scheme, which will be a fairer representation of the ammonite faunal successions.

## 3. THE ORGANISATION AND SCOPE OF THE THESIS

The arrangement of material within this thesis does not follow the generally accepted practice of subdivision into closely related chapters. Instead an attempt has been made to present the material in the form of self-contained papers, which are either in a readily publishable form, or indeed have already been accepted for publication. In consequence there is a certain amount of duplication between sections, mainly in the reference lists, as well as some disparity in style, as individual papers have been tailored to the 'house

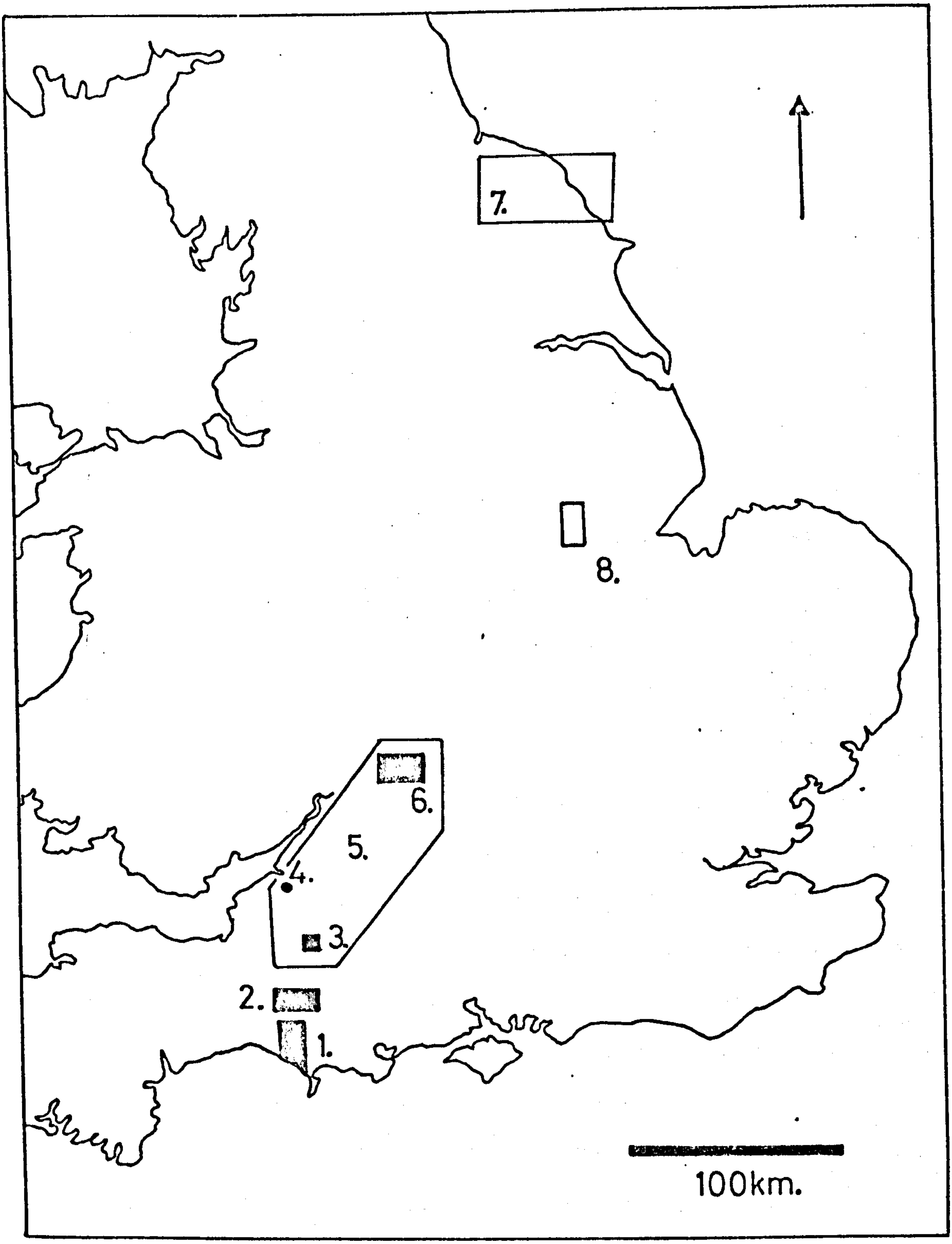


Figure 2

A sketch-map showing the location of the main areas of the Inferior Oolite, and other, Bajocian rocks, which are described in the following sections: 1, south Dorset (Bridport /Beaminster); 2, north Dorset (Sherborne-Yeovil); 3, Doulting district; 4, Dundry Hill, near Bristol; 5, the Cotswold and Mendip Hills; 6, the north Cotswolds; 7, the north Yorkshire Moors; 8, south Lincolnshire (the Grantham district).

style' of their intended destinations. Another result of this method of arrangement has been to produce a degree of discontinuity between individual sections. The aim here is thus to draw together the individual strands, and to clarify the underlying objectives of this work.

(a) The stratigraphic range of the study

In the course of this work, the zonal scheme for the Lower Bajocian (Middle Bajocian, Arkell,1956), was found to be the most unsatisfactory. Hence most attention has been paid here to a revision of the horizons between the concavum and garantiana Zones. The first two sections (1A,1B) are thus devoted to a discussion and revision of the 'sowerbyi' (now discites & laeviuscula Zones) - sauzei Zones, and the humphriesianum -subfurcatum Zones, whilst the third section (1C) gives an account of the garantiana and parkinsoni Zones. These, and subsequent units set out to apply this revised stratigraphic scheme to the British Bajocian. This work has not been totally restricted to this horizon, since the Aalenian beds of Dundry Hill (section 2A), have been the subject of some attention. All of the above work, together with a few additional points, are summarised in the final section (4).

(b) The geographical range of the study

The geographical limits of the study have been wide,and included much of Europe, but in the revision of the zonal scheme, most attention has been paid in sections 1A-C, to the Sherborne area of Dorset (Figure 2,area 2). In the stratigraphic revision of parts of the British Bajocian rocks, there has been a concentration on specific areas ; on Dundry Hill (section 2A- area 4,Fig.2) and the Cotswold and Mendip Hills (section 2B - area 5,Fig.2). Accounts of the stratigraphy of the Doulting district,Somerset (area 3), the north Cotswolds (area 6) and south Dorset (area 1) have been given elsewhere (Parsons,1975a, 1976 & 1975b respectively). There is a sparcity of Bajocian ammonites in Britain north of the Anglo-Paris basin, but there are several horizons, which have yielded isolated, but important faunas. Thus in section 2C the stratigraphy of the Yorkshire Scarborough Formation is revised (area 7), whilst in a paper from the Proceedings of the Yorkshire geological Society (Parsons,1974b), there is a brief discussion of ammonites from the Lincolnshire Limestone Formation (area 8); a subject which in collaboration with Dr.M.Ashton, is being treated in greater detail elsewhere. I have refrained from any detailed discussion of the Hebridean basin, apart from a brief reference in section 4, since my field-work has added little to the recently published studies of this area by Dr.N.Morton (1965,1971,1976).

## 4.ACKNOWLEDGEMENTS

Individual acknowledgements follow each of the separate sections. Here I will restrict myself to thanking Hugh Torrens for his help during his supervision of this research project, which was initially supported by a University of Keele Research Studentship : this award is gratefully acknowledged. Finally I must express a great debt of thanks to my wife Marion,who for longer than she would care to remember, has had to put up with living twenty-four hours of the day with ammonites !

## 5.REFERENCES

Most of the references cited in the Introduction will be found in the reference lists following the individual sections, particularly 1A-B,2B & 4.

# 1. TOWARDS A REVISION OF THE STANDARD ZONAL SCHEME FOR THE BAJOCIAN AND PARTS OF THE AALENIAN STAGES

There are inherent problems in the interpretation of the Bajocian stratigraphy of southern England, which are the result of vagaries in preservation and exposure of the rocks concerned.These difficulties fall into two groups. First the so called 'Sowerbyi' and Sauzei Zones are preserved in a series of disjunct and discontinuous, but highly fossiliferous 'fossil-beds' . The faunal sequence for this part of the column has thus to be pieced together from separate exposures. The problems with this part of the stratigraphic scheme,have thus been the result of previous mis-correlation of these various exposures. The second difficulty is the result of limited preservation, linked with lack of exposure. Thus the Humphriesianum/Subfurcatum Zones are only preserved to any great thickness in a small area to the north-east of Sherborne. Considering these difficulties,Buckman (1893),did a superb job in unravelling the stratigraphy of this period.Unfortunately most of the ammonites, which he subsequently figured (Buckman, 1909-30), were based on poorly localised material. A serious past omission has been the lack of work on the Garantiana Zone rocks. These beds,which are thick and relatively fossiliferous, have been largely ignored, subsequent to Buckman's introduction of the garantiana hemera. The aims of this part of the work are thus to redescribe the faunal successions,to locate as many topotypes as is possible of Buckman's species, and lastly to use this more reliable stratigraphic information to re-interpret the zonal scheme.

# IA. THE SAUZEI AND 'SO CALLED' SOWERBYI ZONES OF THE LOWER BAJOCIAN (MIDDLE JURASSIC) OF EUROPE

## SUMMARY

The Sauzei and Sowerbyi Zones of the Lower Bajocian (Middle Jurassic) are discussed in the light of new evidence from Normandy (France), Schwabia (South Germany) and Southern England. The Sauzei Zone is re-interpreted as a 'fauni-zone'. The Sowerbyi Zone is rejected and evidence is given for its replacement by the Laeviuscula Zone (HAUG, 1894). It is shown that the subzonal divisions of the Sowerbyi Zone were based on incorrect stratigraphic evidence. The Laeviuscula Zone is subdivided into a redefined Laeviuscula subzone (senior synonym of the Trigonalis subzone) and an Ovalis subzone; the Discites subzone being elevated to full Zonal rank. A detailed analysis is given of the ammonite faunas of Southern England from the Sauzei to the Concavum Zones, as well as a brief summary of the correlation of equivalent horizons in Normandy and Schwabia.

Modified from: "The Sauzei and 'so called' Sowerbyi Zones of the Lower Bajocian".
Newsl. Stratigr. 3 (3.) pp 153-179.

CONTENTS

## 1. INTRODUCTION

Although one of the first stages in the Jurassic to succumb to modern, detailed, stratigraphic methods, (S. BUCKMAN, 1893), the Bajocian has been largely ignored by later workers. The early work done by Buckman in the Sherborne area (Dorset, England) was readily accepted by Spath (1936) and Arkell (1954, 1956) in an only slightly modified form: 'Thanks to the work of the late S.S. Buckman and Mr. L. Richardson, the Inferior Oolite Series from Dorset to Northamptonshire is so thoroughly known that almost perfect generalisation is possible: a detailed section of the beds can be drawn right across the country'. (ARKELL, 1933 p.vi). This has created the erroneous impression that the fundamental stratigraphic work, particularly in the Lower Bajocian (= middle Bajocian _olim_) has long since been completed. However, current research has suggested that the existing Zonal and Subzonal scheme (see Table 1), far from being acceptable, is often based on erroneous or inadequate information. In this the Sauzei and 'so-called' Sowerbyi Zones have proved to be the most serious offenders. It has been found necessary to re-examine in some detail the stratigraphic basis for the very existence of these two Zones and attendant subzones.

The Sauzei and Sowerbyi Zones, introduced by Oppel, (OPPEL, 1856 and 1862), were replaced by Buckman with a series of smaller units, hemerae, based on the acme of a particular species or genus, (BUCKMAN, 1893, 1895, 1910). Subsequently Spath reinstated Oppel's Zones on grounds of priority, relegating Buckman's earlier hemerae to subzonal status, (SPATH 1936). It was this latter scheme which was accepted by Arkell as the standard for the World Bajocian,

<table>
<tr><th>OPPEL 1856-62</th><th>S. BUCKMAN 1891</th><th>S.BUCKMAN 1893-6 'Hemerae'</th><th>BUCKMAN, 1930, Inferred position of Hemerae, from range of ammonites assigned to them.</th><th colspan="2">SPATH, 1936 ARKELL, 1956</th><th colspan="2">SCHEME SUGGESTED HERE</th></tr>
<tr><td rowspan="2">SAUZEI (1856)</td><td>SAUZEI</td><td>SAUZEI</td><td>alsaltica<br>propinquans<br>pars sauzei<br>" Labyrinthoceras<br>" mollis</td><td colspan="2">SAUZEI</td><td colspan="2">SAUZEI</td></tr>
<tr><td rowspan="2">SOWERBYI</td><td>WITCHELLIAE</td><td>ruber<br>brocchii<br>Shirbuirnia<br>Witchellia<br>pars sauzei<br>" Labyrinthoceras<br>" mollis</td><td rowspan="3">SOWERBYI</td><td>Laeviuscula<br>Trigonalis</td><td>Laeviuscula</td><td rowspan="2">LAEVIUSCULA</td></tr>
<tr><td rowspan="2">SOWERBYI (1862)</td><td>SONNINIAE (1896)<br>non<br>SHIRBUIRNIAE (1910)</td><td>fissilobatum<br>hebes<br>ovalis<br>pars mollis<br>? Bradfordia</td><td>?<br>?</td><td>Ovalis</td></tr>
<tr><td rowspan="2">CONCAVUM</td><td>DISCITAE</td><td>Docidoceras<br>Trilobiticeras<br>Rudidiscites<br>Depaoceras<br>Reynesella<br>Platygraphoceras<br>? eudmetum</td><td>Discites</td><td colspan="2">DISCITES</td></tr>
<tr><td>MURCHISONAE</td><td>CONCAVI</td><td>stigmosum<br>crassispinata<br>casta<br>cornu<br>concava</td><td colspan="2">CONCAVUM</td><td colspan="2">CONCAVUM</td></tr>
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Table 1.

Development of the standard zonal scheme for parts of the British Aalenian and Bajocian.

(ARKELL, 1954, 1956, etc), and which up to recently (TORRENS, 1969) no one has seriously questioned. None the less serious confusion has, and still does exist over the exact boundaries and faunas of these two Zones. This has at least in part arisen from the publication of Buckman's 'Type Ammonites' (BUCKMAN, 1909-1930). In this work Buckman created large numbers of new genera and species of ammonites, which were figured, but only accompanied with the most abbreviated of descriptions. Many of these figured ammonites were unlocalised specimens, which Buckman had acquired from various sources, and then assigned to their respective hemerae purely by matrix. Whilst in his early years Buckman had an extensive first hand knowledge of the Inferior Oolite and an intuitive judgement which probably still could not be bettered, towards the end, his work came to be based more on doubtful 'Biological Laws' and slight differences in matrix, than on _in situ_ collection. This regrettable fact led to many key species of ammonites, common and highly characteristic of certain horizons, being recorded by Buckman, as coming from a whole series of, largely fictional, hemerae. As an example one may cite the fauna of the 'green marl bed' of Frogden quarry, Sherborne, Dorset (BUCKMAN, 1893, Sect. xv, bed 9), where the Stephanoceratid ammonites, (such as _Frogdenites spiniger_) were recorded by Buckman as coming from the _Sauzei_ hemera, whilst the _Witchellia_ spp. were recorded from the _Witchellia_ hemera, in spite of their occurrence together in the same bed. This confusion, once created, became firmly entrenched in the subsequent literature, until Arkell was able to quote faunal lists from the Lower Bajocian of Dorset, which bore no resemblance to those produced by _in situ_ collection (ARKELL, 1956, p.33).

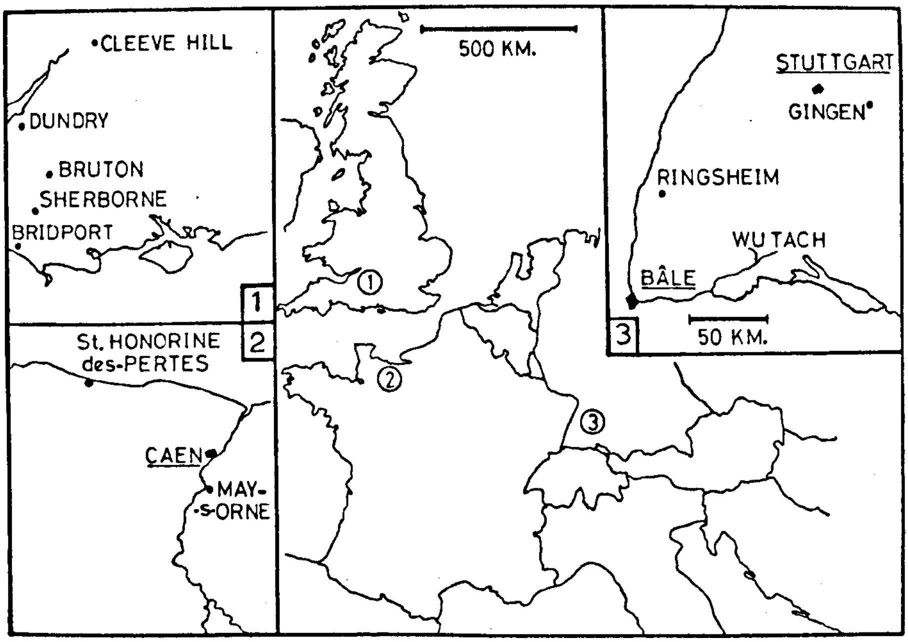


Figure 1.

A map showing the main areas of Europe under discussion : 1. Southern England ; 2. Normandy, north-west France ; 3. Schwabian Albe, south-west Germany.

The time has thus come for a critical re-appraisal of Lower Bajocian stratigraphy, based on accurately localised collections. The following account is an attempt at a long overdue revision of the stratigraphy of beds of this age in certain key areas of North-West Europe. The main areas under discussion are those which figured largely in the work of the earlier stratigraphers, Oppel, Haug, Buckman etc., that is the Schwabian Albe, Normandy and Southern England, (see fig. 1).

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For much help and discussion in the field, I would like to thank J. Callomon, U. Bayer, M. Gatrall, J. Senior and in particular H. Torrens.

NOTE

In the following work, numbers prefixed by these abbreviations refer to specimens in the following Institutions and private collections.

| | | |
|---|---|---|
| BMNH. | - | British Museum (N.H.), London. |
| Ce | - | Geologisch-Paläontologisches Museum, Tübingen. |
| ST | - | Staatliches Museum, Stuttgart. |
| CP | - | The author's collection. |
| Bayer Collection | - | Private collection of U. Bayer, Deizisau, near Stuttgart, W. Germany. |
| Morton Collection | - | Private collection, N. Morton, Birkbeck College, London. |
| Whicher Collection | - | Private collection, J. Whicher, Bristol, England. |

## 2. THE SAUZEI ZONE

Oppel first introduced the term 'beds with Ammonites sauzei', for the lower part of his Humphriesianum Zone (OPPEL, 1856-58, p.305) but later separated them first as a Subzone (op. cit., p.334) and later as a full Zone (op. cit., p.369). For the defining fauna of the Sauzei Zone Oppel gave Ammonites sauzei, A. brocchii, A. brongniarti (op. cit., p.305 ) and subsequently added A. bayleanus, A. jugosus, A. sowerbyi and A. tessonianus (op. cit., p.334 ). It is almost impossible to interpret these specific names in terms of the present more restricted concepts of these species. Hence in order to define the fauna of the Sauzei Zone in modern terms it is necessary to examine the actual strata cited by Oppel as belonging to his Zone and to re-identify any ammonites produced by these beds. Amongst other regions noted as having representatives of the Sauzei Zone (Horizon 21 in Table 64, OPPEL, 1856-58) Oppel specifically included three areas; Schwabia, South-western Germany, Normandy, North-west France and Southern England, (see Text Fig. 1).

### a/ Schwabia

The bed cited by Oppel in this area was described as ...... "Blaulich, graue, harte, sandige kalke, mit Ammonites sauzei of Neuffen and Hohenzollern" ..... (OPPEL, 1856-58, Table 64). There can be no doubt that Oppel was here referring to Quenstedt's Blaukalke, since in this connection he refers to the Blaukalke (QUENSTEDT, 1843) as ..... "Die blauen kalke sind das lager des A. sauzei" .... (op. cit., p.336). It is to be stressed that the Blaukalke must be considered the type horizon of the Sauzei Zone and Schwabia the type area (ARKELL in DONOVAN & HEMINGWAY, 1963, p.307).

The Blaukalke is only sparsely fossiliferous and it is now poorly exposed. The few fossils present tend to occur in clusters on the upper surface of the bed which in the Beuren region has recently yielded several ammonites (Emileia (E.) cf. polyschides (Waagen) & E. (Otoites) sp. - U. Bayer collection). The matrix of this bed is sufficiently characteristic to enable use to be made of geographically localised material. The following have been recognised in museum collections (see also BUCK, HAHN & SCHADEL, 1966):-

Emileia (E.) polyschides, Bayer Collection & ST10028.

E. (E.) pseudocontrahens Maubeuge, ST22551.

E. (Otoites) contractus (S. Buckman non Sow.) - sauzei (d'Orb.) group, Bayer col.

Kumatostephanus aff. kumaterus S. Buck., ST22549.

K. triplicatum (Renz), Ce5-66-13.

K. turgidulum (Qu. emend. Welsch), Ce5-66-3.

b/ Normandy

The bed which Oppel correlated with the Sauzei Zone in Normandy was the basal member of the 'Oolithe Ferrugineuse de Bayeux', which rests on top of the Malière. This horizon agrees well with the 'Couche verte' of subsequent French authors (BIGOT, 1900; BRASIL, 1895). Although most of the famous exposures of this latter bed have disappeared, the extensive coastal exposures at St. Honorine-des-Pertes, Normandy, are still available for study (RIOULT, 1962; RIOULT & GABILLY, 1967). The matrix of this bed; rich in glauconite, which often replaces the shells of the fossils (DANGEARD, 1940); is unmistakable even in unlocalised museum material. The following have been collected *in situ* from the coastal exposures:-

*Emileia* (*E.*) *polyschides*, CP 1591.

*E.* (*E.*) *pseudocontrahens*, CP 1590.

*E.* (*E.*) cf. *polymera* (Waagen), CP 1593.

*Kumatostephanus turgidulum* (= *K.* *bigoti*, Haug *ex.* Munier-Chalmas m.s. per. QUENSTEDT, 1886, pl. 65, fig. 9), CP 1585.

*K.* cf. *perjecundus* S. Buckman, CP 1586.

*Mollistephanus* sp. nov., CP 1597.

*Sonninia felix* (S. Buckman), CP 1607.

*S.* cf. *propinquans* (Bayle), CP 1605.

Amongst numerous other specimens which I have seen in various museum collections, the following, cited by d'Orbigny (1842-51) from the Tesson collection are now in the British Museum:-

*Skirroceras bayleanum* (Oppel), BMNH,37069.

*Emileia* (*E.*) *polymera*, BMNH,37320.

*Labyrinthoceras meniscum* (Waagen), BMNH,37268.

All three specimens come from the old quarry at St. Vigor and are of considerable value for the correct interpretation of these three species.

c/ Southern England

The localities cited by Oppel in Southern England as having Sauzei Zone rocks were Burton Bradstock (Dorset), Dundry Hill near Bristol and the Cheltenham area of the Cotswolds (OPPEL, 1856-8). The beds of Sauzei Zone age near Cheltenham are the Bourguetia/ Phillipsiana beds (BUCKMAN, 1897), at Burton Bradstock the Red Bed (BUCKMAN, 1910) and at Dundry the 'Brown Iron-shot bed' (BUCKMAN &

WILSON, 1896). Ammonites are relatively rare at the first two localities and it is only at Dundry that abundant Sauzei Zone faunas may be collected. The following have been collected _in situ_ from South Main-road Quarry, Dundry (BUCKMAN & WILSON, 1896, p.691, section ix, bed 4):-

_Emileia_ (_E._) _polyschides_, CP 2414.

_E._ (_E._) _polymera_, CP 2423.

_E._ (_Otoites_) cf. _sauzei_ (d'Orb.), CP 2448.

_E._ (_O._) cf. _fortis_ Westermann, CP 2425.

_Kumatostephanus kumaterus_, CP 2413.

_Labyrinthoceras_ sp. CP 2402.

_Skirroceras bayleanum_, CP 2400.

_Sonninia_ aff. _felix_, CP 2422.

_Witchellia_ (_W._) _hebridica_ (Morton), CP 2442.

_W._ (_Pelekodites_) cf. _sulcata_ (S. Buckman), CP 2451.

A further discussion of other Sauzei Zone ammonite faunas from Southern England is given in Section 7.

d/ The typical Faunal and zonal Index of the Sauzei Zone.

It is impossible to be certain of the absolute range of _E._ (_O._) _sauzei_ as no collections have yet been made through continuous and 'expanded' beds of this age, hence the Sauzei Zone must be considered as an assemblage zone, based on the occurrence of the following characteristic fauna:-

_Emileia_ (_E._) _bulligera_ S. Buckman - _greppini_ Maubeuge group.

_E._ (_E._) _polymera_

_E._ (_E._) _pseudocontrahens_

_Kumatostephanus kumaterus_

K. perjucundus S. Buckman - triplicatum (Renz) group.

K. turgidulum

Labyrinthoceras meniscum

Skirroceras bayleanum

Sonninia propinquans - felix group.

The index species of the Sauzei Zone, Emileia (Otoites) sauzei (d'Orb.) is at this moment under rather a cloud. Whilst specimens do exist which are very close to d'Orbigny's original figure (such as BMNH,37323, St. Vigor, near Caen, Normandy, ex. Tesson collection), the subsequently designated neotype (WESTERMANN, 1954) has completely changed the interpretation of this species. However, this neotype designation must be considered totally invalid under article 75c, 3 & 5, of the Code of Zoological Nomenclature, since syntype material still exists. The specimen figured by d'Orbigny was only one of at least eight syntypes mentioned by him, of which the specimens figured by Westermann from the d'Orbigny collection form two (WESTERMANN, 1954, pl.1 fig. 1 - neotype; pl. 1, fig. 2). No type specimen was designated by d'Orbigny and no subsequent author has designated any of the syntypes lectotype. It was thus impossible for Westermann to erect a neotype as a replacement for a type specimen which in fact has never, as yet, existed. The d'Orbigny collection has not yet been re-organised, it would thus be impossible to be certain of the absence of the original figured specimen of E. (O.) sauzei. Thus no action should be taken until it is certain that the latter is missing, then one of the original syntypes (which need not be from the d'Orbigny collection) should be chosen as lectotype. There is no need for the suppression of the existing neotype via the International Commission on Zoological Nomenclature, since it was both invalid from its inception and published prior to 1961 (Article 75c of the 'code').

Until the d'Orbigny collection has undergone its present re-organisation, E. (O.) sauzei must remain in a state of flux. This need not however effect its status as Zonal index, since its position will finally be stabilised by the selection of a lectotype; its existing use is merely as a 'label' for an assemblage zone.

### 3. THE 'SO CALLED' SOWERBYI ZONE

Unlike the Sauzei Zone and most of the other Zones erected by Oppel (1856-8) in 'Die Juraformation' the Sowerbyi Zone was a poorly documented after thought by Oppel (1862-3) in 'Uber Jurassiche Cephalopoden'. Whilst the Sowerbyi Zone's relative position was clearly indicated ..... 'rather lower than Ammonites sauzei and higher than A. murchisonae ..... base above the ferruginous sand-stone of Gingen, Fils and neighbouring exposures' ... (Oppel, 1862-3, p.128), (the sandstone referred to is the Concavum or Donzdorf sandstone of subsequent German authors), no reference was made to the characteristic ammonite fauna of the new Zone. It was left to his pupil Waagen who monographed the Sowerbyi Zone over much of extra-alpine Europe, to produce the still generally accepted interpretation of this Zone (Waagen, 1867). The beds which have been correlated with the Sowerbyi Zone in its type area (Gingen, Wurtemburg, South Germany) are the clays and 'Wedel' sandstones below the Blaukalke down to and including the 'Sowerbyi Bank' or 'Oolite', all of which have been included in the 'Sowerbyi Schichten', (see fig. 3). Thus, whilst the litho-stratigraphic limits of the Zone in the type area are clearly delimited and, thanks to the work of Quenstedt (1886), Stahlecker (1926), Dorn (1935) and Oechsle (1958), its fauna is adequately described, the use of Sonninia sowerbyi, as its index is totally unsuitable. The impediment to its continued use is the incorrect identification of S. sowerbyi by Oppel, Waagen and most subsequent workers.

The type specimen of S. sowerbyi is an exceedingly poorly preserved ammonite, of which Sowerby's figure leaves much to be desired. It has however been carefully re-figured (BUCKMAN, 1904, pl.52) and after examining the holotype in the Bristol City Museum, I have come to very similar conclusions to those of Buckman (op. cit.), which are:-

i. The type specimen came from the top most, densely 'iron-shot' horizon at Dundry Hill, which is entirely Sauzei Zone in age (BUCKMAN & WILSON, 1896).

ii. It is the totally septate inner whorls of what would be, if complete, a large species. It is impossible to compare it with any but similarly incomplete specimens. Unfortunately a spinose nucleus is a feature common to the Sonninids.

iii. Taking into account its type horizon, whorl cross-section and spinose nature, the holotype of S. sowerbyi is most easily reconciled with a nucleus of a specimen of the Papilliceras mesacantha (Waagen) group.

Sonninia sowerbyi, whose type specimen is quite indeterminate and which came from the Sauzei Zone, is thus totally unsuitable as an index for the bio-stratigraphic unit previously called the 'Sowerbyi Zone'. This is a conclusion obviously reached by Buckman

(1887-1907, p.63-4), who rejected its use and replaced it with a series of hemerae (BUCKMAN, 1893, et seq.). Arkell (1954 & 1956) was of the opinion that Buckman had never found the true horizon of S. sowerbyi and taking into account reports of the occurrence of the latter in the Sauzei Zone, suggested the possible inclusion of the senior Sauzei Zone in the junior Sowerbyi, as a subzone (ARKELL, 1956), an indefensible recommendation subsequently followed by the British Geological Survey (WILSON, WELCH, ROBBIE & GREEN, 1959).

The type horizon of S. sowerbyi was identified as the Sauzei Zone by Buckman, and has been confirmed as such here. The reports of this species in the 'so called' Sowerbyi Zone sensu stricto are due to the presence of other spinose Sonninids, such as Euhoploceras, to which the type of S. sowerbyi has a great superficial similarity. This inconsistency has two possible solutions:-

i. keep to the boundaries of the present Sowerbyi Zone and merely choose a new index species.

ii. revert to one or more of the zones proposed as replacements for the Sowerbyi Zone .

On grounds of priority the second alternative must be accepted. The first, partial replacement was the Concavum Zone, which as originally described (HUDLESTON, 1887), included the present Discites Subzone. The remainder of the Sowerbyi Zone can be replaced by the Laeviuscula Zone, which had considerable popularity in France at the turn of the Century. It was rejected by Arkell (1954, p.73) as a synonym of the Sowerbyi Zone , on the grounds that Haug (1910) had cited S. sowerbyi as part of its characteristic fauna. However it is unlikely that Haug's identification of S. sowerbyi would be any more reliable than Waagen's or Oppel's, there thus seems no barrier to the use of Witchellia (Witchellia) laeviuscula as an index for a replacement Zone for the Sowerbyi Zone , which is here recommended.

A problem does exist with the positioning of the Discites Subzone, the basal unit of the Sowerbyi Zone . Whilst it would be logical to combine the Discites faunas within an extended Concavum Zone, as originally described (HUDLESTON, 1887; BUCKMAN, 1887-1907), this creates considerable problems concerning the finally accepted Aalenian/Bajocian boundary. The best, indeed the only solution to this problem is to elevate the Discites Subzone to full Zonal rank, a procedure which is followed here. The lectotype of the index species of the Discites Zone appears to be lost (J. Callomon pers. com.). However since Waagen (1867, p. 600) mentions twenty-six syntypes of Hyperlioceras ('Ammonites') discites, of which at least one survives (the holotype of the invalid species H. desori (Moesch non Pictet), refigured by BAYER, 1969); there should be no problem in designating a new type specimen.

## 4. THE LAEVIUSCULA ZONE

Based on the earlier use of a 'Witchellia horizon or beds', between the Concavum and Sauzei Zones (HAUG, 1893), Haug introduced the Zone of Witchellia laeviuscula (type specimen, recently refigured, WESTERMANN, 1969, Text fig. 35), in 'La Grande Encyclopédie' (HAUG, 1894). Earlier Haug had discussed the possibility of the existence of such an horizon (HAUG, 1893) and had referred the so called Sowerbyi Zone of Toulon (DOUVILLÉ, 1885), the 'Witchellia beds' of Normandy (MUNIER-CHALMAS, 1892) and Dundry

(S. BUCKMAN, 1887-1907) as being its possible equivalents. The exact biostratigraphic limits of the Laeviuscula Zone can be defined precisely. Haug used the Concavum Zone in its original extended sense, including the fauna, now separated within the Discites Zone (HAUG, 1891). Although originally including the Sowerbyi Zone of Toulon in his interpretation of the Sauzei Zone, Haug was well aware of the true fauna of the latter Zone, as found on the Normandy coast in the 'Couche Verte' and in the Blaukalk of Wurtemburg (HAUG, 1891, p.67). The limits of the Laeviuscula Zone can thus be defined at the base, as coming above the Discites fauna, and at the top, as coming below the Sauzei Zone, as redefined here. Haug's next use of the Laeviuscula Zone was in connection with a description of the Bajocian of the Basses Alpes(HAUG, 1900), and this area would probably be the most suitable for the designation of Type area and Horizon for this Zone.

Recent work in the Basses Alpes has produced a slightly clearer picture of the stratigraphic succession (PAVIA & STURANI, 1968). It is noticeable that these authors had some difficulty in distinguishing any more than one fauna between their Sauzei Zone and Discites subzone, which they included in the Laeviuscula subzone of the Sowerbyi Zone . Thus whilst the Laeviuscula Zone can be recognised in the Basses Alpes, its precise basal limits must be determined by those of its basal Ovalis subzone. However, it has not yet been possible to recognise the latter subzone in the Basses Alpes, an omission which will no doubt be rectified by future collecting.

## 5. THE SUBZONES OF THE SOWERBYI ZONE

The subzonal divisions of the Sowerbyi Zone, in present use, are based on the Buckman scheme of hemerae, as modified by Spath, (SPATH, 1936).

After having given reasons for rejecting 'Ammonites', (Sonninia) sowerbyi, as Zonal index, (BUCKMAN, 1887-1907, p.63-4), Buckman introduced a series of hemerae as replacements, (BUCKMAN, 1893). At first he was content with two, the Witchellia hemera, based mainly on the lower half of the 'Sandford Lane Fossil Bed; (BUCKMAN, 1893, Sect. IX), and the Discites. Buckman later confined the Witchellia hemera to the middle and introduced the Sonniniae hemera for the basal third of the 'Fossil bed', (BUCKMAN 1895). The table which Buckman produced for the correlation of the Cotswold Inferior Oolite, (BUCKMAN, 1895, Tab. V.) perhaps gives the most accurate picture of Buckman's mature views on the correlation of these beds, and it is reproduced here in a slightly modified form, (Tab. 2). After the restriction of the genus Sonninia to those ammonites of the S. propinquans Bayle group, the Sonniniae hemera took the new generic name Shirbuirnia, (BUCKMAN, 1910) - see Tab. 1 for fuller details of the evolution of these Subzones.

These Buckman hemerae were merely modified by Spath, who gave them valid specific, rather than generic indices, when he incorporated the Witchellia and Shirbuirnia hemerae in the reinstated Sowerbyi Zone as the Laeviuscula and Trigonalis subzones. Although these two latter subzones were recognised by Buckman, (as hemerae), at several localities in Southern England, (BUCKMAN, 1887-1907, p.ccvii), the faunas he figured from them were almost entirely from the Sandford

Lane 'Fossil Bed'. This single bed, thin and highly condensed, (less than 0.6m. in thickness) was virtually the sole source of ammonites of, in particular, the Trigonalis subzone. It is surprising that no one has seriously questioned Buckman's division of this thin bed initially into 2-3 horizons, and later into more than 9 hemerae (BUCKMAN 1909-30). Of the three hemerae described by Buckman up to 1910, the Shirbuirnia hemera or Trigonalis subzone was the most restricted in its distribution; Buckman himself was the first to admit that this fauna from Sandford Lane was virtually unique. He could not point out any other horizon in England with an exactly comparable fauna to the latter, but none the less, thought it the direct equivalent to that described by Waagen from Gingen (WAAGEN, 1867). For the last sixty years, the stratigraphic divisions, on which the subzones of the present Sowerbyi Zone rest, have been based on the faunas collected from one bed, in one isolated quarry. This quarry was only commercially worked for a short period of time in the 1870's, and was reopened under the direction of Buckman and Hudleston in 1892, in order to collect its well preserved and abundant fauna. However, most of the ammonite species later figured by Buckman from this locality were unlocalised specimens from the Darrel Stephens collection. No one in the last eighty years has seen the need for a re-examination of this key section, which is still available for study. It was thus with considerable interest, that, with the consent and assistance of Sherborne Castle Estates and their tenant farmer, I re-excavated the 'Fossil Bed' (in 1970-1), in order to test the validity of Buckman's subdivisions. The results of this work are to be found in the sections on the Subzones of the Laeviuscula Zone and on the successive ammonite faunas of S. England.

In brief, it was found that it was impossible to separate a *Witchellia* and *Shirbuirnia* fauna from the basal half of the 'fossil bed': the two were totally mixed together. Underlying the 'fossil bed' were found sandy limestones, containing *Sonninia* ( *Fissilobisceras* ) *ovalis*, following the faunal sequence originally described by Buckman from the Cotswolds (BUCKMAN, 1895) and Dundry, (BUCKMAN and WILSON, 1896). There has been much confusion over the stratigraphic relationship between the genus *Shirbuirnia* and the *Sonninia ovalis* group. Thus for example the alleged occurrence of *Shirbuirnia* directly above the Discites fauna in Skye (Inner Hebrides, Scotland, MORTON, 1965), has been accepted as proving the present subzonal scheme, (WESTERMANN and RICCARDI, 1972). The fact that this particular occurrence of *Shirbuirnia* is in fact based on misidentified *Sonninia* of the *S. ovalis* group, (J. Callomon, pers. comm.), and that the true *Shirbuirnia*, as in Dorset, occur at a higher horizon, makes a nonsense of any stratigraphic or systematic conclusions, based on such erroneous records, (WESTERMANN and RICCARDI, 1972).

## 6. THE SUBZONES OF THE LAEVIUSCULA AND CONCAVUM ZONES

The re-examination of the Sandford Lane 'fossil bed' has proved that it is impossible to separate the faunas of Buckman's Witchellia and Shirbuirnia hemerae, as based on this bed. Since *Witchellia laeviuscula* has precedence over *Shirbuirnia trigonalis* as index for this subzonal fauna, it is used as such here. Whilst it would be possible to use *S. trigonalis* in order to prevent the double use of *W. laeviuscula* as both Zonal and subzonal index, too much confusion

| HEMERAE | COTSWOLDS | SANDFORD LANE |
|---|---|---|
| SAUZEI | BOURGUETIA and PHILLIPSIANA BEDS | Limestone with Otoites sauzei and Sonninia propinquans (6a) |
| WITCHELLIAE | WITCHELLIA GRIT | Limestone with Witchellia (6b) and |
| | NOTGROVE FREESTONE | |
| SONNINIAE | GRYPHITE GRIT with S. fissilobatum-ovalis | Sonninia cf. fissilobatum - ovalis, mainly at the bottom. (6c) |
| | | Sandy limestone with S. ovalis (7-8) |
| 'POST DISCITAE' | BUCKMANI GRIT with Terebratula buckmani | Sandy parting with Terebratula cortonensis (9) |
| DISCITAE | LOWER TRIGONIA GRIT | Sandy limestone with Hyperlioceras (10) |
| CONCAVI | SNOWS HILL CLAY, TILE STONE etc. | Sandy stone (11-13) |

Table 2.

A correlation of parts of the Middle Inferior Oolite by S.S. Buckman ; modified from Buckman (1895), table 2, with bed numbers inserted after Buckman (1893).

would be created by its use in a position very different to that originally intended by Buckman and Spath. However if there were any strong objections to the double use of W. laeviuscula, Shirbuirnia stephani, inadvertently validated as a Zonal index by Arkell (ARKELL, 1933, plate 33), prior to Spath's Trigonalis Subzone (SPATH, 1936), would make a good alternative choice. The horizon below the 'fossil bed' at Sandford Lane yields a fauna which may be correlated with that obtained from the 'lower white iron-shot' of Dundry and the Gryphite Grit of the Cotswolds. This was recognised at an early stage by Buckman (see Tab. 2), who later confused the issue by wrongly correlating the fauna from this lower horizon, with that artificially split from the basal third of the Sandford Lane 'fossil bed', and combining both within the Shirbuirnia hemera; Spath's Trigonalis Subzone. This lower horizon, originally designated by Buckman as the 'Sonninia fissilobatum - ovalis horizon', (BUCKMAN, 1895) can take a pre-existing subzonal index, Sonninia ( Fissilobisceras ) ovalis (Qu. emend. S.B. 1893) as used by Oechsle in South Germany, (OECHSLE, 1958, p.182, with Lectotype designation). This follows current French practice, (GABILLY, 1964; CONTINI, 1970; GABILLY et al. 1971) and is in line with Buckman's use of S. ovalis as a hemeral index, (BUCKMAN, 1930 in 1909-30).

The use of a Discites Zone produces few problems. The fauna of this Zone is easily recognisable, in spite of the fact that further, more detailed stratigraphic division of it may be possible (BAYER, 1969, p.35). Problems arise in the recognition of an additional subzone above the Concavum s. str.,variously called the 'Amplectens faunule' or subzone (WESTERMANN, 1969; BAYER, 1970) and the Formosum subzone, (CONTINI, 1970; GABILLY et al. 1971). There are indications

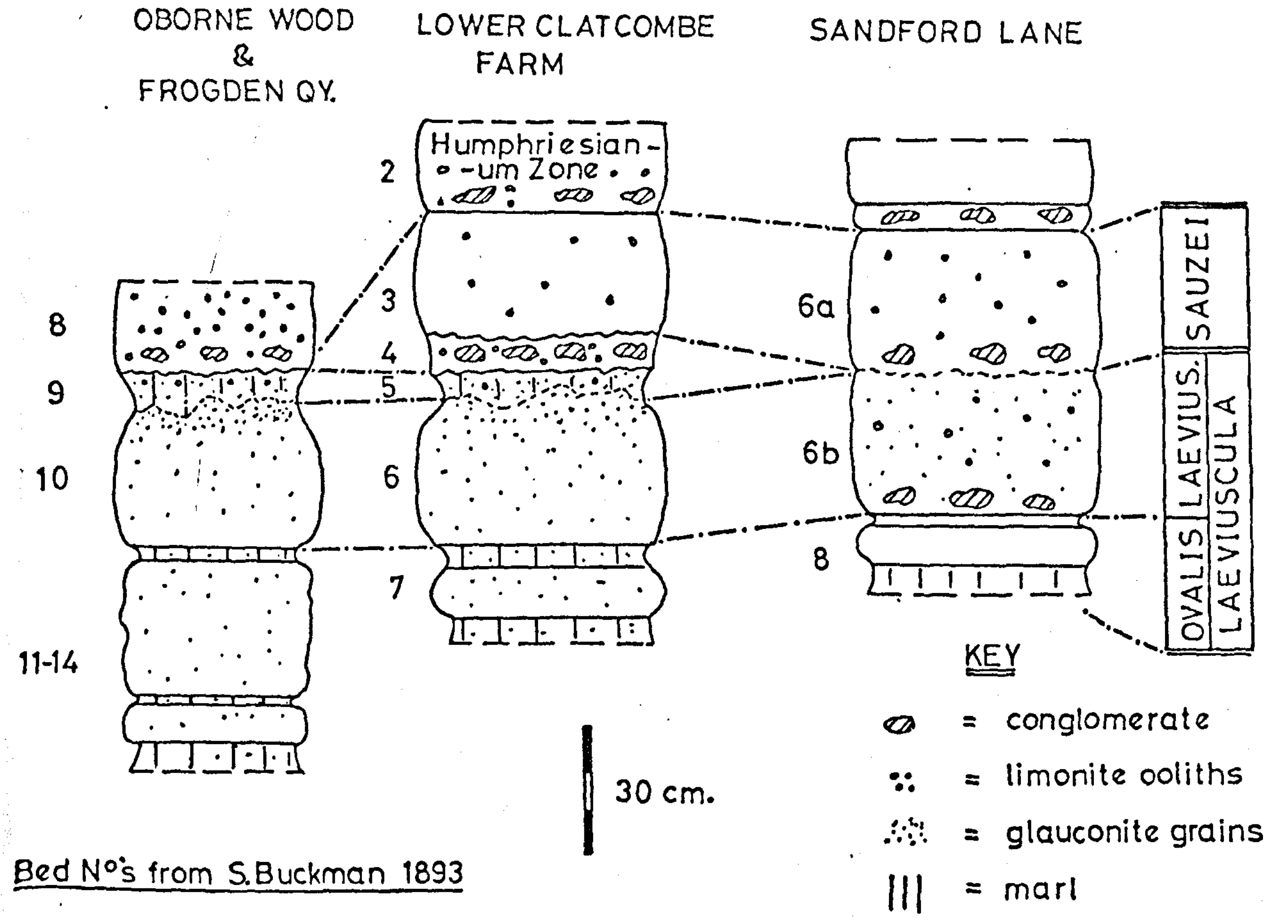


Figure 2.

A correlation of certain beds of the Inferior Oolite in the Sherborne area, north Dorset.

that the middle part of the Bradford Abbas 'fossil bed' yields a fauna equivalent to those from this 'so called subzone'. However until a detailed revision of the Graphoceratid ammonites has been completed, no final decision should be made on this point.

## 7. THE SUCCESSIVE AMMONITE FAUNAS OF THE SAUZEI, LAEVIUSCULA, DISCITES AND CONCAVUM ZONES IN SOUTHERN ENGLAND

The following can only be a summary of work, which will be published in greater detail elsewhere. Beds of this age in Southern England tend to be both highly condensed and laterally impersistent. This attempt to establish a series of consecutive ammonite faunas can only be considered provisional, as it is often difficult to establish any correlation between isolated exposures. In this respect, the beds of this age in the Sherborne district of Dorset were particularly difficult to place in sequence until an exposure at Clatcombe Farm, (BUCKMAN, 1893, section xiv) was examined. This enabled a correlation to be made between the Blue Bed of Oborne (op. cit. section xv, bed 10) and the Sandford Lane 'Fossil Bed', (op. cit. section ix, bed 6), which was at variance with the results obtained by Buckman (see fig. 2 for further details). The faunal sequence established by this revised correlation was fully upheld however by the continuous series of faunas which it has recently been possible to collect from Dundry Hill, near Bristol **(fig.3)**. Certain limits were needed to restrict the extent of this study and the prominent unconformities at the base of both the Humphriesianum and Concavum Zone rocks in the Sherborne district formed natural lines of division.

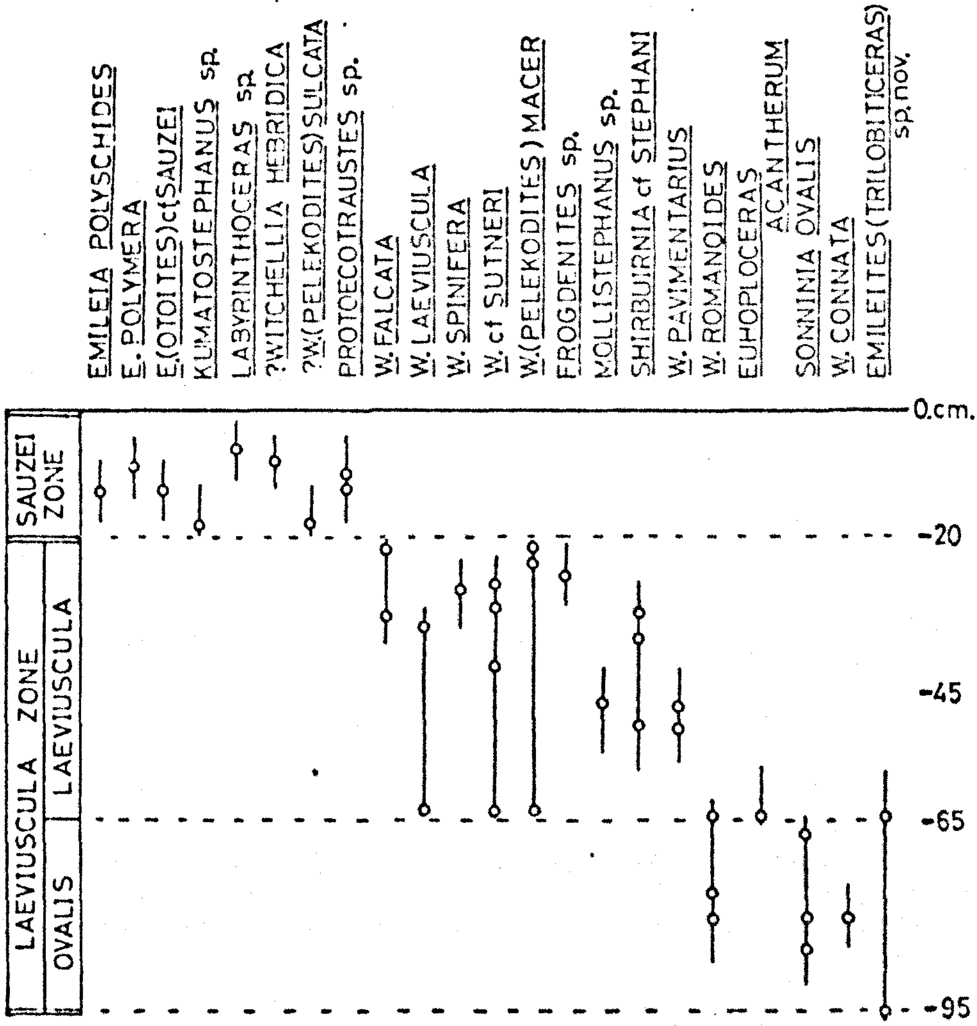


Figure 3

The stratigraphic distribution of certain ammonites from the South Main-road quarry, Dundry Hill, Avon. The 0.0cm. line marks the planed surface at the top of the Lower Bajocian rocks.

The ammonite records which are given here are all based on material from my own collection, collected in situ, unless otherwise stated. In the following lists:-

T = Topotype

C = Chorotype

M = Macro-conch

m = Micro-conch

a/ The Sauzei Zone

The fauna of part of the Irony Bed (GATRALL, JENKYNS & PARSONS, 1972, p.81) to the west of Sherborne, together with that from the top half of the Sandford Lane 'Fossil Bed' and its equivalent at Clatcombe (BUCKMAN, 1893, pp.493-5) are all identical to those from the Couche Verte and Blaukalke of Normandy and Schwabia; as is that from the upper part of the Brown Iron-shot Bed of Dundry (BUCKMAN & WILSON, 1896). The Pecten Bed of the Bruton district of Somerset (RICHARDSON, 1916), the Phillipsiana/Bourguetia Beds of Cleeve Hill near Cheltenham (BUCKMAN, 1897; BUCKMAN in RICHARDSON, 1904) and the upper part of the Red Beds of South Dorset (SENIOR, PARSONS & TORRENS, 1970) have also yielded typical Sauzei Zone faunas.

The following ammonites come from the most extensive Sauzei Zone fauna collected during the course of this work, that is from the top of the Sandford Lane 'Fossil Bed'. This bed was found to be divisible into only two horizons; at the base a light yellow-green coloured limestone with yellow ooliths and green glauconite grains and at the top a deep blue coloured 'iron-shot' limestone, which weathers to a brown colour; hence the third matrix and hemera of Buckman. These two highly distinctive matrices are separated by an irregular parting, which in fact marks the position of an extensive 'hard-ground', on to the top of which the blue 'iron-shot' limestone has been cemented. The 'hard-ground' shows half eroded ammonites, limonite- and serpulid-encrustation and is surmounted by a conglomerate of soft, light grey coloured limestone lithoclasts.

Sandford Lane ST628,179*1

(BUCKMAN, 1893, section ix, bed 6a)

Emileia (Emileia) bulligera S. Buckman, T.M.

E. (E.) pseudocontrahens Maubeuge, M., J. Whicher Collection.

E. (Otoites) fortis (Westermann), m.

E. (O.) sauzei (d'Orbigny, pl.139 non neotype), m.

E. (O.) cf. delicata (Buckman), m.

Kumatostephanus cf. kumaterus S. Buckman (J. Whicher collection), T,M.

?Normannites aff. kialagvikensis Imlay, m.

?N. aff. sauzeiformis Westermann, m.

Labyrinthoceras meniscum (Waagen), M.

Sphaeroceras manselii (J. Buckman), C, M & m.

Skirroceras kalus (S. Buckman), T,M.

Sonninia felix (S. Buckman), T,M.

S. cf. propinquans (Bayle),M.

S. cf. corrugata (J.de C. Sowerby),? M.

Witchellia (?Witchellia) hebridica (Morton),M.

W. (Pelekodites) sulcata (S.Buckman), C,m.

Lissoceras semicostulatum S. Buckman, T,M.

---

*1 = National Grid Reference.

Strigoceras (Strigoceras) strigifer (S. Buckman),T,M.

Toxamblyites aff. arcifer S. Buckman,? m.

The conglomerate at the base of this bed has a thicker lateral equivalent at Clatcombe Farm (see fig 2, = bed 4, BUCKMAN, 1893, p.498). This stratigraphically lower horizon yields ammonites which are too poorly preserved for anything other than generic identification. The next ammonite fauna is difficult to place, since it is transitional in character between the Sauzei and Laeviuscula Zones. Taking into account the wealth of Witchellia present and the absence or rarity of many species characteristic of the Sauzei Zone, this has been placed in the Laeviuscula Zone.

b/ The Laeviuscula Zone and Subzone

i. The 'Green grained marl' of Oborne

The highly glauconitic marl bed of the Oborne area, Sherborne, Dorset (BUCKMAN, 1893, Frogden quarry, p.500, bed 9) has yielded extensive and superbly preserved faunas, which, apart from specimens from the lower part of the main 'Iron-shot' bed at Dundry (BUCKMAN & WILSON, 1896, p.681, bed 6), have no other English equivalent. The following collection is from the Marl Bed at a recent temporary exposure at Oborne, near Sherborne, Dorset (WHICHER & PALMER, 1971) although a similar fauna was obtained from the South Main-road quarry, Dundry, near Bristol, (BUCKMAN & WILSON, 1896, p.691, bed 5)

Oborne Wood, ST648,188

(Equivalent to bed 9, Frogden quarry)
(BUCKMAN, 1893)

Emileia (E.) brocchii (J. Sowerby), ?T,M.

E. (E.) bulligera, J. Whicher collection, M.

E. (E.) polyschides, M.

E. (Otoites) contracta (S. Buckman non Sow.), m.

Frogdenites spiniger S. Buckman, T, M & m.

F. cf. profectus S. Buckman, m.

Mollistephanus aff. mollis S. Buckman, M.

Skirroceras aff. kalus S. Buckman, M.

S. leptogyrale S. Buckman (including S. macrum Buckman non Quenst.), M.

Bradfordia cf. inclusa S. Buckman.

'Ambloxyites' amblys S. Buckman, M.

Protoecotraustes spiniger (S. Buckman), m.

Papilliceras arenatus (Quenst. emend. Buckman), M.

Shirbuirnia superba (S. Buckman), T, M.

S. cf. trigonata (Quenst. emend. Dorn), M.

Witchellia (Witchellia) falcata S. Buckman, T, M.

W. (W.) glauca S. Buckman, T, M.

W. (W.) actinophora S. Buckman, T, M.

The above three 'species' form part of a highly variable plexus, varying from smooth involute to coarsely ribbed evolute morphotypes.

W. (W.) cf. patefactor S. Buckman, M.

W. (W.) plena (S. Buckman), T, M.

W. (Pelekodites) aurifer (S. Buckman), m.

W. (P.) macra (S. Buckman), T, m.

ii. The basal half of the Sandford Lane 'Fossil-bed'

The 'green grained marl' of the Oborne district grades down into a hard glauconitic limestone (= bed 10, Frogden quarry, BUCKMAN, 1893), which contains a fauna very similar to that obtained from the basal part of the Sandford Lane 'Fossil-bed'. Comparable faunas have also been collected from the basal part of the Pecten Bed of the Bruton district, Somerset (RICHARDSON, 1916, p.495, bed 4), the Witchellia Grit of the Cotswolds (BUCKMAN in RICHARDSON, 1904) and from the middle of the 'Iron-shot' beds on Dundry Hill, near Bristol (BUCKMAN & WILSON, 1896, p.681, bed 8). Due to the intractable nature of the Sandford bed it has not proved possible to collect topotypes of all the ammonite species figured by Buckman from this horizon. However the matrix of specimens from this horizon is so characteristic as to preclude any error in the identification of their horizon.

It cannot be over stressed that it has proved totally impossible to separate two faunas from the basal half of the 'Fossil-bed'; Witchellia and Shirbuirnia are inextricably mixed together. Indeed one of the highest ammonites found in this portion of the bed was a specimen of Shirbuirnia stephani (S. Buckman), CP 1930, at 0.31m. below the top of the 'Fossil-bed'.

Sandford Lane, ST628,179
(BUCKMAN, 1893, bed 6c)

Emileia (E.) catamorpha S. Buckman, J. Whicher collection, T, M.

E. (E.) cf. polyschides (Waagen), J. Whicher collection, M.

E. (Otoites) contracta (S. Buckman non Sow.), m.

E. (O.) cf. delicata (S. Buckman), T, m.

Mollistephanus (M.) cf. mollis S. Buckman, T, M.

Trilobiticeras (Emileites) liebi (Maubeuge), M.

Bradfordia cf. liomphala S. Buckman

*Euhoploceras acantherum* (S. Buckman), T, M.

*Shirbuirnia stephani* (S. Buckman), T, M.

*Sonninia gingensis* (Waagen), M.

*Witchellia* (*W.*) *gelsina* (S. Buckman), T, M.

*W.* (*W.*) *plena* (S. Buckman), M.

*W.* (*W.*) *sutneri* (Branco), M.

*W.* (*W.*) *glauca* S. Buckman, M.

*W.* (*W.*) *patefactor* S. Buckman, M.

*W.* (*W.*) cf. *pavimentaria* (S. Buckman), M.

The last three 'species' form part of a plexus of variation, similar to that of the 'Marl Bed' fauna, but they are consistently smoother and more evolute.

*W.* (*Pelekodites*) *macra* (S. Buckman), m.

c/ The Ovalis Subzone of the Laeviuscula Zone

The beds immediately below the Sandford Lane 'Fossil-bed' yield large members of the *Sonninia ovalis* (Quenst. emend. Buckman) group and evolute Witchellids, which enable a correlation to be made with a bed on Dundry Hill yielding a similar fauna, that is the 'Lower white iron-shot' bed (BUCKMAN & WILSON, 1896, p.676, beds 4-8). Other areas which have produced similar ammonite faunas include the Bruton district of Somerset (RICHARDSON, 1916, p.495, bed 4b), the 'Gryphite Grit' of the Cotswolds (BUCKMAN, 1895, p.393) and Seavington St. Mary, Somerset (PARSONS & TORRENS in TORRENS, (Editor) 1969, p.A27, bed 4a). The following ammonite fauna comes from the 'Lower white iron-shot' bed of Barns Batch Spinney, Dundry Hill.

Barns Batch Spinney, ST557, 659,
(BUCKMAN & WILSON, 1896, p.689) bed 2.

Sonninia ( Fissilobisceras ) ovalis (Quenst. emend. Buckman), M.

Witchellia (W.) albida (S. Buckman), T, M.

W. (W.) connata (S. Buckman), M.

W. (W.) romanoides (Douvillé), M.

W. (W.) cf. sutneri (Branco), M.

W. (Pelekodites) pelekus (S. Buckman), T, m.

W. (P.) cf. macra (S. Buckman), m.

Bradfordia cf. inclusum S. Buckman

Strigoceras (S.) compressum (S. Buckman), T, M.

Docidoceras (D.) cylindroides S. Buckman, M.

Trilobiticeras (T. ) aff. punctum (Vacek), m.

T. (Emileites) liebi (Maubeuge), m.

Emileia (Otoites) sauzei (Douvillé non d'Orb.), m.

d/ The Discites and Concavum Zones

The most important single locality for the study of the Discites and Concavum Zones in England is undoubtedly the Bradford Abbas district, near Sherborne, Dorset. Here a relatively thin (0.50 - 70m.) highly condensed limestone bed yields abundant ammonite faunas, which were minutely studied by Buckman (1893; 1887-1907). Above this Bradford Abbas 'Fossil-bed' there is a large stratigraphic break. The junction between the Discites and Laeviuscula Zones can however be studied at Dundry (Castle Farm and Barns Batch Spinney, BUCKMAN & WILSON, 1896), Lusty quarry, Bruton, Somerset (RICHARDSON, 1916, p.495) and Frogden quarry, Oborne, Dorset (BUCKMAN, 1893). Whilst all of the quarries made famous by J. and S.S. Buckman in the Bradford Abbas district are now filled in, the extensive section of the 'Fossil-bed' in the Bradford Abbas Railway-cutting is still available for study. The following faunas are all in situ collections from this locality and bed. It is to be noted that the Graphoceratid ammonites, like the Witchellids, are extremely variable and until a full systematic revision is made of them, any specific names given merely represent single morphotypes.

Buckman mainly on lithological criteria, divided the Bradford Abbas 'Fossil-bed' into two horizons; an upper black stained 'iron-shot' limestone and a lower soft brown 'iron-shot', which he included in the Discites and Concavum hemerae respectively. In the Bradford Abbas Railway-cutting the 'Fossil-bed' was found to be divided by two marl partings into three approximately equal components. The upper, main parting, which separates the black stained limestone from the rest is consistent in thickness over the length of the cutting, whilst the second, lower parting is less persistent, but it is still traceable over most of the cutting. These two partings enabled three successive ammonite faunas to be collected.

i. The top third of the Bradford Abbas 'Fossil-bed'

Whilst the following fauna comes from the Bradford Abbas 'Fossil-bed', exactly similar ammonites have been found in the lower exposure at Frogden quarry (BUCKMAN, 1893), in the 'Snuff-box' bed of South Dorset (SENIOR, PARSONS & TORRENS,1970), in the lower Trigonia Grit of the Cotswolds (BUCKMAN, 1895) and on Dundry (BUCKMAN & WILSON, 1896)

Bradford Abbas Railway-Cutting, ST594, 145
(Equivalent to bed 7, BUCKMAN, 1893, p.485)

Braunsina aspera S. Buckman

*Graphoceras* (*Graphoceras*) cf. *apertum* (S. Buckman)

*G.* (?*G.*) *hamatum* (S. Buckman)

*G.* (? *Ludwigella*) *carbatinum* (S. Buckman)

*G.* (?*L.*) *recticostata* (S. Buckman)

*Darellia* cf. *coela* (S. Buckman)

*D.* cf. *laxa* (S. Buckman)

*Hyperlioceras* (*Hyperlioceras*) *walkeri* (S. Buckman)

*H.* (*H.*) *liodiscites* S. Buckman

*Reynesella* *piodes* S. Buckman

*Nannoceras* *nannomorphum* S. Buckman

*Nannolytoceras* cf. *liocyclum* (Brasil)

*Euhoploceras* *acanthodes* (S. Buckman)

*E.* *submarginata* (S. Buckman)

*Trilobiticeras* (*Trilobiticeras*) *trilobitoides* S. Buckman

*T.*(*Emileites*) aff. *liebi* (Maubeuge)

ii. The middle of the Bradford Abbas 'Fossil-bed'

The middle of the 'Fossil-bed' yields a fauna intermediate in character between the previous and that from the basal part of the 'Fossil-bed' (Concavum Subzone *sensu stricto*). Similar faunas have been collected from the top of the Iron-shot' Bed at Horn Park quarry, south Dorset (SENIOR *et al.*, 1970) and from bed 3, Seavington St. Mary (PARSONS & TORRENS in TORRENS (Editor), 1969).

Bradford Abbas Railway-Cutting

*Graphoceras* (*G.*) *apertum* (S. Buckman)

*G.* (*G.*) *scriptitatum* S. Buckman

*G.* (*Ludwigella*) *compactum* (S. Buckman)

*G.* (*L.*) *limitatum* S. Buckman

*G.* (*L.*) *subrudis* S. Buckman

*Bradfordia liomphala* S. Buckman

*Eudmetoceras amplectens* S. Buckman

*Euhoploceras acanthodes* (S. Buckman)

*E. simplex* (S. Buckman)

*Haplopleuroceras subspinatum* (S. Buckman)

*Trilobiticeras* (*T.*) cf. *punctum* (Vacek)

iii. The lower part of the Bradford Abbas 'Fossil-bed'

The lower part of the 'Fossil-bed', together with the main 'iron-shot' bed at Horn Park quarry, Dorset (SENIOR *et al.*, 1970), bed 2 Seavington St. Mary (PARSONS & TORRENS, in TORRENS (Editor), 1969), and the lower limestones at Dundry (BUCKMAN & WILSON, 1896) have all yielded a similar fauna, that of the Concavum Subzone *sensu stricto*.

Bradford Abbas Railway-Cutting

*Graphoceras* (*G.*) *concavum* (Sow.)

*G.* (*G.*) *magna* (S. Buckman)

*G.* (*G.*) *sublineata* (S. Buckman)

*G.* (*Ludwigella*) *attenuata* S. Buckman

*G.* (*L.*) *cornu* (S. Buckman)

*G.* (*L.*) *flexilis* S. Buckman

*G.* (*L.*) *micra* S. Buckman

*G.* (*L.*) *rotabilis* (S. Buckman)

*G.* (*L.*) *stigmosum* S. Buckman

*Bradfordia liomphala* S. Buckman

*Euhoploceras* cf. *crassiformis* (S. Buckman)

## 8. THE CORRELATION OF SCHWABIA AND NORMANDY

The correlation of the 'Couche verte' and 'Blaukalk' with the Sauzei Zone, has already been discussed in some detail, and presents no problems; unfortunately the same cannot be said of the subjacent strata.

### a/ Schwabia

Correlation of the beds between the 'Blaukalk' and the 'Oberer Donzdorf' sandstone (= Concavum Zone), with the British succession present considerable problems for the following reasons. Firstly these Schwabian horizons are poor in ammonites, secondly many typical British ammonites, such as Witchellia are rare or absent and thirdly there exists a prominent unconformity, showing a marked discordance, which at some localities cuts out several beds, (The 'Unter Wedel Sandstein', see Fig. 4). Exposures in the Gingen area, notable in the past for its 'Sowerbyi Zone' ammonites (WAAGEN, 1867, DORN, 1935, OECHSLE, 1958), are now very poor. The following is an undescribed stream section at Grunbach near Goppingen, and less than 10 km. from Gingen, which had a very similar succession, (OECHSLE, 1958, with extensive list of ammonites etc.).

i. Stream section in a wood just to the east of Grunbach

(4) "Mittel -$\gamma$- tone"

A blue tenacious clay limonite streaked at the base, and with intercalations of thin, sandy limestone ('Wedel Sandstein') in the upper part.

seen to 1.0 m. ++

(3) A conglomerate consisting of dark blue 'iron-shot'

limestone lithoclasts, heavily limonite-encrusted and set in soft blue limestone matrix, which becomes harder and more indurated towards the base.

There is a fairly prolific remanié ammonite fauna, mainly distorted, broken and limonite-encrusted internal moulds, resting on the irregular and limonite coated basal erosion surface.

Shirbuirnia cf. stephani, CP. 1810.

Shirbuirnia spp.

0.15m.

——————— prominent 'hard-ground' ———————

(2) "The Sowerbyi Oolith"

A hard, blue, heavily 'iron-shot' limestone, with a tendency to be conglomeratic; very hard at the top and softer below, with a lighter, more grey coloured matrix.

Euhoploceras cf. adicra (Waag.), CP. 1818.

0.45m.

(1b) A thin sandy parting 0.04m.

(1a) "The Oberer Donzdorf, or Concavum Sandstein"

A massive, brown sandstone, heavily ironstained and with some "box structure" weathering.

seen to 1.0 m. +

The "Sowerbyi Oolith", (Discites Zone) is undoubtedly the source of Waagen's type specimens of Euhoploceras adicra and E. polycantha. The others, apart from Hyperlioceras discites, came either from the suprajacent remanié bed or the 'Unter Wedel sandstein", which in the

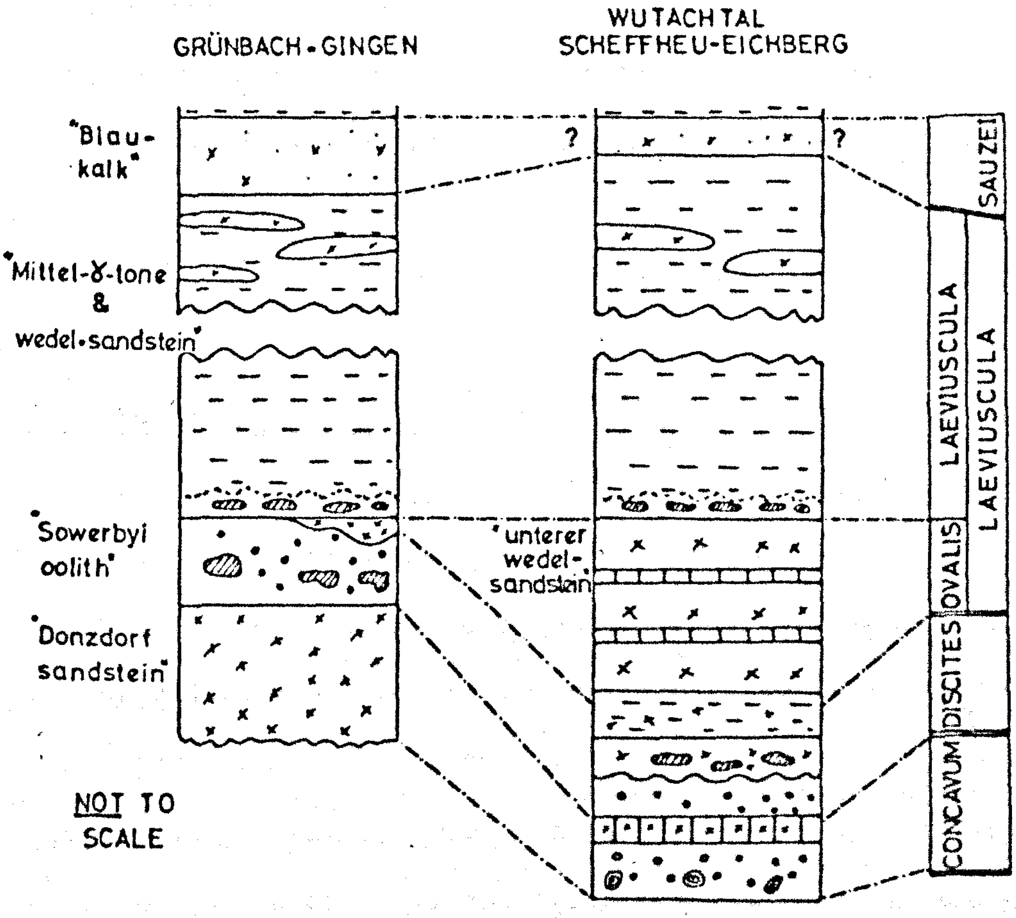


Figure 4

A schematic correlation of parts of the Lower Bajocian and Aalenian, in the Schwabian Albe, southern Germany.

past have all been grouped, together with the 'Sowerbyi Oolith', in the 'Sowerbyi bank' or 'Schichten'.

b/ The Wutach

There is a slightly more expanded sequence in the Wutach, with several courses of very sandy limestone (the 'Unter Wedel Sandstein') coming in below the erosion plane, and above the 'Sowerbyi Oolith' equivalent, (BAYER, 1970; BUCK, HAHN & SCHADEL 1966; and HAHN, 1971). The 'Sowerbyi Oolith' equivalent (Eichberg, Fig. 4), yields Hyperlioceras cf. rudidiscites (CP.2397) (see RIEBER, 1963, p.6) and brachiopods, Sphaeroidothyris eudesiana and 'Rhynchonella' forbesi, identical to those from southern England. The 'Unter Wedel Sandstein' has produced several Sonninia (Fissilobisceras) cf. ovalis (Bayer Col.), whilst resting on the overlying erosion plane are poorly preserved, remanié ammonites which can be referred to the genus Shirbuirnia, (cf. S. trigonata (Qu. emend.Dorn), Scheffhue, CP 1820). The correlation of the 'Wedel Sandstein' with the Ovalis subzone is further strengthened by the isolated occurrence of Trilobiticeras (Emileites) cf. liebi (Maub.), above the highest occurrence of Hyperlioceras, (BAYER, 1968 and pers. comm.).

To the west, at the old Iron-stone mines at Ringsheim, similar sections are visible to those of the Wutach, (BAYER, 1970) where a reduced 'Unter Wedel Sandstein', yielding Fissilobisceras ovalis (CP.1821) overlies beds containing Hyperlioceras spp. and Euhoploceras cf. polycantha

The correlation of the Schwabian lower Bajocian is summarised in a general way in Fig. 4.

c/ Normandy

Below the 'Couche Verte' on the Normandy coast, there is a series of light grey, slightly sandy limestones, rich in black chert bands - the Malière. At St. Honorine des Pertes, the upper part of the Malière has yielded Kumatostephanus cf. triplicatum (CP.1600 & 1601),and Emileia (E.) greppini Maubeuge, (N. Morton col.), and is thus still Sauzei Zone in age. At lower horizons the Malière is less fossiliferous, but past records suggest that it ranges down, at least as far as the Murchisonae Zone, (RIOULT and GABILLY, 1967).

The large inland quarries at May-sur-Orne show numerous exposures of the Iron-shot Aalenian/Bajocian resting on steeply dipping palaeozoics. The Murchisonae - Concavum Zones are well represented as are the Upper Bajocian Zones, but the intermediate horizons tend to be very lenticular (BIGOT, 1900). From the work of Munier-Chalmas (1892) Brasil (1895), Bigot (1900) and more recently Rioult and Gabilly (1967) it seems likely that at least the Ovalis subzone has been represented by a small lens of 'iron-shot' limestone. The preservation and mode of deposition of the Lower, Bajocian in Normandy thus follows a very similar pattern to that of South Dorset.

## 9. CONCLUSION

The following is a resumé of the Standard Zonal scheme for parts of the Aalenian-Bajocian Stages, including any changes made necessary by the present work.

### a/ The Zone of Graphoceras (Graphoceras) concavum (J. Sow.)

| | |
|---|---|
| Author:- | Hudleston (1887, in 1887-96) restricted by Buckman (1889, in 1887-1907). |
| Type area:- | North Dorset. |
| Type Horizon:- | Basal part of the Bradford Abbas 'Fossil-bed'. |
| Characteristic fauna:- | The wealth of Graphoceras s. str., particularly G. (G.) concavum, G. (G.) magna, G. (Ludwigella) cornu and G. (L.) stigmosum, which is typical of the Concavum Zone sensu stricto. There may be a possibility of subdivision of this unit, with a higher horizon characterised by Eudmetoceras and Haplopleuroceras. |

### b/ The Zone of Hyperlioceras (Hyperlioceras) discites (Waagen)

| | |
|---|---|
| Author:- | Buckman (1893). |
| Type area:- | North Dorset. |
| Type Horizon:- | Top of the Bradford Abbas 'Fossil-bed'. |
| Characteristic Fauna:- | This Zone is characterised by the abundance of the genus Hyperlioceras, particularly H. (H.) walkeri - rudidiscites S. Buckman group, as well as by the genus Reynesella and by Trilobiticeras trilobitoides. |

c/ The Zone of _Witchellia_ (_Witchellia_) _laeviuscula_ (J. de C. Sow.)

Author:- Haug (1894).

Type area:- To be designated.

Type Horizon:- To be designated.

Characteristic Fauna:- The abundance of the dimorphic pair _Witchellia_ (_W._) and _W._ (_Pelekodites_) and the species _Trilobiticeras_ (_Emileites_) _liebi_ (Maubeuge) characterise this horizon.

i. The Subzone of _Sonninia ovalis_ (Quenst. emend. Buckman)

Author:- Oechsle (1958).

Type area:- The Schwabian Albe.

Type Horizon:- The 'Unterer Wedelsandstein'.

Characteristic Fauna:- This horizon is typified by the presence of large smooth Sonninids, such as _S. ovalis_, and by the appearance of _T._ (_E._) _liebi_ and the genus _Witchellia_.

ii. The Subzone of _Witchellia_ (_Witchellia_) _laeviuscula_ (J. de C. Sow.)

Author:- Haug (1894), restricted Spath (1936).

Type area:- Still to be designated.

Type Horizon:- Still to be designated.

Characteristic Fauna:- This subzone is characterised by the more involute, costate Witchellids and by the genus _Shirbuirnia_. There is a possibility that this unit may be subdivided on the basis of the distribution of certain species of _Witchellia_ and _Shirbuirnia_, the higher horizon being defined by the appearance of the genus *Frogdenites*.

d/ The Zone of *Emileia* (*Otoites*) *sauzei* (d'Orb.)

Author:- Oppel (1856 in 1856-8).

Type area:- Schwabian Albe.

Type Horizon:- The Blaukalke.

Characteristic Fauna:- This has already been given in some detail (section 2), but the base of this Zone is defined by the appearance of the genera *Kumatostephanus* and *Labyrinthoceras* and the species *Sphaeroceras manselii* and *Witchellia hebridica*.

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# IB. A STRATIGRAPHIC REVISION OF THE HUMPHRIESIANUM/SUBFURCATUM ZONE ROCKS (BAJOCIAN STAGE, MIDDLE JURASSIC) OF SOUTHERN ENGLAND


ABSTRACT

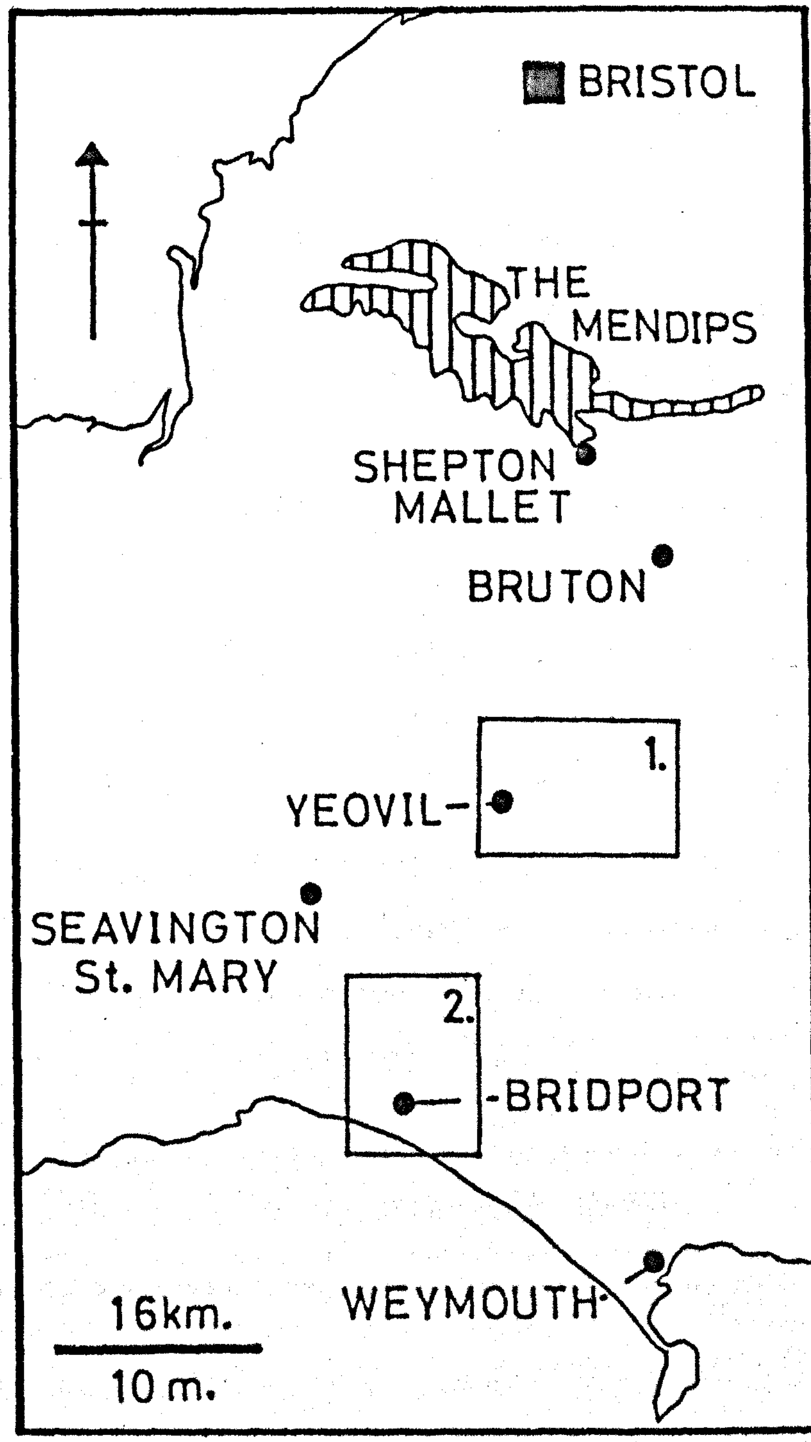
The development of the Standard Zonal scheme for this part of the Bajocian Stage is discussed, and a detailed, bed by bed, analysis of rocks of this age in Southern England (mainly Dorset) is given. The type horizons of Smith's, the Sowerbys' and Buckman's ammonite species are discussed, and as many as possible of these are placed in their correct stratigraphic position. A detailed description of the stratigraphic distribution of the major ammonite species and genera is given. Finally the subzonal divisions of these Zones, which have been recognised in Southern England are redefined; that is the Romani, Humphriesianum and Blagdeni Subzones of the Humphriesianum Zone and Banksi, Polygyralis and Baculata Subzones of the Subfurcatum Zone.

CONTENTS

## 1. INTRODUCTION AND ACKNOWLEDGEMENTS

The Humphriesianum and Subfurcatum Zones are some of the most poorly represented of all the British Bajocian Zones. Humphriesianum Zone rocks are only found sporadically in the British Isles, South of the Mendips in Dorset and Somerset, in Yorkshire (Cross's record of Stephanoceras humphriesianum (Sow.) from the Lincolnshire Limestone cannot be confirmed ( Cross, 1875, p.121)) and in the Inner Hebrides, Skye and Raasay in particular. The Subfurcatum Zone is even more restricted in its distribution, rocks of this age having only been found in a few isolated areas of Southern England. The supposed Subfurcatum Zone ammonites from Skye and Raasay are too fragmentary and poorly preserved to be certain of their true identity or horizon, (Morton, 1971). The Scottish occurrences of these two Zones have been the subject of recent detailed work, and little needs to be added to this, (Morton, 1965, 1971), whilst I aim to revise the ammonite faunas from the Yorkshire,Scarborough Formation elsewhere.

The main areas of preservation of these Zones to be discussed here are those of Dorset and Somerset - see Text fig. 1. These have not been the subject of a detailed study for over half a century, (S. Buckman, 1893, and Richardson 1931 - most of whose field work was completed before the first World War). Considering that this region of England is the type area for numerous Zonal and subzonal indices, (S. humphriesianum, Teloceras blagdeni (Sow.), T. banksi (Sow.) etc.) as well as numerous other characteristic species of ammonites, (S. Buckman, 1909-30), a revision of the stratigraphy of these beds is long overdue. Hence an attempt is made here, firstly to re-interpret the present standard Zonal scheme, secondly to give a




Text figure 1

A sketch map of part of south-west England, showing the location of the main localities mentioned in the text. The area 1. is that shown in Text fig. 2, and the area 2. is that shown in Text fig. 4.

detailed bed by bed analysis of beds of this age in Southern England and lastly to determine the type horizons of the numerous ammonite species which have been described from this area.

At this point I should like to thank the curators of the various museums, who have allowed me to study type material in their care, particularly those in the British Museum (N.H.) and Institute of Geological Sciences, London; the Sedgwick Museum Cambridge and the Manchester City Museum. I should also like to thank various individuals who have allowed me access to their private collections, notably Brigadier G. Bomford, Dr. J.R. Senior and Dr. J. Whicher. Lastly I should like to give my special thanks to Dr. J. Callomon and Dr. H.S. Torrens for both help in the field and in the discussion of the numerous problems which arose during the course of this work. The majority of the work for this paper was undertaken during the tenure of a University of Keele research studentship, at that University; this award is gratefully acknowledged.

## 2. DEVELOPMENT OF THE STANDARD ZONAL SCHEME

### 2.1 The Zone of Stephanoceras (Stephanoceras) humphriesianum (J. de C. Sow.)

Oppel (1856) restricted his Humphriesianum Zone, in the Schwabian Albe (S. Germany), to the beds below the subfurcatum Oolithe, (included by him in the Parkinsoni Zone) and above the Blaukalke (= Sauzei Zone by original definition - Oppel, 1856, pp. 308, 344, etc.); that is the giganteus Tone, Ostreen-Kalke and blagdeni Schichten of subsequent authors. Many later workers were of the opinion that S. humphriesianum was not restricted to its Zone,

<table>
<tr><th>OPPEL, 1856</th><th>BUCKMAN, 1891 1893 & 1898</th><th>BUCKMAN, 1910 & 1913</th><th>BUCKMAN, 1909-1930</th><th>ARKELL, 1933</th><th>SPATH 1936</th><th>MULLER, 1941</th><th>ARKELL, 1956</th><th>STURANI 1971</th><th>SCHEME USED HERE</th><th></th></tr>
<tr><td>PARKINSONI</td><td>GARANTIANA<br>(1893)</td><td colspan="8">GARANTIANA</td><td></td></tr>
<tr><td>SUBFURCATUM<br>OOLITHE</td><td>CADOMENSIS<br>(1891)<br>=<br>NIORTENSIS<br>(1893)</td><td>NIORTENSIS<br>BANKSI</td><td>NIORTENSIS<br>LEPTOSPHINCTES<br>(1923)<br>BANKSI</td><td>NIORTENSIS</td><td>NIORTENSIS</td><td>SUBFURCATUM</td><td>SUBFURCATUM</td><td>BACULATUM<br>POLYGYRALIS<br>BANKSI</td><td>BACULATA<br>POLYGYRALIS<br>BANKSI</td><td>SUBFURCATUM</td></tr>
<tr><td>HUMPHRIESIANUM</td><td>HUMPHRIESIANUM<br>=<br>BLAGDENI<br>(1898)</td><td>BLAGDENI<br>STEMMATOCERAS<br>(1913)</td><td>UMBILICATA<br>(1926)<br>PYGMAEUM<br>(1927)<br>EPALAXITES<br>(1922)<br>PARCICARINATUS<br>(1924)<br>MASCKEITES<br>(1920)</td><td>BLAGDENI</td><td>BLAGDENI<br>ROMANI</td><td>BLAGDENI<br>HUMPHRIESIANUM<br>ROMANI</td><td>BLAGDENI<br>HUMPHRIESIANUM</td><td>BLAGDENI<br>'STEPHANOCERAS'<br>CYCLOIDES</td><td>BLAGDENI<br>HUMPHRIESIANUM<br>ROMANI</td><td>HUMPHRIESIANUM</td></tr>
</table>

Table 1. The development of the standard zonal scheme for the British Humphriesianum/Subfurcatum Zones.

and hence introduced, what they considered, were more suitable indices, such as Dorsetensia romani (Oppel), Haug(1891); D. edouardiana (D'Orb.), Brasil(1895), etc. However, reports of S. humphriesianum from the Sauzei Zone are due to mis-identification of such forms as Skirroceras and in any case an extended stratigraphic range would not preclude its use as a Zonal index.

Subdivision of the Humphriesianum Zone commenced at an early stage, with Waagen probably being the first to recognise the distinct stratigraphic distribution of 'Ammonites' (Teloceras) blagdeni Sow. (Waagen, 1867, p.539). However, the first use of Teloceras blagdeni as a stratigraphic index was as a replacement for the Humphriesianum Zone, (Six, 1879; Gosselet, 1881; Buckman, 1898). The first real attempt to subdivide the Humphriesianum Zone into separate horizons was made by Mascke, whose work on the North German Bajocian was unfortunately only published in an abbreviated 'Innaugural Dissertation', (Mascke, 1907). The four zones erected by Mascke were thus poorly defined and largely un-interpretable. The publication of Mascke's work, however, prompted Buckman to subdivide his blagdeni hemera; introduced previously as a replacement for the humphriesianum hemera (Buckman, 1898); into a restricted blagdeni hemera and an 'inter-Zone' (Buckman, 1910) or following Mascke a Stemmatoceras zone, (Buckman, 1913, in 1909-30). Subsequently Buckman introduced a whole series of hemerae (stratigraphic units approximately equivalent to the subzone in present usage), of which even the relative order is doubtful, (Buckman, 1909 - 1930) - see Table 1 for further details. Spath (1936) returned to the earlier zonal concepts, when he suggested the use of a Humphriesianum Zone with Blagdeni and Romani subzones, a scheme followed by Arkell (1956), who, however, preferred the use of a Humphriesianum subzone to that of a Romani (Arkell 1954, p.596).

In North Germany attempts have been made to give some validity to the zones introduced by Mascke; thus Kumm (1952) and Westermann (1967) introduced a series of valid modifications to these zones.

| Mascke 1907 | Kumm 1952 | Westermann 1967 |
|---|---|---|
| Teloceras zone | = blagdeni zone | = blagdeni subzone |
| Stepheoceras zone | = humphriesianum zone | = humphriesianum subzone |
| Stephanoceras zone | = umbilicum zone | = umbilicum subzone |
| Stemmatoceras zone | = coronatum zone | = frechi subzone |

Some attempts were also made in Germany to use species of Dorsetensia for stratigraphic indices for the basal part of the Humphriesianum Zone, with Westermann's use of a 'pinguis Schicten' and a 'romani/complanata Schicten', (Westermann, 1954). Huf's use of the pinguis Zone (Dorn, 1935), however, was as a synonym of Oppel's Sauzei Zone, (Huf, 1968).

The most important recent work on the Bajocian is probably that of Pavia and Sturani (1968) in the Basse Alpes of S.E. France. Here a thick limestone/marl sequence provides one of the standards of reference for the world Bajocian, (Arkell, 1956, p.157). Unfortunately the base of the Humphriesianum Zone is difficult to define, since certain ammonites, particularly the genus Dorsetensia, are either absent, or poorly preserved. None the less a three-fold subdivision of the Humphriesianum Zone was suggested by the study of this sequence, into Blagdeni, 'Stephanoceras' and 'Poecilomorphus' subzones, (Pavia & Sturani, 1968, p.312). The latter subzone was subsequently given a more valid, specific rather than generic, index by Sturani (1971, p.50), who suggested the use of Poecilomorphus cycloides (d'Orb.). This three-fold subdivision of the Humphriesianum Zone appears the most satisfactory, and further subdivision into six 'horizons', (Gabilly et al., 1971) would seem unnecessary.

2.2 The Zone of Strenoceras (Strenoceras) subfurcatum (Zieten)

Oppel recognised the distinct nature of the Subfurcatum Zone fauna (Oppel, 1856, p.308), but Terquem and Jourdy, (1869, p.2) were the first to give it Zonal status. Their Zone was later restricted by Buckman's introduction of a Garantiana hemera (Buckman, 1893) or Zone, (Buckman, 1913 in 1909-30), the basal subzone of which; the Dichotoma; must define the top of the Subfurcatum Zone. There have been numerous, subsequently designated, alternative indices for the Subfurcatum Zone, mainly related species of Strenoceras, such as S. bajociensis, S. niortensis, etc. but S. subfurcatum must have priority.

The first person to grasp the possibility of subdivision of the Subfurcatum Zone was undoubtedly Buckman, whose banksi hemera is only partly the equivalent to Mascke's Teloceras zone, (Buckman, 1910). Buckman later further restricted his niortensis hemera, by the introduction of a leptosphinctes hemera, (Buckman, 1923 in 1909-30). Whilst Buckman never clearly indicated the actual beds to which these hemerae referred, they can be deduced by a study of the ammonite species assigned to them in 'Type Ammonites', (Buckman, 1909-30) - see Morley-Davies in Richardson (1931, p.48).

| | | | |
|---|---|---|---|
| | | niortensis | - Bed 3, Frogden Quarry, Dorset. |
| niortensis | = | leptosphinctes (1923) | - Bed 4, Frogden Quarry, Dorset. |
| hemera , (1893), | | banksi (1910) | - Bed 5, Frogden Quarry, Dorset. |
| Zone (1913) | | | |

Subsequent to Buckman, most work on the Subfurcatum zone has been done on the thick clay, sequences of north-west Germany. Here, mainly following the work of Althoff, (1914 and 1928) and Bentz (1924 and 1928), the following horizons have been recognised -

| | Althoff 1928<br>Bentz 1928 | Kumm 1952 | Westermann 1954 and 1967 |
|---|---|---|---|
| Subfurcatum Zone | Upper Subfurcatum Zone = | schroederi zone | = schroederi subzone |
| | Lower Subfurcatum Zone = | baculata zone | = subfurcatum subzone |
| | 'Leptosphinctes Schicten' | - | = phaula subzone |

The faunas recorded from these horizons, (Althoff, 1928; Kumm, 1952) show that they closely follow the stratigraphic succession worked out by Buckman in North Dorset. Pavia and Sturani (1968), whose work has already been discussed in connection with the Humphriesianum Zone, have largely confirmed the German results, and they recognised the following horizons in the Basse Alpes -

Subfurcatum Zone (
- schroederi subzone
- baculatum subzone
- phaulus/polygyralis subzone
- aplous subzone

Subsequent modifications of this scheme have included the selection of Caumontisphinctes polygyralis Buckman, as the sole index for the polygyralis/phaulus horizon (Sturani, 1971) and the recognition of the priority of Buckman's banksi zone (Buckman 1910) over Pavia and Sturani's aplous subzone, (Parsons in Sturani, 1971, p.49). French workers have only accepted a three-fold subdivision of the Subfurcatum Zone, with the omission of the schroederi subzone, (Gabilly et al.

1971). Pavia's recent work on the upper Bajocian (Pavia,1973) has largely confirmed this three-fold division, since it proved impossible to separate the schroederi and baculatum subzones in the Basse Alpes. It must be noted at this point that Pavia and Sturani's baculatum subzone is not the same as Kumm's baculata zone, (Kumm, 1952, Gabilly et. al., 1971) since the index is Apsorroceras baculatum (Qu.) rather than Garantiana baculata (Qu.).

3. DISCUSSION OF THE SUB-ZONAL SCHEME

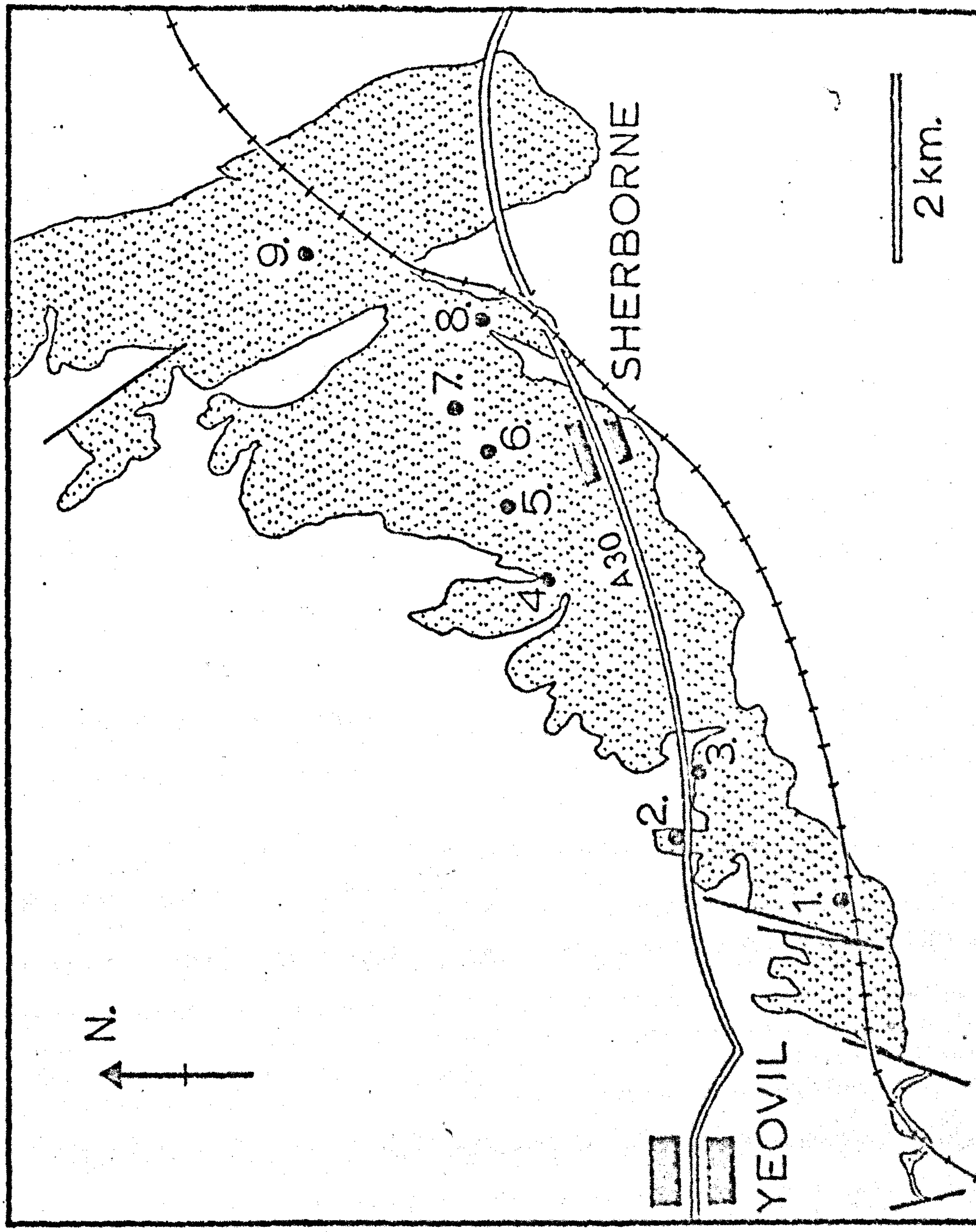
During a recent study of the Bajocian rocks of Britain, the subzonal scheme shown in Table 1 was found to give the best interpretation of the ammonite distributions. The subzones of the Humphriesianum Zone follow Pavia and Sturani's work on the Basse Alpes, but using pre-existing indices. The middle of the Humphriesianum Zone, the 'Stephanoceras subzone', (Pavia & Sturani, 1968), is characterised by the wealth of Stephanoceras s. str., and since it is the type horizon of S. humphriesianum (Sow.) in Dorset, it would seem logical to adopt this species as both the Zonal and subzonal index. This subzone would thus approximate to Kumm's restricted humphriesianum zone of N.W. Germany, which is distinguished by the occurrence of a large variety of different Stephanoceratids, including S. crassicostatum (Qu. emend. Renz), S. mutabile (Qu. emend. Mascke), S. triplex (Mascke in Weisert) and S. zieteni (Qu. emend. Renz), (Kumm, 1952, p.388). As index for the basal subzone of the Humphriesianum Zone, I here suggest the use of Dorsetensia romani (Oppel), which was originally introduced, like Teloceras blagdeni, as a replacement index for the Humphriesianum Zone, (Haug, 1891). However, this zone has since been used in a more restricted sense, as a subzone of the Humphriesianum Zone, (Spath,

1936) and as a separate zone below a vestigal Humphriesianum Zone, (Huf, 1968). Arkell's rejection of D. romani as the index for the lower subzone of the Humphriesianum Zone (Arkell, 1954, p.596), was based on the assumption that this species occurred above S. humphriesianum, in the Blagdeni subzone. However, there is now ample evidence to show that D. romani occurs abundantly at a relatively low level in the Humphriesianum Zone; in any case an extended range up into the Blagdeni subzone would not preclude its use as an index for the lower horizon. In much of N.W. Europe the basal part of the Humphriesianum Zone is characterised, not by the fauna ascribed to the cycloides subzone, (Sturani, 1971, p.50), but by a wealth of the genus Dorsetensia. Thus in Skye, N.W. Scotland, there is a profusion of Dorsetensia and only relatively rare members of other genera, whilst the Scarborough Formation of Yorkshire, England, like North-West Germany, (Westermann, 1954) and South Germany, (Stahlecker, 1935), has an abundance of Dorsetensia, often to the virtual exclusion of other genera. Taking this distribution of Dorsetensia into account, along with the priority of D. romani over Poecilomorphus cycloides (d'Orb.) as a subzonal index, there seems no alternative but to accept the former as the valid, basal index for the Humphriesianum Zone. The choice of a type horizon for the Romani subzone is clear. In his original description of the romani zone, Haug said of the 'Les couches à ammonites ferrugineuses de Beaumont', near Digne, Basse Alpes ..... "they form one of the best types of the zone of Sonninia Romani" (Haug, 1891, p.70). The section in these beds at Truyas, Beaumont, is thus formally designated as the type locality of the Romani subzone. Since these very beds were cited in the description of the 'Poecilomorphus' subzone (Pavia & Sturani, 1968, p.312), which was later renamed the *cycloides* subzone (Sturani, 1971, p.50), then the latter must by original definition be totally synonymous with the Romani subzone. The subzonal scheme for the Humphriesianum Zone suggested here, thus coincides with that already put forward by Muller (1941, Table 2).

The subzones of the Subfurcatum Zone adopted here, are essentially those utilised by Pavia and Sturani (1968) in the Basse Alpes, but with certain modifications. Kumm's *baculata* Zone (Kumm, 1952) has priority over Pavia and Sturani's *baculatum* subzone, (Gabilly *et. al.* 1971), and is used as the highest subzone of the Subfurcatum Zone, since there is very little published evidence for a separate *schroederi* subzone, (Gabilly *et. al.* 1971; Sturani, 1971, p.49; Pavia, 1973, p.86).

## 4. THE HUMPHRIESIANUM AND SUBFURCATUM ZONE ROCKS OF SOUTHERN ENGLAND

The Humphriesianum/Subfurcatum zone rocks of Southern England are now preserved in five distinct areas and in two different litho-facies. The thickest deposit of rocks of this age is just to the east of Sherborne, Dorset, where they attain a maximum thickness of approximately 2.0m. The 'iron-shot' limestones from this area are relatively 'condensed' and are rich in well preserved ammonites, but the faunas have not been re-worked or mixed, and accurate collecting enables detailed stratigraphic subdivisions to be made - see Fig.3. Elsewhere the Subfurcatum and Humphriesianum Zones are only sporadically preserved in highly condensed, remanié horizons, which are rich in limonite laminae and limonitic,algal concretions, (= 'snuff-boxes', q.v. Gatrall, *et. al.* 1972). These latter horizons are useless for




Text figure 2.

A sketch map of the Sherborne-Yeovil district, showing the position of the localities cited in the text :

1 - Bradford Abbas Railway-cutting, 2 - Halfway-House road-cutting, 3 - Louse Hill quarry, 4- Sandford Lane quarry, 5- Clatcombe Road section, 6 - Frogden quarry, 7 - Oborne Wood section, 8 - Oborne Lane section and 9 - Milborne Wick Lane section.

most stratigraphic purposes, but they have yielded some well preserved faunas, and they are interesting, since they give an indication of the original area of deposition, during this period.

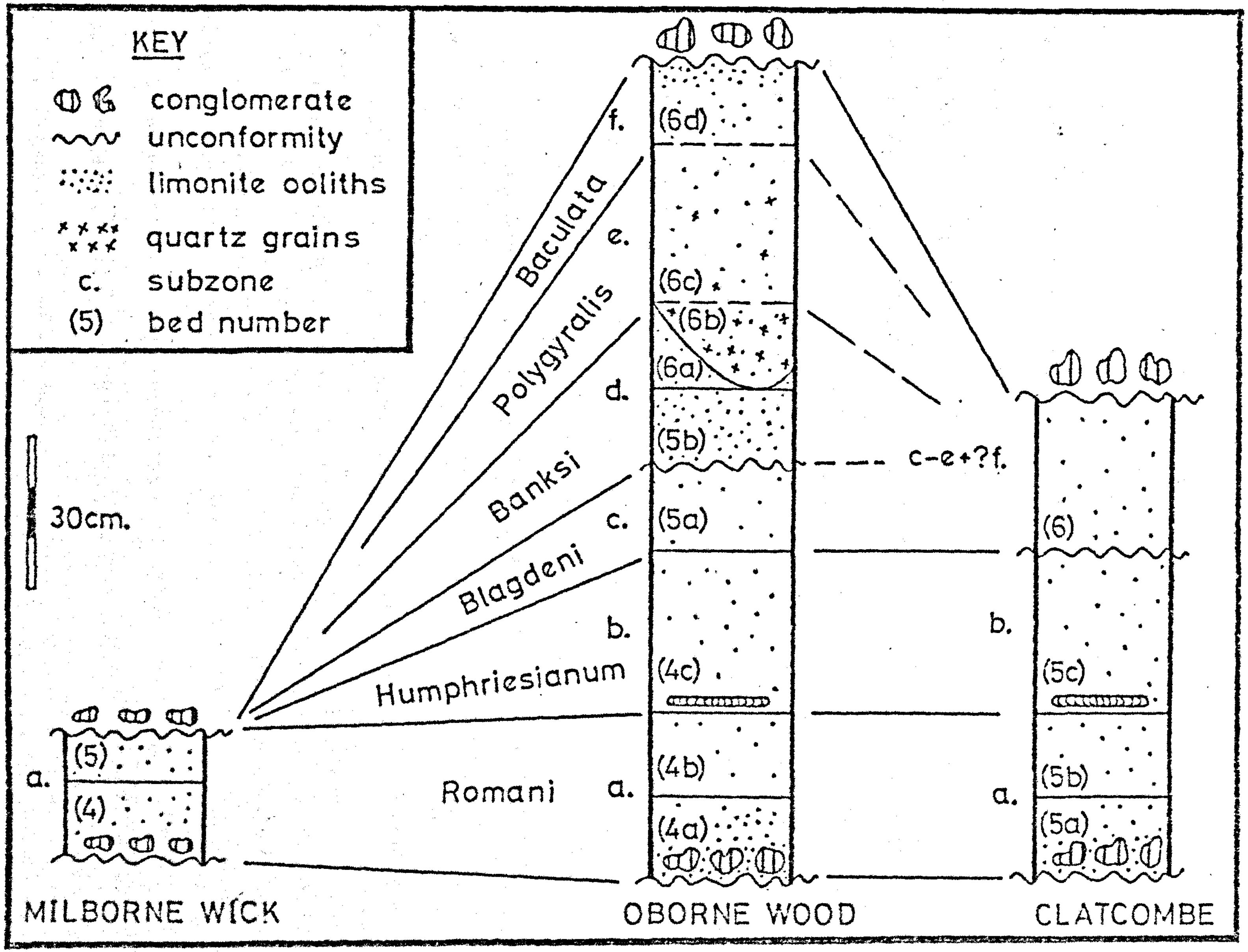
No new formal lithostratigraphic terminology will be introduced here, as this must await a complete revision of the Dorset Inferior Oolite. Thus the existing informal bed names are used where they are applicable. The thickest deposit of Humphriesianum/Subfurcatum Zone rocks, to the east of Sherborne (beds 6-4, Oborne Wood section), have been collectively called the 'Oborne Road-stone' (Buckman, 1893, p.501; 1887-1907, p.ccvi). The upper, Subfurcatum Zone, part of these rocks (beds 6b-d, Oborne Wood), has been separated as the '*cadomensis* beds' (Hudleston, 1886, p.193 ; Buckman, 1891, p.655), whilst the lowest layer of the latter beds has been called the '*Sphaeroidothyris* bed' (Hudleston, 1886, Buckman, 1909-30, Pl. 543). Elsewhere the Humphriesianum/Subfurcatum Zone rocks are more condensed and thinner; thus in north Dorset and Somerset they are represented by one, thin, hard limestone bed called the 'Irony bed' (Buckman, 1893, p.487), whilst in south Dorset these Zones are represented in a thin remanié horizon here called the 'Red conglomerate' (Richardson, 1915, p.58; Catrall, Jenkyns & Parsons, 1972, p.81).

## 4.1 The Sherborne Region

The area directly to the east of Sherborne, North Dorset, is a classic locale for the study of the Humphriesianum and Subfurcatum Zones; since apart from having produced the type specimens of so many Zonal and subzonal index species figured by the Sowerbys, (1812-46) and Buckman, (1909-30), it was the scene of the first real attempts

Text figure 3.

A correlation of the three main exposures in the Humphriesianum and Subfurcatum Zones of north Dorset.



to elucidate the more detailed stratigraphy of this period, (Buckman, 1893, 1910, 1909-30). The main localities described by Buckman (1893) are now poorly exposed, and many have disappeared. The following sections (see Text Fig. 2), represent all those now visible in the district, and two; Oborne Wood and Clatcombe; although very similar to nearby sections described by Buckman, were not actually seen by him. All the faunas listed in the following sections, unless otherwise stated, are based on material in the author's collections. All the bed numbering of the sections has been revised, but where applicable Buckman's numbers are given in brackets, following the new ones. The sections are described starting with those nearest Sherborne and thence eastwards to Milborne Wick. The correlation of the four main exposures in the Sherborne district is given in Text figure 3.

4.1.1 Clatcombe farm section

This is a shallow, poorly exposed, road-cutting on the west side of the road from Sherborne to the Golf course (ST636184); an old, virtually ploughed out quarry to the east of the road also shows some exposures in the condensed Humphriesianum/Subfurcatum Zones. This section must be very close to the location of that described by Buckman (1893, p.498, section XIV).

Subfurcatum Zone - Humphriesianum Zone; Blagdeni subzone

6. (7, at Lower Clatcombe, Section XIII, Buckman, 1893)

A very coarsely oolitic limestone, from which the large limonite ooliths tend to drop out, giving the rock a porous, sponge like texture. Poorly exposed as a loose rubble at the top of the hedge, this bed is more extensively represented in the small quarry in the field opposite.

*Teloceras* cf. *blagdeni* (Sow.) CP.1276

*Orthogarantiana* sp.

*Caumontisphinctes* (*Infraparkinsonia*) *phaulus* (S.B.) CP.1277

*C.* (*C.*) sp.

seen to
0.2m. +

Humphriesianum Zone & subzone

5c (*pars* 1)

A grey coloured limestone, with matt brown limonite ooliths. The base of the bed is marked by a poor parting, with abundant ammonite fragments, at 0.63 m. above the top of bed 2.

*Stephanoceras* cf. *humphriesianum* (Sow.) CP.1305

*S.* sp.

*S.* (*Normannites*) sp.

*Sphaeroidothyris sphaeroidalis* (Sow.)

0.18m.

Romani subzone

5b (*pars* 1)

A grey coloured limestone, with dark brown, shiny, ooliths.

*Chondroceras* aff. *evolvescens* (Waag.), CP.1273

*Stephanoceras* cf. *plicatissimum* (Qu. emend. Hyatt)(= *S. humphriesianum*, J. Buckman, 1881, *non*. Sow.) CP.1310

*S.* (*Normannites*) sp.

*Dorsetensia tecta* S.B. CP.1296

*Lissoceras oolithicum* (d'Orb.) CP.1293

*Oppelia* cf. *subradiata* (Sow.) CP.1297

*Poecilomorphus cycloides* (d'Orb.) CP.1292

0.16m.

5a (2)

A grey, densely oolitic limestone, with numerous dark brown ooliths.

*Emileia* sp. (derived)

*Pseudomelania* sp.

0.15m.

Sauzei Zone

——————— Planed surface, bored and limonite-encrusted ———————

4 (3)

A light grey limestone, with yellow-brown limonite ooliths, which are sparser than in bed 5a. The top of the bed contains serpulid-encrusted, rolled and reworked ammonites. There is a very irregular junction with bed 3.

*Emileia* (*Emileia*) *multifida* S. Buckman CP.1269

*E.* (*E.*) cf. *polyschides* (Waag.) CP.1270

*Skirroceras* cf. *leptogyrale* S.B. CP.1291

*Pelekodites sulcata* (S.B.) CP.1281

*Sonninia* cf. *propinquans* (Bayle) CP.1284

*Lissoceras semicostulatum* S.B. CP.1283

*Acanthothiris paucispina* S.B. & Walker

0.19-
0.28m.

3 (4)

A light grey, soft limestone, with yellow ooliths. This bed contains many badly preserved, rolled and broken ammonites, which have a characteristic soft, light grey fill to their casts. The bottom of the bed is very irregular and conglomeratic.

*Emileia* (*E.*) sp.

*E.* (*Otoites*) sp.

*Bradfordia* sp.

*Sonninia* sp.

*Acanthothiris paucispina* (S.B. & Walk.)

'*Pleurotomaria*' *granulata* Sow.

0.05–
0.12m.

Laeviuscula Zone and subzone

2 (5)

A soft, light grey, marly limestone, with sparse limonite ooliths, speckled with glauconite grains, and typical of the unweathered 'green grained marl' of Oborne, (see Buckman, 1893, Frogden Qy. bed 9).

?*Witchellia* cf. *nodatipinguis* (S.B.) CP.1278, (= *Sonninia* sp. nov. top bed 6, Milborne Wick, L. Richardson, 1916)

*Mollistephanus* (*M.*) aff. *mollis* S.B. CP.1290

*Cenoceras* sp.

0.0–
0.1m.

1 (6)

A 'blue hearted', crystalline, slightly sandy and glauconitic limestone, (= 'Blue bed', bed 10 Frogden) which forms a 'kerb' on the west side of the road.

?*Witchellia* cf. *nodatipinguis* (S.B.) CP.1279

seen to 0.15m.

4.1.2 Frogden Quarry Oborne see also Appendix I 559

The section described by Buckman from this quarry (ST642185) is still visible from his bed 6 up (Buckman, 1893, p.500, section XV).

This quarry was the source of numerous specimens figured by Buckman (1883, 1909-30) and Hudleston (1887-96) and has been described by Hudleston (1886), Richardson (1932) and more recently by Macfadyen (1970, p.158). The bed numbers used here are the same as those for the Oborne Wood section.

7 (pars 2)

A sandy, marly limestone, heavily stained with limonite and with a conglomerate of limonite-stained, re-worked ammonites at its base. 0.30m.

- - - - - - - - - - - - - - - planed surface - - - - - - - - - - - - - - -

'Oborne Road-stone' (6-5), - 'cadomensis Beds' (6)

Subfurcatum Zone, Baculata subzone

6d (pars 3)

A highly fossiliferous, hard oolitic limestone. There are many fragmentary fossils, which towards the top of the bed, are often limonite coated.

Caumontisphinctes (Infraparkinsonia) cf. bonarellii (Parona), CP.3099

Leptosphinctes (Leptosphinctes) cf. leptus S. Buckman, CP.2802

L. (L.) cf. davidsoni (S. Buckman), CP.2803

L. (Cleistosphinctes) cf. asinus (Zatvornitzki), CP.2796

Strenoceras (S.) subfurcatum (Zieten), CP.2795

Strenoceras (Garantiana) baculata (Qu.), CP.2793

S. (G.) spp.

Apsorroceras baculatum (Qu.), CP.2792

Lissoceras (Lissoceras) oolithicum (d'Orb.), CP.2797

L. (L.) psilodiscus (Schloenbach) s. sp. inflatum Wetzel, CP.2798

*L.* (*Microlissoceras*) cf. *pusillum* Sturani, CP.2799

*Strigoceras* (*Strigoceras*) sp.

*S.* (*Cadomoceras*) *sullyense* Brasil, CP.2801

*S.* (*C.*) *nepos* (Parona), CP.2800

*Chondroceras* *canovense* (de Gregorio), CP.2331

*Sphaeroceras* *auritum* cf. subsp. *auritum* Parona, CP.2332

0.15-
0.20m.

Polygyralis subzone

6c. (*pars* 3)

A hard, blue 'hearted', oolitic limestone, highly bioturbated, with a mixture of more sandy limestone. This bed is poorly fossiliferous, with the few fossils being badly preserved and difficult to extract. There is a very large species of *Pholadomya* present, which was probably the source of the bioturbation.

*Caumontisphinctes* (*Caumontisphinctes*) cf. *polygyralis* S. Buckman, CP.2806

*Leptosphinctes* (*Cleistosphinctes*) sp.

*Oppelia* (*Oecotraustes*) cf. *longarae* Sturani, CP.2805

0.35-
0.40m.

'*Sphaeroidothyris* Bed'

6b. (4)

Lenticular masses of hard, blue 'hearted', crystalline, 'iron-shot' limestone, which are very irregular in thickness, and are sometimes only with some difficulty separated from the bed above. This bed is very sandy in patches, and 'nests' of *Sphaeroidothyris* are common.

*Caumontisphinctes* (*Infraparkinsonia*) *phaulus* (S.Buckman), CP.2808

*Strenoceras* (*Strenoceras*) sp.

*Orthogarantiana* (*Orthogarantiana*) cf. *densicostata* (Qu. emend. Douv.), CP.2809

*O.* (*O.*) *haugi* Pavia, CP.2807

*Torrensia gibba* (Parona), CP.2804

*Oppelia* (*Oppelia*) sp.

*Strigoceras* (*Cadomoceras*) sp.

*Cadomites* (*Cadomites*) sp.

*Chondroceras canovense* (de Gregorio), CP.2345

0.10–0.20m.

Banksi subzone

6a. (*pars* ? 5)

A soft brown, oolitic limestone only sporadically preserved, where the large specimens of *Teloceras*, resting on the basal erosion plane, 'stick up' into the overlying bed.

*Teloceras banksi* (Sow.), CP.2647

0.0–0.18m.

*Total* for bed 6 = 0.66–0.71m.

– – – – – – – – – – – – – – planed surface – – – – – – – – – – – – – –

5b. (5)

A thin, soft, marly limestone; densely oolitic, with shiny, brown limonite ooliths set in a yellow-brown, often purple stained, matrix. Belemnites are particularly common. Divided by two poor partings, into three courses.

Caumontisphinctes (Caumontisphinctes) cf. aplous S. Buckman, CP.2811

C. (Infraparkinsonia) sp.

Leptosphinctes (Leptosphinctes) sp.

L. (Cleistosphinctes) sp.

?Cadomites cf. humphriesiformis Roche, CP.3071

Chondroceras cf. tenue (West), CP.2278

Teloceras banksi (Sow.), CP.2810

T. aff. blagdeni (Sow.), CP.2968

T. sp.

0.31 - 0.37m.

Humphriesianum Zone, Blagdeni subzone

5a. (6)

A hard, limestone with shiny orange ooliths set in a grey-brown matrix. There are patches of more sandy limestone, due to bioturbation, and numerous belemnites present.

Teloceras blagdeni (Sow.)

seen to 0.30m.

. . . . . . . . . . . . . . Break in outcrop, it . . . . . . . . . . . . . .
continues in the bank,
some 3m. below.

Laeviuscula Zone, Ovalis subzone

1b. (13)

A series of thin bedded, grey, glauconitic limestones, with soft, glauconitic marl partings.

Trilobiticeras (Emileites) aff. liebi (Maub.), CP.1503

seen to 1.0m.

Explanation of Plate 1.

Figure 1.

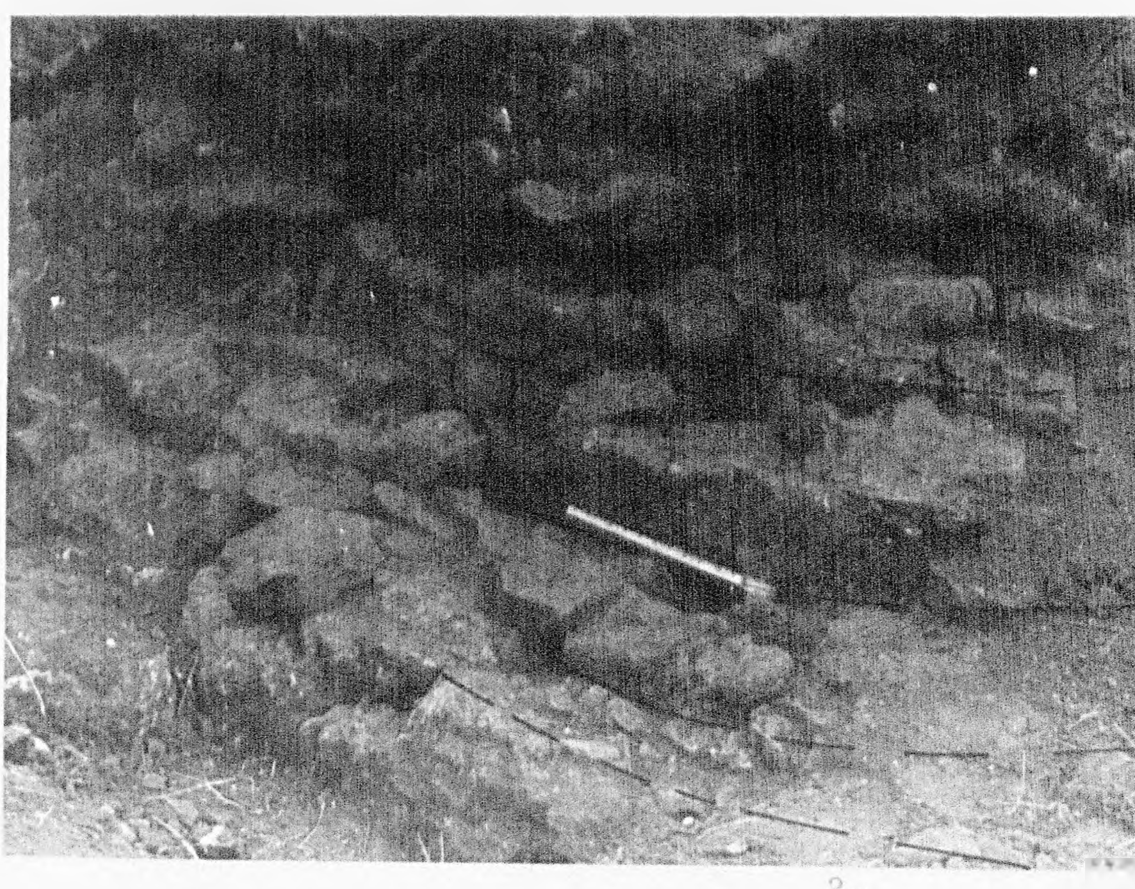
A general view of the temporary section at Oborne Wood, near Sherborne, showing the 'Oborne Road-stone' , cadomensis beds and the basal part of the Sherborne Building-stone. The bed marked 'C' , with the flat top is the massive block of the cadomensis beds.

Figure 2.

A close-up of the Humphriesianum Zone beds at Oborne Wood.

PLATE 1.

Figure 1.



Bed 4c.

4b.

4a.

2.

3.

Figure 2.

Discites Zone

1a. (14)

A soft, grey, slightly conglomeratic, glauconitic limestone, with many fossils, particularly ammonites, which are preserved as distorted internal moulds.

<u>Docidoceras</u> (<u>Docidoceras</u>) <u>cylindroides</u> S. Buckman, CP.1637

<u>Trilobiticeras</u> (<u>Trilobiticeras</u>) <u>platygaster</u> S. Buckman, CP.1723

<u>T.</u> (<u>T.</u>) cf. <u>punctum</u> (Vacek), CP.1724

<u>Euhoploceras</u> cf. <u>polycanthum</u> (Waagen), CP.1710

<u>Hyperlioceras</u> (<u>Hyperlioceras</u>) <u>walkeri</u> (S.Buckman), CP.1630

<u>Reynesella</u> sp.

0.30m.

4.1.3 Oborne Wood

This is a large temporary section (ST648188), very near to, and showing an exactly similar succession to that of Frogden Quarry (see previous section). A series of exposures have been available for study at various times (see Plate 1, figs. 1 and 2), and at different points the beds exposed showed a considerable variation in thickness; the section recorded here is thus to a certain extent a composite one. These exposures have already been the subject of a general description (Whicher & Palmer 1971).

Garantiana Zone? + ?Subfurcatum Zone (see Section 4)

'The Sherborne Building Stone Series'

9 (1)

A massive, grey, crystalline, sandy and slightly oolitic limestone which weathers to a yellow-brown colour.

seen to 1.2m.

8 (<u>pars</u> 2)

A series of five (a–e) hard, yellow-grey limestone bands very similar to the bed above, alternating with, grey, sandy marls. These beds are relatively unfossiliferous, bed 8b having yielded –

*Cadomites* (*Cadomites*) cf. *deslongchampsi* (d'Orb.) CP.2812

*Acanthothiris* sp. – common

Total 1.1m.

7 (<u>pars</u> 2)

Two thin (0.08m.) yellow-brown oolitic limestone bands. The upper bed (b), has an iron-stained upper surface, whilst the lower bed is slightly softer. These beds are separated by brown sandy marls of similar thickness.

0.3m.

A planed surface, with a conglomerate of derived, iron-coated fossils, cemented to the bed below by a limonite crust.

'The Oborne Road-stone' (6–4)

Subfurcatum Zone

'The *cadomensis* beds' (6)

This is a solid block of 'iron-shot' limestone of variable lithology, being more oolitic and fossiliferous in the top 0.15m., whilst elsewhere, due to bio-turbation, there are patches of sandy material mixed with more crystalline limestone. Bounded at top and bottom by two prominent erosion planes, this bed is divisible into four horizons (6a–d), by three irregular partings.

Baculata subzone

6d. (<u>pars</u> 3)

A highly fossiliferous, brown oolitic limestone. The fossils are often fragmentary, particularly at the top of the bed, where they are also abraded and limonite stained.

<u>Strenoceras</u> (<u>S.</u>) <u>subfurcatum</u> (Zieten), CP.3103

<u>Strenoceras</u> (<u>Garantiana</u>) <u>baculata</u> (Qu.), CP.3100

<u>S.</u> (<u>G.</u>) spp.

<u>Orthogarantiana</u> cf. <u>inflata</u> (Bentz), CP.3105

<u>Leptosphinctes</u> (<u>Leptosphinctes</u>) cf. <u>leptus</u> S.B., CP.3082

<u>L.</u> (<u>L.</u>) <u>rotula</u> (Parona), CP.3101

<u>L.</u> (<u>Cleistosphinctes</u>) <u>asinus</u> (Zat.), CP.3102

<u>Chondroceras</u> <u>canovense</u> (de Greg.), CP.2321

<u>Sphaeroceras</u> <u>auritum</u> (Parona) cf. subsp. <u>auritum</u>, CP.2724

<u>Apsorroceras</u> <u>baculatum</u> (Qu.), CP.2695

<u>Spiroceras</u> spp.

<u>Lissoceras</u> (<u>L.</u>) <u>oolithicum</u> (d'Orb.)

<u>Oppelia</u> (<u>Oppelia</u>) <u>flexa</u> (S. Buckman), CP.3083

<u>Strigoceras</u> (<u>Strigoceras</u>) sp.

<u>S.</u> (<u>Cadomoceras</u>) <u>sullyense</u> Brasil, CP.3104

0.15-
0.18m.

Polygyralis subzone

6c. (<u>pars</u> 3)

A bio-turbated mixture of blue oolitic and sandy limestone. Much of this bed is unfossiliferous, the fossils being concentrated at the base, just above the parting which divides the whole of bed 6 in half.

<u>Leptosphinctes</u> (<u>L.</u>) cf. <u>davidsoni</u>, CP.2701

<u>L.</u> (<u>L.</u>) <u>leptus</u>, CP.2702

<u>L.</u> (<u>Cleistosphinctes</u>) <u>asinus</u>, CP.2700

Strenoceras (Strenoceras) cf. subfurcatum

S. (S.) apleurum S. Buckman, CP.3106

Caumontisphinctes (C.) aff. polygyralis S. Buckman

C. (Infraparkinsonia) phaula (S. Buckman), CP.3107

Cadomites (C.) cf. deslongchampsi, CP.3081

C. (Polyplectites) sp. nov.

Chondroceras canovense

Sphaeroceras aff. auritum CP.2336

Lissoceras oolithicum, CP.3109

Oppelia (O.) flexa (S. Buckman), CP.3108

O. (Oecotraustes) pulchra (S. Buckman), CP.3110

0.18m.

'The Sphaeroidothyris Bed'

6b. (4)

A lenticular mass of blue 'hearted', crystalline, 'iron-shot' limestone, with a large amount of detrital quartz. This bed is very irregular in thickness, it fills the umbilical areas of the Teloceras in the bed below, and where these are absent, it extends down to the basal erosion plane. Sphaeroidothyris sphaeroidalis (Sow.) is very common, both as individuals, and in 'nests'.

Caumontisphinctes (C.) polygyralis, CP.2698

C. (Infraparkinsonia) phaula, CP.2699

Leptosphinctes (L.) davidsoni, CP.2690

L. (L.) leptus, CP.2683

L. (Cleistosphinctes) asinus

Strenoceras (S.) cf. subfurcatum

Strenoceras (Garantiana) sp.

_Orthogarantiana_ cf. _densicostata_ (Qu.)

_O. haugi_ Pavia, CP.3079

_Cadomites_ (_C._) _deslongchampsi_, CP.2969

_C._ (_C._) aff. _homalogaster_ S. Buckman, CP.2693

_C._ (_Polyplectites_) sp. nov. cf. _P. linguiferus_ (d'Orb.)

_Chondroceras canovense_, CP.2335

_Torrensia gibba_ (Parona), CP.2804

_Oppelia_ (_O._) aff. _flexa_

_O._ (_Oecotraustes_) cf. _pulchra_

_Lissoceras oolithicum_

_Strigoceras_ (_Cadomoceras_) _sullyense_

0.08–
0.25m.

Banksi subzone

6a. (_pars_ ?5)

A soft,brown,oolitic limestone, very similar to the bed below, but which is often absent, especially when the common _Teloceras banksi_ (Sow.), which lay flat on the basal erosion surface, are also missing.

0.0–
0.18m.

Total for bed 6 = 0.5–
0.56m.

A planed surface 0.90 – 1.0m. above bed 3, surmounted by 0.05m. of marl

5b. (5)

A soft, brown, 'earthy', oolitic limestone, divided by two irregular partings into three courses. There are numerous small corals, _Discocyathus_, and Belemnites present. The larger ammonites lay parallel to the bedding, with their upper surfaces planed off.

*Caumontisphinctes* (*C.*) *aplous* S. Buckman, CP.2981

*C.* (*C.*) *diniensis* (Pavia), CP.2982

*C.* (*Infraparkinsonia*) cf. *phaula*, CP.2983

*Leptosphinctes* (*L.*) sp. nov.

*L.* (*Cleistosphinctes*) sp. nov.

*Stephanoceras* (*Normannites*) sp.

*Teloceras* (*T.*) *banksi* (Sow.)

*T.* (*T.*) cf. *blagdeni* (Sow.)

*T.* (*T.*) *lotharingicum* Maubeuge

*T.* (*Epalaxites*) sp.

0.08-
0.3m.

- - - - - - - - - - - - - - - Marl parting - - - - - - - - - - - - - - -

Humphriesianum Zone, Blagdeni subzone

5a. (6)

A hard, grey-brown, oolitic limestone, with a brittle fracture. This bed is highly bio-turbated; with the introduction of softer, sandier material. The common, large ammonites tend to be 'rotten', - they have a soft limonite rich fill to their inner whorls, - and, unlike the bed above, they occur at all angles to the bedding.

*Teloceras* (*T.*) *blagdeni*, CP.2646

*T.* (*Epalaxites*) sp.

*Stephanoceras* (*Normannites*) sp.

0.2-
0.25m.

- - - - - - - - - - - - Marl parting 0.01 - 0.1m. thick - - - - - - - - - -

A hard, grey, oolitic limestone, divisible by fauna, and to a lesser extent by lithology into three horizons, (4a-c).

Humphriesianum subzone

4c. (pars 7)

A hard, grey limestone with matt brown ooliths and soft sandy patches, particularly at the top. The bottom of the bed is marked by a poor parting, associated with a layer of large, serpulid-encrusted, flat lying ammonites, indicating a pronounced pause in sedimentation.

Teloceras (T.) acuticostatum Weisert, CP.2714

T. (T.) cf. lotharingicum, CP.2686

T. (Epalaxites) sp.

Stephanoceras (S.) gibbosum (S. Buckman), CP.2705

S. (S.) crassicostatum (Qu. emend. Renz)

S. (S.) humphriesianum (Sow.), CP.2719

S. (S.) pyritosum (Qu. emend. Renz), CP.2972

S. (S.), cf. scalare (Mascke emend. Weisert), CP.2712

S. (S.) mutabile (Qu. emend. Renz), CP.2716

S. (S.) zieteni (Qu. emend. Renz), CP.2718

S. (Skirroceras) sp.

S. (Normannites) formosum (S. Buckman), CP.2977

S. (N.) latansatus (S. Buckman), CP.2979

Chondroceras evolvescens (Waag.)

C. gracile (Westermann), CP.2273

Poecilomorphus (P.) cycloides (d'Orb.), CP.2457

Dorsetensia regrediens Haug, CP.2720

0.15m.

Romani subzone

4b. (*pars* 7)

A hard, grey oolitic limestone. This horizon is extremely fossiliferous and it is characterised by the very shiny ooliths, by the soft, light grey coloured limestone fill to the fossils casts, and by the abundance of ammonite fragments.

*Chondroceras delphinus* (S. Buckman), CP.2266

*C. evolvescens*, CP.2225

*C. gervillii* (Sow.), CP.2267

*Sphaeroceras brongniarti*, CP.2325

*Phaulostephanus paululum* S. Buckman, CP.2978

*Stephanoceras* (*S.*) *nodosum* Hyatt, CP.1532

*S.* (*Normannites*) *bicostatum* (Westermann, 1954, Pl.30, fig.3 *non.* 1)

*S.* (*N.*) *latansatum*, CP.2980

*S.* (*N.*) cf. *orbignyi* (S. Buckman)

*Teloceras* (*T.*) *blagdeniformis* (Roche), CP.2965

*T.* (*Epalaxites*) cf. *laticostatus* (Westermann), CP.3070

*T.* (*E.*) *portitor* (Maubeuge), CP.2966

*Dorsetensia alsa tica* (Buckman, 1909-30, pl.528, *non* Haug.), CP.2116

*D. complanata* S. Buckman, CP.2496

*D. pulchra* S. Buckman, CP.2497

*D. regrediens* Haug, CP.2498

*D. subtecta* S. Buckman, CP.2502

*Oppelia* (*O.*) *subradiata* (Sow.), CP.2477

*O.* (*Oecotraustes*) *genicularis*, CP.2488

*Poecilomorphus* (*P.*) *cycloides*, CP.2455

*P.* (*Micropoecilomorphus*) *vicetinus* (Parona), CP.2473

*Stegoxyites parcicarinatus* S. Buckman, CP.2493

*Strigoceras* (*S.*) *bessinum* Brasil, CP.2453

*S.* (*Cadomoceras*) sp.

*Nannolytoceras pygmaeum* (d'Orb.), CP.2399

0.15–
0.20m.

4a. (8)

A dark brown, densely oolitic limestone with a basal conglomerate consisting of derived lumps of, 'green grained marl' and soft grey limestone with yellow-brown ooliths. As well as re-worked pebbles there are also limonite coated fossils and rare 'Snuff-boxes', analagous with those of south Dorset, (Catrall, Jenkyns & Parsons, 1972, p.81).

*in situ* *Dorsetensia subtecta*, CP.1357

*Chondroceras delphinus*, CP.1351

*Sphaeroceras brongniarti*, CP.1352

derived

*Emileia* (*E.*) sp.

*Frogdenites spiniger* S. Buckman, CP.1189

'*Skirroceras*' cf. *skolex* (S. Buckman), CP.1192

*Sonninia* sp.

*Witchellia* (*W.*) sp.

*W.* (*Pelekodites*) sp.

0.1–
0.15m.

Laeviuscula Zone and subzone

3 (9)

A soft, light grey limestone, speckled with green glauconite grains and with patches of yellow-brown ooliths. On weathering this bed has the appearance of a soft white marl. There is no sharp boundary with the bed below, only a gradual transition. This bed is full of fossils, many of which are oyster-and serpulid-encrusted and, at the top of the bed, eroded and iron stained.

Emileia (E.) brocchii (Sow.), CP.1353

E. (E.) polyschides (Waag.), CP.1359

E. (Otoites) contracta (S.B. non. Sow.), CP.1334

Frogdenites spiniger S. Buckman, CP.1210

F. cf. profectus S. Buckman

Chondroceras sp. nov.

Mollistephanus aff. mollis S. Buckman

Skirroceras aff. kalus (S. Buckman), CP.1332

S. leptogyrale S. Buckman, CP.1333

Bradfordia inclusa S. Buckman, CP.1371

Oppelia (O.) amblys (S. Buckman), CP.2996

Papilliceras arenatus (Qu. emend. S.B.), CP.1373

Shirbuirnia superba (S. Buckman), CP.1374

S. cf. trigonata (Qu. emend. Dorn), CP.1375

Witchellia (W.) actinophora S. Buckman

W. (W.) falcata S. Buckman

W. (W.) glauca S. Buckman, CP.1394

W. (W.) plena (S. Buckman), CP.1390

W. (Pelekodites) aurifer (S. Buckman)

W. (P.) macra (S. Buckman), CP.1387

0.07-
0.15m.

2 (10)

A hard, blue 'hearted', glauconitic limestone. The upper surface of the bed is the most fossiliferous and it is also softer and more glauconitic. Elsewhere fossils are sparse and poorly preserved. This bed has been extensively bored, the narrow vertical borings allowing the marl bed to be 'piped down'.

Emileia (E.) crater S. Buckman, CP.1638

E. (E.) aff. catamorpha S. Buckman, CP.1641

E. (E.) polyschides, CP.1640

E. (Otoites) sp.

Papilliceras arenatus, CP.2406

Sonninia sp.

Witchellia (W.) laeviuscula (Sow.)

W. (W.) rubra (S. Buckman), CP.2407

W. (Pelekodites) sp.

Lissoceras semicostulatum S. Buckman, CP.2408

0.23m.

Ovalis subzone

1c.

A more massively bedded top to the subjacent thinly bedded glauconitic limestones. This bed is only occasionally present.

Sonninia ovalis (Qu. emend. S.B.)

0.0–
0.45m.

1b. (13)

A series of thin, yellow-grey, sandy, glauconitic limestones, interbedded with soft, brown, sandy marls. These beds are not very fossiliferous and have not been well exposed.

_Witchellia_ (_W._) sp.

_Sonninia_ sp.

_Emileia_ (_E._) sp. nov. aff. _E._ _catamorpha_ S. Buckman, CP.1624

_circa_ 4.0m.

Discites Zone

1a. (14)

A grey, glauconitic limestone, slightly conglomeratic and with many fossils, particularly distorted internal moulds of ammonites.

_Sonninia_ (_Euhoploceras_) cf. _polycantha_ (Waag.), CP.1616

_Hyperlioceras_ cf. _liodiscites_, CP.1619

_Reynesella_ sp.

_Graphoceras_ _apertum_ S. Buckman, CP.1621

seen to 0.30m.

4.1.4 Oborne Lane Section

A very poor section is still visible in the floor of this lane (ST.656186). The old cutting is too slipped and overgrown to make out anything of Buckman's section (Buckman, 1893, section XVI).

4 (4)

A soft, brown, 'iron-shot' limestone.

seen

Laeviuscula Zone and subzone

3 (5)

A soft, white glauconitic marl.

_Witchellia_ (_Witchellia_) _laeviuscula_ (Sow.), CP.3098

_Papilliceras_ aff. _arenatus_ (Qu. emend. S.B.), CP.3097

0.10m.

2 (6)

A massive, hard, glauconitic limestone.

0.25m.

1

Hard, thin bedded, glauconitic limestones, with marl partings.

seen

( Further up the lane a single specimen of <u>Teloceras</u> sp. was found <u>in situ</u>, in the basal part of the Sherborne Building Stones. This shows that, as at Milborne Port, (Kellaway & Wilson, 1941, p.154), the Subfurcatum Zone beds, become more 'expanded' and less 'iron-shot', towards the east, and thus become indistinguishable from the overlying Building Stones. ) **See p. 146 below.**

4.1.5 Milborne Wick Lane Section

Although now poorly exposed and overgrown, this road-cutting (ST663205), still shows a similar section to that of Buckman's, (Buckman, 1893, section XVII). This section has always been famous for the abundant and superbly preserved Romani subzone fauna, which may be collected from bed 5. Material from this bed has found its way into virtually every museum in the United Kingdom, as well as many abroad.

6 (1)

A hard, crystalline, light yellow coloured, sandy limestone. The basal few centimetres contain pebbles derived from bed 5, as well as eroded, limonite coated fossils.

seen to 0.90m.

- - - - - - - - - - - - - - Planed surface - - - - - - - - - - - - - -

Humphriesianum Zone, Romani subzone

5 (2)

A soft, white, marly limestone with numerous yellow limonite ooliths and black dendritic manganese staining. This bed is highly fossiliferous, with many of the shells having been replaced by a pink coloured calcite.

<u>Chondroceras</u> <u>evolvescens</u> (Waagen), CP.2178

<u>C.</u> <u>gervillii</u> (Sow.), CP.2214

<u>Phaulostephanus</u> cf. <u>paululum</u> S. Buckman, CP.2616

<u>Stephanoceras</u> (<u>Stephanoceras</u>) cf. <u>scalare</u> (Mascke, emend. Weisert), CP.2601

<u>S.</u> (<u>S.</u>) spp. (many fragments)

<u>S.</u> (<u>Normannites</u>) <u>crassicostatum</u> (Westermann), CP.2606

<u>S.</u> (<u>N.</u>) <u>mitis</u> (West.), CP.2610

<u>S.</u> (<u>N.</u>) cf. <u>portitor</u> (Maubeuge), CP.2604

<u>S.</u> (?<u>Germanites</u>) <u>bicostatus</u> West., CP.2605

<u>Teloceras</u> <u>blagdeniformis</u> (Roche), CP.2555

<u>Dorsetensia</u> <u>deltafalcata</u> (Qu.), CP.2550

<u>D.</u> <u>edouardiana</u> (d'Orb.), CP.2556

<u>D.</u> <u>liostraca</u> S. Buckman, CP.2554

<u>D.</u> <u>regrediens</u> Haug, CP.2551

<u>Lissoceras</u> (<u>Lissoceras</u>) <u>oolithicum</u> (d'Orb.), CP.2575

<u>Oppelia</u> (<u>Oppelia</u>) <u>subradiata</u> (Sow.), CP2562

<u>O.</u> (<u>O.</u>) aff. <u>skrodzkii</u> Brasil, CP.2574

<u>O.</u> (<u>Oecotraustes</u>) <u>genicularis</u> Waagen, CP.2576

<u>Poecilomorphus</u> (<u>Poecilomorphus</u>) <u>cycloides</u> (d'Orb.), CP.2558

<u>P.</u> (<u>Micropoecilomorphus</u>) <u>vicetinus</u> (Parona), CP.2599

<u>Stegoxyites</u> (<u>Stegoxyites</u>) aff. <u>parcicarinatus</u> S. Buckman, CP.2563

0.07–
0.10m.

4 (3)

A hard limestone, with yellow-brown ooliths set in a light blue-grey matrix. In contrast to the bed above, there is very little manganese staining, and fossils are sparser and more difficult to extract. There is a layer of bivalves towards the centre of the bed , and a conglomerate of derived lumps of bed 3 at the base.

Stephanoceras (Normannites) formosum (S. Buckman), CP.2679

S. (N.) portitor (Maub.), CP.2644

Dorsetensia liostraca S. Buckman, CP.2678

Oppelia (Oppelia) subradiata (Sow.), CP.2638

Stegoxyites (Stegoxyites) parcicarinatus, CP.2634

0.20-
0.25m.

- - - - - - - - - - - - - - Unconformity - - - - - - - - - - - - - -

?Sauzei Zone

3 (4)

A soft, white marl, speckled with green glauconite grains. There are no limonite ooliths present.

Kumatostephanus (Kumatostephanus) cf. perjucundus S. Buckman, CP.1563

K. (?Gerzenites) rugosus Westermann, CP.1580

?Labyrinthoceras sp. nov.

Skirroceras bayleanum (Oppel), CP.1531

S. skolex (S. Buckman), CP.1564

Emileia (Emileia) polyschides (Waag.), CP.1565

E. (Otoites) contractus (S.B. non. Sow.), CP.1574

Papilliceras arenatus (Qu. emend. S.B.), CP.1551

0.10-
0.15m.

Laeviuscula Zone and subzone

2b. (<u>pars</u> 5)

A hard, blue-green limestone, highly glauconitic and forming a softer, irregularly preserved, top to the sub-adjacent bed.

<u>K.</u> (?<u>Gerzenites</u>) cf. <u>rugosus</u>, CP.1576

<u>Mollistephanus</u> (<u>Mollistephanus</u>) sp.

<u>Emileia</u> (<u>Emileia</u>) sp.

<u>E.</u> (<u>Otoites</u>) sp.

<u>Witchellia</u> (<u>Witchellia</u>) <u>laeviuscula</u> (Sow.)

<u>W.</u> (<u>Pelekodites</u>) aff. <u>macra</u> (S. Buckman), CP.1559

0.0–
0.10m.

2a. (<u>pars</u> 5)

A hard, blue limestone, in two-three layers, and more sparsely glauconitic than the bed above.

<u>Emileia</u> (<u>Emileia</u>) cf. <u>brocchii</u> (Sow.), CP.1543

<u>Shirbuirnia</u> (<u>Stiphromorphites</u>) cf. <u>nodatipinguis</u> S. Buckman.

0.45–
0.60m.

1 (6)

A series of hard, sandy, sparsely glauconitic limestones, intercalated with soft, sandy marls.

<u>Witchellia</u> (<u>Witchellia</u>) aff. <u>zugophorus</u> (S. Buckman) CP.1545

seen to 3.0m.

<u>Note</u>

There has been some confusion in the past literature concerning this section. Richardson (1916, p.516) considered that Buckman (1893) had been overzealous in splitting up of some of his beds (5-3, here), since Richardson considered that all three were of the same age and lithology. However in this case there can be no doubt that Buckman was correct, since bed 3 is the only one of this group of marly limestones to contain glauconite grains and it is also older, yielding as it does Sauzei rather than Humphriesianum Zone ammonites.

4.2 The North-west Dorset - South Somerset Area

The Humphriesianum/Subfurcatum beds thin rapidly to the west of Sherborne and at Sandford Lane (ST628179), they have disappeared completely. West from this point, these Zones are represented in the highly condensed deposit known as the 'Irony bed', (S. Buckman, 1893, p.485). This bed, which consists of a thin (-0.18m.), hard, crystalline limestone, containing numerous large, limonite ooliths, comminuted crinoid debris and many small 'snuff-boxes' (limonite rich, algal concretions), is consistently heavily stained with limonite; hence its name. The 'Irony' bed is always non-sequentially related to adjacent beds and it is found as far west as Seavington-St.-Mary, the most westerly outcrop of the Inferior Oolite, and as far south as Bradford Abbas, beyond which the Inferior Oolite is mainly faulted out (see Fig.2). Although this horizon has yielded ammonites representative of all the Lower and basal Upper Bajocian Zones (Gatrall, Jenkyns & Parsons, 1972, p.83), several localities have produced exclusively Humphriesianum and Subfurcatum Zone faunas.

4.2.1 Halfway House - Louse Hill.

There were once several old quarries in this area, showing exposures of the 'Irony-Bed' normally resting on Discites Zone rocks. There are now only two exposures; Buckman's old locality - Louse Hill, (ST608152), (Buckman, 1893, p.488), where this bed has yielded a Romani subzone fauna - Chondroceras gervillii (Sow.), Sphaeroceras brongniarti (Sow.), Stephanoceras (Normannites) variecostatus (Westermann, 1954, Pl.25, fig. 5 non 3), Oppelia (Oppelia) sp., O. (Oecotraustes) genicularis (Waag.) and Poecilomorphus cycloides (d'Orb.); and a new road cutting at Halfway House, (ST602163), where the 'Irony Bed' has produced a Banksi subzone fauna of, Caumontisphinctes (Infraparkinsonia) cf. phaulus (S.B.), Leptosphinctes (Cleistosphinctes) sp. and L. (Cleistosphinctes)/C. (Infraparkinsonia), (intermediate sp.).

4.2.2 Bradford Abbas

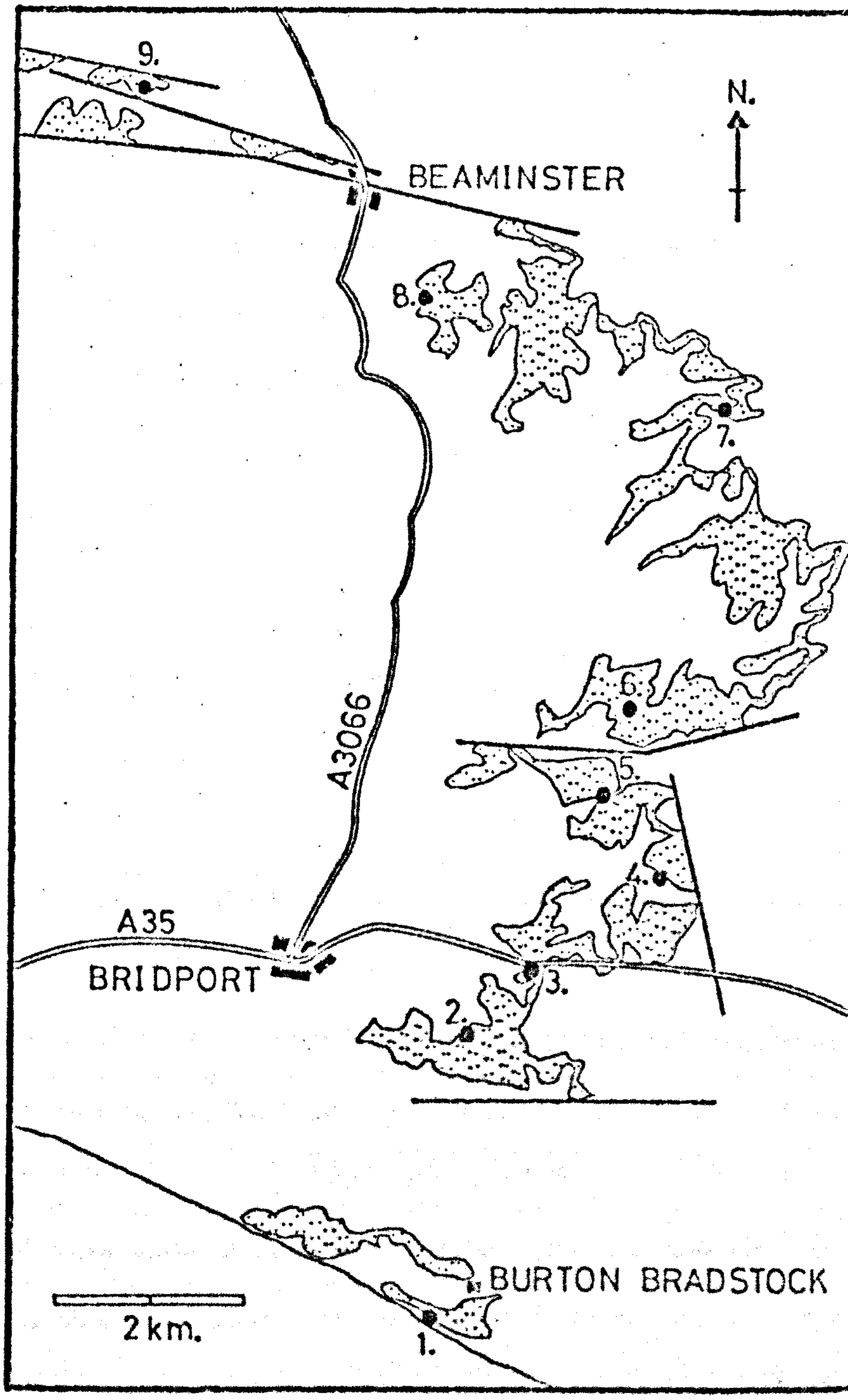
The 'Irony Bed' now exposed in the Bradford Abbas railway cutting, as well as that once exposed in the old quarries, is mainly Sauzei Zone in age. However a recent Gas Pipe trench in this area has yielded numerous Subfurcatum Zone ammonites from the top of the 'Irony Bed', mainly Strenoceras (Strenoceras) subfurcatum (Zieten), (teste H.S. Torrens).

4.2.3 Seavington-St.-Mary

The outlier at Seavington-St.-Mary is the most westerly outcrop of the Inferior Oolite - see Fig.1. This section (ST398144), has recently been described in detail (Parsons in Torrens 1969, p.A26), but further collecting has revealed the presence of a Romani subzone fauna in bed 7, directly below the stromatolite layer, including, Stephanoceras (Stephanoceras) sp., Oppelia (Oppelia) sp., Poecilomorphus cycloides (d'Orb.) and Strigoceras (Strigoceras) bessinum (Sturani non Brasil).

4.3 The South Dorset Area

In South Dorset the Humphriesianum Zone is represented in the




Text Figure 4.

A sketch map of the Burton Bradstock - Beaminster district, showing the position of localities cited in the text : 1 - Burton Cliff section, 2- Bonscombe Hill section, 3 - Stony Head Cutting, 4 - Upton Manor Farm quarry, 5 - Loders Pipe trench, 6 - Welcome Hill quarry, 7 - North Poorton, 8 - North Warren Hill and 9 - Horn Park quarry.

'Red Conglomerate'. This consists of re-worked and remanié fossils set in a limonite rich red clay or marly limestone replete with crinoid ossicles and pebbles, and which is cemented to the top of the 'Red Bed', (Richardson, 1928-30, p.48). There is some evidence at Burton Bradstock that this bed was subsequently further re-worked during the Subfurcatum Zone. Whilst the 'Red Conglomerate' is not present at every South Dorset Inferior Oolite locality, its position is always marked by a limonite stained and encrusted surface, - see Text fig. 4.

4.3.1 Burton Bradstock

The 'Red Conglomerate' is well exposed at the Cliff Hill section, Burton Bradstock, (SY487891), but it is easier to collect from the fallen blocks at the foot of Burton Cliff (SY482892). Both of these localities were described by Richardson (1928-30), the second having produced the following ammonites; Stephanoceras (Stephanoceras) kreter (S.B.), S. cf. humphriesianum (Sow.), S. aff. nodosum Hyatt, S. trichalus (Westermann), S. (Normannites) cf. orbignyi (S.B.), Teloceras sp., Oppelia (Oppelia) flexa (S.B.), O. (O.) lectotypa S.B. and Poecilomorphus cycloides. At the latter locality a more white coloured matrix has penetrated down into the 'Red Conglomerate' and this has yielded Subfurcatum Zone ammonites; Strenoceras (Strenoceras) sp., Leptosphinctes (L.) aff. davidsoni (S.B.) and Spiroceras sp., (Gatrall et al. 1972, p.82).

4.3.2 Bonscombe Hill - Hyde Quarry

A recent temporary section at Bonscombe Hill (SY488919), produced Humphriesianum Zone ammonites from bed 29 (Senior, Parsons & Torrens, 1970, p.116); Stephanoceras humphriesianum (Sow.) and

Sphaeroceras sp. The nearby Hyde Quarry (SY484922) has also produced a specimen of S. humphriesianum (Woodward, 1894).

4.3.3 Loders Cross

There are several localities in this area which have produced Humphriesianum Zone ammonites. A new road cutting at Stony Head (SY496927) yielded Sphaeroceras brongniarti (Sow.) and Stephanoceras cf. plicatissimum (Qu. emend. Hyatt) from the 'Red Conglomerate', whilst the old Stony Head quarry to the North (SY497929) has produced a specimen of S. humphriesianum (Sow.) - I.G.S. 56552, from the same horizon. The small exposure to the north-east of Loders Cross (SY506929), described by Bomford (1948) has also produced Humphriesianum Zone ammonites, mainly uninterpretable stephanoceratid nuclei, and one specimen of Chondroceras cf. gracile (Westermann).

4.3.4 Upton Manor Farm

The section at Upton Manor Farm (SY512936) was described by Richardson (1928-30, p.164), since which time a Humphriesianum Zone fauna has been found at the top of the 'Red Bed', (Senior et al. 1970, p.117, bed 6). This fauna is the most extensive from this Zone found in South Dorset, and includes - Sphaeroceras brongniarti, Stephanoceras (S.) kreter (S.B.), S. cf. humphriesianum, S. plicatissimum, S. (Phaulostephanus) paululum (S.B.), S. (Normannites) cf. orbignyi and Oppelia (O.) flexa.

4.3.5 Other 'Red Conglomerate' localities

Most exposures at the top of the 'Red Bed' show signs of the presence of remanié style deposits, (Richardson, 1928-30, p.45). Limonite rich, red clay yielding small, unidentifiable ammonite nuclei has been found at : Loders Pipe trench, (SY503945 - Parsons, 1972); North Poorton, (SY520986); North Warren, (SY486998); Welcome Hill, (SY503953) and Horn Park quarry, (ST458022).

4.4 The 'Cole Syncline'

In the area of Bruton (Somerset), a small syncline, possibly a remnant of an original basin of deposition, has preserved an isolated patch of Aalenian and Lower Bajocian rocks some way to the north of the main Sherborne outcrops, (Richardson, 1916) - see Fig. 1. At the Lusty quarry, Bruton, (ST679344), a thin, hard limestone bed, very like the 'Irony Bed' to the south, has yielded a solitary specimen of _Teloceras_, (Richardson, 1916, p.496, bed 4). This specimen, now in Reading University collections, (3134), undoubtedly shows the Blagdeni subzone age of this bed. Unfortunately it has not been possible to find any further ammonites _in situ_.

4.5 The Doulting District

The Doulting Conglomerate bed, of the Doulting district, near Shepton Mallet, (Somerset), - see Fig. 1 - a thin bioclastic limestone (- 0.40m.), with numerous iron stained oncolites, was once well exposed in the Doulting rail-way cutting, (ST645425- Richardson, 1907, p.390, bed vi). This bed can now only be seen in temporary exposures and in fragments excavated by rabbits and badgers! From such unpromising sources the following basal Subfurcatum Zone fauna has been recorded, (Parsons, 1975) - _Cadomites deslongchampsi_ (d'Orb.), _Stephanoceras_ sp., _Teloceras banksi_ (Sow.), _Strenoceras_ (_Strenoceras_) _subfurcatum_ (Zieten), _Orthogarantiana_ sp. and _Leptosphinctes_ aff. _davidsoni_ (S.B.). This is the most northerly, fully authenticated, Subfurcatum Zone fauna yet found in the British Isles.

## 5. THE HORIZONS OF SMITH'S, THE SOWERBYS' AND BUCKMAN'S TYPES

One of the prime aims of this work was to determine the stratigraphic range of the numerous ammonite species which have been described from the Humphriesianum/Subfurcatum Zones of southern England. These fall essentially into two groups, firstly those described by earlier workers, such as W. Smith (1817) and J. and J. de C. Sowerby, (1812-46) at the beginning of the nineteenth century and secondly those described by S. Buckman, (1881, 1883, & 1909-30). I was fortunate in being able to locate topotypes of most of these species and thus to determine their type horizon, often for the first time.

### 5.1 Smith's and the Sowerbys' specimens

#### 5.1.1 Stephanoceras calix (W. Smith, 1817)

The lectotype of this, the earliest species described from these beds in England, is said to have come from Sherborne; its matrix would suggest a provenance from beds equivalent to 4b/c at Oborne Wood. This specimen, (BMNH, C671) refigured by Cox (1930, Pl.12, fig.10) is wholly septate, and, contrary to Cox's opinion, is very different to the following species.

#### 5.1.2 Stephanoceras brodiei (J. Sow.)

The holotype of this species, (BMNH,43905), was said to have been found on the Isle of Portland, by J. Brodie, (Sowerby, J., 1822 in 1812-46), but the matrix would indicate a provenance from the 'iron-shot' Inferior Oolite of the Sherborne area. Contrary to Cox's opinion (Cox, 1930, p.303) this specimen is not conspecific with the previous species, S. calix, although in terms of preservation it is extremely similar. The matrix would suggest beds 4b/c at Oborne Wood as the probable type horizon; somewhat similar topotypes have been acquired from bed 4c.

5.1.3 Stephanoceras humphriesianum (J. de C. Sow.)

The lectotype of this species (Buckman & Secretary, 1908, Pl. vii, fig. 1a & b) came from the Sherborne area, but there is insufficient matrix on this sectioned specimen, (BMNH,43908a) to enable an accurate idea of the original bed to be obtained. However several topotypes, with a similar excellent style of preservation have been found in Oborne Wood bed 4c, the undoubted type horizon.

5.1.4 Teloceras banksi (J. Sow.)

The holotype of this species (BMNH,43910) has a highly characteristic matrix, and comparable specimens have only been commonly found at Oborne Wood and Frogden quarry in bed 6a, the undoubted type horizon.

5.1.5 Teloceras blagdeni (J. Sow.)

The type specimen of this species (BMNH,43908) has a unique mode of preservation, as may clearly be seen in Buckman's refiguring of it (Buckman & Secretary, 1908, Pl. III, fig.1); the back of the ammonite has been planed off, and a later limestone bed, containing Perisphinctid ammonites, 'welded' on. This mode of preservation is typical of bed 5a Oborne Wood, where numerous specimens of T. blagdeni have been found, many of which, especially at the top of the bed, are flat lying. These have been eroded in half, and had the overlying limestones, cemented to the eroded surface. This then is unquestionably the original type horizon of this species.

5.2 Buckman's Specimens

5.2.1 'Type Ammonites'

Buckman in a series of papers from 1881 onwards described and figured a large number of ammonite species from these two zones. Whilst Buckman's early stratigraphic work is a classic of its kind, his later published work often had little or no factual basis. In 'Type Ammonites' in particular, (1909-30 Buckman) figured more than 35 new species from the Dorset Humphriesianum/Subfurcatum Zones, of which only a small fraction were founded on stratigraphically well localised material. The 'hemerae' to which Buckman assigned these ammonites were based more on differences in matrix and inferred phylogenetic links, than on actual stratigraphic evidence. Whilst this sorry tale is true of most of the hemerae erected in 'Type Ammonites', it is particularly relevant to those here included in the Humphriesianum Zone (see Table 1), since many of these hemerae are some of the most inadequate members of Buckman's polyhemeral scheme. An analysis of the ammonite species included by Buckman in his hemerae, shows that those hemerae now relegated to the Humphriesianum Zone were pure artifacts of Buckman's imagination, bearing no relationship to the actual stratigraphic distribution of the ammonites.

Most of the specimens figured by Buckman from the Sherborne area came from the old Frogden quarry. Oborne Wood section has shown an identical succession to this quarry, and it has provided topotypes of virtually all the species described from this area. The stratigraphic horizons of these topotypes is given in Table 2 : the more doubtful topotypes are indicated by a question mark, since these indicate specimens which either may not be from the type horizon of the holotype, or which show some differences in preservation or matrix. Several other localities in the Dorset area yielded ammonites which

| AMMONITE SPECIES | VOLUME | PLATE | OBORNE AND FROGDEN BED Nº's | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nº. | Nº. | 6d | c | b | a | 5b | 5a | 4c | b | a |
| Cadomoceras simulacrum | 5 | 458 | T | | | | | | | | |
| Plectostrigites symplectus | 5 | 471 | T | | | | | | | | |
| Flexoxyites flexus | 5 | 525 | | T | | | | | | | |
| Oppelina pulchra | 6 | 670 | | T | ? | | | | | | |
| Poecilomorphus primiferous | 7 | 756 | | | | | | | | T | |
| Stegoxyites parcicarinatus | 5 | 474 | | | | | | | | T | |
| Cadomites homalogaster | 5 | 543 | | | T | | | | | | |
| C. septicostatus | 5 | 432 | | | ? | | | | | | |
| Gibbistephanus gibbosus | 7 | 780 | | | | | | | ? | | |
| Epalaxites formosus | 3 | 151 | | | | | | | T | | |
| E. latansatus | 3 | 159 | | | | | | | | T | |
| Phaulostephanus paululus | 7 | 754 | | | | | | | | T | |
| Teloceras banksii J.Sow. | 6 | 660 | | | | T | | | | | |
| T. multinodus Quenst. | 7 | 788 | | | | | X | | | | |
| Chondroceras delphinus | 5 | 431 | | | | | | | | T | |
| C. gervillii J.Sow. | 7 | 724 | | | | | | | | X | |
| C. grandiforme | 4 | 357 | | | | | | | | T | |
| C. wrighti | 4 | 415 | | | | | | | | T | |
| Baculatoceras baculatum Qu. | 6 | 581 | X | | | | | | | | |
| Caumontisphinctes aplous | 3 | 241 | | | | | T | | | | |
| C. bifurcus | 3 | 192 | | | T | | | | | | |
| C. polygyralis | 3 | 163 | | | T | | | | | | |
| Strenoceras apleurum | 3 | 239 | | T | | | | | | | |
| Rhabdoites rhabdodes | 4 | 374 | T | | | | | | | | |
| Leptosphinctes cleistus | 3 | 161 | | | T | | | | | | |
| L. coronarius | 3 | 202 | | | ? | | | | | | |
| L. davidsoni | 3 | 201 | | | ? | | ? | | | | |
| L. leptus | 3 | 160 | ? | | ? | | | | | | |
| Sonninites alsaticus Haug | 5 | 528 | | | | | | | | X | |

Table 2.

The type horizons of some of those species of ammonites described by Buckman (1909-30), from Frogden Quarry and the Oborne District, Dorset.

T = topotype

? = possible topotype, original horizon uncertain

X = original horizon of Buckman's specimen

Buckman figured in 'Type Ammonites', namely Milborne Wick, Clatcombe, Louse Hill, and Burton Bradstock. Only at the first two of these localities are the beds sufficiently expanded to yield any reliable stratigraphic information, hence only these will be discussed here.

(a) Clatcombe Farm

Buckman acquired a large quantity of material from the old quarries in the area immediately to the north of Sherborne, around Clatcombe farm. Whilst the Humphriesianum Zone rocks of this district are virtually identical to those of Oborne, the Subfurcatum Zone is much more condensed; it is represented by one thin bed (bed 6, section 4.1.1). The specimens described from this latter horizon, Caumontisphinctes phaulus and C. nodatus S.B., could thus be Banksi-Polygyralis subzones in age, as there is no evidence for the Baculatum subzone in this bed. The specimen of Poecilomorphus regulatus figured by Buckman (1909-30, Plate 746) from this district must have come from the equivalent of bed 5b at Clatcombe Farm, which is on exactly the same horizon as bed 4b Oborne Wood. Topotypes of all three of these species have been collected from Clatcombe.

(b) Milborne Wick

Whilst Humphriesianum Zone fossils are extremely common in this district, Buckman described only one 'species' from here; Poecilomorphus angulinus S.B. (1909-30, Plate 757); of which topotypes have been collected from bed 5, Milborne Wick lane section.

5.2.2 The Monograph

It is fortunate that the Monograph of the Inferior Oolite Ammonites (Buckman, 1887-1907), ceased publication before Buckman had a chance to 'get to grips' with the majority of Bajocian ammonite groups. Only a small number of ammonites from the Humphriesianum Zone were figured in this work, notably members of the genera Poecilomorphus and Dorsetensia, and they all originate from the Romani subzone. Topotypes of Poecilomorphus evolutus (Buckman, 1887-1907, Pl. 22, figs. 21 & 22) have been collected from the 'Irony Bed' of Louse Hill, whilst topotypes of P. asper (loc. cit., figs. 3 & 4) and P. cappilaceous (loc. cit., figs 11 & 12) have been collected from bed 4b, Oborne Wood. Specimens similar to the syntypes of Dorsetensia regrediens (Haug), (op. cit., Pl.52, figs. 8-24) have been collected from beds 4b-c, Oborne Wood, whilst a specimen of the fine ribbed variant of this species (loc. cit., figs. 11 & 12), has been collected from bed 5, Milborne Wick. Similarly topotypes of D. complanata (op. cit. Pl.53, figs 3-5), D. pulchra (op. cit. Pl.52, figs. 25-27), D. subtecta (op. cit. Pl.54, figs. 4 & 5), D. liostraca (op. cit. Pl.55, fig. 3) and D. tecta (op. cit. Pl.56, figs. 2-4) have been collected from beds 4a-b, Oborne Wood.

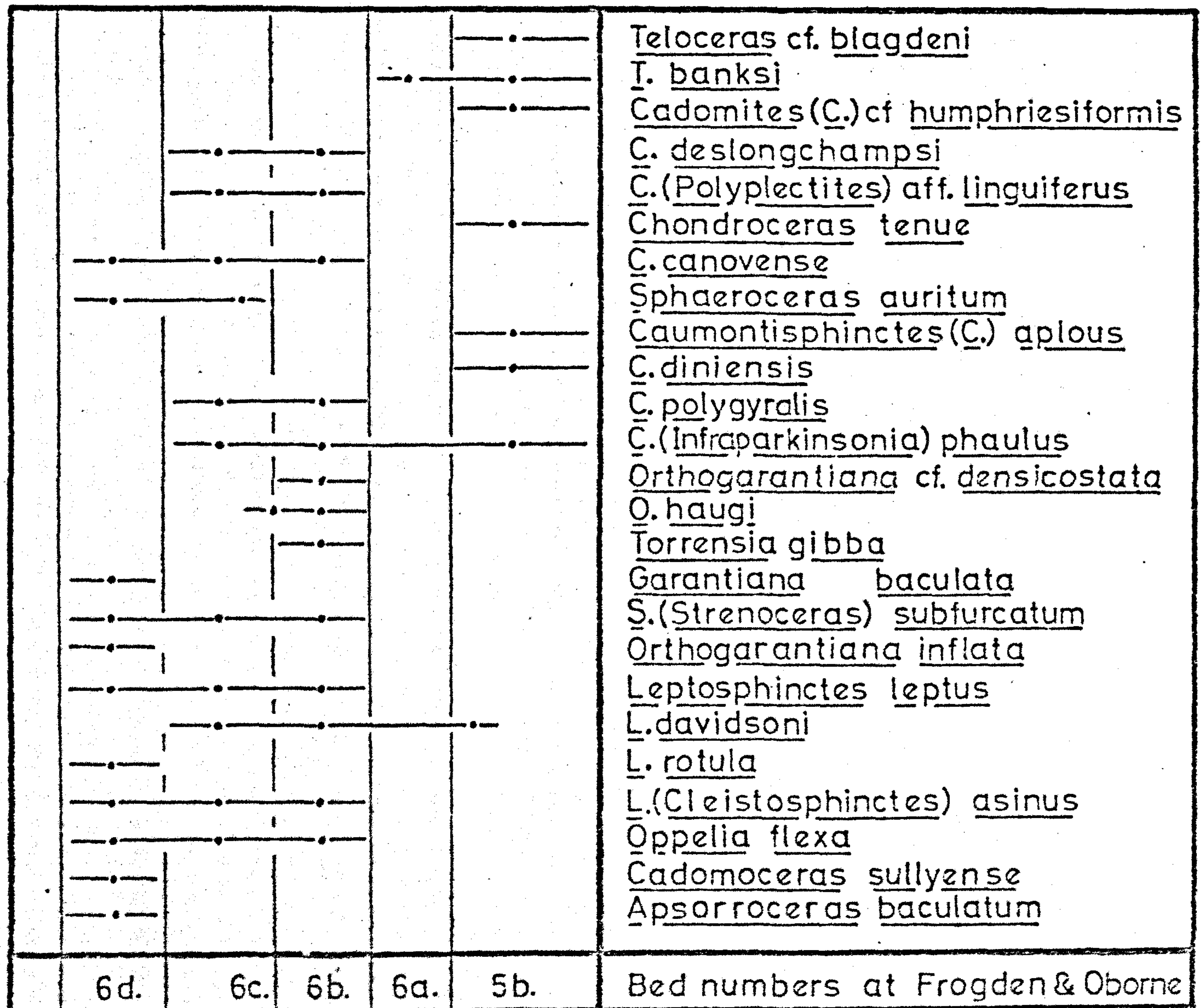
## 6. CONCLUSIONS

### 6.1 The Geographical distribution of the Humphriesianum and Subfurcatum Zones.

Buckman (1923, in 1909-30, p.54), considered that the present patches of Humphriesianum/Subfurcatum Zone sediments represented relicts of once more extensive deposits. His argument was that subsequent erosion, especially during the 'Vesulian Transgression', (basal Garantiana Zone), had removed most of the rocks of this age in southern England. That reworking and erosion was at least partly responsible for the present restricted distribution of these Zones is confirmed by their fragmentary and conglomeratic nature. However

Text figure 5

The stratigraphic distribution of the main ammonite species within the Subfurcatum Zone rocks of Frogden quarry and Oborne Wood.



these rocks, where preserved, invariably consist of thin, 'iron-shot' limestones, highly fossiliferous and with abundant evidence of a slow rate of deposition (Fatrall *et al.*, 1972). There is thus every reason to suspect that these beds were not of any great thickness to start with. Their present restricted distribution is thus as much due to initial deposition, as to subsequent erosion. In these circumstances, it is certain that the original area of deposition was considerably larger than the present restricted outcrop pattern would suggest.

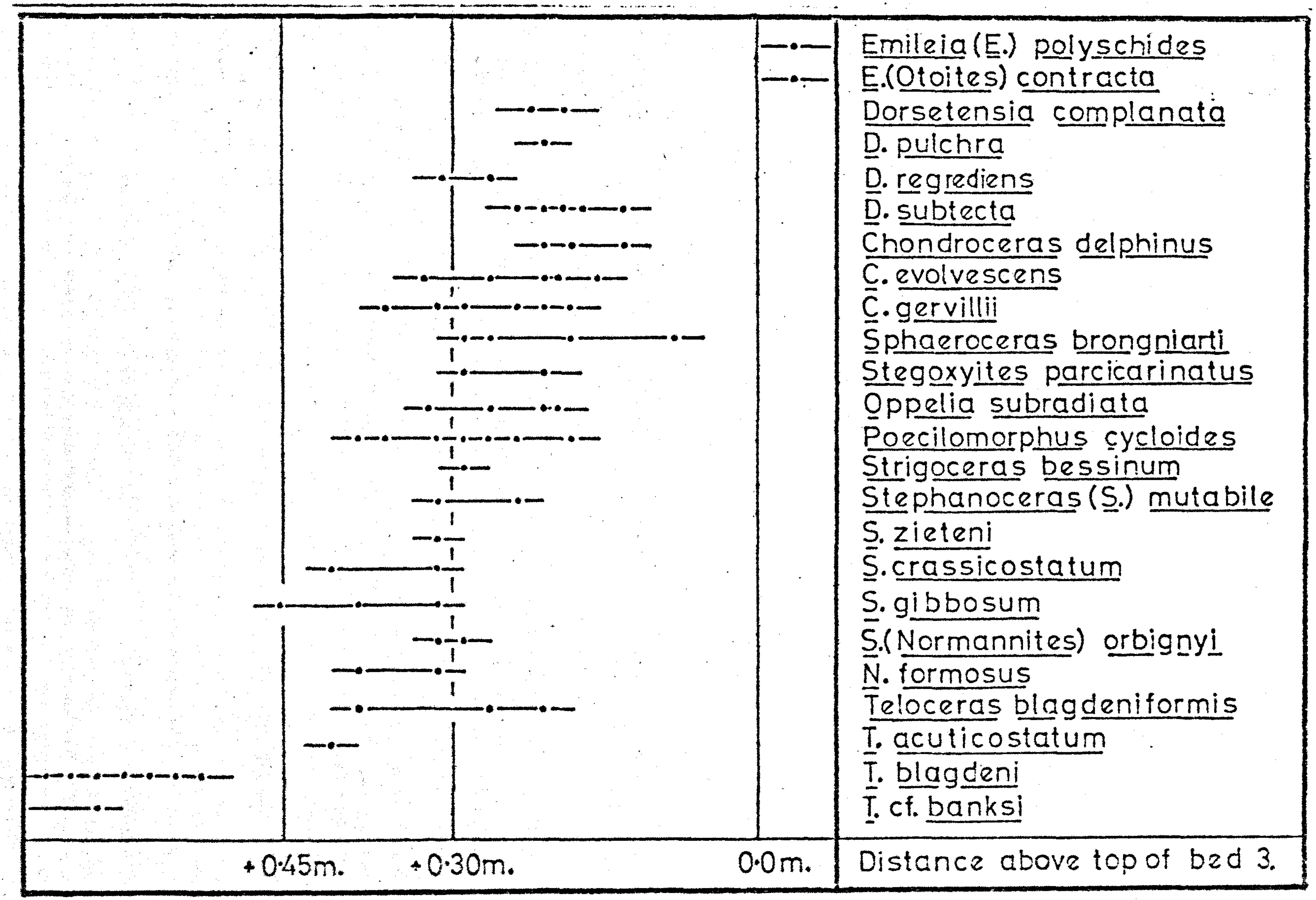
It is now certain that Morley-Davies's concept of a northerly overlap of the Humphriesianum/Subfurcatum rocks by the basal Garantiana Zone transgression, (Morley-Davies, 1930, p.232; Arkell, 1933, p.235), is untenable. The Doulting Conglomerate , of Subfurcatum Zone age, outcrops well to the north of the Sherborne district, where the main, isolated patches of the Subfurcatum/ Humphriesianum Zone rocks occur. This northerly occurrence of Subfurcatum Zone rocks thus rules out any possibility of the more southerly outcrops having been overlapped. The more convincing explanation is Buckman's original one : that the existing outcrops are relicts of once more continuous deposits, broken up and most commonly removed by subsequent erosion.

## 6.2 The Stratigraphic distribution of ammonites in the Humphriesianum/ Subfurcatum Zones.

The only sections in Southern England which show thick enough deposits of these Zones to warrant a study of the stratigraphic distribution of their ammonites are Frogden Quarry and Oborne Wood, (sections 4.1.2-3 here). The exposures in the Subfurcatum Zone rocks at these two localities are identical, thus the ammonite records from

Text figure 6

The stratigraphic distribution of the main ammonite species within the Humphriesianum Zone rocks of the Oborne Wood section.



these beds have been combined in text figure 5. The Humphriesianum Zone beds are now only exposed at Oborne Wood as this part of the section at Frogden is now grassed over; thus the distribution of the more common ammonite species from the Humphriesianum Zone of this former locality is shown in text figure 6. Lastly the overall distribution of the major genera within the Humphriesianum/Subfurcatum Zones of the Sherborne district is shown in text figure 7. To summarise this data, all the subzones are clearly recognisable in terms of the distribution of species, although the base of the Romani subzone, the top of the Humphriesianum subzone and the base of the Banksi and Polygyralis subzones are perhaps the most clearly delimited. At higher taxonomic levels, the greatest turnover of genera and sub-genera, comes at the base of the Humphriesianum Zone, and at the base of the Polygyralis subzone of the Subfurcatum Zone. Many taxa however, particularly those within the Haplocerataceae, are wide ranging.

## 6.3 The Standard Zonal Scheme

### 6.3.1 The Zone of _Stephanoceras_ (_Stephanoceras_) _humphriesianum_ (J. de C. Sow.)

Author:- Oppel, 1856.

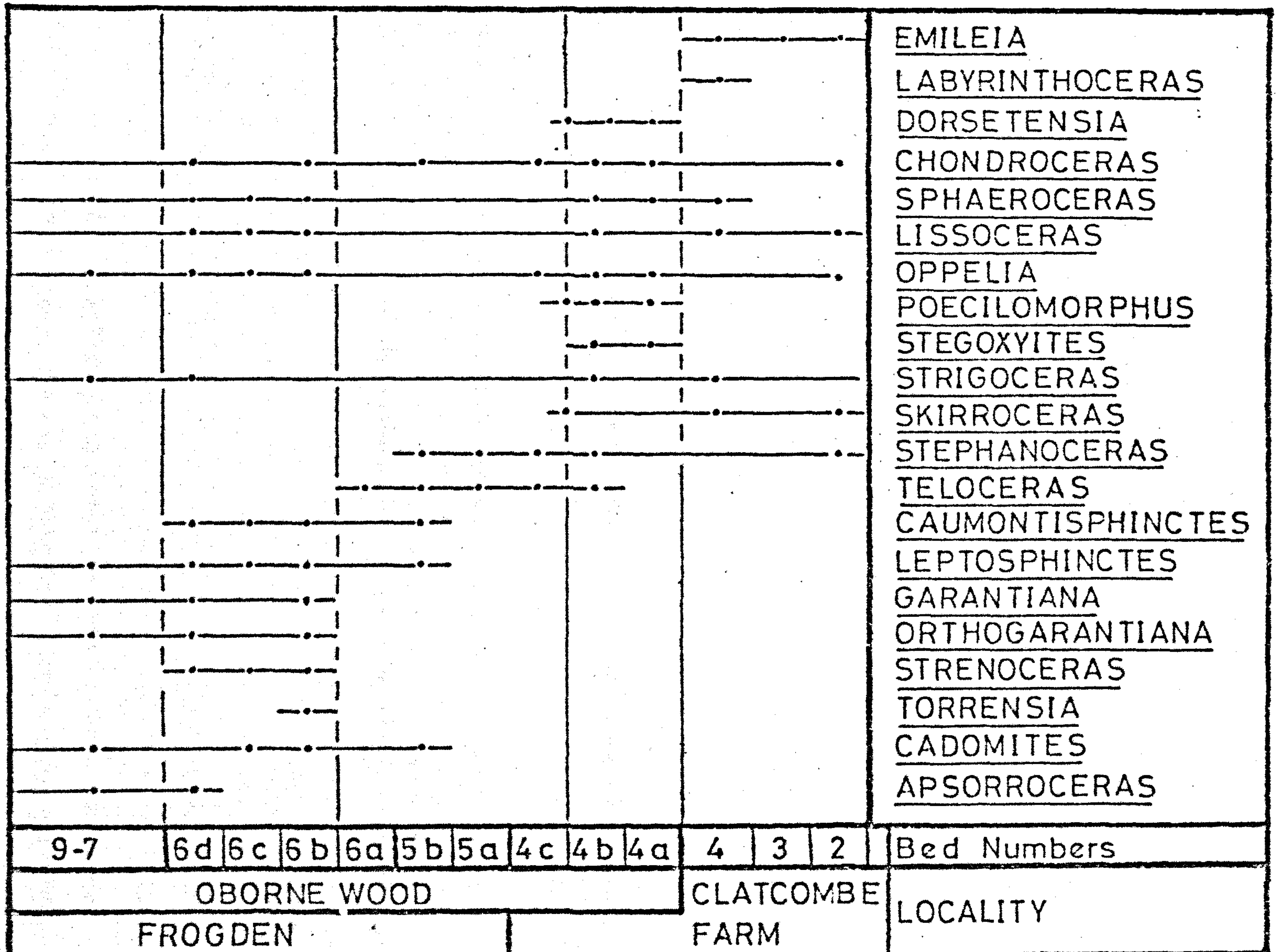
Type area:- Schwabian Albe, south Germany.

Type horizon:- The beds above the Blau Kalke and below the Subfurcatum Oolithe.

Fauna:- At its base it is characterised by the abundance of _Dorsetensia_, whilst _Stephanoceras_ and _Teloceras_ are abundant throughout.

Text figure 7

The stratigraphic distribution of the major ammonite genera and subgenera within the Humphriesianum and Subfurcatum Zone rocks of the Sherborne district of Dorset.



(i) The subzone of Dorsetensia romani (Oppel)

Author:- Haug, 1891, restricted Muller, 1941.

Type area:- The Basse Alpes, south-east France.

Type horizon:- The 'Couches à ammonites ferrugineuses de Beaumont' (Haug, 1891, p.70) near Digne, south-east France (Pavia & Sturani, 1968, p.312).

Fauna:- This horizon is characterised by a fauna, which includes abundant Dorsetensia - D. romani, D. edouardiana (d'Orb.), D. complanata Buckman and D. subtecta Buckman - as well as Chondroceras evolvescens, Sphaeroceras brongniarti, Teloceras blagdeniformis, Epalaxites portitor, Poecilomorphus cycloides and Stegoryites parcicarinatus.

Typical British horizon:- Oborne Wood, bed 4b.

(ii) The subzone of Stephanoceras (S.) humphriesianum

Author:- Oppel, 1856, restricted Muller, 1941.

Type area:- The Schwabian Albe.

Type horizon:- To be designated.

Fauna:- This horizon is characterised by the abundance of Stephanoceras s. str., including S. crassicostatum (Qu. emend. Renz), S. humphriesianum, S. pyritosum, (Qu. emend. Renz) and S. mutabile (Qu. emend. Renz).

Typical British horizon:- Oborne Wood, bed 4c.

(iii) The subzone of Teloceras (Teloceras) blagdeni (J. Sow.)

Author:- Six, 1879, restricted Spath, 1936.

Type area:- Ardennes, north-east France.

Type horizon:- To be designated.

Fauna:- This is a range Zone, based on the abundant occurrence of Teloceras blagdeni and other members of this genus.

Typical British horizon:- Bed 5a Oborne Wood.

6.3.2 The Zone of Strenoceras (Strenoceras) subfurcatum (Zieten)

Author:- Terquem and Jourdy, 1869.

Type area:- Département de la Moselle, France.

Type horizon:- Marnes à Longwy (in part).

Fauna:- Characterised at its base by the appearance of Leptosphinctes and Caumontisphinctes, the main feature of this Zone is the abundance of Garantiana and Strenoceras.

(i) The subzone of Teloceras (Teloceras) banksi (J. Sow.)

Author:- Buckman, 1910, restricted Sturani 1971.

Type area:- Sherborne area, North Dorset.

Type horizon:- Buckman's bed 5, Frogden quarry.

Fauna:- This horizon is marked by the appearance of Leptosphinctes and Caumontisphinctes and by the presence of the last Stephanoceratids which were typical of the Humphriesianum Zone, such as Teloceras and Stephanoceras s. str.

Typical British horizon:- Bed 5b Frogden quarry.

(ii) The subzone of <u>Caumontisphinctes</u> (<u>Caumontisphinctes</u>) <u>polygyralis</u> S. Buckman

| | |
|---|---|
| Author:- | Sturani, 1971. |
| Type area:- | Digne, Basse-Alpes, South-east France. |
| Type horizon:- | The limestone/marl sequence, particularly of the 'Ravin du Feston', (Pavia & Sturani, 1968), beds 119-138, (Pavia 1973). |
| Fauna:- | This horizon is marked by the abundance of, the dimorphic pair <u>Caumontisphinctes</u> (<u>C.</u>) <u>polygyralis</u> and <u>C.</u> (<u>Infraparkinsonia</u>) <u>phaula</u> S.B., <u>Leptosphinctes davidsoni</u>, and <u>Orthogarantiana haugi</u> Pavia, as well as by the first appearance of the genus <u>Strenoceras</u>. |
| Typical British horizon:- | Bed 6b Frogden Quarry. |

(iii) The subzone of <u>Strenoceras</u> (<u>Garantiana</u>) <u>baculata</u> (Qu.)

| | |
|---|---|
| Author:- | Kumm 1952, restricted Gabilly <u>et al</u>. 1971. |
| Type area:- | Bielefeld area, North-west Germany. |
| Type horizon:- | 'Untere Strenoceraten Schichten', (Althoff 1928). |
| Fauna:- | This horizon is marked by the abundance of <u>Garantiana baculata</u> and <u>Strenoceras subfurcatum</u>, as well as by the appearance of the Spiroceratid ammonites, <u>Appsoroceras</u> <u>baculatum</u> (Qu.) in particular. |
| Typical British horizon:- | Bed 6d, Frogden Quarry. |

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# 1C. A STRATIGRAPHIC REVISION OF THE *garantiana* AND *parkinsoni* ZONE (UPPER BAJOCIAN, MIDDLE JURASSIC) ROCKS OF SHERBORNE, DORSET

C.F. Parsons

SUMMARY : A new formal lithostratigraphic scheme for the Stroud Formation of the Inferior Oolite Group, in the Sherborne area of Dorset, is erected. The development of the zonal and subzonal scheme for the *parkinsoni* and *garantiana* Zones is discussed in the light of new evidence from Dorset. All the currently accepted subzones of the *garantiana* Zone (*dichotoma*, *subgaranti*, *tetragona* and *acris*) are recognized in Britain for the first time. All the existing exposures of *garantiana/parkinsoni* Zone rocks in the Sherborne area are described, their ammonite faunas discussed and correlated with other areas of southern England and Europe.

The Sherborne district of north Dorset has a considerable historical significance as the type area for the *garantiana* Zone and the *truellei* subzone of the *parkinsoni* Zone (Upper Bajocian, Middle Jurassic). The need for a detailed stratigraphic revision of the beds of this age has long been recognized (Richardson, 1932, p.82). The aim of the present work is to undertake a revision of the ammonite faunas from all the existing exposures in the area of *garantiana/parkinsoni* Zone rocks, (see Fig.1). These rocks, which have been previously included in the 'Upper Inferior Oolite', are a continuation of the Stroud Formation of the Inferior Oolite Group, a unit recognized in the Cotswolds, but which has been shown to be laterally persistent across much of southern England (Parsons, 1979a). The exposures

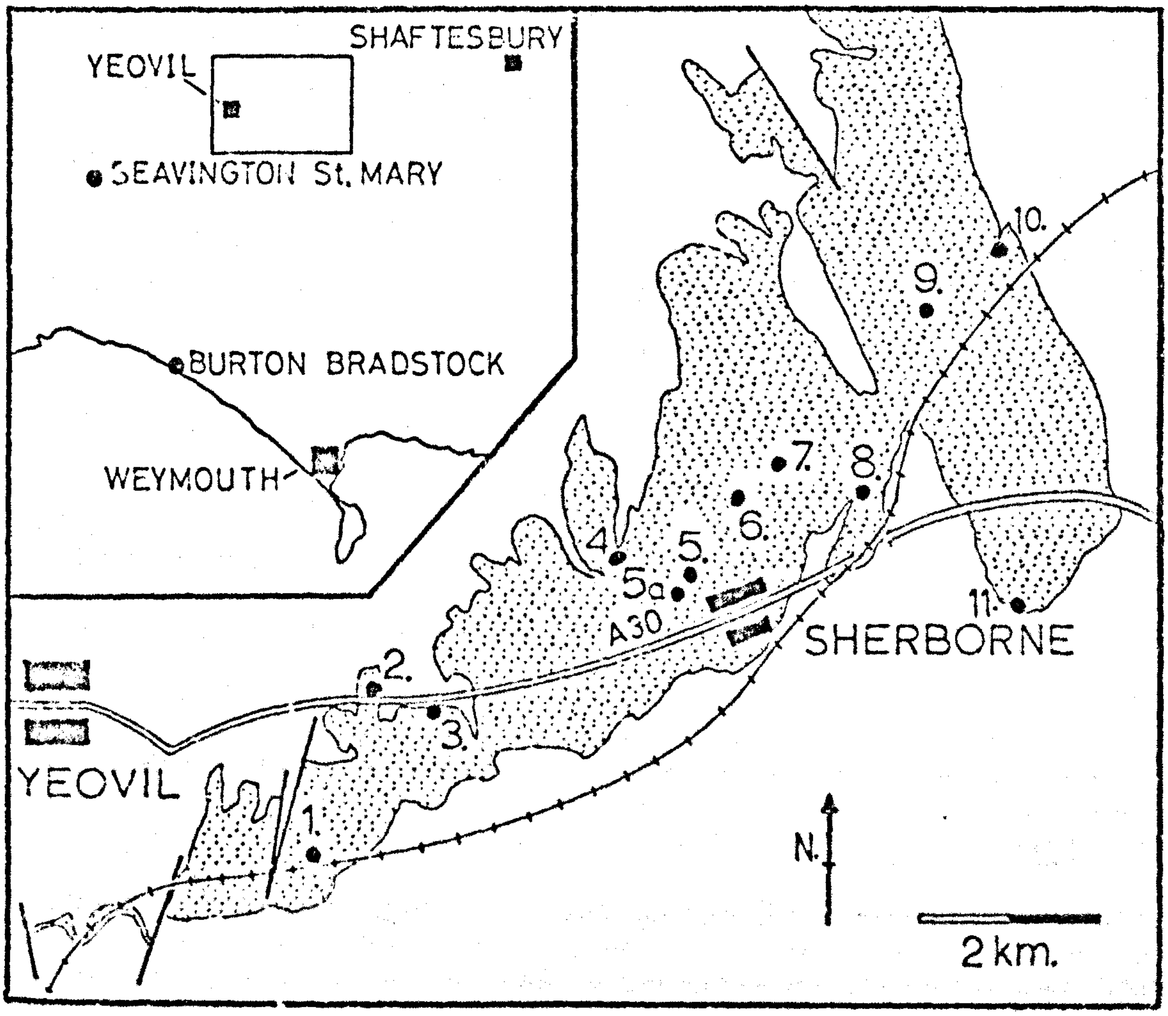



Figure 1.

A sketch map of the Sherborne district, showing the location of the main exposures described in the text. Locality 1 = Bradford Abbas railway cutting, 3 = Louse Hill quarry, the rest will be found on Figure 7.

in the immediate Sherborne area (localities 4-11, Figs.1 & 7), are dominated by extensive faces of garantiana Zone beds, and the parkinsoni Zone has only been recognized in situ at two small, isolated exposures. The latter unit is undoubtedly widely represented, although inaccessible at the top of the high, vertical quarry faces, thus only the garantiana Zone can be treated in any detail. Because of the historical, and international significance of the area, the development of the european zonal and subzonal divisions of the garantiana and parkinsoni Zones have been discussed in detail, and in part re-interpreted in the light of the new Dorset evidence. All of these Zones and subzones are essentially 'concurrent-range biozones' (Holland, et al., pp.13-14; Hedberg, 1976, pp.56-8), although the overall ranges of several taxa in the Sherborne area, are still to be precisely determined.

A new formal, hierarchical, lithostratigraphic terminology for the Stroud Formation in the Sherborne area has been erected (see Figure 2). Although exposures are now poor in the upper part, the new terminology has not been restricted to the garantiana Zone beds, and the whole Formation has been divided into Members and Beds of mainly local significance. There is a broad dichotomy of facies, between the thin, ferruginous, highly 'condensed' beds found in the west (localities 1-3, Fig.1), and the thicker, sparsely glauconitic, 'expanded' facies found to the east. Although the exact point of transition between the two cannot be seen, it must be extremely sharp and clear cut. The change in thickness is certainly more abrupt than that shown by Gatrall et al. (1972, fig.1), since the supposed intervening garantiana Zone, ferruginous, intraclastic limestone recorded (ST617,165), by them (op. cit., fig.3), is now known to be of upper

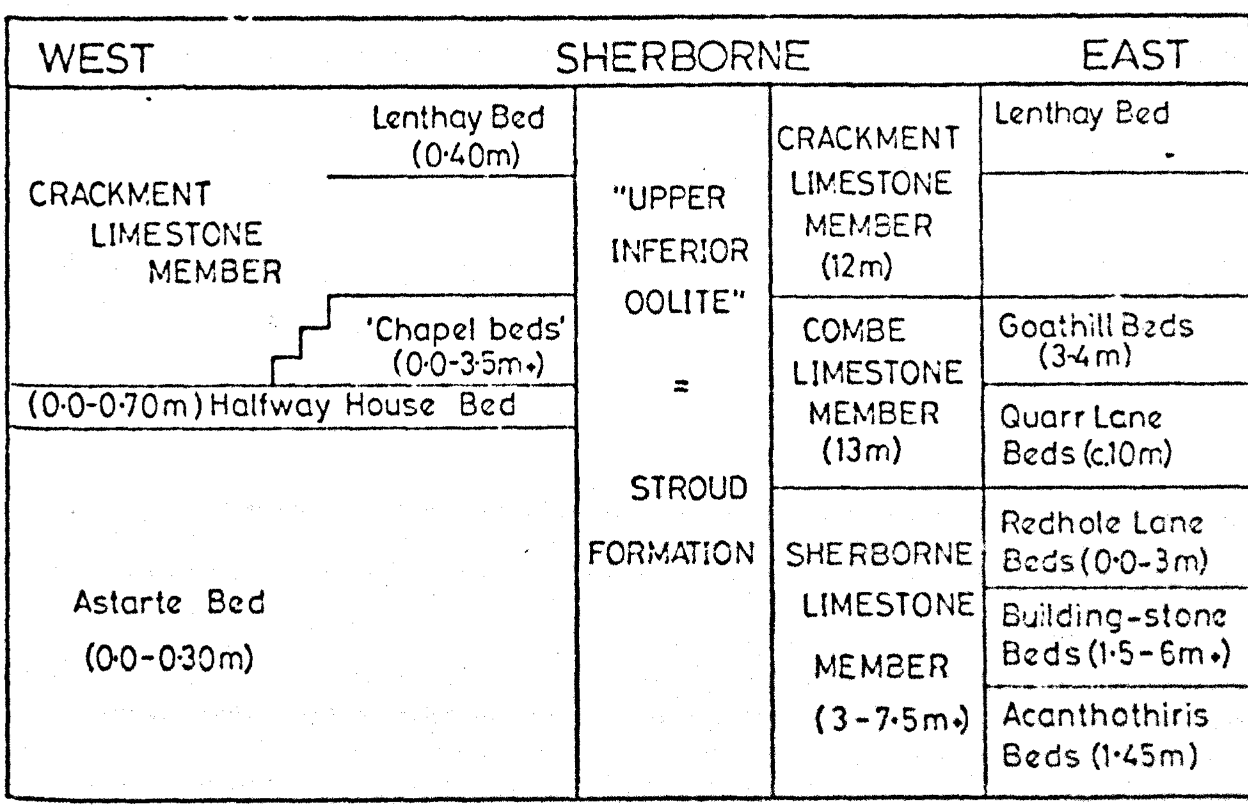



Figure 2.

The proposed lithostratigraphic terminology for the subdivisions of the Stroud Formation found in the Sherborne area of north Dorset.

parkinsoni Zone age (Whicher, 1969). The garantiana Zone/truellei subzone beds at this point are still highly attenuated, (op. cit.). The northern and eastern boundaries of the 'expanded facies' are less certain. The lack of ammonites from the small and sporadic exposures in the north around Charlton Horethorne and Blackford, confuses our understanding of the lateral passage into the 'Hadspen stone' (see Gatrall, et al., 1972, fig.3). To the east the Sherborne and Combe Limestone Members appear to pass, virtually unchanged beneath the Bathonian outcrop, and have been detected at the subsurface in the Stowell borehole (Pringle, 1909, 1910).

## LITHOSTRATIGRAPHY

The 'Upper Inferior Oolite' of the Sherborne district (Milborne Wick-Sandford Lane; see fig.1), has in the past been divided between three, broad, informal units : the 'Sherborne building-stone' (Richardson, 1932), the 'Rubbly beds' (Buckman, 1893) and 'Crackment Limestones' (Osborne-White, 1923). These units, with some modification and subdivision, largely form the basis for the formal members defined below (see fig.2). To the west of Sherborne, the above beds rapidly attenuate, and are replaced by thin, highly fossiliferous, 'condensed' beds.

### Vertical limits of the Formation.

#### The base of the Stroud Formation

The lower boundary of the Stroud Formation (largely equivalent to the 'Upper Inferior Oolite' sensu Arkell, 1933), is here drawn at a well defined disconformity, with an iron-stained conglomerate, at the base of the Acanthothiris Beds of the Sherborne Limestone Member. These latter beds rest on 'iron-shot' subfurcatum Zone beds at Frogden quarry (Parsons, 1976a, p.125), whilst at Sandford Lane, they have cut down to the sauzei Zone top of the 'fossil-bed' (Parsons, 1974, p.164). Although the subfurcatum Zone beds (= the 'cadomensis beds', Hudleston, 1886), have previously been included in the 'Upper Inferior Oolite' (Kellaway & Wilson, 1941; Wilson et al., 1959, p.96), they clearly lie beneath the above mentioned disconformity. In addition the lithology and general facies of these beds has more in common with the equally 'condensed' humphriesianum/sauzei Zone rocks, than with the overlying, more 'expanded', garantiana Zone beds.

## The upper boundary of the Stroud Formation

The top of the Stroud Formation in the Sherborne district is less easily defined than its base. Richardson (1932) took this boundary at the top of what is now called the bomfordi subzone, and included the 'Limestone beds' (= Crackment Member) in the overlying Fuller's Earth 'series'. However, this is rather an arbitrary boundary, based more on palaeontological, rather than lithological criteria, and is difficult to trace in most sections. Subsequently, most authors (Kellaway & Wilson, 1941; Arkell, 1951-9; Fowler, 1957; Wilson et al., 1959; Torrens, 1969) have included these beds in the Inferior Oolite Group, since the main mappable feature is produced by the top of the Crackment Limestones weathering out against the Fuller's Earth Clay. Although slightly problematic, the precise boundary can be taken below the 'knorri clay', which acts as a basal marker bed for the Fuller's Earth Formation. The Lenthay Bed is thus included in the top of the Crackment Limestone Member (cf. Torrens, 1969, fig.2).

The Sherborne Limestone Member

The beds previously known as the 'Sherborne Building-stone' (Richardson, 1932) or 'Building-stone' (Buckman, 1893), and including the 'stone used for lime' (op. cit.), are here included in a single, new, formal unit : the Sherborne Limestone Member of the Stroud Formation. At its type locality, here designated as Sandford Lane quarry, it consists of 3.0m of massive, sparsely glauconitic and oolitic, sandy, recrystallized biomicrite, with subsidiary marl partings (Buckman, 1893, p.492; Richardson, 1932, p.75, beds 4-6; see fig.3). Relatively unfossiliferous, with only sparse clusters of *Sphaeroidothyris*, these beds are at their thickest in the region of Redhole Lane quarry, where over 7.5m have been recorded (Richardson, 1932, p.73; see fig.5). Although generally massive, variation in the relative thickness of the marl partings allows some lithostratigraphic subdivision to be made.

*Acanthothiris Beds*

The lowest beds within the Sherborne Limestone Member, consisting of brown, sandy biomicrites, interbedded with thick, brown marls, are here formally named the Acanthothiris Beds, after the common occurrence of *A. obornensis* Buckman & Walker. At their type locality, Frogden quarry, they are 1.45m thick and consist of five, brown, sandy limestone courses (c.20cm thick), interbedded with brown sandy marls, underlain by a brown, ferruginous, rubbly limestone and marl, with a basal conglomerate, totalling 0.30m. A very similar sequence has been recorded from Oborne Wood (Parsons, 1976a, p.128), whilst the limestone courses are slightly thicker at Sandford Lane, where the beds are again 1.45m thick.

*Building-stone Beds*

The thick, massive biomicrites, which were formerly worked as a 'free-stone' are here formally named the Building-stone Beds, following Buckman's (1893, p.496), original usage. Although at their thickest in the region of Redhole Lane quarry, where more than 6.0m have been recorded (Richardson, 1932, p.73), only Sandford Lane, here designated the type locality, now shows a complete sequence of these beds, which are 1.5m thick (op. cit., p.76, bed 4).

Redhole Lane Beds

The thin bedded limestones previously known as the 'stone used for lime' (Buckman, 1893, p.496), which are less massive than the underlying Building-stone *sensu stricto*, are here formally named the Redhole Lane Beds. At their type locality, Redhole Lane quarry, they are made up of 1.5m of thin bedded biomicrites, with subsidiary marls and well burrowed, especially down towards the basal marl parting (Richardson, 1932, p.73, beds 4-5). These beds become thicker and more massive towards the east (e.g. Oborne Lane section - see fig.7), whilst to the west they become more nodular and marly, so that at Sandford Lane (see fig.3), they are indistinguishable from the overlying Combe Member .

Combe Limestone Member

The beds previously known as the 'Rubbly beds' are here formally named the Combe Limestone Member, after the excellent exposures on either side of the 'Combe' (Combe quarry = Sandford Lane, Buckman, 1893, p.492). The term 'Rubbly beds' (op. cit.), is rejected as it has a prior use in the Portland Beds (Blake, 1880), as well as for other beds in the Inferior Oolite of the Bath district (Richardson, 1907). Redhole Lane quarry is here chosen as type locality, in order to prevent any uncertainty in relation to the boundary with the underlying Redhole Lane Beds. The maximum thickness of this unit is unknown, although in excess of 5.6m have been recorded from Redhole Lane (Richardson, 1932, p.73) whilst 13m can probably be assigned to this Member in the Oborne Borehole (Wilson *et al.*, 1959, p.96). Taking the first appearance of *Parkinsonia s. lat.* as a datum level, the base of this unit appears to be diachronous. Thus in the east at Milborne Wick (see fig.6), the first *Parkinsonia* is only 0.15m from the base, at Redhole Lane 2.2m (see fig.5), whilst at Sandford Lane, the most westerly exposure, they appear 3.0m above the base. This is partly illustrated in figure 7, where the first appearance of *P. rarecostata* is plotted. A degree of lithostratigraphic subdivision is possible, since the upper beds tend to be more massive.

## Quarr Lane Beds

These beds, named after the excellent exposures either side of Quarr Lane, Sherborne, at Blackberry Lane and Redhole Lane quarries, are the typical 'Rubbly beds' *s. str.* At their type locality, here designated as Redhole Lane quarry, they consist of 5.0m (Richardson, 1932, p.73), of hard, grey, nodular, sparsely oolitic, recrystallized biomicrite, highly bioturbated and interbedded with soft brown marl, to give an overall rubbly and nodular appearance. Fossils are rare, apart from distorted ammonite body-chambers, and the beds usually have a brown, iron-stained appearance, which separates them from the Crackment Limestone Member.

## Goathill Beds

The *parkinsoni* Zone limestones previously recorded from Goathill (ST674122; Torrens, 1969, p.317) as 'Rubbly beds' are more evenly bedded than the bulk of the Combe Member. At this, the type section, and an exposure 100m to the south by the side of the path, the Goathill Beds consist of +2.4m of brown, sparsely oolitic, fossiliferous biomicrites, evenly bedded, with subsidiary brown, marl partings. These beds are consistently more evenly bedded and fossiliferous, with common echinoids (*Holectypus*, *Pygomalus* and *Pygorhytis*), than the subjacent Quarr Lane Beds, and are very like the Burton Limestone on the Dorset coast (Parsons, 1975a). Unfortunately there is currently no good exposure of the base of these beds, although it may be represented at both the Milborne Port 'station cutting' (Richardson, 1916, pp.510-1) and at the Redhole Lane quarry, where 0.70m of more regularly bedded limestone has been recorded from the top of the section (Richardson, 1932, p.73). No complete exposure of these beds has been seen, thus their complete thickness is unknown, although the 3.0m of grey, shelly limestone overlying the Quarr Lane Beds (= 'Rubbly beds') in the Oborne borehole (Wilson, *et al.*, 1959, p.96) are probably their equivalent.

Crackment Limestone Member

The existing informal unit, the 'Crackment limestones' (Osborne-White, 1923; = 'the Limestone beds'; Buckman, 1893, p.486; Richardson, 1932, p.49), is here redefined as a formal Member, with the retention of the original type locality; Crackment or Crachment Hill (ST667183); selected by Arkell (in Donovan & Hemingway, 1963, p.103-4). Here only an upper part of the unit is visible, where it typically consists of thin limestones, alternating with relatively thick, brown clay/marl bands. These beds are very badly exposed at present, and most existing stratigraphic information has come from temporary sections (Arkell, 1951-9, p.10; Fowler, 1957; Torrens, 1969). Evidently the proportion of clay increases towards the top, and the Lenthay Bed, here defined as the topmost bed of the Crackment

Limestone Member, is separated from the bulk of the limestone below by 2.1m of clay (Torrens, 1969, p.315). Although lack of exposure makes any estimate of the total thickness of this unit difficult, in the region of 12m have been recorded from the Oborne borehole (Wilson et al., 1959, p.96).

'Condensed' beds of Nether Compton

The lithostratigraphic units described above are applicable to the area between Sandford Lane and Milborne Wick. However, west of Sherborne many of these units, particularly the Sherborne and Combe Members, thin rapidly (Gatrall et al., 1972, figs. 1 & 3), until at Halfway House, Nether Compton, they are represented only by some very thin, ferruginous, highly 'condensed' beds.

The Astarte Bed

The beds representing the whole of the garantiana Zone in much of north and south Dorset, are extremely thin (generally less than 0.20m), and of highly variable lithology. At its type locality, here designated as the Rock Cottage quarry, the Astarte Bed consists of 0.13-0.17m of moderately hard, light-grey, highly fossiliferous oobiomicrite, with yellow/orange shell replacement, iron and manganese staining, sparse pisoliths and common, often serpulid encrusted Astarte (Neocrassina) and belemnites (Richardson, 1932, p.62). However, other lithologies are common, such as ferruginous conglomerates at Louse Hill and highly limonitic marls with 'snuff-boxes' (q.v. Gatrall et al., 1972), at Bradford Abbas railway-cutting. Following previous usage all these are here included in the Astarte Bed (Buckman, 1893, p.487, = 'Shell bed', 'Rotten bed'; Richardson, 1932, p.48), including the overlying, impersistent marl bed, which is mainly the result of the weathering of the Astarte Bed s. str., such as at Bradford Abbas (Buckman, 1893, p.485, bed 4 = 'Marl bed' or 'Dirt bed').

Halfway House Bed

The horizon previously known as the Halfway House 'fossil-bed' (Buckman, 1893, p.487, bed 4; Richardson, 1932, p.62) is here formally named the Halfway House Bed. At its type locality, Rock Cottage quarry, it consists of 0.30m of soft, light-grey/off-white, biomicrite, with yellow shell replacement. At other localities it is thicker, with 'snuff-boxes' (e.g. Bradford Abbas railway-cutting, 0.70m), whilst elsewhere (e.g. Clifton Maybank, ST577140), it is more ferruginous, with abundant ammonites. Although precise correlation is difficult, this bed is probably a 'condensed' equivalent of parts of the Combe Member.

'Chapel beds'

West of Sherborne the upper parts of the Combe Member (mainly Goathill Beds) pass into a ferruginous, grey-brown, sandy, relatively unfossiliferous, thin bedded, sparsely crinoidal, iron-stained, intraclastic limestone, with brown, sandy marl partings. In the western part of the new road-cutting, adjacent to the old Chapel quarry, Halfway House (Wilson et al., 1959, p.95), c.3.0m of these beds are visible. They have not been formally defined here, as their exact stratigraphic position is still problematic, although they are certainly, at least in part, of immediately post-truellei subzone age (Whicher, 1969, p.326). Their overall distribution is restricted. They first appear 3km west of Sherborne (ST617165; loc. cit.), and are also visible at Louse Hill (Richardson, 1932, p.67) and Rock Cottage quarry (*op. cit.* p.62), but are absent from the Bradford Abbas railway-cutting, where the Crackment Limestone Member rests directly on the Halfway House Bed. However, the presence of *Parkinsonia parkinsoni* (Buckman *non* Sow.), in the bottom of the Crackment Limestone at the latter locality suggests that a lateral facies change may have occurred, and that the base of the Crackment Limestone Member may be the equivalent here, of the 'Chapel beds' to the east.

## BIOSTRATIGRAPHY

The age range of the Stroud Formation in the Sherborne area is similar to that of the '*parkinsoni* zone' as originally defined (Oppel, 1856 in 1856-8, p.344). Although in his early papers on this area, Buckman (1881, 1883) utilized this zone in its original, broad sense, he rapidly recognized the need for its subdivision. Thus in 1891, Buckman used the '*cadomensis*' (= *subfurcatum* Zone), '*truellei*' and '*zigzag* zones' at least in part to fulfil this need. In a subsequent paper (Buckman, 1894, tab.1), he clearly delimited these zones and compared them with the zonal schemes of earlier authors. A significant feature of these papers, relates to the introduction of the '*truellei* zone', which was based on .... "the bed at Halfway House, which yields the large *Parkinsoniae*" ..... (Buckman, 1891, p.656). The Halfway House Bed (= 'fossil-bed'), of the present area must thus be taken as the type horizon for this unit (Arkell in Donovan & Hemingway, 1963, p.355). Buckman (1893), in his detailed description of the Sherborne area introduced a further subdivision, in the form of a *garantiana* hemera between his *niortensis* (= previous '*cadomensis* zone') and *truellei* hemerae, whilst he was later to use a *schloenbachi* hemera between his *truellei* and *zigzag* hemerae (Buckman in Richardson, 1908; Buckman, 1910, p.78). Although

| BUCKMAN 1891, 1893 | BUCKMAN 1910 | ARKELL 1933 | SPATH 1936 | | ARKELL 1951-9 & 1956 | TORRENS 1969 | | PARSONS 1976 | | SCHEME USED HERE | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | zigzag sz. | parkinsoni Zone | | | | | | zigzag Zone | |
| | schloenbachi hemera | Schloenbachi Zone | schloenbachi subzone | | Parkinsoni Zone | bomfordi | parkinsoni Zone | bomfordi | parkinsoni Zone | bomfordi | parkinsoni Zone |
| | | | | | | parkinsoni | | | | | |
| truellei hemera (D) (zone, 1891) | truellei hemera | Truellei Zone | truellei subzone | | | truellei | | truellei | | truellei | |
| (E) | garantiana hemera | Garantiana Zone | garantiana s.s. | | Garantiana Zone | garantiana Zone | | acris | garantiana Zone | acris | garantiana Zone |
| garantiana | | | | | | | | | | tetragona | |
| hemera (F) | | | | | | | | dichotoma | | subgaranti | |
| | | | | | | | | | | dichotoma | |
| niortensis hemera (G) | | | niortensis s.z. | | | | | | | subfurcatum Zone | |

Table 1. Development of the classification of the garantiana and parkinsoni Zones in Great Britain.

Buckman (1909-30) introduced further, but less well defined hemerae, only the above mentioned units were used by Arkell (1933), as the basis for the zonal scheme, which he used in his description of the British 'Upper Inferior Oolite'. Spath (1936, p.15), returned to the original, wide definition of the '*parkinsoni* zone', with the use of Buckman's hemerae as subzones. Arkell (1951-9, pp.8-9; 1956, p.31), subsequently preferred the use of a more restricted, but undivided *parkinsoni* Zone for World correlation, since he considered the *truellei* subzone to have no more than local significance. Up until recently (Parsons, 1976b, p.48), no attempt has been made to subdivide the British *garantiana* Zone. The development of the *garantiana* and *parkinsoni* Zones in Britain is summarized in Table 1.

The *garantiana* Zone

Buckman (1893, p.483), introduced the *garantiana* hemera in his description of an area, which largely coincides with that presently under discussion. Its introduction as a zone must also date from this publication (Arkell, 1951, in 1951-9, p.9), rather than from its subsequent use in a list of zones (Buckman, 1913 in 1909-30). The original theoretical differences between chronological (= 'hemerae') and strictly stratigraphical units (= zones), were misunderstood by many authors (see the discussion of Buckman's 1893 paper), and this clear cut division was in any case destroyed by Buckman's (1913 in 1909-30; 1915) later confused interchange of hemerae and zones (*contra*, Dean *et al.*, 1961, p.440). Additionally, it could be argued that Buckman's original hemerae (Buckman, 1893, pp.481-2; see Arkell, 1933, pp.20-1), have more in common with the present standard Zones (Holland *et al.*, 1978, p.7) or chronozones (Hedberg, 1976, p.67), than with the poorly defined 'biozones' then in use. The Sherborne district must thus be taken as the type area for the _garantiana_ Zone (Arkell in Donovan & Hemingway, 1963, p.144).

In his description of the _garantiana_ hemera, Buckman (1893), recorded very few ammonites : "_Parkinsonia garantiana_, _P. praecursor_, _P. rarecostata_, _Perisphinctes triplicatus_, _Oppelia_ sp. and _Ancylyoceras_ sp.". Whilst these taxa must now be interpreted in a very broad sense, his records of "_P. rarecostata_" (_op. cit._, pp.496, 497), suggest that the _garantiana_ Zone must overlap with the range of a species, which would now be referred to _Parkinsonia_ s. str. This is confirmed by his subsequent assignation of "evolute _Parkinsonae_" and "_Garantiana_" to the ... "General Ammonite Facies" .. of the _garantiana_ hemera (Buckman, 1910, Tab.1), at a time when the definition of Bajocian ammonite genera was closer to that of the present day. The recognition that members of the _P. rarecostata/acris/subarietis_ group make up an essential part of the _garantiana_ Zone fauna, as originally defined, confirms that the first appearance of the genus _Parkinsonia_ _cannot_ be taken as defining the base of the _parkinsoni_ Zone (_contra_ Mouterde, 1953; Westermann, 1967; Pavia & Sturani, 1968; Gabilly _et al._, 1971). Thus the ammonite fauna showing the overlap of _S._ (_Garantiana_) and early _Parkinsonia_; the _acris_ zone (Kumm, 1952) or subzone (Westermann, 1967); is essentially synonymous with much of the _garantiana_ hemera, and must be included in the top of the _garantiana_ Zone (Parsons, 1976b, p.48). Fortunately the definition, and subsequent recognition, of the lithological units, which Buckman (1893), originally assigned to the _garantiana_ hemera is clear cut. Thus it has proved possible (see below), to rectify some of the gaps in our knowledge of the _garantiana_ Zone's ammonite faunas, in its type area. It is evident that Buckman (_op. cit._), recognized, from its first inception, the possibility of subdivision, since he divided the garantiana hemera between two of his labelled horizons ("E" & "F"; e.g. op. cit., p.496, section xi, beds 1 & 2). These horizons coincide with the lower part of the Combe Member (lower 'Rubbly beds' = "E") and the Sherborne Member ('Building-stone' = "F"), which do indeed show some differences in their ammonite faunas (see below). However, this early lead was not followed up until relatively recently (Parsons, 1976b, p.48), and most of the more detailed stratigraphic work, upon which the present subzonal scheme is based, has been undertaken in the thick clay sequences of north Germany.

The first person to recognize, and so name the garantiana Zone in Germany was Mascke (1907), and it is interesting to note that he closely followed Buckman (1893), and drew the base of his 'Parkinsonia-Zone', at the base of the truellei zone. However, many subsequent german authors rejected the use of Buckman's hemerae/zones, and relied on a less formal terminology. Thus initially the garantiana Zone beds were divided between the lower half of the 'Parkinsoni-Schichten' and the upper part of the 'Subfurcaten-Schichten' (Wetzel, 1911; Althoff, 1914). Further subdivision followed, with the recognition between these two of the 'Perisphinctesschichten' (Althoff, 1920, p.4) or 'Bigotiten-Schichten' (Wetzel, 1954, p.549), which was to be named the tetragona zone (Kumm, 1952, p.334) or subzone (Westermann, 1967, tab.1). Other refinements included the renaming of the upper 'Subfurcaten-Schichten', first as the 'Pseudogarantien-schichten' (Bentz, 1928; Althoff, 1928, pp.8-9), and then as the dichotoma Zone (Kumm, 1952, p.334) or subzone (Westermann, 1967, tab.1), whilst the 'untere Parkinsonien-schichten' (Althoff, 1928), was redefined as the acris zone (Kumm, 1952, p.334), or subzone of the parkinsoni zone (Wester-

| | MASCKE 1907 | WETZEL 1911 ALTHOFF 1914 | ALTHOFF 1920 | BENTZ 1924 | BENTZ 1928 ALTHOFF 1928 | KUHM 1952 | WESTERMANN 1967 |
|---|---|---|---|---|---|---|---|
| Parkinsoni z. | Garantiana Zone ↓ | 'Untere Parkinsonien Schichten' | 'Untere Parkinsoni Schichten' | 'Untere Parkinsonien Schichten' | 'Untere Parkinsonien Schichten' | Acris Zone | acris subzone |
| Garantiana Zone | | 'Subfurcaten (Bifurcaten) Schichten' (pars) ↓ | 'Perisphincten Schichten' | 'Oberer Subfurcaten Schichten' (?pars) | 'Perisphinkten Schichten' | ('Bigotiten Schichten') Tetragona Zone | tetragona subzone |
| | | | 'Subfurkaten Schichten' (pars) ↓ | | 'Pseudogarantien Schichten' | Dichotoma Zone (pars) ↓ | garantiana subzone |
| | | | | | | | dichotoma subzone |

Table 2. Development of the subdivision of the garantiana Zone beds in Germany.

mann, 1967, tab.1). An additional subdivision, the garantiana subzone was erected by Westermann (loc. cit.) between the dichotoma and tetragona subzones, but its relationship to either pre-existing or subsequent schemes is difficult to establish (Hinkelbein, 1975, p.154). This german terminology, the development of which is summarised in Table 2, formed the basis of the subzonal scheme used in the Basse-Alpes of south-east France (Pavia & Sturani, 1968; Pavia, 1973). The main modification consisted of a new subzone, the subgaranti, between the dichotoma and tetragona horizons (Pavia & Sturani, 1968, p.314), which was later renamed the trauthi subzone (Pavia, 1973, p.87), because of the previous misidentification of the specimens of 'Hlawiceras'. However, this was an unnecessary change, since S. (G.) subgaranti undoubtedly occurs (contra Pavia, 1973) at this horizon (Althoff, 1928, p.8; Kumm, 1952, p.390; and herein), although it ranges up into the acris subzone (op. cit.). This wide range does not rule out its use (Hedberg, 1976, pp.52, 60-1), and it must have priority over the trauthi subzone. It has been suggested (Sturani, 1971, p.48), that the subgaranti subzone was introduced as a replacement for Westermann's (1967), garantiana subzone. This is difficult to substantiate, since the latter was so poorly defined.

The four subzones adopted by Pavia (1973), including the acris subzone (see above and table 1), can be recognized in the Sherborne area. However, it should be stressed that this subzonal scheme is still very provisional. The lower limits of several subzones are difficult to establish and many important taxa appear to range throughout the bulk, if not all of the Zone (e.g. S. (G.) garantiana, S. (G.) alticostata, S. (G.) depressa, S. (G.) subgaranti, S. (G.) suevica, S. (G.) tetragona; Althoff, 1928, pp.7-9;

Kumm, 1952, pp.390, 430). Some of these problems are discussed in more detail below, and there is little doubt that more work on the ammonite distributions is needed before the subzonal scheme for the garantiana Zone is fully stabilised.

The parkinsoni Zone and its base

Since the original zone (Oppel, 1856) has been considerably restricted, its limits must be determined in relation to the ranges of the subsequently erected, adjacent zones. Its top is defined by the base (see Sturani, 1967, pp.10-1) of the Bathonian zigzag Zone (Oppel, 1865), thus only the lower boundary of the parkinsoni Zone need be discussed here. As detailed above, the original upper limit of the garantiana hemera was drawn at the base of the truellei zone/hemera. This boundary has been implicitly accepted by all British workers (Richardson, 1916, 1932; Arkell, 1933, 1951-9, 1956; Torrens, 1969, etc.), since the bulk of the deposits assigned by Buckman and later workers to the garantiana hemera, and subsequently correlated with the garantiana Zone, are of acris subzone age (= Astarte Bed, south and much of north Dorset; Hadspen Stone of Somerset; Upper-Trigonia-grit of the Cotswolds). If the acris subzone were to be included in the parkinsoni Zone, then the restricted garantiana Zone would be almost unrepresented in southern England, including its type area (Parsons, 1976b, p.48). Thus the truellei zone (Buckman, 1891) is here defined as the basal subzone of the parkinsoni Zone. As originally defined (Buckman, 1891, p.656), this horizon was based on the 'fossil-bed' at Halfway House, yielding .... "large Parkinsoniae" ... Ammonites more recently collected from this horizon (Torrens, 1969, p.308; Whicher, 1969, p.330; see below), confirm Buckman's (1910, p.55), subsequent assignation of "compressed Parkinsoniae" (of the "*P.-parkinsoni* type", *op. cit.*, p.78), and "*Strigoceras*" to the *truellei* hemera. The *truellei* subzone is thus synonymous with the *densicostata* subzone (Pavia & Sturani, 1968, p.315), and must have priority. The fact that *S. truellei* has a wide range beyond that of its subzone, does not discredit its use as an index, as it occurs abundantly in the assemblage-biozone (Holland *et al.*, p.13), for which it acts as a label.

The horizon between the *zigzag* and *truellei* hemera was assigned by Buckman (1907, p.424), to the 'pre-*zigzag*/post-*truellei*' hemera or *schloenbachi* hemera (Buckman, 1908, 1910, tab.1). This horizon was said to be characterised by *Parkinsonia* .... "massive forms, with stout, somewhat squared whorls" ... (Buckman, 1910, p.78), which Buckman (1907, p.424), assigned to the '*P. schloenbachi*, Schlippe' group. These specimens; a typical representative of which was figured by Buckman (1921 in 1909-30, pl.493); were said by Arkell (1951-9, p.9) to have been misidentified, and were renamed by him as *P. bomfordi* Arkell (*op. cit.*, pp.149, 157). Thus this horizon has subsequently been known as .... "horizon à *Parkinsonia bomfordi* Ark. (= *P. schloenbachi* S. Buck. non Schlippe)"..... (Gabilly, 1964, p.73) or *bomfordi* subzone (Sturani, 1967). This is an occasion, where there can be little dispute (cf. Dean *et al.*, 1961, p.439), in applying Arkell's rule relating to the priority of zonal indices, which have been misidentified by their original author (Arkell, 1946, p.3, 'rule 4'). Since they are largely identical in all but their corrected name, the *bomfordi* subzone can take its authorship from Buckman's introduction of the *schloenbachi* hemera/zone.

The presence of a further subzone, the *parkinsoni* subzone, between the truellei and bomfordi subzones has been suggested (Gabilly, 1964, p.73, fig.1; Torrens, 1969, p.302). Whilst evidence for this unit has up to now only been slight, there are some indications (see below) in its support, which will have to be verified by further, more detailed stratigraphic work. Until such work has been undertaken, there is still insufficient evidence to support its use.

## DESCRIPTION OF SECTIONS

Since one of the main aims of this work was to undertake a biostratigraphic revision, only those sections which have recently yielded relevant ammonites are described here (see Fig.1), starting at the most westerly and working east.

### Bradford Abbas

Although all of the exposures in the Bradford Abbas district described by Buckman (1893, pp.485-6) and Richardson (1932, pp.54-62) are now obscured, a good section can still be made out in the railway-cutting (ST594145). Here above an impersistent, limonitic Astarte Bed (0-0.20m), are seen the Halfway House Bed (0.35-0.70m); with Parkinsonia (Okribites) cf. pseudoparkinsoni Wetzel, CP2881; overlain by more than 2m of the Crackment Limestone Member, with P. (O.) parkinsoni (Buckman non Sow.), CP2994, in the basal 10cm. Rare specimens of P.(?P.) pachypleura Buckman from the upper part of the latter beds indicate the presence of the lower part of the zigzag Zone, although it is difficult to determine its base.

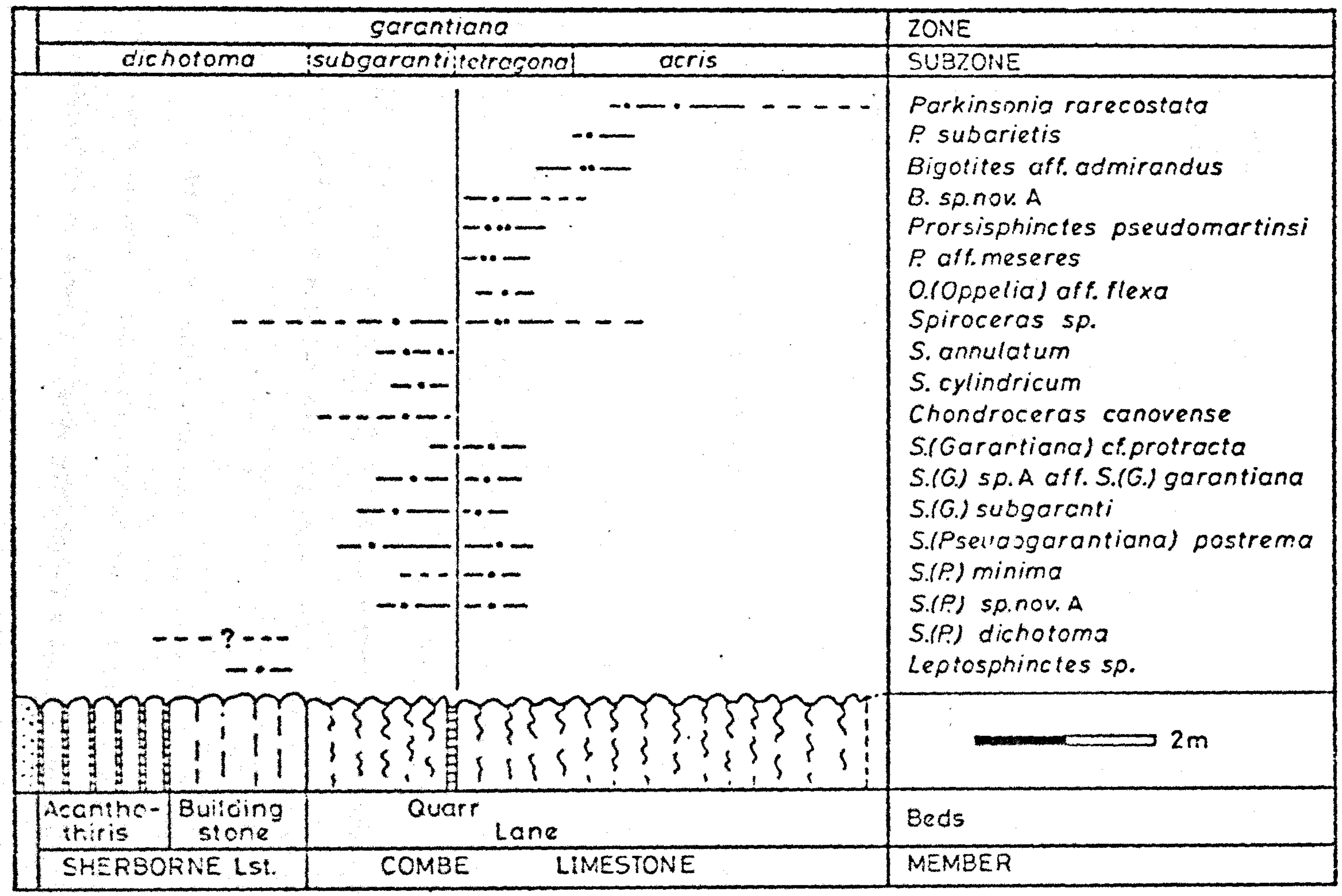
### Halfway House

Some of the sections in this area have been obliterated, but several important exposures are still available for study (Torrens, 1969, pp.308-10, fig.1). Approximately 3.0m of 'Chapel beds' are visible in a cutting adjacent to the old Chapel quarry (Richardson, 1932, p.65), whilst more extensive exposures are available at the new road-cutting (ST602163; Whicher, 1969, p.329) and at the Rock Cottage quarry (ST601165). The latter section (Buckman, 1893, p.487; Richardson, 1932, pp.62-3), which is more weathered and amenable to collecting, shows 0.20m of Astarte Bed, overlain by the Halfway House Bed (0.30m) and +1.5m of 'Chapel beds'. The Halfway House Bed, which has yielded the most ammonites : numerous *Parkinsonia* (*P.*) *dorsetensis* (Wright), topotypes; *P.* spp.; *Prorsisphinctes* spp; *Cadomites* sp. and *Strigoceras truellei* (d'Orb.), (Torrens, 1969, p.308; Whicher, 1969, p.330): is the type horizon of the *truellei* subzone.

Louse Hill quarry

At this section (ST609151), which has been previously described by Buckman (1893, pp.488-9) and Richardson (1932, pp.67-70), 0.13m of intermittently conglomeratic Astarte Bed is overlain by +0.20m of brown, sandy, crinoidal limestone (= 'Chapel beds'). Richardson (1932, p.67) followed Buckman (1893, p.488) in correlating the latter bed with the *garantiana* hemera. However, there is little evidence for this correlation, and it is more likely that they are *parkinsoni* Zone, 'Chapel beds', similar to those seen in a section further east (ST617165; Whicher, 1969, pp.325-9, bed 7). Here 2.1m of undoubted *parkinsoni* Zone 'Chapel beds', with *Aulacothyris* cf. *cucullata* Buckman, overlay a 0.10m bed, which probably represents a 'condensed' equivalent of both the Astarte and Halfway House Beds (*loc. cit.*). The Astarte Bed at Louse Hill has yielded an extensive, although

Figure 3. An outline section of the Sandford Lane quarry, showing the relative distribution of the ammonite faunas and their correlation.



rather fragmentary, garantiana Zone, subgaranti subzone ammonite fauna : Strenoceras (Garantiana) platyrryma (Buckman), CP3311-2; topotypes; S. (G.) cf. wetzeli (Trauth), CP3313-4; S. (Pseudogarantiana) minima (Wetzel), CP3316; S.(P.) postrema (Wetzel, 1937, pl.10, fig.11),CP3317; S. (P.) cf. dichotoma (Bentz), CP3315; Spiroceras annulatum (Deshayes), CP3681-2 and S. cylindricum (Baugier & Sauzé), CP3680.

Sandford Lane

There are several exposures on either side of the 'Sandford Lane', Sherborne, of which the most important (ST628178), the Sandford Lane or Combe quarry (Buckman, 1893, pp.492-5; Richardson, 1932, pp.75-7) is found on the west side. A similar section (see Fig.7) is found directly opposite, on the east side, whilst a slightly less well exposed section is found further north (ST629181). The main, or Sandford Lane quarry, is one of the most important Bajocian sections in northern Europe. Apart from the importance of the sauzei/laeviuscula Zone ammonite faunas from the Sandford Lane Bed (= 'fossil-bed'; Parsons, 1974, pp.163-8), this locality is the only one to show a complete section through the Sherborne Limestone Member, as well as an important exposure in the Quarr Lane Beds of the Combe Limestone Member. The distribution of its garantiana Zone ammonite faunas is shown in Figure 3. These specimens were accurately located in relation to a datum level; a thin, marl band (Richardson, 1932, p.76, bed 2); which appears to be laterally persistent and can be traced in most sections (see Fig.7). All of these records are based on material in the author's collection, apart from the S. (P.) dichotoma, which is based on a specimen in the Buckman collection, BMNH.C80969. This was recorded as coming from the 'Building-stone', and its matrix and preservation is not

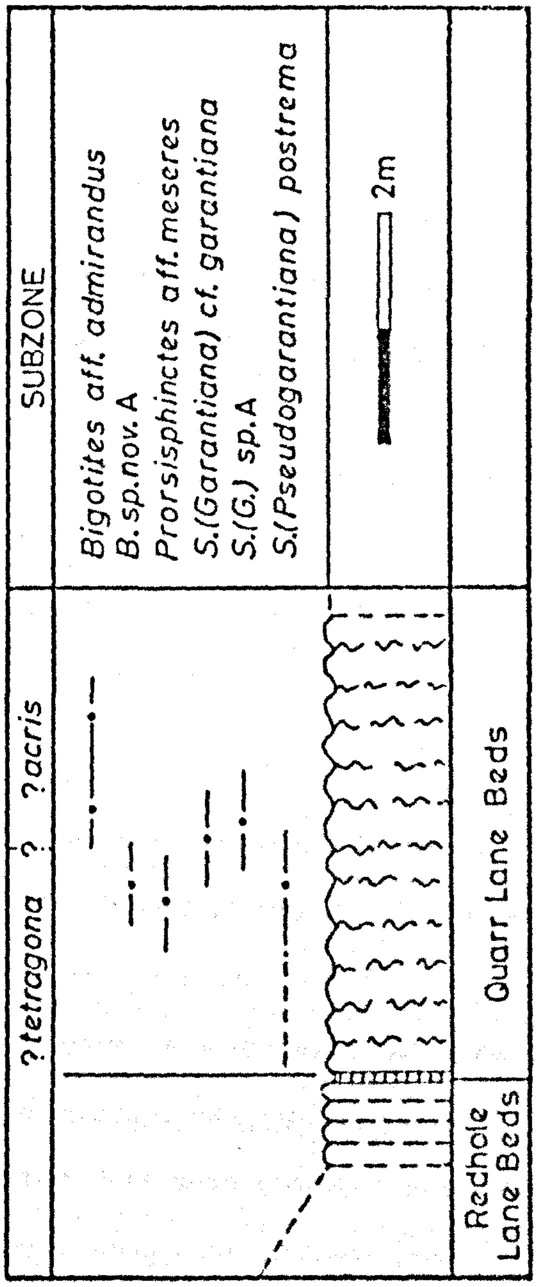



Figure 4.

An outline section of the Blackberry Lane quarry, showing the distribution of its ammonite fauna.

out of keeping with the Building-stone Beds of the Sherborne Limestone Member.

Blackberry Lane

This section (Richardson, 1932, p.74), is well exposed in a long face on the west side of Quarr and Blackberry Lanes. The present section (Fig.4), was measured at the southern end (ST635174), where the top of the Redhole Lane Beds is visible. These beds disappear at some point between here and Sandford Lane. At the latter locality they are represented by the basal part of the Quarr Lane Beds, which are slightly better bedded than the bulk of this deposit.

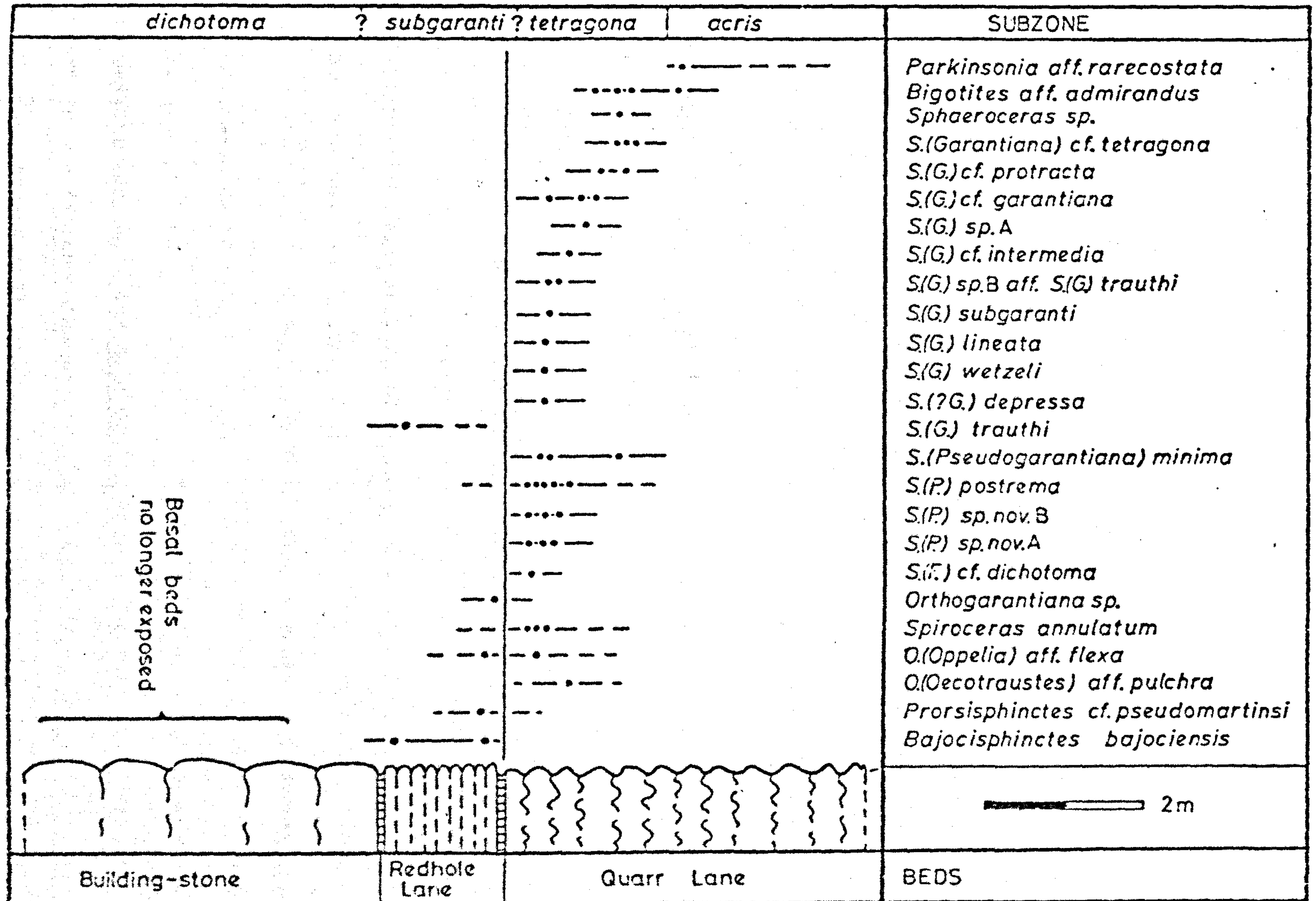
Redhole Lane

This large quarry, which is now a caravan park, has been previously described by Buckman (1893, p.496) and Richardson (1932, p.73). The lower part of the main quarry has now been filled in, so that a large part of the Building-stone Beds is obscured. The ammonites from the Quarr Lane Beds recorded in Figure 5, have mainly come from the long, low faces found to the south of the main quarry. A specimen from this quarry, cited as '*Parkinsonia praecursor*' by Buckman (1893, p.496), BMNH.C9209, is close to *S.* (*G.*) *garantiana* (Douvillé, 1916, pl.1, fig.1 *non* d'Orb). Ammonites similar to this specimen have been recorded in Figures 3-5 as *S.* (*G.*) sp. A. The specimens recorded in Figure 5 as *S.* (*G.*) sp. B are fine ribbed variants of *S.* (*G.*) *trauthi* (Bentz), [*op. cit.*, cf. pl.2, fig.8; = ? *S.* (*G.*) *trauthi* (Pavia, 1973, pl.19, fig.3 ?*non* Bentz)] .

Oborne

There are several important sections in this district, including

Figure 5. An outline section of the Redhole Lane quarry, showing the distribution and correlation of its ammonite faunas.



Frogden quarry (ST642185; Buckman, 1893, p.500; Richardson, 1932, pp.78-9; Parsons, 1976a, pp.125-7) and the Oborne Lane section and quarry (ST656186; Buckman, 1893, p.502; Richardson, 1932, p.81). The only relevant ammonite, which has come from the lower part of the Acanthothiris Beds at a temporary section at Oborne Wood (ST648188; Parsons, 1976a, pp.128-133, bed 8b), is Cadomites (C.) cf. deslongchampsi (d'Orb.), CP2812. The Teloceras sp. recorded from the basal part of the Sherborne Limestone Member at the Oborne Lane section (op. cit., p.133) has proved to be derived. This has been confirmed by a specimen of Stephanoceras (S.) sp. recently collected from the same horizon, which has a strongly 'iron-shot' matrix in its camerae.

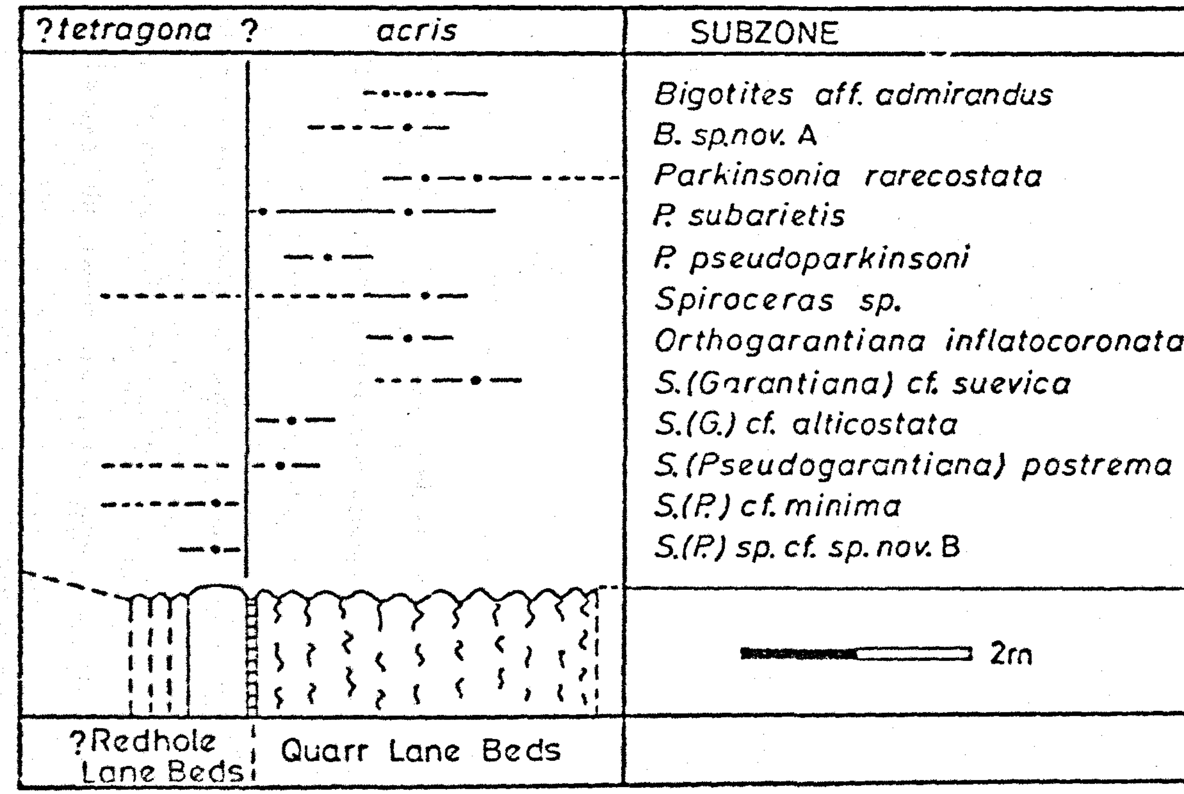
Milborne Wick

East of Oborne, the Stroud Formation is poorly exposed. The conglomeratic base of the Sherborne Limestone Member is visible at the Milborne Wick Lane section (ST663205; Buckman, 1893, pp.502-3; Richardson, 1916, pp.516-7; Osborne-White, 1923, p.13; Parsons, 1976a, pp.133-5), and a similar horizon must have been exposed nearby, at the site of the Poyntington reservoir excavations (Kellaway & Wilson, 1941, p.154). These latter beds were originally described (loc. cit.) as being a sandy limestone facies of the subfurcatum Zone. However, the specimens variously recorded as 'Strenoceras niortensis (D'Orbigny)', (loc. cit.), or 'S. bajocense (Defrance)', (Wilson et al., 1959, p.75), have been misidentified, and prove to be S. (Pseudogarantiana) cf. dichotoma, IGS.GK311 & 313. There is no evidence for the subfurcatum Zone in this immediate area.

The most important exposure in the district is at Barrow Hill (ST672210), and although briefly mentioned in previous accounts (Woodward,

Figure 6.

An outline section of the Barrow Hill quarry, showing the relative distribution of its ammonite fauna.



1894, p.80; Richardson, 1916, p.511; Osborne-White, 1923, p.16), it has never been described in detail. Here an old, shallow quarry, shows a long, rather slipped face in predominantly rubbly limestones (= Quarr Lane Beds). At the extreme western end, below an impersistent marl band, the rocks are more evenly bedded, and probably represent the top of the Redhole Lane Beds. Because much of the section has no obvious datum level, some of the ammonite records shown in Figure 6, are probably slightly less accurately localized than is the case elsewhere. A specimen in the Buckman collection, BMNH.C80967, from Barrow Hill; a complete, small macroconch, with mouth-border, akin to S. (G.) suevica (Wetzel), (cf. Quenstedt, 1886, pl.71, fig.18); probably came from a similar horizon to that of the related specimen recorded in Figure 6. The specimens of S. (Pseudogarantiana) sp. nov.B, recorded both in the latter and Figure 5, are of an undescribed, relatively large, inflated microconch species, which is found in the acris subzone, Astarte Bed of south Dorset (Parsons, 1975a, p.9). The specimens recorded here as P. subarietis are probable microconchs (cf. Wetzel, 1911, pl.14, figs.3-4, pl.15, fig.1), whilst the specimen from Sandford Lane (Fig.3), is larger and is an undoubted small macroconch (op. cit., cf. pl.14, fig.6). The specimens recorded as Bigotites sp. nov. A. in Figures 3-4 & 6, represent a problematic group, of medium sized, relatively compressed macroconchs. They have strong constrictions, well marked interdigitation and interruption of the ribs on the venter, no tubercles and only rounded, relatively weak ribs on the internal mould. Unfortunately the state of preservation in most cases is not good, but enough details are shown to suggest that these ammonites form an intermediate link between Bigotites and Parkinsonia, particularly P. rarecostata Buckman.

The only other relevant section in this area, is the old road-cutting, near the now disused Milborne Port railway station (ST675209). Although rather poorly exposed and overgrown, a similar section to that recorded by Richardson (1916, pp.510-1) can still be made out. The lower half consists of rubbly limestones, probably equivalent to the top of the Quarr Lane Beds, whilst the upper 1.5m is more evenly bedded, massive, oolitic and has yielded a specimen of Parkinsonia (P.) sp. from the top 10cm. They are thus parkinsoni Zone Goathill Beds.

Goathill

There have been several sections in this area of the Crackment Limestone Member (Torrens, 1969, pp.318 & 321), but they are not now well exposed. A section in a silage pit (ST674172), on the line of the Poyntington Fault, showed on the east side c.3m of Crackment Limestones, whilst on the west wide 2.3m of Goathill Beds were preserved (op. cit., pp.317-8). A section in the Goathill Beds, almost identical to the latter, can be seen just to the south, in the bank next to the path (ST674171). The ammonites from both these sections [Parkinsonia (P.) cf. subplanulata Wetzel (cf. Sturani, 1967, pl.8, fig.2), CP3489; P. (O.) cf. parkinsoni Buckman non Sow., HT4881; P. (Gonolkites) sp., HT4737], suggest a correlation with the parkinsoni Zone and possibly the bomfordi subzone.

Temporary sections in Sherborne

Castle View

Large areas of shallow, highly disturbed exposures in the Quarr Lane Beds were (July 1968 - Feb.1969) visible during the excavation of foundations for this housing estate (ST646172). Ammonites were abundant and included : S. (G.) platyrryma, CP2093; S. (G.) cf. inflatocoronata

(Wetzel), CP1181; S. (P.) minima (Wetzel), CP1185; S. (P.) cf. dichotoma, CP1183 (specimen with square cross-section, similar to those recorded in Figure 5); S. (?P.) pompeckji (Wetzel), CP2096; S. (P.) sp. nov. A., CP2095 (a small undescribed, fine ribbed microconch, with a round whorl cross-section, see Figures 3 & 5); Orthogarantiana inflata Bentz, CP1184; O. cf. uncinata (Qu.), CP1186; Parkinsonia cf. gracilis Wetzel (1937, pl.12, fig.4), CP2094; Prorsisphinctes pseudomartinsi (Siemiradzki), CP1179; Bigotites cf. tuberculatus (Nicolesco), CP1182; Sphaeroceras cf. globosum Buckman, BMNH.C80371; Cadomites (C.) sp., CP1180, Oppelia (O.) cf. flexa (Buckman), CP1178. This assemblage, of garantiana Zone, and probably subgaranti- tetragona subzone age, is important because of its high diversity : it contains forms not found in situ.

Newell

A relatively small section was produced (March, 1978) during the excavation of an access road and drains for a new house overlooking Newell, Sherborne (ST634170). The basal exposure in +1.20m of thin bedded limestones : with Parkinsonia (P.) depressa (Qu.), inner whorls cf. Pavia, (1973, pl.23, fig.3), CP3335, (a similar specimen, IGS.GSM62717 has come from a temporary section at Lenthay); P. (P.) cf. bomfordi, CP3488; P. (Gonolkites) sp., CP3337 and Prorsisphinctes sp., CP3336: was overlain by a massive bed 0.50m thick. These beds, which are probably on the same horizon as those exposed at Goathill (see Fig.7), are of bomfordi subzone age. Above came 2.10m of thin bedded limestones with marls, capped by 0.80m of thin limestones interbedded with clay bands. The latter undoubtedly represent a lower part of the Crackment Limestone Member. A similar section in the Goathill Beds, yielding abundant Parkinsonia, was

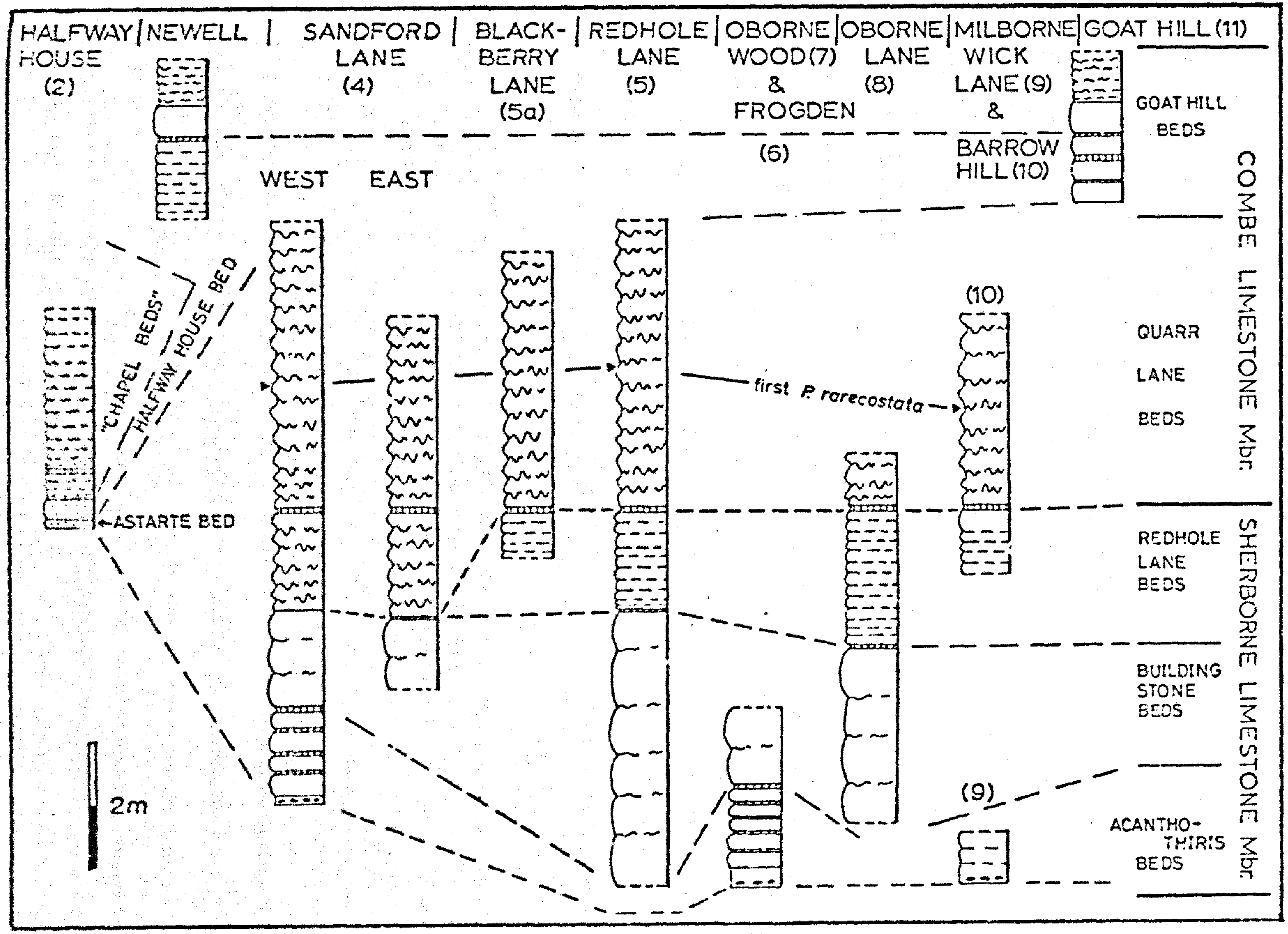



Figure 7.
A correlation of the main exposures of garantiana and parkinsoni Zone rocks in the Sherborne area.

probably seen at a temporary section at Sheeplands, Sherborne (Kellaway & Wilson, 1941, p.156).

## DISCUSSION OF AMMONITE FAUNAS

### *garantiana* Zone

### *dichotoma subzone*

The *dichotoma* subzone is based on the first appearance and acme of *S.* (*P.*) *dichotoma* (Pavia & Sturani, 1968, p.314). However, all the *in situ* specimens allied to this species have in the Sherborne area come from relatively high horizons (see Fig.5), although specimens very close to its type (Bentz, 1928, pl.19, figs.2a-b), but unfortunately less well localized, are known. These ammonites from Sandford Lane (BMNH.C80969) and Poyntington reservoir (IGS.GK311 & 313, see above), from both their matrix and location, undoubtedly come from the lower part of the Sherborne Limestone Member. The previous confusion of the latter specimens with members of *S.* (*Strenoceras*) *s. str.* (e.g. Kellaway & Wilson, 1941), only tends to confirm both their stratigraphic position at the base of the *garantiana* Zone (cf. Althoff, 1928; Kumm, 1952) and their phylogenetic position (Wetzel, 1954, fig.7), as the earliest members of *S.* (*Pseudogarantiana*), and transitional to *S.* (*Strenoceras*). It thus seems reasonable to correlate the lower part of the Sherborne Limestone Member (Acanthothiris & Building-stone Beds) with the *dichotoma* subzone, although the scarcity of ammonites prevents any precise definition of its limits.

### *subgaranti subzone*

The first abundant *garantiana* Zone ammonites occur at the base of the Quarr Lane Beds at Sandford Lane, and in their partial lateral equivalent, the Redhole Lane Beds, at Redhole Lane quarry (see Figs.3 & 5). The most significant members of this fauna, *S.* (*G.*) *subgaranti* and *S.* (*G.*) *trauthi*, belong to a group previously included in *G.* (*Subgarantiana*) Bentz 1928, (= *Hlawiceras* Buckman 1921). However, the separation of *Subgarantiana* from *Garantiana* *s.* *str.* on both morphological and stratigraphical grounds (cf. Wetzel, 1954, fig.7) appears artificial, and the two are closely associated throughout much of their vertical ranges. Separate subgeneric status for two such similar macroconchs would thus seem unnecessary.

The original definition of the *subgaranti* subzone (Pavia & Sturani, 1968, p.314) was based on the first appearance and abundant occurrence of *S.* (*G.*) *subgaranti*. The associated ammonite fauna from the Basse Alpes is less diagnostic, as it has a wider range, although subsequent additions to the typical fauna include *S.* (*G.*) *platyrryma* (Gabilly *et al.*, 1971, p.88). Unfortunately the specimens of *S.* (*G.*) *subgaranti* from the Basse Alpes (Pavia & Sturani, 1968), were later re-identified as *S.* (*G.*) *trauthi*, with a consequent change in subzonal index (Pavia, 1973). However, if the specimen of the latter taxon figured by Pavia (1973, pl.19, fig.3) is typical of the rest of his material, then there must, even now be doubts as to the correct identification of these specimens. The type of *S.* (*G.*) *trauthi* (Bentz, 1928, pl.18, fig.2), is fairly coarse ribbed, and on the evidence of topotype material from Louse Hill, it is possibly conspecific with *S.* (*G.*) *platyrryma* (Buckman, 1921). Pavia's (*loc. cit.*) specimen is finer ribbed, rather like a specimen figured by Douvillé (1916, pl.2, fig.8), and is very similar to ammonites recorded here (Fig.5), from an horizon probably to be correlated with the *tetragona* subzone. Taking into account these uncertainties in identification, the basal boundary of this subzone is best defined by the first appearance of any '*Subgarantiana*' : i.e. members of the *S.* (*G.*) *platyrryma*/*subgaranti*/*trauthi* group: rather than by that of any one individual species. *S.* (*G.*) *subgaranti* can be retained as index species, since it undoubtedly occurs at this horizon, in Dorset (Fig.3), in the upper half of the '*dichotoma*-schichten' (= *garantiana* subzone, Westermann, 1966; *subgaranti* subzone, Sturani, 1971), in north Germany (Althoff, 1928; Kumm, 1952; Wetzel, 1954) and in Spain (Hinkelbien, 1975, figs.11-12). It is difficult to establish if the first appearance of *S.* (*G.*) *subgaranti*/*trauthi* in the Sherborne area, as recorded here (Figs.3 & 5), in fact marks their absolute range. Unfortunately their appearance coincides with that of the general ammonite fauna, which may mark a switch to an ammonite rich biofacies, rather than a biostratigraphic event. A more accurate boundary between the *dichotoma* and *subgaranti* subzones, if it can be established at some future date with the aid of the rare ammonites to be found at this horizon, is likely to be in an upper part of the Building-stone Beds. However, it must be stressed that there is a possibility, based on their general morphology and some stratigraphic evidence (Hinkelbein, 1975, fig.12), that the *S.* (*G.*) *platyrryma*/*trauthi* group represent the macroconch counterpart to the microconch *S.* (*P.*) *dichotoma*. If this were to be confirmed at other exposures, it would totally destroy the basis for the separation of the *subgaranti* and *dichotoma* subzones.

*tetragona subzone*

The base of this subzone is taken here at the marl band (Richardson, 1932, p.76, bed 2), which appears to be laterally persistent, and is probably approximately isochronous over the short distances involved (see Fig.7). At Sandford Lane (Fig.3), its base is marked by the first appearance and abundant occurrence of large Perisphinctids : *Prorsisphinctes* and *Bigotites* (*B*.sp.A), which seem to be transitional to *Parkinsonia*. Although it is possible that we are again dealing with a change in biofacies, since the large Perisphinctids are noticeably absent from earlier beds, their appearance does seem to be a biostratigraphic event, which can be traced in both north Germany (= 'Bigotiten/Perisphinctes-schichten'; Althoff, 1928, etc.) and France (Gabilly *et al*. 1971). However, it should be noted that there are areas where the larger Perisphinctids are absent (e.g. east Spain, Hinkelbein, 1975) or rare (e.g. south-east France, Pavia, 1973). In the latter area (*op. cit*., tab.2-3), the limits of the *tetragona* subzone were determined by the absolute range of specimens allied to *S.* (*G.*) *tetragona* (Wetzel). This would appear to be very unreliable, as this species has been recorded in both the *acris* subzone (Althoff, 1928; Kumm, 1952, p.430), and at an horizon now to be correlated with the *dichotoma/subgaranti* subzones (Althoff, 1928, p.8). In north Dorset there are less problems in its recognition, since an influx of large Perisphinctids usually mark its base (see Fig.3), whilst specimens closely allied to the subzonal index only occur towards the top of the subzone (see Fig.5). It should be noted that many of the taxa recorded in the latter figure probably have a wide range down into the *subgaranti* subzone (e.g. *S.* (*G.*) *subgaranti* itself, as in Fig.3). The sharp cut-off at the probable *subgaranti/tetragona* subzone boundary is at least in part due to collection failure, as ammonites are much rarer in the Redhole Lane Beds.

*acris subzone*

The base of the *acris* subzone has been defined by the first appearance of *Parkinsonia s. lat.* (Kumm, 1952, p.430; Pavia & Sturani, 1968, p.314), and this is relatively clear cut in most Dorset sections (see Figs.3, 5-6). One area of uncertainty has come to light in the study of the Barrow Hill section (Fig.6). It is evident that many of the microconch *Bigotites* are very similar to *Parkinsonia*, and have stronger, sharper ribbing, with less well marked constrictions (cf. Pavia, 1973, pl.29, fig.3), than their macroconch partners. Taking into account that macroconch *Bigotites* have been found ('*B*.sp.A'), which are transitional to *P.* (*Parkinsonia*), it is logical to expect their microconch partners, to be even closer to, and virtually indistinguishable from, *Parkinsonia* s. lat. Such indeed, does appear to be the case. The specimens of *P.* (*Okribites*) *subarietis* Wetzel and *P.* (*O.*) *pseudoparkinsoni* Wetzel recorded in Figure 6, are microconchs which appear some distance below the first macroconch *Parkinsonia s. str.*, *P.* (*P.*) *rarecostata*. It is possible that these are the microconch partners of macroconchs which would be best assigned to *Bigotites*, rather than *Parkinsonia* (*P.*). If it should be confirmed from other sections, that the microconch *P.* (*Okribites*) makes its appearance before the macroconch *P.* (*Parkinsonia*), then in order to prevent any possible confusion with the earlier *Bigotites* microconchs, the base of the *acris* subzone should be redrawn below the first macroconch *Parkinsonia* s. str. Only in the case of Figure 6 would any future change be required. Here the boundary would have to be moved up to below the first *P.* (*P.*) *rarecostata*. Unfortunately the upper limits of this subzone cannot be discussed, as no fossiliferous exposures of an unbroken contact with the *truellei* subzone have been observed.

*parkinsoni* Zone

*truellei* subzone

This subzone, which is defined by the first appearance of the macroconch, P. (Parkinsonia) parkinsoni (J.Sow.), [? = P. (P.) dorsetensis (Wright)], is well represented by the condensed Halfway House Bed. However, I have not been able to recognize it in the more expanded facies of the Sherborne district, nor establish its contact with the underlying garantiana Zone. This boundary must fall within the upper part of the Quarr Lane Beds, where the previous records of 'P. dorsetensis and Strigoceras truellei' (Buckman, 1893, p.496), suggest that the truellei subzone fauna can only be a short distance above the last in situ elements of the acris subzone. Unfortunately this horizon is only exposed towards the top of the precipitous faces at Sandford Lane and Redhole Lane quarries, from which it has proved impossible to collect any in situ specimens. Future work, possibly with the aid of extending ladders, may solve this problem.

There is a level at the top of the acris subzone, where the last S. (Garantiana) and S. (Pseudogarantiana) have died out, and only Parkinsonia are common (e.g. P. rarecostata, P. subarietis). This horizon, (? = "horizon à Parkinsonia orbignyana Wetz."; Contini, 1970, p.154; Gabilly et al., 1971, p.88), is poorly defined, and must be included in the top of the garantiana Zone, since it falls below the base of the truellei subzone, here defined as the lowest unit of the parkinsoni Zone.

bomfordi subzone

The two exposures in the Sherborne area yielding Parkinsonid ammonites, described here, are stratigraphically isolated, and their contact with adjacent faunas cannot as yet be established. These faunas, with inflated macroconch Parkinsonids (e.g. P. (P.) bomfordi, P. (Gonolkites) spp.), are very similar to those from the middle of the Burton Limestone in south

Dorset (Parsons, 1975a), and are thus of bomfordi subzone age. The topmost fauna of the latter, characterised by Planisphinctes (Sturani, 1967, pl.1), which has been found 10-20cm below the zigzag Bed in south Dorset (Stony Head & Burton Bradstock, pers. obs.), has not been observed in north Dorset. However, it is possibly the same age as the 'Oecotraustes nodifer Fauna' (Torrens, 1974, p.584), recorded from the Crackment Limestone Member at Bradford Abbas (Arkell, 1951-9, p.10), and now correlated with the top of the parkinsoni Zone.

Similarly little can be deduced as to the nature of the contact between the bomfordi and truellei subzones in the Sherborne area, although the record of P. (Okribites) parkinsoni (Buck. non Sow.), from the base of the Crackment Limestone at Bradford Abbas railway cutting (see above) is perhaps significant. This 'species' is characteristic of the lower part of the bomfordi subzone in south Dorset (pers. obs.) and in the mid and north Cotswolds (Parsons, 1976b, p.55). There is thus some evidence for the recognition of a 'parkinsoni subzone' (see above), although it would need confirmation from more detailed work on an ammonite rich sequence, such as the Burton Limestone of south Dorset.

## CORRELATION WITH OTHER AREAS

Because of the discontinuous nature of the Sherborne exposures in the parkinsoni Zone, only the garantiana Zone will be dealt with here in any detail.

### Southern England

Upper Bajocian rocks are found between the south coast at Burton Bradstock, and Hook Norton in Oxfordshire. North of this point, with the exception of the poor ?*garantiana*/?*subfurcatum* Zone fauna from the Inner Hebrides (Morton, 1971; Parsons, 1975b, p.192), no upper Bajocian ammonites have been recovered.

The present study has done little to improve the correlation of the *parkinsoni* Zone beds; such as the Cotswold Clypeus-grit Member (Parsons, 1976b, p.55), the Dundry Freestone and 'Coralline beds' of Dundry Hill, Bristol (Parsons, 1979b, p.149), the Doulting beds of the Mendips (Parsons, 1975b, pp.203-4) and the Burton Limestone of south Dorset (Parsons, 1975a, p.12) and south-west Somerset (Parsons & Torrens in Cope *et al*., 1969, p.A26); which are broadly equivalent of the lower part of the Crackment Limestone, the Goat Hill Beds and an upper part of the Quarr Lane Beds. On the other hand, the finer subdivisions of the *garantiana* Zone, which have been recognized here, have confirmed the wide extent of the stratigraphic hiatus, which is present over much of southern England (Parsons, 1976b, p.48). Thus the Cotswold Upper-Trigonia-grit Member (Parsons, 1976b, pp.52-5), the Dundry Maes Knoll Conglomerate (Parsons, 1979b, p.149) and the Astarte Bed of south Dorset (Senior *et al*., 1970) and south-west Somerset (Seavington St. Mary; Parsons & Torrens, in Cope *et al*., 1969, p.A26), have all yielded a combination of *S.* (*Garantiana*) and *Parkinsonia*, mainly *P. rarecostata*. They are thus *garantiana* Zone, *acris* subzone in age, as with much of the Quarr Lane Beds of the Combe Limestone Member. A similar age is indicated for the 'Hadspen Stone' (Richardson, 1916, p.486) of Somerset, a relatively thick deposit of ferruginous, intraclastic limestone. Here at the Horsecombe Bottom (ST656315) and Limekiln quarries (ST655314), (Richardson, 1916, pp.504-6) an *acris* subzone fauna : of *Parkinsonia pseudoparkinsoni*, CP1128; *S.* (*Garantiana*) aff. *garantiana*, CP3266; S. (Pseudogarantiana) minima, CP3281 and Prorsisphinctes sp., CP3308: has been found, thus confirming Richardson's (op. cit., pp.505, 508-9), records of Parkinsonia of the P. rarecostata group. It is thus evident that the major Upper Bajocian unconformity, present across much of southern England (= 'Vesulian Transgression'), is both isochronous and of immediately pre-acris subzone age. Similarly, only a small area around Sherborne now preserves any beds of early garantiana Zone age at the surface, since elsewhere they are absent, due to subsequent erosion and/or non-deposition. There are however, indications that more extensive and complete garantiana Zone sequences are preserved at the subsurface elsewhere in Dorset.

Europe

It is only recently that there has been a revival of interest in the detailed stratigraphy of the Upper Bajocian (Pavia & Sturani, 1968; Pavia, 1973). Unfortunately in the latter works, there was a great reliance on the earlier german studies (Bentz, 1928; Westermann, 1967), since the sequence between the subfurcatum Zone and the bomfordi subzone in the Basse Alpes has a rather sparse and often poorly preserved ammonite fauna. The pre-war work on the north German garantiana beds, summarized in Kumm (1952) and Westermann (1967), suffered from relatively poor localization of material, which was increasingly split into an excessive number of 'species' (Bentz, 1928; Wetzel, 1954). These faunas are in urgent need of a modern revision, and as consequence the long species lists (Althoff, 1928; Kumm, 1952) are very difficult to interpret. Taking this into account, together with the fact that the faunas of the subgaranti and tetragona subzones are rarely separated, it is not surprising that only a two-fold subdivision of the garantiana Zone has been commonly attempted. These divisions, which have rested on the first appearance of Parkinsonia (= acris subzone), underlain by a fauna dominated by Pseudogarantiana (= dichotoma, subgaranti & ? tetragona subzones), have been widely recognized throughout Europe, and indeed were accepted by the present author (Parsons, 1975b, 1976b, 1979b), prior to this study. Areas where these subdivisions can, or have been recognized include; Württemberg, south Germany (Dietl, Flaig & Gluck, 1978), north-east of the Massife Central (Mouterde, 1953) and the Jura, France (Contini, 1970), north-east Spain (Westermann, 1955), south-east Spain (Hinkelbein, 1975) and northern Italy (Sturani, 1964, 1971).

## STRATIGRAPHIC CONCLUSIONS

1. Following both original definitions and subsequent British usage, the garantiana/parkinsoni zonal boundary is here drawn below the truellei subzone. The acris subzone must thus be included in the garantiana Zone.

2. All the currently accepted subzones of the garantiana Zone (dichotoma, subgaranti, tetragona & acris), have been recognized in its type area, the Sherborne district.

3. As it provides the only complete section through the garantiana Zone beds in the district, Sandford Lane quarry (ST629181), is here designated as the type locality for this Zone (see Figure 3).

4. Only two of the subzones of the garantiana Zone, the acris and dichotoma subzones, are both relatively well defined and widely recognized in other areas of Europe. It is possible that the subgaranti (= trauthi

subzone, Pavia, 1973) and tetragona subzones, will not survive any future, detailed revision based on complete, ammonite rich sections.

5. Although a continuous sequence through the parkinsoni Zone is probably present in the Combe Limestone Member of the Sherborne area, only the bomfordi subzone has been recognized in this work.

6. It is possible that an additional subzone (= the 'parkinsoni' subzone) can be recognized between the truellei and bomfordi subzones, but this must be confirmed by future, more detailed work, probably in the south Dorset area.

7. The "Upper Bajocian Unconformity" (= site of "Vesulian transgression") is demonstrably isochronous (pre-acris subzone age), and only in the Sherborne district are any rocks of early garantiana Zone age preserved at the surface.

8. The area containing the rocks of dichotoma-tetragona subzone age is small and very sharply defined. The lateral changes in thickness and facies are very abrupt (see Figure 7), and some penecontemporaneous structural control must be postulated (? = fault bounded 'graben').

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## 2. A STRATIGRAPHIC REVISION OF THE BAJOCIAN ROCKS OF CERTAIN AREAS OF ENGLAND

Much of the detailed stratigraphy of the most important area of Bajocian rocks in England ; the Sherborne district; has already been discussed in section 1. Here I am restricting myself largely to the application of the revised zonal scheme, to three specific areas. First there is Dundry Hill, near Bristol, which with its abundant Lower Bajocian ammonite faunas, figured prominently in the works of d'Orbigny, Oppel and Buckman. Secondly the stratigraphy of the Middle and Upper Inferior Oolite of the Cotswold Hills is discussed, since this region was both a key area in the development of Middle Jurassic palaeontology, and was an important factor in the development of Buckman's polyhemeral concept. Lastly the Scarborough Formation of north-east Yorkshire, with its poorly known ammonite faunas, is discussed and revised.

# 2A. A STRATIGRAPHIC REVISION OF THE INFERIOR OOLITE OF DUNDRY HILL BRISTOL

CONTENTS

ABSTRACT: The Lithostratigraphy of the Inferior Oolite Group (Aalenian and Bajocian, Middle Jurassic) of Dundry Hill, Bristol, Avon, is revised and several new lithostratigraphic units are erected: the Barns Batch, Grove Farm and Elton Farm Limestones. The depositional environment and present pattern of preservation of these beds are discussed and four exposures are described in detail. An analysis of the Aalenian-Bajocian ammonite faunas is made and they are correlated with their equivalents elsewhere in southern England, particularly those recently collected from the Bruton district of Somerset. Finally the type horizons of the Sowerbys' and Buckman's ammonite species are discussed, and the majority assigned to their correct stratigraphic position.

## 1. INTRODUCTION

The Inferior Oolite (Aalenian-Bajocian stages) of Dundry Hill, near Bristol, Avon, is one of the World's most famous fossiliferous deposits. The quarries on this hill, which were opened during the exploitation of the famous Dundry Freestone ("Upper Inferior Oolite"), often showed sections in the highly fossiliferous and 'condensed' "Lower and Middle Inferior Oolite" (Aalenian-Lower Bajocian). It was the abundant ammonites from these horizons, which attracted the attention of the early palaeontologists and stratigraphers, such as d'Orbigny (1842-51), Oppel (1856-8), the Sowerbys (1812-46) and Wright (1860). Other sections of the fauna, such as the brachiopods, gastropods and bivalves are equally prolific and they figured in the early work of numerous palaeontologists, such as S.S. Buckman, Moore, Stoddart, Tawney and S. Woodward. However,

| STAGE | ZONE | SUBZONE |
|---|---|---|
| UPPER BAJOCIAN | Parkinsoni | Bomfordi |
| | | Truellei |
| | Garantiana | Acris |
| | | Dichotoma |
| | Subfurcatum | Baculata |
| | | Polygyralis |
| | | Banksi |
| LOWER BAJOCIAN | Humphriesianum | Blagdeni |
| | | Humphriesianum |
| | | Romani |
| | Sauzei | |
| | Laeviuscula | Laeviuscula |
| | | Ovalis |
| | Discites | |
| AALENIAN | Concavum | |
| | Murchisonae | Bradfordensis |
| | | Murchisonae |
| | | Haugi |
| | Opalinum | Scissum |
| | | Opalinum |

Table 1.

The standard Zones and Subzones of the Aalenian and Bajocian Stages.

as early as the 1890's these famous exposures were becoming obscured, as the quarries closed down, owing to the depletion of the Freestone. Our knowledge of the stratigraphy of these beds has thus rested on the classic work of S.S. Buckman and E. Wilson (1896 and 1897), who re-opened many already disused quarries and carefully described those still in work. Whilst Buckman was later to figure numerous Dundry ammonites as new species and genera in 'Type Ammonites' (Buckman, 1909-30), all subsequent accounts of the stratigraphy have rested on the earlier work. Thus the South Main-road quarry, perhaps the most famous Dundry section has been re-described several times by Tutcher (1903, and in Reynolds *et al.*, 1930) and Macfadyen (1970), but these accounts have only been slight modifications of Buckman and Wilson's work.

The sections now available for study on Dundry have deteriorated even more since Buckman's day. However, there are strong reasons for giving a modern description of these rocks. The ammonite faunas from the Dundry *laeviuscula* and *sauzei* Zones (see Table 1) are unparalleled in Europe for their abundance and diversity: they are thus of extreme importance in elucidating both, the stratigraphy of this period and the phylogeny and systematics of the ammonites, particularly the Stephanoceratidae. Whilst Buckman (1909-30) figured a number of ammonites from Dundry, often little is known of their stratigraphic range. The following account is thus primarily an attempt to revise the litho- and biostratigraphy of the Dundry Inferior Oolite and to determine the correct stratigraphic position of as many as possible of the previously recorded ammonites.

NOTE: In the following, specimen numbers preceded by, BUGM. refer to ammonites in the collections of the Department of Geology, University of

Bristol; by J. to the Oxford University Museum and by CP to the author's collection. In the faunal lists the citing of a single specimen number refers to the specimen, upon which the identification is based, and is no indication of the number of individuals collected.

## 2. THE PRESERVATION, DEPOSITIONAL ENVIRONMENT AND LITHOSTRATIGRAPHY OF THE DUNDRY INFERIOR OOLITE

### (a) Preservation and depositional environment

In terms of depositional environment and existing pattern of preservation, the Inferior Oolite on Dundry Hill falls into two divisions (Cleak, 1930). Firstly there is the Stroud Formation (="Upper Inferior Oolite"), a series of bioclastic and oolitic limestones of variable thickness, which are present over all the hill. Secondly there is the "Lower and Middle Inferior Oolite", a series of thin, 'condensed', more or less 'iron-shot' limestones, which are found only on the western half of the hill. In general facies and lithology, the Stroud Formation is very similar to its equivalents in the Cotswolds, whilst the "Lower and Middle Inferior Oolite" have no similarity to their Cotswold equivalents, but rather to the north Dorset deposits of the same age. These differences are not due to any physical barrier separating the Dundry and Cotswold areas during the Aalenian-Bajocian, as suggested by Buckman (1889, 1901), but of course to original variations in depositional environment. The Lower Bajocian rocks of Dundry show the closest similarity in facies to Dorset, with the prevalence of limonite ooliths, 'snuff-boxes' (complex laminated limonite concretions, _q.v._ Gatrall _et_ al., 1972), limonite-incrustation, thick shelled bivalves and abundant ammonites. These characters all point to a very slow rate of deposition, dominated by ferruginous, authigenic minerals, in a shallow sea. This area of shallow water was probably caused by the presence of a broad shelf, or similar palaeo-topographic feature, to the west of the Cotswold basin, which acted as a 'clastic trap'. The Stroud Formation on the other hand also shows signs of a relatively strong current regime, which however, was insufficient to remove the fragmented by-products of a high rate of primary carbonate production.

Separating these two very different facies is a prominent 'hard-ground'; a very flat, bored, sparsely oyster-encrusted surface. Resting on this 'hard-ground' is usually a conglomerate, consisting of limonite coated lithoclasts, derived from subjacent beds. Taking this evidence of erosion into account, Buckman's explanation of the varied preservation of the Aalenian-Lower Bajocian rocks is probably the right one (Buckman & Wilson, 1896, p.695). He attributed it, as in the Cotswolds, to minor flexuring of the rocks, prior to the onset of the Upper Bajocian transgression. Thus a small "down-warp" in the region of the main Bristol road resulted in the local preservation of the Elton Farm Limestone, whilst to the west erosion cut down to the ovalis bed and to the east as far as the Upper Lias (Arkell, 1933, fig.34). Although this is the best overall explanation of the present patterns of preservation, there is some evidence of an original primary control of deposition. Thus the upper part of the Elton Farm Limestone (Brown Iron-shot and Witchellia beds) shows signs of a change in lithology, (sparser ooliths, fewer fossils), as it thickens from the South Main-road quarry, towards

| | | |
|---|---|---|
| INFERIOR OOLITE GROUP | Stroud Formation or "Upper I.O." | Coralline beds (6.0m+)<br>Dundry Freestone Member (0 - 6.0m)<br>Maes Knoll Conglomerate Member (0 - 0.68m) |
| | "Middle I.O." | GAP |
| | | Elton Farm Limestone Member (0 - 1.9m)<br>Grove Farm Limestone Member (0 - 1.0m) |
| | "Lower Inferior Oolite" | SLIGHT GAP |
| | | Barns Batch Limestone Member (0 - +3.0m) |

Table 2.

The lithostratigraphic subdivisions of the Inferior Oolite Group recognised on Dundry Hill.

Rackledown. The possibility must remain that these isolated beds originally filled a shallow negative area on the sea-floor. This in no way contradicts Buckman's original concept of an overall secondary control in preservation, although this "penecontemporaneous erosion" may have in part accentuated some pre-existing minor differences in bed thickness.

(b) A revision of the Lithostratigraphy

The existing informal lithostratigraphic terms for the Dundry Inferior Oolite, introduced haphazardly by Buckman and Wilson are highly ambiguous. This is particularly true of the individual beds in the Elton Farm Limestone. Thus the term 'White Iron-shot', which was used by Buckman for two horizons, is here shown to include three. The division between Buckman's so called 'Iron-shot' and the 'Upper White Iron-shot' must be arbitrary as the boundary between them is usually of a gradational nature; no division between these two should be attempted solely on the basis of lithology. However, this does not totally preclude the use of matrix in determining the position of unlocalised specimens, as the topmost, dark, purple stained, part of the Brown Iron-shot bed is totally characteristic, and restricted to this horizon. It is thus suggested that, in order to reduce confusion, the following named units should be used. These have been based on the degree of lithological similarity between components, and the boundaries taken at sharp lithological changes and unconformities - see Table 2.

In accordance with the recommendations of the Geological Society of London (Harland _et al._, 1972), the Dundry Inferior Oolite should be divided into a series of formal hierarchical units. In terms of its overall lithology,present pattern of preservation and relationship with nearby equivalent beds,the Dundry Inferior Oolite can be divided into three sections, which could be accorded the rank of Formations. However, the area of outcrop, particularly of the "Lower and Middle Inferior Oolite" is so small, that it is thought inadvisable to erect new formational names for these beds. The "Upper Inferior Oolite" is merely an extension of the equivalent Cotswold beds,hence there is no problem in including it in the Stroud Formation of the Inferior Oolite Group (Parsons,1980).The lower beds are more problematic, as there are no pronounced changes in lithology, and they would probably be best placed in a single new Formation (cf.'Oborne beds',Parsons,1980,p.222 here). This is not the place for the erection of such a new unit, thus as an interim measure these beds are included in the existing informal subdivisions - see Table 2. The Inferior Oolite has been divided into six Members, which are described below, starting from the base.

(i) The Barns Batch Limestone Member

The lowest Inferior Oolite now exposed on Dundry Hill is to be seen at Barns Batch Spinney. These beds form a series of hard oolitic limestones,whose massive nature enables them to be easily traced around the hill.The upper surface of this unit,the Barns Batch Limestone,is marked by a prominent 'hard-ground',which is very flat,limonite-encrusted, bored by '<u>Lithophaga</u>' and surmounted by a conglomerate.These beds at Barns Batch Spinney, the type locality , are +1.65m thick (beds 1 - 3, section 3c) and span the <u>murchisonae</u> / <u>haugi</u>

Subzones of the *murchisonae* Zone - see Table 1 for zonal scheme used here. It is impossible to exactly define the lower limits of these beds, as no exposure is now available showing *opalinum* Zone rocks, (Buckman & Wilson, 1896, p.677). Since there is an unconformity at the base of these *opalinum* Zone rocks at Castle Farm (*loc. cit.*), where they rest on blue, argillaceous *aalensis* Subzone rocks (*loc. cit.*); bed 24 at that section may be taken as defining the base of the Barns Batch Member, which are there 2.40m. thick (*loc. cit.*). At Rackledown Farm, these beds are slightly thicker, as they must be in excess of 3.0m. thick (*op. cit.*, p.692).

The upper bed of this unit is one of the most distinctive of those on the hill, and it may be informally separated as the *Pleurotomaria* bed (bed 3a, section 3c) in recognition of the large numbers of this group of gastropods recorded from it, (Buckman & Wilson, 1896, Table Va).

(ii) The Grove Farm Limestone Member

The beds called by Buckman the 'Nodular beds', (Buckman, 1892, in 1887-1907, p.293) or the 'limestone and marl' beds, (Buckman, 1901, p.154) are here named the Grove Farm Limestones, after the exposures in the region of Grove Farm, West Dundry. These beds consist of nodular, slightly 'iron-shot' limestones, interbedded with soft marls. They are best seen at Barns Batch Spinney, which may be taken as the type locality, where they are 0.9m. thick, (beds 4-6, section 3c), and span the *concavum* Zone and the basal part of the *discites* Zone. The basal beds of this unit (e.g. Barns Batch, bed 4), which are rich in *Sphaeroidothyis*, may be informally separated as the *eudesi* beds, (Buckman & Wilson, 1896, p.672).

TABLE 3 Development of the informal lithostratigraphic subdivisions of the Dundry Iron-shot beds.

<table>
<tr><th>BUCKMAN 1892</th><th>BUCKMAN 1893</th><th>BUCKMAN & WILSON 1896</th><th>BUCKMAN 1901</th><th>TUTCHER 1903</th><th>TUTCHER 1929</th><th>TUTCHER 1930</th><th colspan="2">SCHEME USED HERE</th></tr>
<tr><td>IRON-SHOT BED</td><td>IRON-SHOT BED</td><td>THE IRON-SHOT</td><td>THE IRON-SHOT</td><td>THE FOSSIL BED</td><td>THE DUNDRY IRON-SHOT</td><td>BROWN IRON-SHOT</td><td>BROWN IRON-SHOT BED</td><td rowspan="5">ELTON FARM LIMESTONE</td></tr>
<tr><td></td><td rowspan="4">WHITE IRON-SHOT BED</td><td>UPPER WHITE IRON-SHOT = Witchellia bed</td><td rowspan="2">UPPER WHITE IRON-SHOT</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">UPPER WHITE IRON-SHOT</td><td>Witchellia BED</td></tr>
<tr><td></td><td></td><td>LIMONITIC BED</td></tr>
<tr><td>WHITE BED BELOW THE IRON-SHOT</td><td>LOWER WHITE IRON-SHOT</td><td>LOWER WHITE IRON-SHOT</td><td></td><td></td><td>LOWER WHITE IRON-SHOT</td><td>ovalis BED</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>BIVALVE BED</td></tr>
</table>

(iii) The Elton Farm Limestone Member

The beds called by Buckman the 'Iron-shot', (Buckman, 1892 in 1887-1907, p.282) and 'White Iron-shot', (Buckman, 1893, p.508), which was subsequently separated as 'Upper and Lower White Iron-shots', (Buckman & Wilson, 1896, pp.678 & 682), are too thin and poorly defined to warrant formal status as litho-stratigraphic units. The terms 'Iron-shot' and 'Lower and Upper White Iron-shot' were introduced by Buckman for the purpose of recording the ammonite fauna; there is little lithological basis for these divisions. Thus, for example, there is usually a gradational boundary between the 'Iron-shot' and the 'Upper White Iron-shot' at both South Main-road quarry and Rackledown, making it impossible to delimit a formal boundary between these two. There has been considerable confusion over the interpretation of the term 'White Iron-shot'. Buckman first introduced the term 'White bed below the Iron-shot' (Buckman, 1892, in 1887-1907, p.293; Wilson, 1893) for the horizon which he afterwards called the 'Lower White Iron-shot', (Buckman & Wilson, 1896, p.681, bed 9). Buckman later (1893, p.508) introduced the term 'White Iron-shot' for beds equivalent to all those below the 'Brown Iron-shot' and above the 'Limestone/marl beds'. The restricted term 'Lower White Iron-shot' was subsequently solely used for the <u>fissilobatum</u>/<u>ovalis</u> horizon, (Buckman & Wilson, 1896, pp.678 and 676, beds 4-8), whilst the 'Upper White Iron-shot' was restricted to the '<u>Witchellia</u> bed' (<u>op. cit.</u> p.681, bed 6). Unfortunately this refined usage overlooked the middle bed of the original 'White Iron-shot' (<u>loc. cit.</u>, bed 8), which in patches is as densely 'iron-shot' as the true Brown Iron-shot <u>sensu stricto</u>. The time has thus come for some attempt to be made to simplify this muddled litho-stratigraphy, which is summarised in Table 3.

Since there are no grounds for giving formal names to all the thin, highly fossiliferous beds of the 'Middle Inferior Oolite', these may all be grouped together within one formal unit, the Elton Farm Limestone. This is named after the famous exposures in these beds found close to Elton Farm at the South Main-road quarry. The latter quarry may be taken as the type locality of this unit and beds 7-10 (section 3a herein) as the type horizon, which is some 1.7m. + thick. These beds are of discites-sauzei Zones in age. For the smaller sub-divisions of this formal unit the following informal bed names may be used, the ovalis bed (Parsons, 1977, p.101) instead of 'Lower White Iron-shot' (= fissilobatum/ovalis horizon, Buckman & Wilson, 1896, p.681) as for bed 8 at Barns Batch spinney, the Limonitic bed (= bed 9, South Main-road), the Witchellia bed solely for the one bed with the soft, white, pasty matrix (= 'Upper White Iron-shot' sensu Buckman & Wilson, 1896), that is bed 10a South Main-road quarry, since this is closest to Buckman's original usage (Buckman, 1893), and the Brown Iron-shot bed for 10b, South Main-road, and its equivalents.

(iv) The Maes Knoll Conglomerate Member

At the base of the "Upper Inferior Oolite" on Dundry, there is an extensive 'hard-ground', marked by a prominent flat, bored and oyster-encrusted surface. Directly above this 'hard-ground' at various localities there is usually a conglomerate consisting of limonite- and serpulid-encrusted lithoclasts, set in an 'iron-shot' limestone matrix. This conglomerate was first described by Buckman and Wilson, (1896, p.686 & Table IV) and this formal lithological name follows their usage and Buckman's subsequent use of the term 'the conglomerate bed' (Buckman, 1901, p.154), which was later amended to the 'Maes Knoll Conglomerate-bed' (Richardson, 1907, p.420). The type locality of this unit can be taken as Maes Knoll, where according to Buckman and Wilson (1896, p.684) the total thickness of 'iron-shot' limestone present is 0.68m. Only the basal part of these beds at this locality is a true conglomerate, but all the 'iron-shot' limestones below the Dundry Freestone may be included in this formal unit. The ammonites found in these beds would indicate that they are acris Subzone, garantiana Zone in age.

(v) The Dundry Freestone Member

The presence of this limestone on Dundry Hill was the reason for the extensive quarrying activities which have been carried out since the Roman period. The term Dundry Freestone has been suggested as a formal name (Worssam in Donovan & Hemingway, 1963, p.120) and Dundry Hill designated its type locality (loc. cit.). This unit consists of a series of massively bedded freestones at their thickest at the west end of the Hill. One of the few existing sections of this unit on Dundry Down (ST 552666), which shows 4.6m of massive bioclastic limestone, overlain by 1.3m of more thinly bedded limestone, can be taken as its type locality. No exposure now shows a complete section through these beds, it is thus difficult to determine their exact stratigraphic position, although available ammonite evidence would point to a basal parkinsoni Zone age.

(vi) The Coralline beds

These beds were so called by Buckman and Wilson (1896, pp.672 &

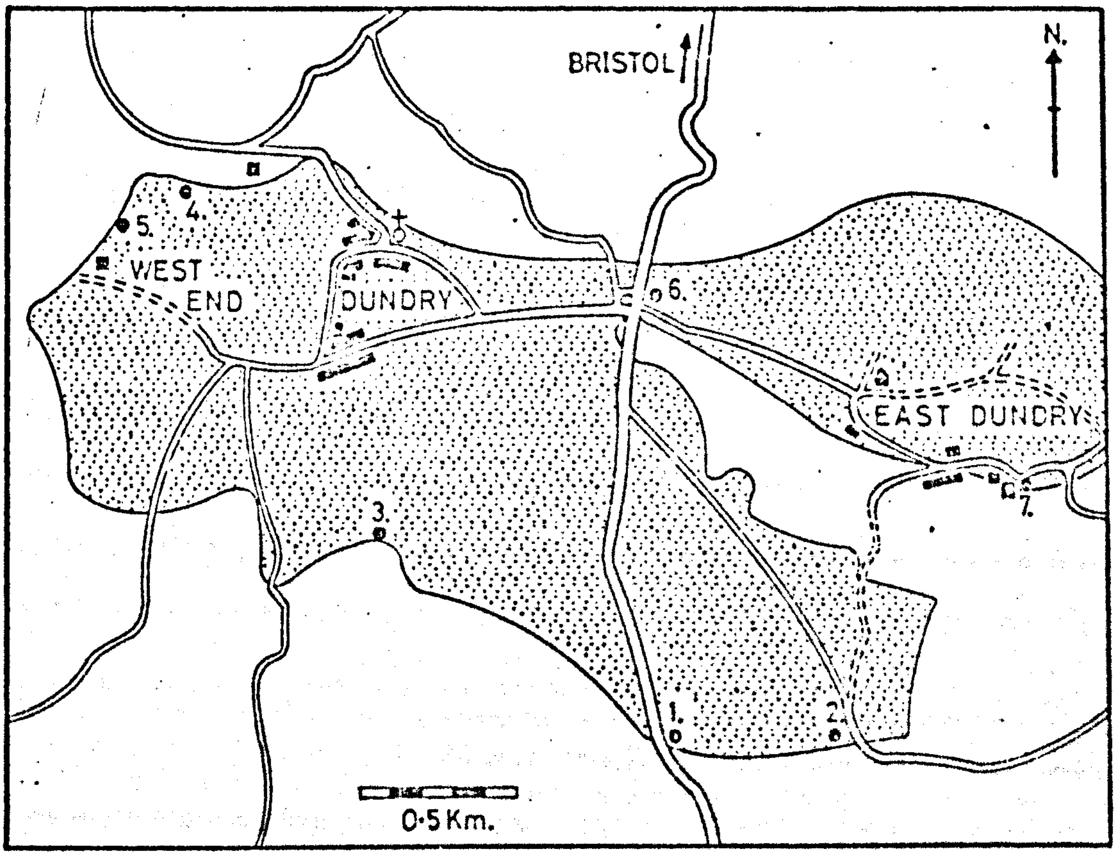


Figure 1.

A sketch map of Dundry Hill, showing the main localities cited in the text. 1 – South Main-road quarry, 2 – Rackledown quarry, 3 – Barns Batch Spinney, 4 – Grove Farm, 5 – Castle Farm, 6 – North Main-road quarry, 7 – Walnut Farm quarry.

679 et seq.) on account of the numerous coral fragments present. Since no complete exposures can be seen of this unit, the total thickness is unknown but it must be in excess of 6.0m. (Donovan, 1958, p.132); no formal type locality is thus designated here, since more information is needed on the lateral and vertical extent of these beds.

## 3. DESCRIPTION OF SECTIONS

Since the main aim of this work was to carry out a stratigraphic revision of the Inferior Oolite of Dundry Hill, only those sections which have yielded ammonites at all abundantly will be described here. This naturally precludes the sections in the Dundry Freestone and Coralline Beds, since these two have produced little or no ammonite evidence as to their age. The following sections are thus all those now showing exposures in the richly fossiliferous "Middle and Lower Inferior Oolite", Aalenian and Lower Bajocian Stages, that is: the 'West End' (Castle Farm-Grove Farm), Barns Batch Spinney, South Main-road and Rackledown quarries, - see Text fig.1. for their location. Although all these exposures were described by Buckman and Wilson, (1896 & 1897), the last 80 years of research on the ammonite faunas has revealed a need for their revision. In these redescribed sections, all the beds have been renumbered using a single set of numbers based on a hypothetical complete sequence (see Text fig.3), but where applicable Buckman and Wilson's numbers follow the new ones in brackets.

### (a) The South Main-road Quarry

This section (ST567655), which according to Buckman and Wilson, (1896, p.691) was very similar to the famous North Main-road quarry, has in recent years been largely obscured. During the period 1955-58, the Bristol Naturalist Society cleared a section down to the murchisonae Zone limestones. Unfortunately the uncontrolled action of fossil collectors soon filled the quarry in again, until little but the Upper Inferior Oolite was visible. Thanks to the recent work (Sept. 1979) of the Nature Conservancy Council the quarry has again been re-excavated:

The Coralline Beds

13. (1)

A series of white, bioclastic limestones, much of which are cambered and slipped material, mixed with clay and rubble.

seen to 1.5m.

The Dundry Freestone

12. (2)

A compact, well bedded limestone, oolitic and slightly 'iron-shot', especially towards the base. The probable lateral equivalent of the thicker Dundry Freestone to the west.

0.48 - 1.0m.

brown marl, resting on flat surface

The Maes Knoll Conglomerate

11. (3)

An ironstained conglomerate, consisting of limonite- and serpulid-encrusted pebbles, set in a slightly 'iron-shot' limestone matrix. The erosion plane, on which this bed rests, is limonite stained, bored and sparsely oyster-encrusted.

Prorsisphinctes sp., CP3787 0.20 - 0.36m.

The Elton Farm Limestone

very flat surface

10b. (4) The Brown Iron-shot bed

A densely 'iron-shot' limestone, with shiny, brown limonite ooliths set in a purple tinged matrix. This, the 'Iron-shot' of Buckman, (Buckman & Wilson, 1896) is the horizon long famous for its fossils, particularly the abundant ammonites. This bed seems to thicken towards the south, and is marked at its base by a very poor parting, due to the presence of large numbers of bivalves; _Liostrea_ and _Ctenostreon_.

_Emileia_ (_E._) _bulligera_ Buckman, CP 3796

_E._ (_E._) _polyschides_ (Wag.) BMNH. C80497

_E._ (_E._) _polymera_ (Wa.) CP.2423

_E._ (_Otoites_) cf. _sauzei_ (d'Orb.) CP 2448

_E._ (_Otoites_) aff. _fortis_ (West.) CP.2425

_Labyrinthoceras_ aff. _meniscum_ (Waagen) CP.2402

_Stephanoceras_ (_Kumatostephanus_) _perjucundus_ Buckman BMNH.C80496

_Stephanoceras_ (_Skirroceras_) _bayleanum_ (Oppel) CP.3771

_S._ (_S._) _macrum_ (Weisert _non_ Qu.), CP 3769

_S._ (_Normannites_) sp.

_Sonninia_ (_S._) _corrugata_ (Buckman _non_ Sow.) CP 3792

_S._ (_S._) aff. _felix_ (Buckman), CP.2422

_S._ (_Papilliceras_) _mesacantha_ (Waagen), CP 3809

_?Witchellia_ (_?W._) _hebridica_ (Morton) CP.2442

_?W._ (_Pelekodites_) cf. _sulcata_ (Buckman) CP.2451

_Protoecotraustes_ _spiniger_ (Buckman) (Torrens Col.)

0.15 - 0.27m.

- - - - - - - - - - - arbitrary boundary - - - - - - - - - - - - - - -

10a. (5) The Witchellia bed

An 'iron-shot' limestone with fewer limonite ooliths, particularly towards the base, than the bed above, and with a whiter coloured soft, pasty matrix. The genus Witchellia is abundant, especially at 0.21 - 0.31m. below the top of bed 10b.

Witchellia (W.) spinifera Buckman, CP.2417

W. (W.) cf. sutneri (Branco), CP.2415

W. (W.) falcata Buckman, CP.2428

W. (W.) laeviuscula (Sow.), CP.2446

W. (Pelekodites) macra (Buckman), CP.2419

Shirbuirnia cf. stephani (Buckman), CP.3783

Sonninia (S.) spp.

S. (Papilliceras) arenata (Qu.), CP.3782

Frogdenites gibberulum (Buckman), CP.2401

Emileia (E.) cf. brocchii (Sow.), CP.3786

E. (E.) cf. contrahens Buckman, CP.3784

E. (Otoites) cf. fortis CP.2424

Bradfordia cf. inclusa (Buckman), CP.2426

Strigoceras (S.) sp.

0.22 - 0.28m.

Total for bed 10 = 0.40 - 0.52m.

- - - - - - - - - - Irregular, limonite coated surface - - - - - - - - - - - - -

9. (?6) The Limonitic bed

A very nodular, hard and 'iron-shot' limestone. The irregular nature of this bed, due to bioturbation, together with the limonite incrustation gives the false impression that it is conglomeratic. The upper surface is thickly coated with limonite, and with some incipient 'snuff-boxes', (q.v. Gatrall, *et al.*, 1972, p.85). There are many fossils present, but they tend to be in either the hard limestone nodules and thus difficult to extract, or in the limonitic partings and hence distorted and badly preserved.

*Stephanoceras* (*Skirroceras*) sp.

*Emileia* (*Otoites*) sp. nov. A., CP.2404

*Trilobiticeras* (*T.*) *cricki* Parsons, CP.2403

*Mollistephanus* (*M.*) aff. *mollis* Buckman, CP.2405

*Shirbuirnia stephani* (Buckman), BMNH. C80498

*Witchellia* (*W.*) aff. *romanoides* (Douvillé), CP.2435

*W.* (*W.*) *pavimentaria* (Buckman), CP.2433

*S.* (*Euhoploceras*) cf. *acanthera* (Buckman), CP.2429

*Lissoceras* aff. *semicostulatum* Buckman, CP.2443

0.20 - 0.25m.

- - - - - - - - - Limonite stained parting - - - - - - - - - - - - - -

8 a + b. (?7) The *ovalis* bed

A finely 'iron-shot' limestone, crystalline and with a pinkish matrix. The top of the bed (8b) tends to be nodular and limonite stained, whilst the base (8a) is more crystalline and massive with sparser limonite ooliths. There is a rich fauna, particularly of bivalves, as in the same horizon at Barns Batch, which has a similar lithology.

*Sonninia* (*Fissilobiceras*) *ovalis* (Buckman *ex.* Qu.), CP.2445

Witchellia (W.) romanoides, CP.2437

W. (W.) aff. connata (Buckman), CP.2441

Trilobiticeras (T.) cricki, CP.2971

0.60m.

- - - - - - - - irregular parting and pockets - - - - - - - - - - - - - of orange/red, sandy marl

7.

A hard, grey-brown, nodular, slightly iron-shot limestone.

Sonninia (Euhoploceras) marginata Buckman (loose, but possibly from here by matrix)

0.20m.

Collections made by the Bristol Naturalists show that horizons lower than that currently visible, were exposed in 1955. The following specimens are from the Stenhouse-Ross collection in Oxford University Museum, and indicate the presence of the discites/concavum Zones in the marly Grove Farm Limestone and the murchisonae Zone in the top of the Barns Batch Limestone. There is also an extensive collection of similar material in the Bristol City Museum.

'bed 7', (7 + 1-4)
- Hyperlioceras (Hyperlioceras) sp. J17779
- Bradfordia sp. J17752
- Reynesella sp. J17788
- Euhoploceras sp. J17777
- Fontannesia sp. J17775

'bed 8', (5-7)
- Graphoceras (Graphoceras) cf. concavum (Sow.) J17805
- G. (G.) aff. apertum Buckman J17803
- G. (Ludwigella) sp. J.17791

Explanation of Plate 1.

Figure 1.

A general view of the South-Main-road quarry, Dundry Hill, showing the highly disturbed and cambered state of the beds.

Figure 2.

South-Main-road quarry, Dundry, showing a close-up of the Dundry 'Iron-shot' beds.

PLATE 1.

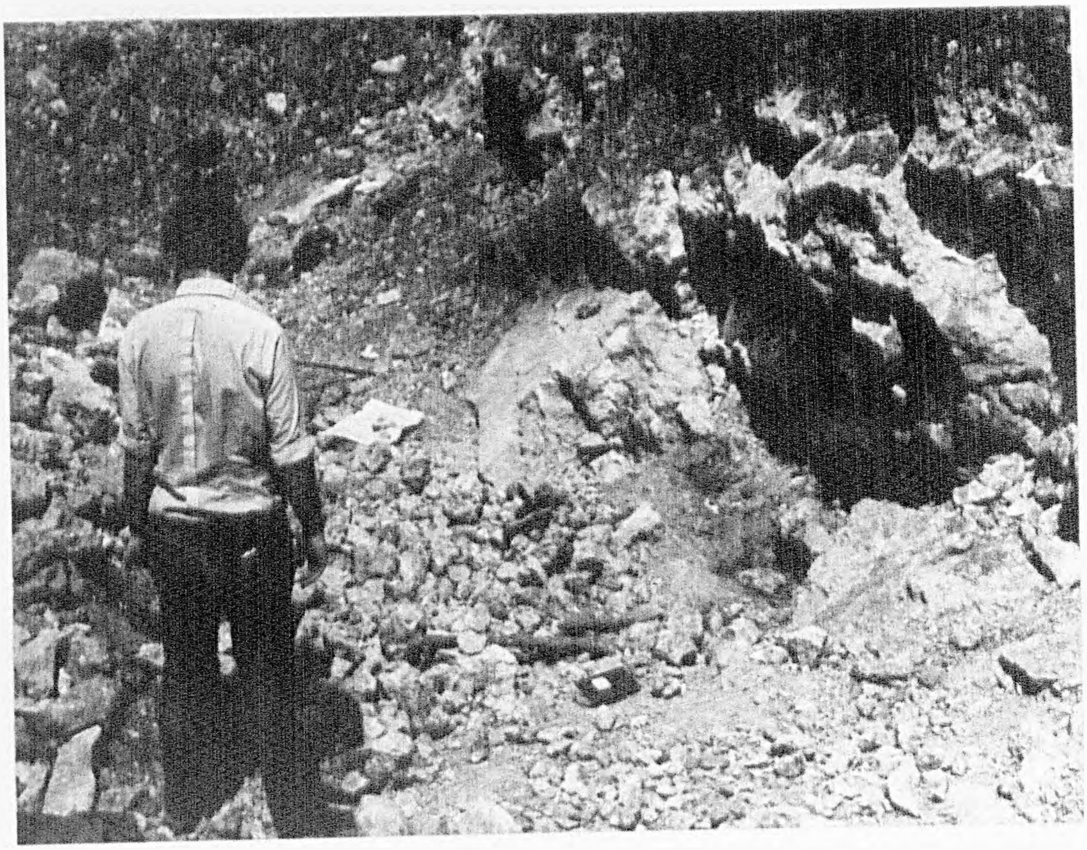

Figure 1.

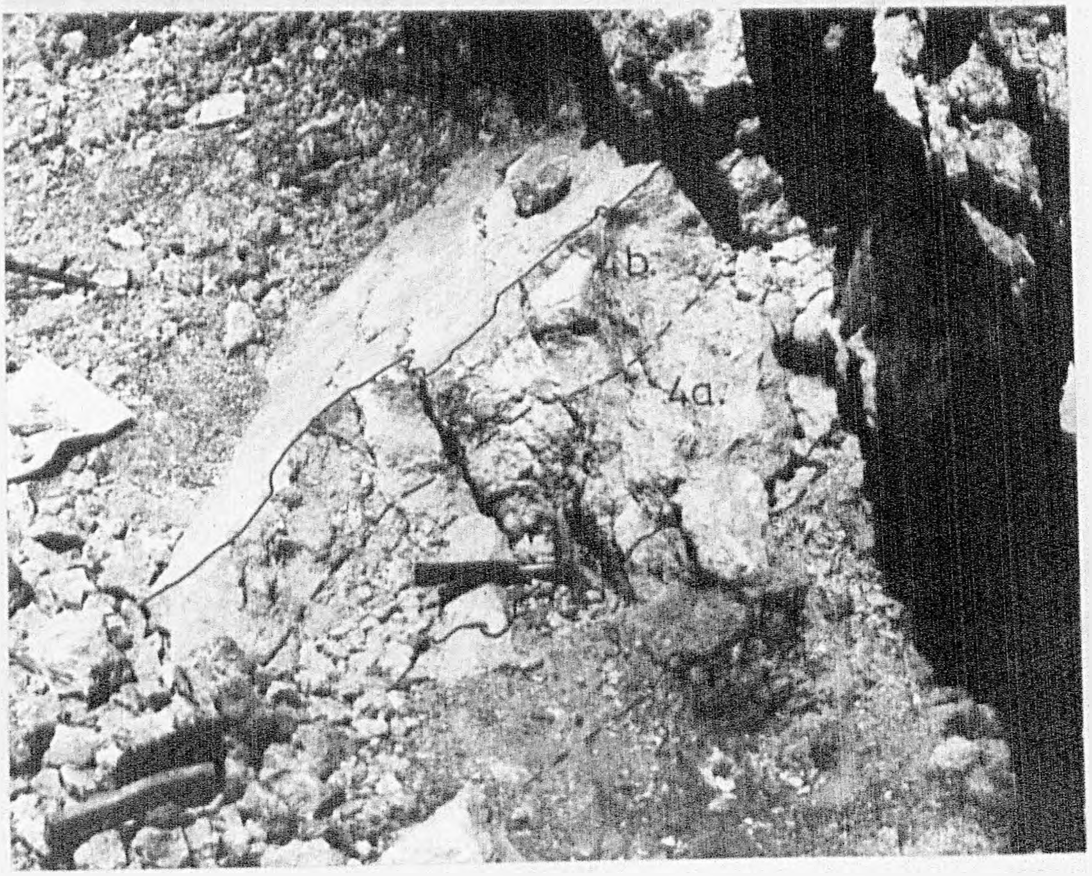


Figure 2.

'Bed 9' (8) Ludwigia (Ludwigia) sp. J16767 (in an iron-shot matrix, with limonite incrustation, pisoliths and small 'snuff-boxes' see Gatrall *et al.*, 1972).

The bed numbers used above are those given by Stenhouse-Ross, whilst those given in brackets are the probable Buckman and Wilson (1896) equivalents.

(b) Rackledown Quarry

This is an old quarry (ST572654), which, even in Buckman's day was not good for detailed stratigraphic collecting, as cambering and tufa coating of the faces made it difficult to interpret. Since then, dumping of rubbish, as well as more natural deterioration has done nothing to help the visiting geologist. It is impossible to see a continuous section of those beds still visible in April 1972; the following is thus a composite description taken from several separate exposures:

The Coralline Beds

13/ (1)

A tumbled mass of white coloured, bioclastic limestone, rich in broken corals; probably not seen anywhere *in situ*.

1.0m.+

The Elton Farm Limestone

10b/ (3) The Brown Iron-shot bed

A densely 'iron-shot' limestone with a dark, almost purple matrix. Visible as a steeply dipping cambered block at the right-hand side of the short quarry face, opposite the road, this bed may also be seen *in situ* on the hill slope to the south. The exact thickness of this bed is difficult to determine, since there is a transition to bed 10a.

<u>Emileia</u> (<u>E</u>.) cf. <u>bulligera</u> Buckman, CP.1476

<u>E</u>. (<u>E</u>.) cf. <u>vagabunda</u>, Buckman, CP.2140

<u>Stephanoceras</u> (<u>Kumatostephanus</u>) sp.

<u>S</u>. (<u>Skirroceras</u>) aff. <u>bayleanum</u> (Oppel)

<u>Bradfordia</u> sp. CP.2138

<u>Strigoceras</u> (<u>Cadomoceras</u>) <u>ellipticum</u>, (Buckman) CP.2139

<u>Sonninia</u> (<u>S</u>.) aff. <u>propinquans</u> (Bayle), CP.2137

c.0.34m.

10a/ (3) The <u>Witchellia</u> bed

A slightly less densely 'iron-shot' limestone than the bed above, with a lighter, more white coloured matrix.

<u>Shirbuirnia</u> aff. <u>trigonata</u> (Buckman <u>ex</u>. Qu.) CP.1479

<u>Sonninia</u> (<u>Fissilobiceras</u>) aff. <u>fissilobata</u> (Waagen.), CP.1480

<u>Witchellia</u> (<u>W</u>.) <u>laeviuscula</u> (Sow.), CP.2129

<u>W</u>. (<u>Pelekodites</u>) <u>aurifer</u> (Buckman), CP.2135

Various other unlocalised specimens, undoubtedly from this horizon, by matrix include:-

<u>W</u>. (<u>W</u>.) <u>spinifera</u> Buckman, CP.2132

<u>W</u>. (<u>W</u>.) cf. <u>sutneri</u> (Branco) CP.2130

c.0.50m.

Total for bed 10 = 0.90m.

- - - - - - - - - - - - Break in section - - - - - - - - - - - - - - - - - -
which continues in the
long southern face

8/(?4 <u>pars</u>) The <u>ovalis</u> bed

A rubble of broken up and weathered 'iron-shot' limestone, which grades into the top of bed 7.

Trilobitioeras (Emileites) aff. malenotatus Buckman, CP.2167

T. (E.) liebi (Maubeuge), CP.1979

Witchellia (W.) romanoides CP.2133

seen to 0.25m.

7/ (4)

A massive, well bedded 'iron-shot', crystalline limestone, with a pink matrix. This is the lowest bed seen in situ in the quarry.

Hyperlioceras (Hyperlioceras) sp.

seen to 0.7m.

------- Break in section, the Grove Farm Limestone is not exposed -----------

The Barns Batch Limestone

3/ (5) The Pleurotomaria bed

In the field, on the hill slope to the south of the quarry, the flat iron stained top to this unit is clearly visible. As at Barns Batch, this finely 'iron-shot', massive limestone, has a conglomeratic upper surface, rich in limonite pisoliths, 'snuff-boxes' and limonite laminae.

Ludwigia (L.) crassa (Contini non Horn), BMNH. C80495

seen to 0.30m.

(c) Barns Batch Spinney

This section was described by Buckman and Wilson (1896, p.689), but it appears to have been subsequently ignored. Although it now only consists of a shallow pit (see Plate 2, figs.1 and 2) in a clump of trees (ST557659), after some excavation in April 1972, it revealed the following details:

The Coralline Beds

13 (1)

White, rubbly, bioclastic limestones, which mainly consist of disturbed and slipped material, although it may be seen *in situ* in the pit next to the road (ST554659).

0.3m. +

——— A planed, limonite-stained surface ———

The Elton Farm Limestone (*pars*)

9. (*pars* 2)

A thin, 'iron-shot', conglomeratic limestone, which thins rapidly towards the west. Much of the fauna from this bed is rolled and worn looking and has been derived from the bed below, since the indigenous forms are much better preserved.

*Emileia* (*E.*) sp. nov. A., CP.1463

Derived *Witchellia* (*W.*) cf. *romanoides*, CP.1461

" *W.* (*W.*) aff. *sayni* Haug, CP.1458

" *Trilobiticeras* (*T.*) *cricki*, CP.1452

" *T.* (*Emileites*) *liebi*, CP.1448

0.0 - 0.1m.

- - - - - An irregular, limonite-stained surface - - - - - - - - - - -

8a - b (*pars* 2)

A cream-grey, rubbly limestone, with numerous small limonite ooliths (8b), which grades down into a harder limestone, with a pinker, more crystalline matrix (8a). This horizon is highly fossiliferous, with the fauna mainly concentrated at 0.1 - 0.15m. and 0.25m. below the top. In the latter case the brittle fracture of the rock makes it more difficult to extract.

*Witchellia* (*W.*) *albida* (Buckman), CP.1455

*W.* (*W.*) cf. *connata* (Buckman), CP.1457

*W.* (*W.*) *romanoides*, BMNH. C80494

*W.* (*W.*) cf. *sutneri*, CP.1424

*W.* (*Pelekodites*) *pelekus* Buckman, CP.2523

*W.* (*P.*) *macra*, CP.2525

*S.* (*Fissilobiceras*) *ovalis*, CP.1459

*S.* (*F.*) *gingensis* (Waagen), CP.2685

*S.* (?*Euhoploceras*) sp.

*Bradfordia* cf. *inclusa*, CP.2508

*Toxamblyites* sp., CP.1418

*Strigoceras* (*S.*) *compressum* (Buckman), CP.1419

*Docidoceras* cf. *cylindroides* Buckman, CP.1481

*Emileia* (*Otoites*) *douvillei* Parsons, BMNH. C79429

*Trilobiticeras* (*T.*) *cricki*, BMNH. C79426

*T.* (*Emileitas*) *liebi*, BMNH. C80493

0.25 - 0.45m.

- - - - - - - - An irregular, sandy parting - - - - - - - - - - - - - -

7 (3)

A hard, massive, crystalline, 'iron-shot' limestone, with a pink matrix, and which, except for a few belemnites, is poorly fossiliferous. This bed is roughly separated into two courses, by an irregular sandy parting, either side of which this bed is sandier and more nodular, due to intense bio-turbation.

*Hyperlioceras* sp.

0.3 - 0.48m.

- - - - - - - - - - - - - - -

A brown sandy marl 0.05m.

- - - - - - - - - - - - - - -

The Grove Farm Limestone (6-4)

6 (4)

A hard, nodular, crystalline limestone, with minor marl intercalations, which becomes softer and whiter towards the base. Divided roughly in half by a poor parting, this bed is extensively bio-turbated, and although fairly fossiliferous, most of the shell material has been leached out, to leave crushed and distorted internal casts.

'Braunsina' cf. projecta Buckman, CP.1497

Hyperlioceras (H.) walkeri Buckman, CP.1496

H. (H.) spp.

?Darellia (?D.) aff. polita Buckman, CP.1495

S. (Euhoploceras) cf. acanthodes Buckman, (from here by matrix), CP.1660

0.3m.

- - - - - - - - - - - - A marl parting - - - - - - - - - - - - - - -

5 (pars 5)

A series of hard, pink-gray, slightly 'iron-shot', limestone nodules, set in a soft marl. There are numerous poorly preserved ammonites present, mainly distorted, internal casts of body-chambers.

Graphoceras (G.) formosum (Buckman), CP.1499

G. (G.) spp.

0.2m.

4 (6) The <u>eudesi</u> bed

A pink-grey, limestone, which is harder and more massive than the bed above. Divided into three courses by two partings; the middle course contains abundant <u>Sphaeroidothyris</u> <u>eudesi</u> (Oppel), whilst the basal course is darker coloured, more crystalline, contains derived pisoliths and has yielded one ammonite.

'<u>Braunsina</u>' aff. <u>rotabilis</u> (Buckman), CP.2158

0.4m.

The Barns Batch Limestone (3-1)

A prominent, flat, limonite-encrusted surface

3b (<u>pars</u> 7) A thin, laminated limonite layer

0.02 - 0.04m.

3a (<u>pars</u> 7) The <u>Pleurotomaria</u> bed

A hard, pink-grey, 'iron-shot' limestone. This bed is particularly 'iron-shot' towards its very irregular top, where it is also highly conglomeratic, bored by '<u>Lithophaga</u>', and where it contains large pisoliths, serpulid- and limonite-encrusted ammonites and small 'snuff-boxes' (q.v. Gatrall, <u>et</u> <u>al</u>., 1972). Particularly hard and massive towards its base, this bed, together with those below, forms a distinctive topographic feature, in contrast to the softer, more marly limestones above.

From the top
- <u>Brasilia</u> (<u>Brasilina</u>) cf. <u>tutcheri</u> (Buckman), CP.2156
- <u>Ludwigia</u> (<u>Ludwigina</u>) sp.

From the middle
- <u>Ludwigia</u> (<u>L.</u>) <u>murchisonae</u> (J. de C.Sow.), CP.2161
- <u>Brasilia</u> (<u>Brasilina</u>) sp.

Explanation of Plate 2.

Figure 1.

A general view of the Barns Batch Spinney section, on Dundry Hill, showing its degraded state.

Figure 2.

A close-up of the ovalis bed at Barns Batch Spinney. The hammer is resting on the flat, planed off top of the latter bed.

PLATE 2.

Figure 1.

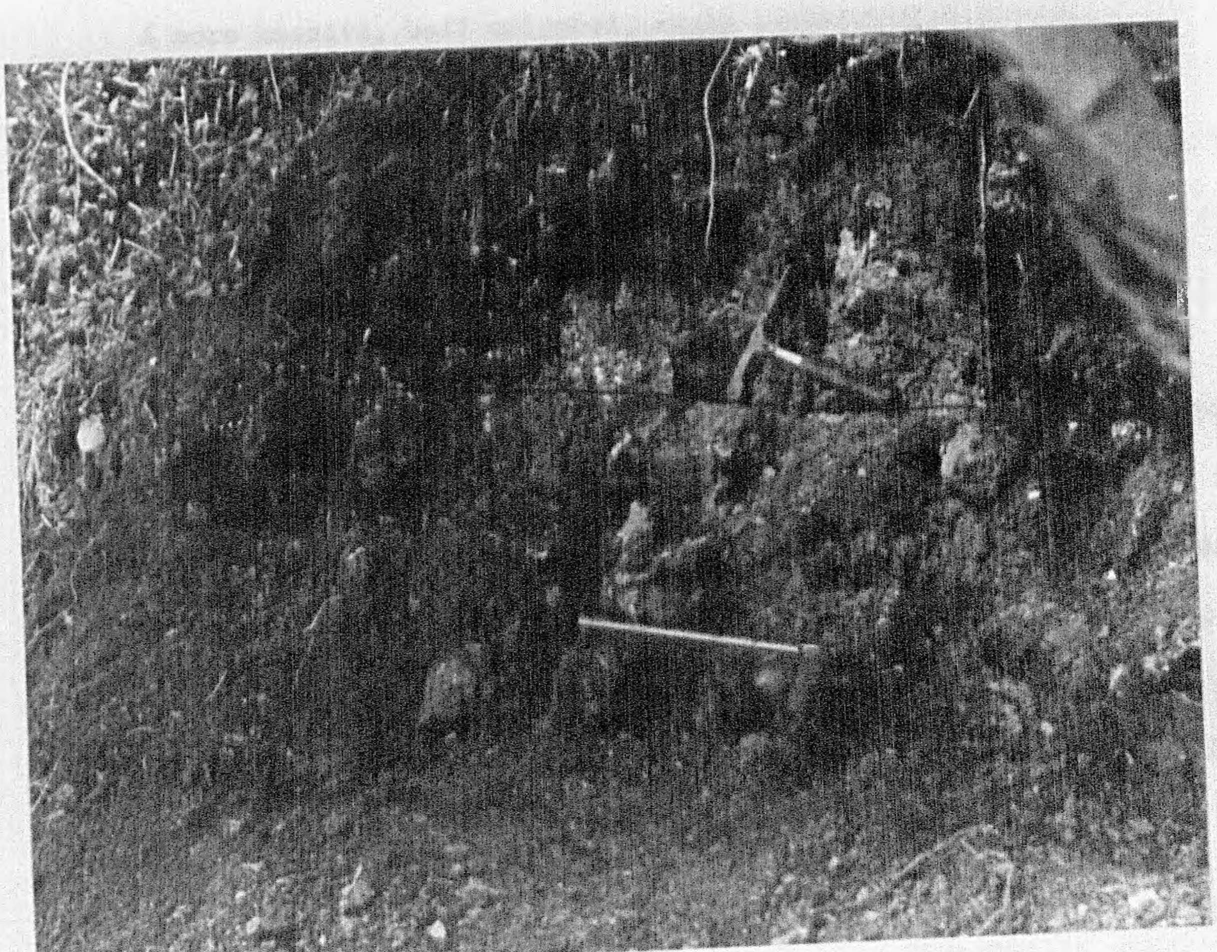

Figure 2

From the base - ?B. (?Brasilia) cf. wilsoni (Buckman) CP.2155

0.5m.

- - - - - - - - - - - - - A marl parting - - - - - - - - - - - - - - - - - -

2 (pars 7)

A hard, pink-grey, crystalline, sandy, sparsely oolitic, very nodular limestone, with some marl layers. This horizon is well bio-turbated, probably by the Pleuromya to be found in life position.

Ludwigia (L.) obtusa (Buckman ex. Qu.), CP.2159

L. (L.) obtusiformis (Buckman), CP.2162

0.28 - 0.30m.

- - - - - - - - - - - A sandy, marl parting - - - - - - - - - - - - - - - -

1 (pars 7)

A more massive, buff coloured, sandy limestone, with small limonite flecks.

seen to 0.85m.

(d) Grove Farm

This exposure at the 'West End' of Dundry, (ST551671), is quite near to the location of the excavations which Buckman and Wilson (1896, pp.676-8) had made at Castle Farm. The present section was measured in July 1975, from a series of natural scarps on the north slope of Dundry Hill, overlooking the road; hence a less detailed subdivision of the beds was possible, than that undertaken by Buckman. Taking this into account, the section described here is very similar to that described from Castle Farm (*loc. cit.*):

The Maes Knoll Conglomerate

11 (3)

A conglomeratic, brown, 'iron-shot', highly fossiliferous limestone.

*Discacyathus* sp.

*Trautscholdia spissa* (Buckman)

0.0 - 0.15m.

The Elton Farm Limestone (8-6)

A limonite-stained, very flat surface

8a-b. (4-7) The *ovalis* bed

A cream-grey, 'iron-shot', limestone, divisible into two courses by a poor parting. The bottom course (8a), is harder and more nodular, with a more crystalline matrix and sparser iron ooliths, than the top course (8b), which is softer, more rubbly and which contains more fossils, particularly bivalves. Most of the fossils recorded here come from -0.10m. below the top of the bed.

*S.* (*F.*) *ovalis*, CP.2846, at -0.40m.

*Witchellia* (*W.*) *romanoides*, CP.1409

*W.* (*W.*) cf. *sutneri*, CP.1407

*W.* (*W.*) aff. *connata*, CP.1408

*S.* ('*Euhoploceras*') sp.

*Docidoceras* aff. *cylindroides*, CP.1417

*Trilobiticeras* (*T.*) *cricki*, CP.1414

T. (Emileites) sp.

Strigoceras (S.) sp.

0.48m

- - - - - - - - - - A sandy, marl parting - - - - - - - - - - - - -

7a-b (9-11)

A hard, crystalline, sandy, slightly 'iron-shot' limestone, divided into two courses by a sandy marl parting, and which has abundant, badly preserved bivalves, particularly in the lower course (7a).

0.43m.

- - - - - - - - - - A sandy, marl parting - - - - - - - - - - - - -

The Grove Farm Limestone

6 (13)

A grey, nodular, slightly 'iron-shot' limestone, intermixed with a soft marl. The common fossils are preserved as distorted internal casts.

Hyperlioceras (H.) deflexum Buckman, BMNH. C80492

H. (H.) spp.

?Darellia (?D.) aff. polita, CP.1406

0.12-0.20m.

5 (14) A soft, grey coloured limestone.

seen - - -

4 (15-18) Massive, slightly 'iron-shot' limestone, with subsidiary marl partings.

Graphoceras (G.) pulchra (Buckman), CP.2839

+ 0.45m.

(e) Old sections

Several other sections on Dundry have in the past exposed the Elton Farm Limestone. The most famous Dundry locality is undoubtedly the North Main-road quarry (locality 6 on Text fig.1), which according to Buckman and Wilson (1896, p.692) showed a very similar sequence to that of the South Main-road quarry. However, as early as the end of the nineteenth century, this quarry had gone 'out of work' and become obscured, (Buckman, 1901). The old road-cutting close to the above section has yielded similar faunas from the upper Elton Farm Limestone, (Buckman, 1901, p.158), and these have found their way into the Bristol University Geological collections. More recently (1977) a fresh cutting has been produced during the widening of the road, and this has confirmed the accuracy of Buckman and Wilson's section (1896, p.692). There have been several exposures on the hill slope to the west of Dundry village, from below the church, past Clement's Yard, (op. cit., p.679) to Grove Farm. The main beds, the ovalis bed and the Grove Farm Limestone appear to have been identical to those exposed at the Grove Farm and Barns Batch exposures. To the east, exposures in the Elton Farm Limestone have been recorded from East Dundry village, (op. cit., 1896, p.682) and from slightly further east at Walnut Farm. A shallow roadside quarry at this latter locality (number 7 in Text fig.1), has produced several ammonites, now in the Bristol University collections, including a rare specimen of Mollistephanus (BUGM.3338). Beyond Walnut Farm the Aalenian/Lower Bajocian rocks are rapidly overstepped by the Maes Knoll Conglomerate, until they disappear from the field rubble about a half a mile east of East Dundry.

## 4. THE AALENIAN AND BAJOCIAN AMMONITE FAUNAS FROM DUNDRY

The stratigraphic distribution of the main ammonite genera within the Dundry Inferior Oolite is shown in Text fig.2, whilst the distribution of the more important ammonite species found at the South Main-road quarry has already been published elsewhere (Parsons, 1974, fig.4). Whilst these two diagrams give the main pattern of the ammonite distributions, a more detailed appraisal of the ammonite faunas from Dundry, and their relationship to other assemblages from Southern England is given below, starting from the base of the Aalenian rocks.

### (a) The *murchisonae* Zone

The lowest ammonites found *in situ* during the course of this work were *Ludwigia* spp. from the basal half of the Barns Batch Limestone, (bed 2, section c). These specimens are not atypical of the *murchisonae* Subzone of the *murchisonae* Zone, although a slightly greater age, the *haugi* Subzone, (= *Ancolioceras* hemera, S. Buckman, 1910), is possible. The ammonites from the upper Barns Batch Limestone, the *Pleurotomaria* bed, are more definitive, as the combination of bullate ribbed *Ludwigia* (*L.* (*L.*) *crassa*) and early *Brasilia*, (?*B.* (?*B.*) *wilsoni*), is characteristic of the *murchisonae* Subzone *sensu stricto*, as with the Paving bed of north Dorset, (Buckman, 1893, p.485). There must be a considerable stratigraphic break above this horizon, as no representatives of the *bradfordensis* Subzone have been found. The one previous record of '*Lioceras* cf. *bradfordensis*' (Buckman & Wilson, 1896, p.677) is based on the misidentification of a specimen of ?*Ancolioceras* sp. (Buckman m.s. note in his own copy of the latter paper).

(b) The concavum Zone

The graphoceratid fauna from the lower part of the Grove Farm Limestone is not well preserved, but it is comparable with the concavum Zone fauna from the lower half of the Bradford Abbas "fossil-bed", Bradford Abbas, near Sherborne, north Dorset, (Parsons, 1974, pp.170-1).

(c) The discites Zone

The graphoceratids from this horizon are also not very well preserved, but they are of interest, since they come from the thickest, ammonite rich development of discites Zone rocks in England. The Lower-Trigonia-grit of the Cotswolds, although often thicker, never yields as many ammonites as the equivalent Dundry beds. As yet it has proved impossible to demonstrate any stratigraphic subdivision of the Dundry discites faunas. This is disappointing, as subzonal division of this Zone has been suggested for equivalent horizons in Germany, (Bayer, 1969, p.35), so perhaps further collecting from these beds is necessary. The main ammonite fauna collected from this horizon (bed 6, section C), is exactly equivalent to those collected from the top of the Bradford Abbas "fossil-bed", (Buckman, 1893) and from the 'Snuff-box' bed of south Dorset, (Parsons, 1972).

(d) The laeviuscula Zone

The ovalis bed of the lower Elton Farm Limestone yields a fauna which is characteristic of the ovalis Subzone of the laeviuscula Zone (Parsons, 1974, p.169). This assemblage, which includes well preserved specimens of Witchellia romanoides (Douvillé), Emileites liebi (Maubeuge) and various species of Emileia and Trilobiticeras, (Parsons, 1977, p.116), is very similar to that recorded by Douvillé (1885) from southern France. The one major stratigraphic error made by Buckman and Wilson (1896) in their fine work, concerned the correlation of this bed with the north Dorset succession. The ovalis bed is not to be correlated with the basal half of the Sandford Lane "fossil-bed", Sandford Lane, near Sherborne, Dorset, (Buckman, 1893, p.492) as suggested by Buckman, (Buckman & Wilson, 1896, pp.708-9), but with the sandy limestones found beneath this horizon, (Buckman, 1893, p.493, bed 8). The fauna which is characteristic of the basal part of the Sandford "fossil-bed", including S. (Euhoploceras) acanthera, Shirbuirnia spp. and Mollistephanus spp., comes in fact from a slightly higher horizon; the Limonitic bed, (see Parsons, 1974, pp.166-9, and fig.4, for details of the distribution of ammonites within the laeviuscula Zone), which is thus lower laeviuscula Subzone in age.

The fauna from the Witchellia bed, which includes well preserved members of the Witchellia glauca - falcata group, as well as specimens of Frogdenites, is characteristic of the upper laeviuscula Subzone, like that from the 'Green grained marl' of Oborne, north Dorset, (Buckman, 1893, p.500, bed 9; Parsons, 1976b, p.132, bed 3).

(e) The sauzei Zone

The ammonite fauna collected from the Brown Iron-shot bed, (upper part of the Elton Farm Limestone), is exactly equivalent to that recently collected from the top half of the Sandford "fossil-bed", north Dorset, (Parsons, 1974, p.166; Buckman, 1893, p.492), it is thus sauzei Zone in age. This assemblage, which includes fine specimens of Kumatostephanus, Labyrinthoceras and a variety of species of Emileia, was, during the nineteenth century, one of the most famous and well collected, european ammonite faunas and numerous specimens from this horizon have found their way into most national museum collections.

(f) The humphriesianum Zone

There is a possibility that higher stratigraphic horizons than that of the sauzei Zone may have been preserved in small pockets of sediment beneath the 'Vesulian transgression', at the centre of the gentle syncline between South Main-road quarry and East Dundry. This would not come as a surprise as humphriesianum Zone rocks have been found in a similar situation both in the Sherborne district of north Dorset (Buckman, 1893) and in the 'Cole syncline' of Somerset (Richardson, 1916). Although the presence of humphriesianum Zone rocks has been suggested (Richardson, 1919, p.152), physical evidence for this is slight. Specimens of the brachiopod Striirhynchia dundriensis (S. Buckman), which has been recorded from the humphriesianum Zone, Irony bed of north Dorset (Richardson, 1932, p.69), have been found in beds of a slightly later date than the Brown Iron-shot bed, at the North Main-road quarry, Dundry (Tutcher in Kellaway & Wilson, 1941, p.153). This tenuous evidence is supported by the occurrence of the holotype of Oppelia subradiata (J. de C. Sow.), which is purported to have come from Dundry. If this is so, then this ammonite is strong evidence for the occurrence of humphriesianum/subfurcatum rocks on Dundry, as this species in only known in situ from this later horizon (Sturani, 1971, p.114). However, before any positive statements can be

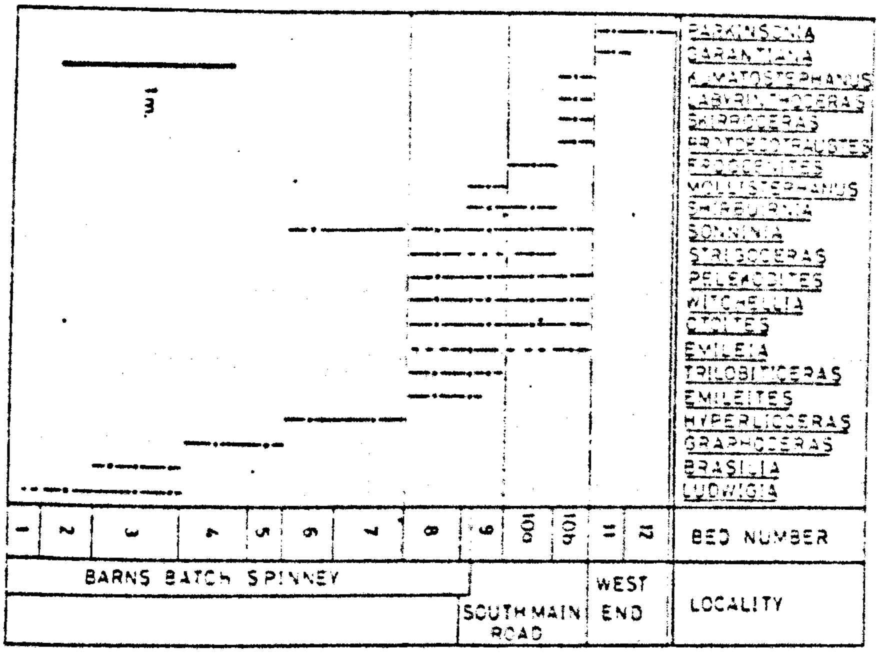


Fig. 2. A stratigraphic distribution of those Aalenian-Bajocian ammonite genera and subgenera so far recorded from Dundry Hill.

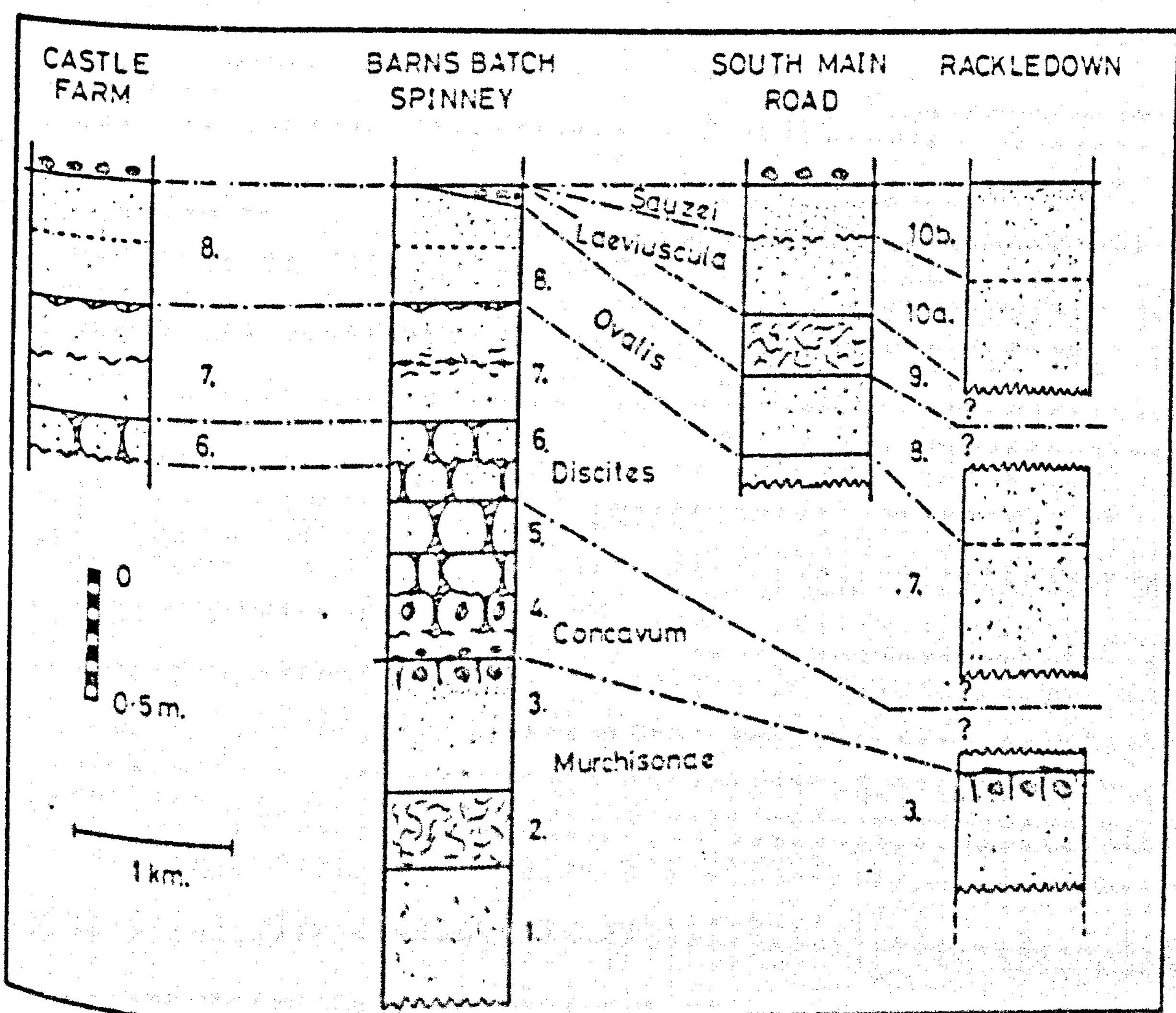


Fig. 3. A correlation of the four most important exposures of the Dundry Inferior Oolite.

made on the presence of rocks of this age on Dundry, further evidence, provided by the *in situ* collection of ammonites, is needed.

(g) The *garantiana* Zone

The few ammonites which have been collected from the Maes Knoll Conglomerate, including *Garantiana* sp., (Buckman & Wilson, 1896, p.685) and *Parkinsonia rarecostata* S. Buckman (BUGM.3397), indicate a correlation with the upper *garantiana* Zone, *acris* Subzone; it is thus the same age as the *Astarte* bed of south Dorset, (Senior, Parsons & Torrens, 1970).

(h) The *parkinsoni* Zone

A solitary specimen of *Parkinsonia* has been collected from the Dundry Freestone, (BUGM.3458, *ex.* T. Fry collection, from ... "3'-4' above the best beds, Dundry Down"), which is most closely related to the *P. parkinsoni* (Sow.) group. The most likely correlation for this horizon is with the *truellei* Subzone of the *parkinsoni* Zone, as with the *truellei* bed of south Dorset, (Senior, Parsons & Torrens, 1970, p.115).

## 5. CORRELATION OF THE DUNDRY INFERIOR OOLITE

The lateral correlation of the exposures described here is shown in a diagrammatic form in Text fig.3. Virtually all the separate lithostratigraphic units described from these sections were found to be isochronous. In this connection the bed, here called the *ovalis* bed, as previously noticed by Buckman and Wilson (1896, pp.678, 681), was found to be particularly valuable as a marker horizon over all the hill west of East Dundry. Similarly the *Pleurotomaria* bed, with its very flat, limonite-encrusted top, is another good datum level.

Where ammonites are abundant stratigraphic comparison with other, equivalent beds in Southern England is much simplified; hence all the beds below the Maes Knoll Conglomerate are easily equated with their lateral equivalents. The detailed correlation of these beds with the Dorset succession has largely been given in the previous section, thus only the Cotswold and Bruton districts need further attention.

(a) The Cotswolds

The recent revised dating of much of the Cotswold Inferior Oolite (Parsons, 1976a & 1980), provides a basis for the detailed correlation of these beds with the Dundry sequence. It is evident that the Cotswold, Hartley Hill Formation is almost the exact lateral equivalent of the Elton Farm Limestone. The most exact correlation is between the "*Witchellia* Grit" and the *Witchellia* bed, both of which have very similar ammonite faunas. However, the Cotswold Lower-Trigonia-grit has yielded *discites* Zone ammonite faunas, it may thus be correlated with either the base of the Elton Farm Limestone, or with the top of the Grove Farm Limestone. There are greater problems in attempting any detailed correlation of the Cotswold Cheltenham Formation (= *pars* Lower Inferior Oolite, Mudge, 1978). The Scottsquar Hill Limestone has produced several specimens of *Brasilia*, which suggests a correlation with the *bradfordensis* Subzone of the *murchisonae* Zone, a horizon which does not seem to be represented on Dundry. Ammonites are relatively rare in the Frocester Hill Oolite - Devil's Chimney Oolite sequence, but it does appear to be the lateral equivalent of at least part of the Barns Batch Limestone.

To the south of Dundry all beds of the above age (Aalenian and Lower Bajocian) disappear, and only representatives of the Stroud Formation ("Upper Inferior Oolite") are now preserved. The Maes Knoll Conglomerate is undoubtedly to be correlated with the Upper-Trigonia-grit to the north and part of the Doulting Ragstones to the south (Parsons, 1975). The lack of ammonites from directly above this horizon makes further correlation difficult. The Dundry Freestone is most likely basal *parkinsoni* Zone in age as is the Doulting Freestone (Parsons, 1975). If this is so, then there is no exact Cotswold equivalent to these beds, as the *Clypeus*-grit appears to be mainly upper *parkinsoni* Zone in age (Parsons 1976a, p.62).

(b) The Bruton district

To the south of the Mendips, Lower Bajocian and Aalenian rocks first make their re-appearance in the 'Cole syncline' of the Bruton district, Somerset (Richardson, 1916). This area is the nearest to Dundry to preserve an ammonite rich development of rocks of this age, and the two faunal sequences are very similar. The previous description of the Bruton sections by Richardson (1916), incorporated Buckman's ammonite identifications. The consequent confused dating of these exposures, often with the occurrence in the same bed of ammonites said to be representative of several different hemerae (cf. Richardson, 1916, p.497, bed 10) is a result of the artificial nature of many of Buckman's hemerae, particularly those based on the Sandford Lane "fossil-bed" (Parsons, 1974, pp.162-4; 1976a, p.47). A revision of these important ammonite faunas, based on recent *in situ* collections from the most complete and presently accessible section; the Bruton railway-cutting

(Richardson, 1916, p.495); is thus essential before any detailed correlation can be made with Dundry.

The 'Pecten bed' (Richardson, 1916, p.495, beds 3-4), which has yielded: Emileia (E.) brocchii, E. (E.) contrahens Buckman, E. (E.) polyschides, E. (Otoites) cf. douvillei, E. (O.) aff. fortis (West.), Trilobiticeras (Emileites) liebi, Mollistephanus cf. mollis, Sonninia (S.) aff. propinquans, S. (?S.) aff. carinodisca (Qu.), S. (?S.) straeleni Maubeuge, S. (Euhoploceras) acanthera, Shirbuirnia aff. trigonata, Witchellia (W.) cf. albida, W. (W.) aff.connata, W. (W.) cf. glauca, W. (W.) laeviuscula, W. (Pelekodites) sp., Lissoceras semicostulatum: is of lower laeviuscula Subzone age, and is thus to be correlated with the Dundry Limonitic bed. Beds 4a and 6 (Richardson, 1916, p.495) have yielded: W. (W.) aff. connata and Sonninia (?S.) sp. (bed 4a); and W. (W.) cf. romanoides, S. (S.) sp., S. (Fissilobiceras) aff. fissilobata, S. (F.) cf. ovalis, S. (F.) aff. subtrigonata (Gillet non Buckman), T. (Trilobiticeras) cf. cricki, from bed 6: they are thus of ovalis Subzone age, as with the Dundry ovalis bed. The 'Ammonite bed' (Richardson, 1916, p.495, bed 8) has yielded from the top: S. (Euhoploceras) substratum Buckman, Docidoceras cf. planulatum, Hyperlioceras (H.) cf. subdiscoideum Buckman, H. (H.) cf. liodiscites Buckman: and from the base: Graphoceras (G.) apertum (Buckman), G. (G.) cf. formosum (Buckman), G. (G.) sublineata (Buckman), G. (Ludwigella) compactum (Buckman), G. (L.) compressum (Buckman), H. (H.) subleve Buckman: and thus spans the discites Zone and part of the concavum Zone, as does the Grove Farm Limestone. The basal Conglomerate Bed (Richardson, 1916, p.495, bed 9), is of murchisonae Zone age (Richardson, 1916, p.501) and is thus at least in part the equivalent of the Barns Batch beds.

## 6. THE HORIZON OF THE SOWERBYS' AND BUCKMAN'S TYPES

Very few of the ammonite species figured from Dundry have had any accurate stratigraphic information associated with them. Whilst Buckman went to some effort in an attempt to trace the original horizons of the Sowerbys' types, (Buckman & Wilson, 1896, p.701, Table V), he himself made the same mistake of figuring over twenty ammonite species from Dundry, of which only a very small minority were collected _in situ_ from known beds. Thus often very little is known of the type horizon's of many Dundry ammonites, and any information on this point must be garnered from the matrix of the type specimen where this is sufficiently characteristic, and from the horizon of any subsequently collected topotypes.

### (a) The Sowerbys' Type specimens

i. _Sonninia corrugata_ (J. de C. Sow.) has a type specimen which is too small for positive identification, (Buckman & Secretary, 1908, Pl. vi, figs.4a,b), although its densely 'iron-shot' matrix points to the Brown Iron-shot bed as its type horizon. Similar specimens to the type have been collected from this latter bed, but the holotype is much too small to be certain if Buckman's larger figured specimen, (Buckman, 1909-30, Pl.412a) is in fact con-specific.

ii. _Sonninia browni_ (J. Sow.) again has a type specimen which is too small and incomplete for accurate identification, (Buckman & Secretary, 1909, Pl.vi, figs.5a,b), and the lack of adherent matrix makes it impossible to even guess at the original horizon.

iii. _Sonninia sowerbyi_ (J. Sow.) is more fortunate, since although its type specimen is again rather fragmentary (Buckman, 1904, Pl.52), the densely 'iron-shot', purple stained matrix points to the Brown Iron-shot as its type horizon. This specimen probably thus represents the inner whorls of a species of Papilliceras, (Parsons, 1974, pp.160-1), and is probably conspecific with S. (P.) mesacantha.

iv. Witchellia laeviuscula (J. de C. Sow.) is perhaps the most easily recognisable of the Sowerbys' species from Dundry, since it has a relatively complete type specimen, which in turn has a distinct matrix. The Witchellia bed is the type horizon for this species, and it has produced numerous topotypes from the South Main-road quarry.

v. Emileia brocchii (J. Sow.) is restricted as a species to the forms closest to the lectotype, (Buckman, in Buckman & Wilson, 1896, p.701), whilst the smaller syntype (J. Sowerby, 1818 in 1812-46) can now be referred to the species Emileites liebi (Maubeuge), specimens of which are common in the ovalis bed, the undoubted source of Sowerby's specimen.

vi. Normannites braikenridgei (J. de C. Sow.) has a fine type specimen, (Buckman, 1909-30, Pl.81), with a densely 'iron-shot' matrix and this together with the topotype specimens recently collected, would indicate the Brown Iron-shot bed as the type horizon.

vii. Otoites contractus (J. de C. Sow.) must be considered a rather dubious species, since owing to the absence of the original type specimen, there is now considerable uncertainty over both its interpretation and type horizon. Westermann's invalid neotype of this species (Westermann, 1954, pp.88-94, Pl.1, figs. 4a,b,c), which is only doubtfully conspecific, comes from the wrong locality and is possibly from a different horizon.

**TABLE 4 The probable type horizons of those Dundry ammonite species figured by Buckman (1909–30) in 'Type Ammonites'.**
**T = horizon of topotype**
**? = probable type horizon, from the matrix of type.**

| | Volume | Plate number | Bed at South Main-road Quarry | | | |
|---|---|---|---|---|---|---|
| | | | 10b | 10a | 9 | 8 |
| *Sonninia corrugata* (Sow.) | 4 | 412 | T | | | |
| *S. corrugata* | 6 | 412A | ? | | | |
| *Dundryites albidus* | 6 | 687 | | | | T |
| *Pelekodites pelekus* | 4 | 399 | | | | T |
| *Spatulites spatians* | 7 | 765 | | T | | |
| *Macerites aurifer* | 7 | 766 | | T | | |
| *Cadomoceras carinatum* | 5 | 456 | T | | | |
| *C. ellipticum* | 5 | 455 | T | | | |
| *Hebetoxyites hebes* | 5 | 475 | | | | ? |
| *Leptostrigites languidus* | 5 | 477B | | T | | |
| *Varistrigites compressus* | 5 | 468 | | | | T |
| *Toxamblyites arcifer* | 5 | 473 | ? | | | |
| *Emileites malenotatus* | 6 | 702 | | | | T |
| *Emileia subcadiconica* | 6 | 711 | | | | T |
| *Frogdenites profectus* | 5 | 430 | | ? | | |
| *Labyrinthoceras amphilaphes* | 4 | 279 | ? | | | |
| *L. extensum* | 3 | 214 | | ? | | |
| *L. gibberulum* | 4 | 278 | | T | | |
| *Oecostephanus dolichoecus* | 3 | 265 | T | | | |

viii. Oppelia subradiata (J. de C. Sow.) has a problematic type specimen. The densely 'iron-shot' matrix of this type (Arkell, 1951-9, Text fig.11, 1a,b) would indicate a provenance from the Brown Iron-shot bed, however no topotypes have subsequently been collected of this species, which is more characteristic of the humphriesianum Zone, rather than the sauzei Zone, in the Sherborne area of north Dorset.

(b) Buckman's specimens

S.S. Buckman described and figured a large number of Dundry ammonites in two main publications; his monograph (Buckman, 1887-1907) and 'Type Ammonites', (Buckman, 1909-30). Very few Dundry ammonites in fact appeared in the 'Monograph on the Inferior Oolite Ammonites', and these are discussed individually in the text. The larger number of Dundry specimens figured in 'Type Ammonites', have mostly been traced to their type horizons and the original source of these specimens is shown in Table 4. The question marks (?) in this table refer to type specimens of which either no topotypes have been collected or which have a rather doubtful matrix. An individual discussion of these specimens would take up too much space, and only the more important specimens and groups will be mentioned here.

i. W. (Pelekodites) dundriensis (Buckman) has a type specimen (Buckman, 1887-1907, Pl.23, figs.5 & 6), which Buckman thought came from the 'Iron-shot bed' of Dundry. However this specimen is so close to W. (P.) macra (Buckman), that it would seem unlikely that it originated from any bed other than the Witchellia bed, where this latter species is common. For further details see the subsequent discussion of the W. (Pelekodites) group.

ii. W. (P.) aff. buckmani (Haug) - (Buckman, 1887-1907, Pl.23, figs. 7 & 8), undoubtedly came, as stated, from the Brown Iron-shot bed, where forms allied to this species are quite common.

iii. Ludwigia obtusa (Buckman, 1887-1907, Sup. Pl.4, fig.10 ex. Qu.), would appear from its matrix to have come from the Pleurotomaria bed of the Barns Batch Limestone. Similar specimens of this species have been found in this and subjacent beds at Barns Batch Spinney, (section c, beds 2 and 3).

iv. ?Brasilia wilsoni (Buckman); the paratype of this species (Buckman, 1887-1907, Sup. Pl.12, fig.7) came from the Pleurotomaria bed, from which horizon several closely related forms have recently been collected.

v. Oedania parvicostata Buckman (1887-1907, Sup. Pl.21, figs.7-9) and

vi. Braunsina projecta Buckman (op. cit., Sup. Pl.20, figs.7-9) are forms characteristic of the discites Zone beds of north Dorset, although only a topotype of the latter species has as yet been collected from the upper Grove Farm Limestone.

vii. Frogdenites is a small sphaeroceratid ammonite genus which so far has only been recorded once from Dundry, (F. profectus, Buckman, 1909-30, Pl.430). However a close study of several specimens from Dundry figured by Buckman as new species of Labyrinthoceras, (L. extensum, Buckman, 1909-30, Pl.214; L. gibberulum, op. cit., Pl.278), reveals their true identity as members of the Frogdenites group. Careful collection of the north Dorset exposures of the Inferior Oolite has shown that Frogdenites has a stratigraphic range restricted to the top of the laeviuscula Zone (Parsons, 1974, p.167); no members of this genus have been collected from the *sauzei* Zone layer of the Sandford Lane "fossil-bed", (Buckman, 1893, p.492, bed 6). Those members of this genus recorded from Dundry are thus most likely to have originated from the *Witchellia* bed, rather than the Brown Iron-shot. Collection *in situ* from the *Witchellia* bed of the South Main-road quarry (Section a, bed 10a) produced one topotype of *F. gibberulum* (Buckman), thus confirming this bed as the type horizon for Buckman's specimen. Buckman relied heavily upon slight differences in matrix for the placing of his specimens of *Labyrinthoceras* and *Frogdenites* in their correct stratigraphic position. Since the differences in matrix between the Brown Iron-shot and *Witchellia* beds can be slight to non-existent, until more topotypes come to light, the *Witchellia* bed should be considered the type horizon of all Buckman's specimens of *Frogdenites*.

viii. *Labyrinthoceras* is a genus closely related to the preceding, from which it evolved, and which is characteristic of the *sauzei* Zone in north Dorset. The specimens of this genus from Dundry; *L. amphilaphes* Buckman (1909-30, Pl.279) and *L. meniscum* (Waagen), (BUGM.3289); thus undoubtedly came from the Brown Iron-shot bed, a position fully in accord both with their matrix and other specimens of this genus subsequently collected *in situ*.

ix. *Pelekodites* is the small microconch subgenus of the genus *Witchellia*, both of which range from the base of the *ovalis* Subzone to the top of the *sauzei* Zone. Five specimens of this subgenus were figured by Buckman from Dundry, of which four were as new species. However, there are only three successive populations to which these different specific names may be applied.

1. The ovalis Subzone is characterised by the Witchellia (W.) romanoides (Douvillé) macroconch group, associated with which there are specimens of W. (Pelekodites) macra (Buckman) and W. (P.) pelekus (Buckman).

2. The laeviuscula Subzone has a more varied Witchellia fauna, which naturally is reflected in its microconch population. W. (P.) macra (including sub. syn. P. dundriensis, P. costulatus, and P. aurifer Buckman) is still present along with the largest member of this subgenus, P. spatians (Buckman).

3. The sauzei Zone has the last members of this subgenus, which are typically inflated and coarsely ribbed as in W. (P.) sulcata Buckman, (including sub. syn. P. buckmani (Haug), ?P. zurcheri (Douv.) and ?P. schlumbergeri (Haug)), and which represent the microconch counterparts of the W. (W.) hebridica Morton group.

The horizons of the topotypes from Dundry of the Buckman species are shown in Table 4.

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# 2B. A STRATIGRAPHIC REVISION OF THE BAJOCIAN (JURASSIC) ROCKS OF THE COTSWOLD HILLS

C.F. Parsons

SUMMARY: A formal scheme of lithostratigraphic subdivisions for the Inferior Oolite 'series' is erected. The Inferior Oolite Group of the mid-Cotswolds is defined as being made up of three Formations; the Cheltenham (= 'Lower Inferior Oolite'), Hartley Hill (= 'Middle Inferior Oolite') and Stroud (= 'Upper Inferior Oolite'); with an additional fourth Formation (the Stanway Hill Formation, with Harford Sands and Snowshill Clay Members), in the north Cotswolds. Three Members of the Hartley Hill Formation are re-defined or newly named; the Lower-Trigonia-grit, Windrush and Notgrove Members; whilst the existing informal units, the Clypeus-grit and Upper-Trigonia-grit are redefined as formal Members of the Stroud Formation. Bajocian ammonite faunas from the Cotswolds are listed (+ 100 specimens) and discussed, whilst the correlation of the Upper Bajocian rocks of the south Cotswolds is discussed and compared with the successions in the Doulting and Dundry districts.

The Inferior Oolite rocks (Aalenian-Bajocian Stages, Middle Jurassic) of the Cotswold Hills are superbly displayed in a series of natural scarps and artificial exposures created by the exploitation of their famous building stones. This wealth of exposure, together with the abundance of fossils led several generations of geologists to turn their attention to the stratigraphic problems of these rocks. In broad terms the Inferior Oolite of the Cotswolds may be divided into two divisions, an upper series of mainly bioclastic limestones (the Upper and Middle Inferior Oolite *sensu* Arkell, 1933) of Bajocian age and a lower group of predominantly oolitic limestones and marls (Lower Inferior Oolite) of Aalenian age. This simple grouping was recognized at an early stage by workers such as Lycett (1850), who included the upper beds within his 'Ragstones' and the lower beds within the 'Freestones'. The aim of this work is to revise the detailed bio- and litho-stratigraphy of the rocks of Bajocian age (the 'Ragstones'), since the Aalenian beds have been the subject of a recent work (Mudge, 1978).

The existing informal lithostratigraphic subdivisions of the Cotswold Inferior Oolite were introduced haphazardly over a period of more than one hundred years, hence they tend to be both poorly defined and ambiguous in use. A rationalization of these units in order to produce a standardized hierarchical scheme, in line with current practice (Holland *et al.*, 1978) is thus long overdue. In particular a more rigorous definition of the lithostratigraphic units is required. In the past there has been a tendency to place more emphasis on the biostratigraphic value of the constituent faunas of a unit, such as the *Witchellia* ammonites of the '*Witchellia* Grit' than on its lithology and value in field mapping. This

| | ZONE | SUBZONE |
|---|---|---|
| UPPER BAJOCIAN | Parkinsonia parkinsoni | P. bomfordi |
| | | Strigoceras truellei |
| | Strenoceras (Garantiana) garantiana | P.acris |
| | | S.(G.) tetragona |
| | | S.(G.) subgaranti |
| | | S.(Pseudogarantiana) dichotoma |
| | S.(Strenoceras) subfurcatum | S.(G.) baculata |
| | | Caumontisphinctes (C.) polygyralis |
| | | Teloceras banksi |
| LOWER BAJOCIAN | Stephanoceras (S.) humphriesianum | T.blagdeni |
| | | S.(S.) humphriesianum |
| | | Dorsetensia romani |
| | Emileia (Otoites) sauzei | |
| | Witchellia (W.) laeviuscula | W.(W.) laeviuscula |
| | | Sonninia ovalis |
| | Hyperlioceras (H.) discites | |

Table 1.

Zones and subzones of the Bajocian Stage (excl. Aalenian), modified after Parsons (1974 & 1976).

has led, particularly in the 'Middle Inferior Oolite', to the use of what in some cases are little more than biostratigraphic units, which do not warrant formal recognition in a hierarchical, lithostratigraphic scheme. If lithological homogeneity and ease of mapping are to be taken as the main criteria for establishing the Cotswold Inferior Oolite Formations and Members (Holland, *et al.*, 1978, p.8), then in many cases only a more limited number of formal units can be recognized. However, this approach does not prevent the continued informal use of lithological units, which have not been incorporated in the formal scheme. A revision of the biostratigraphy has become necessary because of the recent work which has been undertaken on the Bajocian rocks of Dorset and south Somerset. It was during the course of his work in these latter districts that S. Buckman (1893), laid down the biostratigraphic framework, which he was to use to elucidate the stratigraphy of the Cotswolds. It is now evident that Buckman's scheme of hemerae (approx. = subzone in present usage), which he used for this work, contains contradictions and at least one major error, which subsequently became incorporated in the Bajocian Standard Zonal scheme (Spath, 1936; Arkell, 1956). Some new insight, which is now available into the ammonite faunas of Dorset (Parsons, 1974, 1976), has enabled a more accurate correlation to be made of the Cotswold deposits. The previous Zonal scheme for the Lower Bajocian (Middle Bajocian *olim*) has been found to contain the greatest inconsistencies and hence most attention has been given to the ammonite faunas of this age. The Upper Bajocian rocks of the south Cotswolds have been treated in some detail, as they appear to have been mis-correlated in the past. Since the Inferior Oolite rocks found just to the south of the Mendips, in the

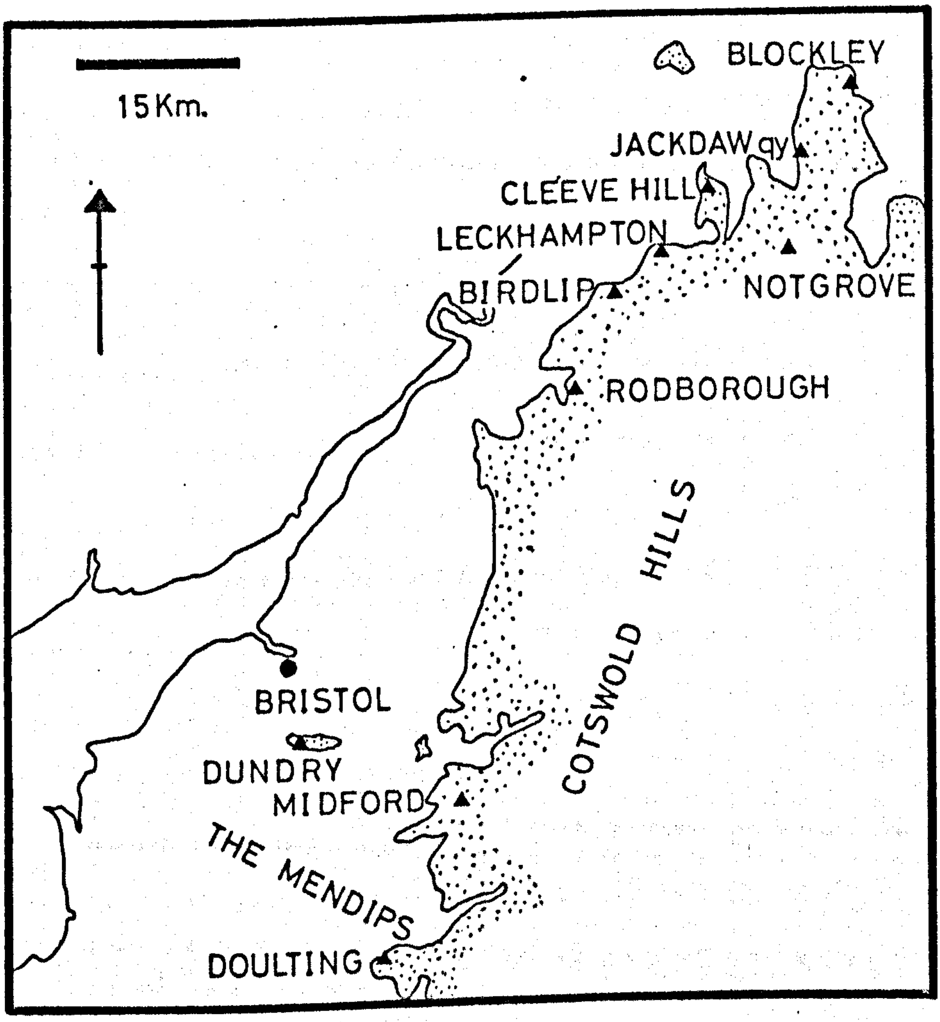



Figure 1.

A sketch map showing the relative positions of the main exposures mentioned in the text.

Doulting district, are of importance for the understanding of the succession in the south Cotswolds, some details of these are also given.

The revised Zonal scheme for the Bajocian used in this work is shown in Table 1, whilst the general area under discussion and the location of some of the more important exposures is shown in Figure 1.

THE LITHOSTRATIGRAPHY OF THE COTSWOLD INFERIOR OOLITE

The following revision of the lithostratigraphy of the Cotswold Inferior Oolite (see Table 2), is an attempt to implement the stratigraphic procedure recommended by the Geological Society of London (Holland et al., 1978). As far as is possible I have retained existing well proven terminology within the new hierarchical scheme of Group, Formation and Member. However in some cases, where several existing units have been combined, the use of the earliest available name, such as the Gryphite Grit, for the combined 'L. buckmani/Gryphite Grits', would only create confusion and ambiguity. In these circumstances new formal names have been introduced.

The Inferior Oolite Group

The mid-Cotswold Inferior Oolite is a relatively thick deposit (60 m.+ at Leckhampton) containing various lithologies and facies, which may be divided into three main divisions or Formations. These Formations are broadly similar; they overwhelmingly consist of limestones; and since together they constitute a naturally related association in comparison with the Lias below and the Great Oolite above, it is logical to

| DORSET → SOUTH SOMERSET | SOUTH COTSWOLDS → MENDIPS | MID-COTSWOLDS | | NORTH COTSWOLDS | | |
|---|---|---|---|---|---|---|
| STROUD FORMATION 1.5-30m | STROUD FORMATION 8-18m | STROUD FORM. 14m | CLYPEUS-GRIT MBR. 12m | STROUD FORMATION 12-14m | | INFERIOR OOLITE GROUP |
| | | | UPPER-TRIGONIA-GRIT MBR. 1.5-3m | | | |
| "OBORNE BEDS" 0- 10m | GAP | GAP | | GAP | | |
| | | | | HARTLEY HILL FORM. 0-21m | "CLEEVE HILL BEDS" 0-8.5m | |
| | | HARTLEY HILL FORM. 0.35 - 15m | NOTGROVE LST. MBR. 0-9m | | | |
| | | | WINDRUSH LST. MBR. 0.35-3.5m | | | |
| | | | LOWER-TRIGONIA-GRIT MBR. 0.25-2.3m | | | |
| | | GAP | | STANWAY HILL FORM. 0-10m | "TILESTONE BEDS" 0-5m | |
| | | | | | SNOWSHILL CLAY MBR. 0.5-3.5m | |
| | | | | | HARFORD SANDS MBR. 0-4m | |
| | | CHELTENHAM FORMATION 40-43m | | CHELTENHAM FORMATION 36m | | |

Table 2.

A revised lithostratigraphic scheme for the Inferior Oolite Group in the mid and north Cotswolds, showing its relationship to equivalent beds in Southern England.

combine them in a single formal Group. In deference to existing usage, this has been called The Inferior Oolite Group (McKerrow and Kennedy, 1973, p.2).

The existing informal divisions of the Inferior Oolite 'Series' into Upper, Middle and Lower Inferior Oolite (Arkell, 1933), although similar in their boundaries to three of the Formations proposed here, can never have any formal status (Holland, et al., 1978, pp.10-1). Firstly these terms have been used with a variety of different meanings (see below), thus even after formal re-definition, the possibility of ambiguity would exist. Secondly, it has been recommended, that when an established unit is broken down into two or more formally defined formations, the existing name should only either be raised to group status, or abandoned (Hedberg, 1976, p.44). Since the former course has been taken, new formational names become necessary.

The limits of the currently used divisions derive from Buckman, who was the first to recognize the two major unconformities which naturally subdivide the Cotswold Inferior Oolite (Buckman, 1897, and 1901). However, several other alternative subdivisions of the Inferior Oolite have been popular, including a two-fold division into Upper and Lower Inferior Oolite (Woodward, 1894) and yet another three-fold subdivision with Upper ('Ragstones'), Middle ('Freestones') and Lower ('Pea Grit') Inferior Oolite subdivisions (Murchison, 1834), which were commonly accepted throughout much of the nineteenth century (Lycett, 1850; Witchell, 1882). The revised three-fold division of the Inferior Oolite suggested by Cave and Penn, (1972) utilizes yet a different set of vertical limits, with the inclusion of the Tilestone/Snowshill Clay/Harford Sands in the Middle rather than the Lower Inferior Oolite. For a further discussion of the vicissitudes of these various subdivisions of the Inferior Oolite, one should refer both to Cave and Penn (1972) and to the Lexique Stratigraphique (Worssam and Donovan, pp.174-6 in Donovan and Hemingway, 1963). There is thus a strong case for establishing formal, named units to stabilize this inconsistent and informal nomenclature. An obvious and apparently logical move, would be to accredit the status of Formation to the majority of the existing lithostratigraphic subdivisions of the Inferior Oolite, as has largely been done with the Great Oolite (Sellwood and McKerrow, 1974). A step in this direction has been taken with the use of the term'*Clypeus*-grit Formation' (Kennedy, Sellwood and McKerrow, p.2 in Ager *et al*., 1973; see also, Murray, 1969). There are however problems associated with this seemingly straightforward approach.

As already noted there are two prominent unconformities with extensive 'hard-grounds' within the Cotswold Inferior Oolite. These unconformities at the base of the Upper and Lower-Trigonia-grits, constitute the major factors controlling the preservation and present distribution of the 'Middle and Lower' Inferior Oolite (Buckman, 1901, fig.3; Arkell, 1933, fig.35). Any new scheme of lithostratigraphic nomenclature must recognize and reflect the stratigraphic importance of these two erosion surfaces. In this connection Arkell (1933, p.231) made the following pertinent comments concerning the uppermost of the two unconformities ..... "Certainly no better plane for separating two Formations occurs in the Jurassic System, and the failure of our classification to take account of it is one of its worst shortcomings" ..... If the existing lithological subdivisions of the Inferior Oolite were to be considered as Formations, then the only way in which the revised nomenclature could take account of the importance of these unconformities, would be by arranging the constituent Formations into three or more separate Groups. However, this would totally over-emphasise the relative importance of the Inferior Oolite in relation to neighbouring Groups, and this approach must be rejected.

The other alternative is to take the two unconformities as the starting points for the establishment of a more 'natural' classification. The components thus delimited can be considered as Formations, with the existing lithological units being re-defined as constituent Members. These Formations can fulfil all the essential criteria for units of this rank (Holland et al., 1978, p.8) and it is this procedure which is followed here (cf. Mudge, 1978). The Inferior Oolite Group of the Cotswolds is thus here defined as being made up of the Cheltenham, Hartley Hill and Stroud Formations, with an additional fourth Formation; the Stanway Hill Formation; in the north Cotswolds. The mid-Cotswold units are clearly distinguished both by their different lithologies and by the disconformities, which separate them throughout much of Southern England. Thus they are readily recognizable to the east in boreholes in the Hampshire/Weald basin (e.g. Warlingham; Worssam & Ivimey-Cook, 1971, pp.45-6). However, south of Stroud the Hartley Hill and Cheltenham Formations are rapidly over-stepped, so that beyond Chipping Sodbury the Stroud Formation is the only representative of the Inferior Oolite Group. When the Aalenian a. Lower Bajocian rocks reappear from beneath the unconformity at the base of the Stroud Formation, in the Bruton district of Somerset (Richardson, 1916), they have lost their marked differences in facies and are not subdivisible into separate Formations. Here the Upper Bajocian, 'Top beds' (op. cit., p.485) are underlain by a group of thin, 'condensed', highly fossiliferous, glauconitic, lenticular deposits, which further south are very ferruginous and 'iron-shot' (Kellaway & Wilson, 1941, p.148, 'group A beds'). The former are undoubtedly a lateral continuation of the Stroud Formation, whilst the latter are the equivalent of the Hartley Hill, Stanway Hill and Cheltenham Formations of the Cotswolds (Parsons, 1979; see Table 2). The lower beds are informally named the 'Oborne beds' in Table 2, after the excellent sections around the Oborne area of Sherborne, and in the Oborne borehole (Wilson et al., 1959, pp.96-7; 185¾' - 217'). No formal definition as a Formation is made here as this must await a detailed revision of the relevant beds.

Since my aim has been, where possible, to re-define the existing informal units, few details are given of the area of preservation and lateral variation of the various Cotswold beds described, as these may be obtained from the earlier literature (Buckman, 1895, 1897, 1901; Arkell, 1933).

The Cheltenham Formation

All those beds in the mid-Cotswolds below the Lower-Trigonia-grit and above the base of the 'scissum beds' (= Leckhampton Limestone, Mudge, 1978); the 'Lower Inferior Oolite' of Arkell (1933); are here named the Cheltenham Formation. This unit thus includes all the members defined by Mudge (1978), bar the Harford Sands, which have here been transferred to the Stanway Hill Formation (see below). Leckhampton Hill (National Grid reference SO952185-949186) is here designated as the type locality, where the Formation predominantly consists of an alternation of massive oolitic limestones and oolitic and pisolitic marls, some 50m thick (Richardson, 1906, pp.187-9; Murray, 1969, pp.541-5; Mudge, 1978a, log.1).

The Stanway Hill Formation

The beds previously known as the 'Tilestone' (Buckman, 1901), 'Snowshill Clay' (Buckman, 1897), 'Harford Sands' (Buckman, 1888) and 'Naunton Clay' (Richardson, 1929), and jointly included in the '<u>concava</u> beds' (Arkell, 1933) are here transferred to a single, new unit; the Stanway Hill Formation; named after the type section at Jackdaw Quarry (SP078310), Stanway Hill (Parsons, 1976, pp.55-61, beds 4-14). From their original definition (<u>op. cit.</u>), the classification of these beds has proved to be problematic, although most subsequent authors (e.g. Arkell, 1933; Ager, 1956; Green & Melville, 1956; Mudge, 1978), have included them in the 'Lower Inferior Oolite' (= Cheltenham Formation). Doubts as to the precise relationship of these beds to the basal Lower-Trigonia-grit disconformity prompted Cave & Penn, (1972), to include them in the 'Middle Inferior Oolite' (= Hartley Hill Formation). More detailed information on the north Cotswold Inferior Oolite, which has subsequently come to light (Parsons, 1976; Mudge, 1978), has led to the rejection of Cave & Penn's conclusions. However, these problems of classification only help to confirm that these beds are out of place in either of these informal subdivisions.

These beds are a-typical (in facies, original depositional environment and present pattern of distribution) of most of the rest of the

Inferior Oolite Group. The Cotswold Inferior Oolite as a whole, is fully marine and dominated by shallow water, carbonate facies: open shelf, carbonate sands; oolite shoals etc. (Mudge, 1978, pp.622-3). In direct contrast the Stanway Hill Formation is dominated by terrigenous clastic material, with abundant clays, shales and fine quartz sands. There is strong evidence that these horizons are not wholly marine. There is intense bioturbation, with common lignite and plant fragments, together with the presence of strongly depleted faunas, with virtually mono-specific beds of Lucina, Liostrea, Pinna etc. (Parsons, 1976, pp.58-9; Mudge, 1978, p.623); all of which point to deposition in a shallow, marginally marine, coastal plain environment (loc. cit.). The present pattern of preservation of this Formation is also anomalous. The majority of the Inferior Oolite is at its thickest in the centres of the Painswick and Cleeve Hill 'synclines' (Buckman, 1897, pl.46; Arkell, 1933, fig.35; Mudge, 1978, figs.1,3 & 5), with an associated thinning north-east towards the Vale of Moreton 'swell'. By comparison, the Stanway Hill beds are absent from the Painswick 'syncline', extremely attenuated in the Leckhampton-Wistley Hill area, and thicken progressively towards the north-east, where they are thickest in the Blockley-Broadway district (Richardson, 1929), at the northern extremity of the present Inferior Oolite outcrop . Taking into account all the above factors, there can be little doubt that these beds merit the status of Formation, especially since they are readily mappable in relation to adjacent Formations.

With their identical stratigraphic positions (pre-discites Zone/ post-murchisonae Zone) it is likely that the present beds are the lateral equivalent of the Grantham Formation (Kent, 1975), of the East Midlands.

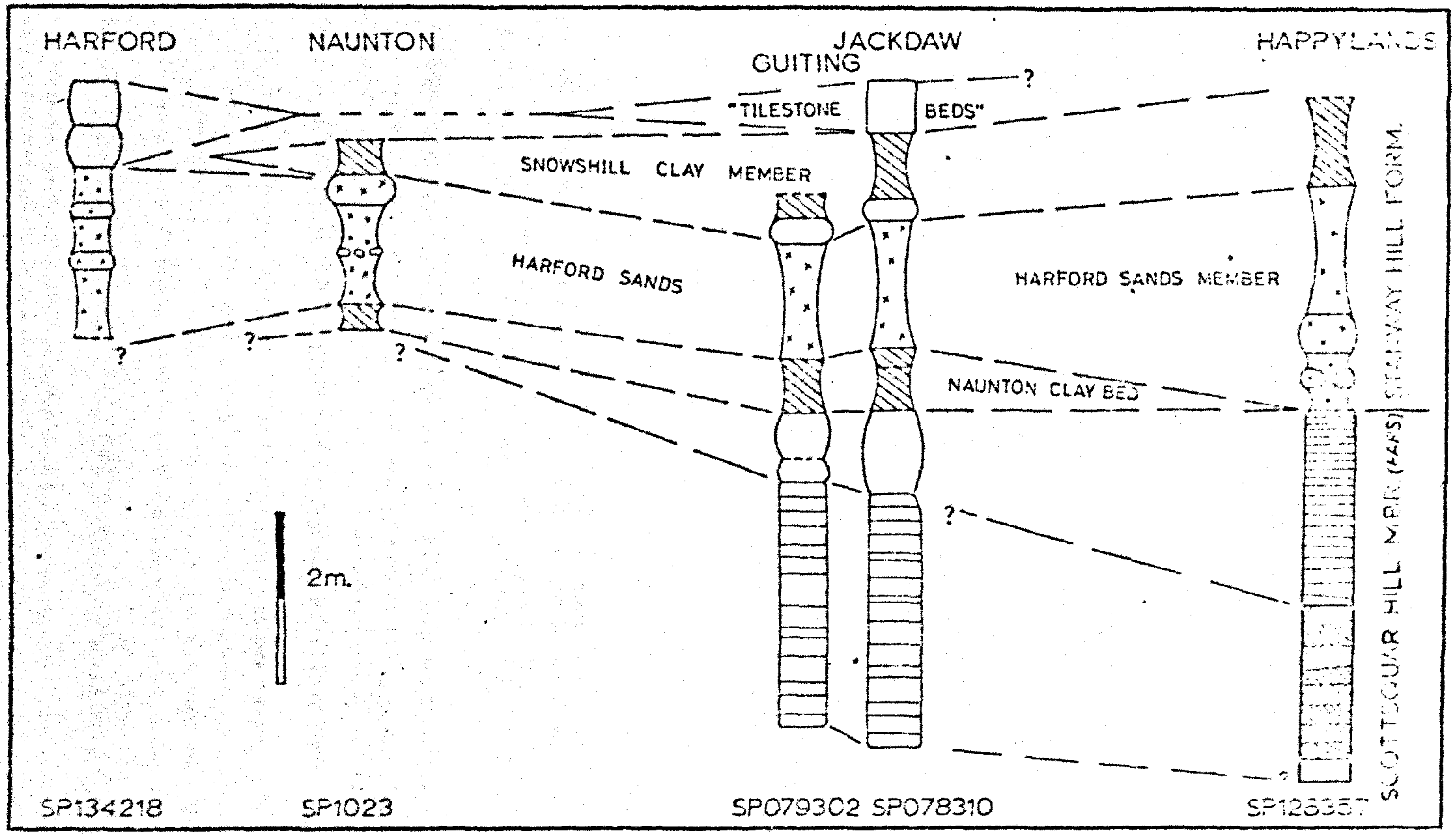



Figure 2. A correlation of the Stanway Hill Formation in the north Cotswolds, showing its relationship to the top of the Cheltenham Formation.

Although now disjunct, due to subsequent periods of intra-Bajocian and Bathonian erosion, it would seem likely that these two once formed a contiguous deposit across the 'Oxfordshire Shallows' (Sylvester-Bradley & Ford, 1968, pp.211-2). Whilst it could be possible to apply the East Midland nomenclature to the north Cotswold beds, the separation of the latter on the periphery of a different depositional basin, merits a distinctive name.

The relationship of the Formation to sub- and suprajacent strata is clear cut. It is overlain throughout the north Cotswolds disconformably by the Lower-Trigonia-grit Member (of proven discites Zone age), of the Hartley Hill Formation (Parsons, 1976, p.62). It is underlain by the Scottsquar Hill Limestone Member of the Cheltenham Formation (= 'Upper Freestone'/or its equivalents, and 'Oolite Marl'), usually, as at Jackdaw quarry (Parsons, 1976, p.62), with a gradational contact - see Fig.2. The Brasilia sp. recorded from the top of the Scottsquar Hill Member at Westington Hill quarry (op. cit., p.58), is very similar to specimens recently collected from the top of this same unit at the Frith quarry, Painswick (Buckman, 1895, p.400, bed 20). This would suggest that not only is the Scottsquar Hill Member virtually complete throughout much of the north Cotswolds, but that it forms a relatively isochronous horizon. This undoubtedly refutes the suggestion made by Mudge (1978, pp.620-1), that the Harford Sands represent a lateral facies variant of part of the more southerly Scottsquar Hill Member. The precise age of the Stanway Hill Formation is still rather speculative, although its overall stratigraphic position (see above), suggests a correlation with the concavum Zone: an age which is not out of step with the one recorded ammonite (Parsons, 1976, p.51).

## The Harford Sands Member

The present member is here restricted to the Harford Sands sensu stricto (Buckman, 1888), excluding the 'Snowshill Clay - Tilestone', included in it by Mudge (1978, p.618). The existing type locality (Harford Cutting : Parsons, 1976, p.48), is unsatisfactory, in that the base of the unit has never been exposed. Hence, Happylands quarry (SP128357), is here designated as a hypostratotype (cf. Hedberg, 1976, p.38), where the complete thickness of the Harford Sands (c.2.6m of orange, silty sands and 'doggers'), is seen underlying the Snowshill Clay, and resting disconformably on the Scottsquar Hill Member (see Fig.2). The Naunton Clay is here redefined as a formal bed within the Harford Sands Member, with Jackdaw quarry as its type locality, where it consists of 0.70m of grey and brown, fossiliferous clay (Parsons, 1976, p.57, beds 4-5).

## The Snowshill Clay Member

The original type locality of the informal unit (Cleeve Hill : Worssam & Donovan, p.324 in Donovan & Hemingway, 1963), is unsatisfactory, as it is uncertain that the thin clays present at this locality are in fact contiguous with the thicker deposits found between Snowshill and Blockley. Hence the nearest existing exposure to Snowshill; Happylands quarry; is here formally defined as the type section of the Snowshill Clay Member. Here 1.4m+ of dark blue, weathering brown, sticky clay, is exposed (including the base); whilst a total thickness of 4.7m have been recorded from a shallow commercial borehole, directly to the west of the present quarry.

The 'Tilestone beds'

It is uncertain that the informal beds, previously recorded from several localities as the 'Tilestone' (Parsons, 1976, p.59), in fact represent a single, homogenous unit. In many cases they may include beds best considered part of the Lower-Trigonia-grit Member. Until further research clarifies this problem, it is thought inadvisable to formally redefine this unit.

The Hartley Hill Formation

Those beds preserved between the unconformities at the base of the Upper and Lower-Trigonia-grit Members (= 'Middle Inferior Oolite', Arkell, 1933), are here named the Hartley Hill Formation. At its type locality; Hartley Hill quarry (SO951180-6); this unit consists of approximately 8.0m of bioclastic limestones (Richardson, 1906; Murray, 1969). Elsewhere, notably Cleeve Hill, this Formation is thicker (up to 21.0m) and contains further beds of bioclastic and 'iron-shot' limestones (Richardson, 1929, pp.46-7). This Formation is here partly divided into three, formal Members - see Table 2.

The Lower-Trigonia-grit Member

The existing informal unit, the 'Lower Trigonia Grit' is here retained as a formal Member of the Hartley Hill Formation. The type locality for the re-defined unit remains the same, that is Leckhampton Hill (selected by Worssam, in Donovan and Hemingway, 1963, p.353), where it is represented by approximately 2.0m of ferruginous, 'iron-shot', bioclastic limestone (Ager in Torrens, 1969, p.B43; Murray, 1969, p.545).

The term Lower-Trigonia-grit should be restricted, where possible, to the'iron-shot', ferruginous facies (= mainly oobiomicrites). However, the newly defined base of the Windrush Member (see below), results in the transfer to the present unit of beds previously included in the '*L.buckmani* Grit' (e.g., Buckman, 1895, p.398, bed 8; p.399, bed 6). Whilst these beds are less ferruginous than the bulk of the Lower-Trigonia-grit Member, their highly fossiliferous nature, with an abundant, varied fauna, contrasts strongly with the succeeding, more sandy Windrush Member. Internal,informal, lithological subdivision of these beds is possible. The characteristic, 'iron-shot', highly bioturbated oobiomicrite, which makes up the bulk of this member, has previously been known as the 'Lamellibranch bed' (*op. cit.*, p.399, bed 8). Similarly the top bed of this unit, previously included in the '*L. buckmani* Grit', has been called the '*Serpula* bed' (*op. cit.*, p.409, bed 6; p.413, bed 6). The bulk of this Member has a well documented *discites* Zone age, whilst in the Painswick 'syncline', the top has locally yielded rare, basal *ovalis* subzone, *laeviuscula* Zone ammonites (see below).

## The Windrush Member

The bulk of the beds previously known as the '*L. buckmani* and Gryphite Grits', are here included in a single formal unit; the Windrush Member of the Hartley Hill Formation. Buckman's main criteria for separating the '*L. buckmani*' from the 'Gryphite Grit', was the greater relative abundance of *Lobothyris* in the former (Buckman, 1895, p.390). This is an inadequate basis for the definition of a formal lithostratigraphic unit, especially since there are no lithological criteria for separating these beds at either their type locality; Leckhampton Hill (Murray, 1969, p.545); or at many other localities such as Harford Cutting (Parsons, 1976) and in the Stowell Park bore-hole (Green and Melville, 1956, p.15). In these circumstances they should both be combined in a single formal unit, here called the Windrush Member, after the excellent exposures of those beds in the valley of the river Windrush. At its type locality, here designated as Harford Cutting (SP137218 = the "third from Bourton-on-the-Water"), the Windrush limestone consists of 3.7m of bioclastic limestones (= sparsely sandy biomicrites), alternating with sandy marls (Parsons, 1976, beds 4-9).

The base of this unit may be difficult to define, since there is often a gradational boundary between it and the Lower-Trigonia-grit Member. Where it is present, the Buckmani Bed acts as a useful basal 'marker bed' (Hedberg, 1976, pp.39-40), since it has a highly characteristic lithology, marking, as it does, a sharp influx of quartz sand. It also produces a strong anomaly in Beta and Gamma logs., which makes it easily traceable at the subsurface (Ponsford in Green & Melville, 1956, p.63, fig.6). Lithostratigraphic subdivision of the bulk of the unit is difficult, as it is highly variable. Thus in the Leckhampton area, the base is relatively massive, with rare Gryphaea, whilst the top is thinner bedded, with abundant Gryphaea. By contrast, in the Stroud district, the reverse is true, and it is the top which is more massive and less fossiliferous. The single most distinctive bed, or group of beds is the basal Buckmani Bed. The term 'buckmani - marl' was originally introduced by Buckman (1895, p.413, bed 5), for a more restricted horizon, now included in the basal part of the formal bed(s). At its type locality; here designated as the Frith quarry (SO866082); it is 0.30-0.35m thick (op. cit., p.399, beds 5-6), and is made up at the base, of a grey-brown, soft marl, with crushed shell fragments, whilst the top consists of a fine, orange, quartz sand and silt, which penetrates the irregular base of the bed above. This sequence is typical of much of the Painswick 'syncline' and the southern part of the Cleeve Hill 'syncline', where the basal marl horizon often yields common specimens of Lobothyris buckmani (Davidson). However, at some localities a more complex sequence is found, often with the interdigitation of a sandy limestone between the sand and marl layers (e.g. Cats Brain quarry, Painswick; SO867114).

In the mid-Cotswolds these beds are wholly ovalis subzone, laeviuscula Zone in age. In the north Cotswolds, much of the Lower-Trigonia-grit Member seems to pass laterally into a sandy limestone facies, since here the base of the Windrush Member has yielded discites Zone ammonites (Parsons, 1976).

## The Notgrove Member

The 'Notgrove Freestone' (Buckman, 1888) is here formally redefined as the Notgrove Member of the Hartley Hill Formation, with Notgrove Cutting (SP085209) as the type locality (selected by Worssam in Donovan & Hemingway, 1963, p.241), where it is represented by 3.6m of oolitic limestones, mainly oomicrites (Richardson, 1929, p.76). Since the basal part of this section is now obscured, it is thought advisable to designate the Harford Cutting as a hypostratotype, where the member is 0.40-2.70m thick (Parsons, 1976, p.49). Although ammonites are very rare, these beds appear to be of laeviuscula Zone and subzone age.

The 'Cleeve Hill beds'

There are at present no good exposures of the beds found between the Notgrove and Upper-Trigonia-grit Members, since although the '*H. phillipsiana* beds' are partly visible at the Rolling Bank quarry, Cleeve Hill (SO987267), there are currently no exposures of the '*Bourguetia* beds' and '*Witchellia* Grit' (= '*Perna* bed', Wright, 1860, p.42). These beds all have a very restricted distribution, centred on a small area adjacent to the Cleeve Hill plateau (i.e. at the centre of the Cleeve Hill 'syncline'). Since their detailed inter-relationship cannot be currently established, no formal lithostratigraphic re-definition of these beds can be attempted. If the presence of a bored 'hard-ground' at the base of the '*Witchellia* Grit' (Buckman, 1895, p.417, beds 5/6) could be confirmed, this would suggest the inclusion of this 'Grit', together with the '*H. phillipsiana* and *Bourguetia* beds' in a single formal member, with the re-definition of individual horizons as formal bed(s). The age of these beds is well established, with abundant *laeviuscula* subzone ('*Witchellia* Grit') and *sauzei* Zone ammonite faunas.

The Stroud Formation

The unconformity below the Upper-Trigonia-grit Member, which marks the base of the Stroud Formation, is one of the most clearly defined in the whole Jurassic (Arkell, 1933, p.231). The Chipping Norton Formation (including the Hook Norton Limestone) has been placed within the Great Oolite Group (Sellwood and McKerrow, 1974), the Stroud Formation is thus restricted in the mid and north Cotswolds to the units previously known as the 'Upper *Trigonia* Grit' and '*Clypeus* Grit'. At its type locality, here designated as Rodborough Hill, Stroud, this Formation consists of +6.0m of predominantly oolitic limestone. The Fort Quarry (SO850041) probably shows the best existing exposures in the district, including a good section across the junction of this Formation, with the subjacent Hartley Hill Formation (Richardson, 1907a, p.76). The Stroud Formation is the most important within the Inferior Oolite Group of the Cotswolds, as it has the widest geographic distribution: it is the only one to be found across the whole Cotswold district, and the Mendips, Dorset and Somerset to the south.

## The Upper-Trigonia-grit Member

The existing informal unit, the 'Upper *Trigonia* Grit', is here defined as a formal Member of the Stroud Formation. At its type locality, Leckhampton Hill (selected by Worssam in Donovan and Hemingway, 1963, p.353), this unit consists of about 1.5m (Ager in Torrens, 1969, p.B42) of bioclastic limestone (highly fossiliferous biomicrites), although at other localities up to 3.5m have been recorded (Richardson, 1907a). The 'Upper coral bed' (Witchell, 1882) is here informally defined as the upper-most bed of the Upper-Trigonia-grit Member, as exposures at its type locality, Rodborough Hill, are now too poor for formal redefinition. It is possible that at some Cotswold localities there may be some remnants of horizons older than the Upper-Trigonia-grit, although still deposited after or during the Upper Bajocian transgression. Just to the south of the Mendips the 'Doulting Conglomerate' Bed, of *subfurcatum* Zone age (Parsons, 1975a), is found in exactly this stratigraphic position and may thus warrant separation as a full Member of the Stroud Formation. The

Upper-Trigonia-grit Member is of acris subzone, garantiana Zone age.

## The Clypeus-grit Member

This unit consists of those beds found below the Stroud, 'White Oolite', Chipping Norton Limestone or other Formations of the Great Oolite Group, and above the Upper-Trigonia-grit. This Member, which coincides in its limits with the informal unit of the same name, consists of 12.0m of rubbly oolitic limestone (= intraclastic, pisolitic biomicrites + oobiomicrites) at its type locality, here designated as the first cutting west of Notgrove (SO085209), (Richardson, 1929, pp.75-6). The Clypeus-grit has a disconformity at its base, which explains its over-stepping of the Upper-Trigonia-grit in the north and east Cotswolds (Richardson, 1929, p.73; Arkell, 1947, pp.28-30). This over-stepping results in the Clypeus-grit being the sole Member of the Stroud Formation over much of the Cotswolds. The status of Formation has been suggested for this unit (Kennedy, Sellwood and McKerrow, in Ager et al., 1973, p.2), but this is rejected here as it would necessitate a similar, but unacceptable status for the Upper-Trigonia-grit Member.

Lithostratigraphic subdivision of this unit will undoubtedly prove possible. In particular the basal beds are more massive and intraclastic, whilst towards the top there are thin, harder, usually highly fossiliferous horizons, often with abundant nerineid gastropods. All these beds are of parkinsoni Zone, and probably bomfordi subzone age.

## The upper boundary of the Stroud Formation

The top of the Stroud Formation is defined by the base of the Great

Oolite Group, which in the north and mid-Cotswolds falls at the base of the Chipping Norton Formation (Sellwood & McKerrow, 1974, pp.190-1). Thus in these areas the Stroud Formation is restricted to the Upper-Trigonia-grit and Clypeus-grit Members. It is because of their wide-spread and clear recognition, that these latter two units have been formally defined as Members of the Stroud Formation. In the south Cotswolds additional limestone units appear either above or as partial lateral equivalents of the Clypeus-grit (Stroud 'White Oolite', '*Anabacia* Limestones' and 'Rubbly beds'; see Fig.5, & Richardson, 1907b), which have been included in the Inferior Oolite (Richardson, 1907b). One of the main criteria for determining the base of a Formation should be its mappability (Holland *et al*., 1978, p.8). In the south Cotswolds there is a relatively sharp lithological break, producing a well marked topographic feature, between the top of the Inferior Oolite Group, and the basal Formation of the Great Oolite Group; the Lower Fullers Earth. There is thus no doubt that the base of the latter Formation should define the top of the Stroud Formation. The *fullonicus* Limestone consists of a series of intermittent, argillaceous limestones, interbedded with clays and marls and resting disconformably on the '*Anabacia* Limestones' (including the 'Rubbly beds': Torrens, 1969, p.B18). When deeply weathered it is difficult to differentiate between these former beds, and the bulk of the Fullers Earth, thus the main mappable feature is produced by the top of the *Anabacia* Limestones. Taking this into account,along with their close lithological and palaeontological affinity with the Fullers Earth, it is logical to include the *fullonicus* Limestone in the latter Formation (cf. Torrens, 1969). The '*Anabacia* Limestones' and the 'White Oolite' are thus an integral part of the Stroud Formation.

No attempt is here made to formally define these units, since, far more work is needed on their lateral variation and distribution. A possible result of such work would be to establish the '*Anabacia* Limestones' as a formal Member of the Stroud Formation, and to re-define the 'White Oolite' as a formal bed(s), within an extended Clypeus-grit Member. For the present, there is no difficulty in continuing to use these informal units, since a Formation need not be completely divided into Members (Holland *et al.*, 1978, p.10).

## THE BAJOCIAN AMMONITE FAUNAS OF THE COTSWOLDS

Ammonites are not common in the Cotswold Inferior Oolite and our present knowledge of their distribution is the result of over one hundred and fifty years of intensive collecting. In the period 1880-1910 S. Buckman assembled a large collection of Cotswold ammonites, containing the cream of the material collected from the numerous small quarries open during this time. As well as ammonites which he had collected himself, Buckman's collection was swelled by material from his numerous friends, such as C. Upton and L. Richardson, as well as by specimens purchased from professional collectors and quarry men. Most of these ammonites are now preserved in the British Museum, Institute of Geological Sciences, Oxford University and Manchester Museum collections. The faunas which are discussed below are largely founded on this material, with various additions and amendations based on specimens which I and others have collected *in situ* (over one hundred specimens).

The discites Zone

The horizons which may be correlated with this Zone are very fossiliferous, and they have probably yielded almost as many ammonites as the rest of the Cotswold Bajocian rocks put together. The most prolific source of discites Zone ammonites has undoubtedly been the Lower-Trigonia-grit of the Frith quarry, near Stroud, where a single bed (Buckman, 1895, p.399, bed 8), has yielded large numbers of ammonites, particularly of the genus Hyperlioceras. Ammonites from this locality include: Hyperlioceras cf. liodiscites Buckman, BMNH.C9934; H. subsectum (Buckman), BMNH.C9944, C9955; H. walkeri (Buckman), BMNH.C9929; Darellia alta Buckman, L11236; D. cf. polita Buckman, BMNH.C9941; Reynesella cf. inops Buckman, OUM.J16166; Docidoceras cf. planulatum Buckman, OUM. J2465; Sonninia (Euhoploceras) sp., BMNH.C9933. The preservation of all these specimens (grey shells, yellow, ferruginous, micritic matrix, with common, very fine ferruginous ooliths), is typical of bed 8, which has been confirmed by the location of an in situ specimen of H. cf. rudidiscites Buckman, CP1313, some 1.0m above the top of bed 18 (Buckman, 1895).

To the south of Frith quarry, the Lower-Trigonia-grit first appears beneath the "Upper Bajocian transgression" at Rodborough Hill, Stroud (op. cit., p.394, bed 4). Here it has yielded H. walkeri (Buckman, 1887-1907, p.94); H. cf. liodiscites, IGS.25319; Darellia sp., BMNH.C9928; Reynesella sp., BMNH.C9937 and Docidoceras cf. planulatum, BMNH.C9935. To the north the Lower-Trigonia-grit Member still yields discites Zone ammonites, such as H. discoideum (Qu. in SSB), CP3478, Frampton Mansell railway cutting (SO914028); H. aff subsectum, BMNH.C56095 and Darellia cf. coela Buckman, BMNH.C56098, from Cooper's Hill (SO887142; Channon, 1950, p.242); *Braunsina* cf. *projecta* Buckman, L11143 and *G.* (*Ludwigella*) aff. *stigmosum* Buckman, BMNH.C79539, Leckhampton Hill; *H.* *subsectum* (Buckman, 1887-1907, p.cxxi = ?IGS24751) and *Darellia* sp., IGS27627, from Wistley Hill (SO975185; Buckman, 1895, p.414) and *H.* aff. *subsectum* CP2529 and *G.* (*L.*) aff. *rudis* (Buckman), CP.3677, from bed 15b, Jackdaw quarry (Parsons, 1976). However over much of the north Cotswolds, because of the newly restricted limits of the Lower-Trigonia-grit, the most prolific *discites* Zone faunas come from the base of the Windrush Member. At Harford cutting this horizon (Parsons, 1976, bed 4), has produced: *Darellia* aff. *toxeres* Buckman, *H.* *subsectum*, *H.* *rudidiscites*, *Reynesella* sp. and *S.* (*Euhoploceras*) sp. (*op. cit.*).

All the ammonites cited above are typical of the *discites* Zone, as characterized by the upper part of the 'fossil-bed', Bradford Abbas, near Sherborne, Dorset (Parsons, 1974, p.170). The base of the *discites* Zone in the Cotswolds would appear to coincide with the unconformity below the Lower-Trigonia-grit, as the 'Tilestone bed' of the Stanway Hill Formation has produced a single ammonite indicating a possible *concavum* Zone age for this horizon (Parsons, 1976).

The *laeviuscula* Zone

The *ovalis* Subzone

The bulk of the Windrush Member of the **Hartley Hill** Formation has yielded few ammonites, but those which have been found in the mid-Cotswolds would indicate a correlation with the *ovalis* subzone of the *laeviuscula* Zone. Specimens of *Sonninia* (*Fissilobiceras*) *ovalis* (Buckman *ex.* Qu.), BMNH.C8787-8, from Leckhampton Hill (Buckman, 1895, p.512); *S* (*F.*) aff.

ovalis, Harford cutting (Parsons, 1976, bed 8); S. cf. patella (Waagen), CP1312, from Harford cutting (op. cit. bed 6a); S. (F.) aff. fissilobata (Waagen), CP3338, Cats Brain quarry, Painswick; Trilobiticeras (Emileites) liebi (Maubeuge), BMNH.C9973, from Swifts Hill, Stroud (SO878067) and Witchellia (Witchellia) romanoides (Douvillé) from Swifts Hill, BMNH. C9969 and Stroud Hill, BMNH.C9974 and OUM.J37882, together make up a fauna similar to that recorded from the 'ovalis bed' of Dundry Hill, near Bristol (Parsons, 1974, p.169). The Windrush Member is also the inferred type horizon of Witchellia ('Zugophorites') zugophorus (Buckman, 1909-30, pl.341).

In the Stroud area, the uppermost part of the Lower-Trigonia-grit has also yielded ovalis subzone ammonites. These include S. (F.) aff. fissilobata, CP3343 from the Frith quarry (Buckman, 1895, p.399, bed 7) and S. (?Euhoploceras) aff. acanthera (Buckman), CP3477, from a similar horizon at the Frampton Mansell railway cutting (see Fig.3).

The laeviuscula subzone

Much of the Notgrove Member is virtually unfossiliferous. Only one ammonite has been previously recorded from this deposit, a specimen of S. (F.) aff. ovalis from Whittington (SP013212; Buckman, 1897, p.608), whilst I have collected S. (?Euhoploceras) sp. CP3663, from the top 10 cm of this unit at the first cutting west of Notgrove. The exact age of the above specimens must remain in doubt, and they may well be of ovalis subzone age. In direct contrast, the thin and highly restricted horizon, the 'Perna bed' or 'Witchellia Grit' of the 'Cleeve Hill beds' has produced extensive ammonite faunas from two localities; Rolling Bank quarry, Cleeve Hill and Cold Comfort Farm. Ammonites from the latter include; _Emileia_ (_Emileia_) aff. _brocchii_ (Sow.), IGS.8077; _E._ (_Otoites_) cf. _fortis_, CP3664; _Witchellia_ (_W._) _patefactor_ Buckman, holotype - IGS.47195 and OUM.J37866-9; _W._ (_W._) _glauca_ Buckman, OUM.J37874 and 37872, _W._ (_W._) cf. _sutneri_ (Branco), RUGC.S3140 and _Shirbuirnia_, cf. _platymorpha_ (Buckman), OUM.J37876-7; whilst Rolling Bank has produced _W._ (_W._) sp., OUM.J37881 and 37878, _W._ (_Pelekodites_) sp. OUM.J37880, _Shirbuirna_ cf. _stephani_ (Buckman), BMNH. C76772; _S._ aff. _superba_ (Buckman), BMNH. C76771 and _S._ cf. _trigonata_ (Qu.), OUM.J37879. These faunas are largely identical to that recorded from the 'green-grained marl' of Oborne, Dorset (Buckman, 1893, p.500, bed 9), which is to be correlated with the top of the _laeviuscula_ Zone and subzone (Parsons, 1974, p.176).

The Notgrove Member is probably represented in some parts of the Cotswolds by a thin (-0.50m), highly bored limestone, variously called the 'Pitching' or 'Bored bed' (Buckman, 1893, p.512). This is the type horizon of _W._ (_W._) _pavimentarius_ (Buckman), holotype - IGS.49330, as has been confirmed by the location of _in situ_ topotypes, CP2125, and 2127, from Leckhampton (_loc. cit._, bed 3).

The _sauzei_ Zone

Only one ammonite is definitely known to have been collected _in situ_ from the upper part of the 'Cleeve Hill beds'. This was the specimen of _Skirroceras_ aff. _leptogyrale_ Buckman, OUM.J10801 collected from bed III.1, Rolling Bank quarry (Buckman, 1897, p.609). However, other ammonites probably from this horizon, including _Emileia_ (_Emileia_) cf. _bulligera_ Buckman, CP.3665; _E._ (_E._) aff. _pseudomultifida_ Maubeuge, BMNH.C79434, and

*E.* (*E.*) *vagabunda* Buckman, holotype - IGS.49313 (cf. Arkell, 1951-9, p.15), would indicate a correlation with the *sauzei* Zone 'Brown iron-shot' of Dundry Hill, Bristol (Parsons, 1979).

The *garantiana* Zone, *acris* subzone

Ammonites are not uncommon in the Upper-Trigonia-grit, and specimens of *Strenoceras* (*Garantiana*) spp. have been found at: Cleeve Hill, BMNH. C8822 and C80971; Harford cutting, BMNH.C79330-1, (Parsons, 1976, bed 11); Leckhampton Hill, L11193; Rodborough Hill, BMNH. C8839; Selsey Hill (SO826026), IGS.GSM25134, BUGM.3396; Stantonbury Hill (ST673636), Cb4982 (Tutcher, 1903, p.162) and Stroud Hill (Buckman, 1895, p.395). The latter specimen came from an horizon which Witchell (1882, p.60) correlated with the 'Upper coral bed'. There is no reliable evidence to suggest that the 'Upper coral bed' is any younger than the *garantiana* Zone. The specimens of *Lissoceras psilodiscum* (Schloenbach) from Wotton-under-Edge, RUGC.J523, (Richardson, 1910a, pp.103-4) and Stantonbury Hill (Tutcher, 1903, p.163), BUGM.89, which Buckman (in Tutcher, 1903, p.163) considered as indicating a *parkinsoni* Zone, *truellei* subzone age for this horizon are not diagnostic. This species ranges throughout the Upper Bajocian from the *garantiana* Zone (Parsons, 1975b, bed 13) up into the Bathonian (Krystyn, 1972, p.249). Other ammonites from the Upper-Trigonia-grit include *Parkinsonia rarecostata* (Buckman) from Long Wood, Stroud, BMNH.C9171; *P.* cf. *subarietis* Wetzel, CP3244, railway cutting west of Notgrove (SP085209); *Leptosphinctes* aff. *meseres* (Buckman), BUGM.3396 and *L.* sp. BMNH.C80972 from Nibley Knoll (ST743956), *Cadomites* (*Polyplectites*) cf. *gracilis* (Westermann) from Upton Cheyney (ST694699), BUGM.3389-3392, (= *P.* cf. *linguiferus*, Richardson, 1910a, p.90); Oppelia (O.) aff. subcostata (J. Buckman), from Brimpsfield, (SO931125), RUGC.R3074, (Richardson, 1903, p.387) and Leptosphinctes sp., BMNH.C9178 from Mount Surat, Rodborough. All these ammonites would support a correlation with the acris subzone of the garantiana Zone, as with the 'Astarte bed' of south Dorset (Parsons, 1975a, fig.2). There is thus no evidence for the presence of any representatives of the bulk of the garantiana Zone (= dichotoma, subgaranti and tetragona subzones).

The parkinsoni Zone, bomfordi subzone

Members of the genus Parkinsonia are not uncommon in the Clypeus-grit. Specimens from this horizon include: Parkinsonia (Parkinsonia) cf. crassa Nicolesco (cf. Arkell, 1951-9, text fig.58), from, Harford cutting, BMNH.C8831 and CP2748; Roundhill Fox-covert (SP130219), CP2835, and Fawler (SP372173), OUM.J1187-8: Parkinsonia (P.) eimensis (Buckman, 1909-30, non Wetzel), from Roundhill Fox-covert, P. Hackling collection and Harford cutting, CP2940; P. (P.) bomfordi Arkell, from Fawler, OUM. J1180 and Upper Coberley (probably the Seven Springs quarry, Richardson, 1933, p.26), BMNH.C8828; P. (?Okribites) aff. parkinsoni (Buckman 1909-30, non Sow.), from Harford cutting, CP3134; the first cutting west of Notgrove, CP2837 and Little Tew (SP372 290), IGS.AH37. These ammonites suggest a correlation with the bomfordi subzone of the parkinsoni Zone. However, the distribution of the Parkinsonids is still very badly known, and further work is needed on the stratigraphy of the Dorset parkinsoni Zone, before any reliable, detailed correlations can be made.

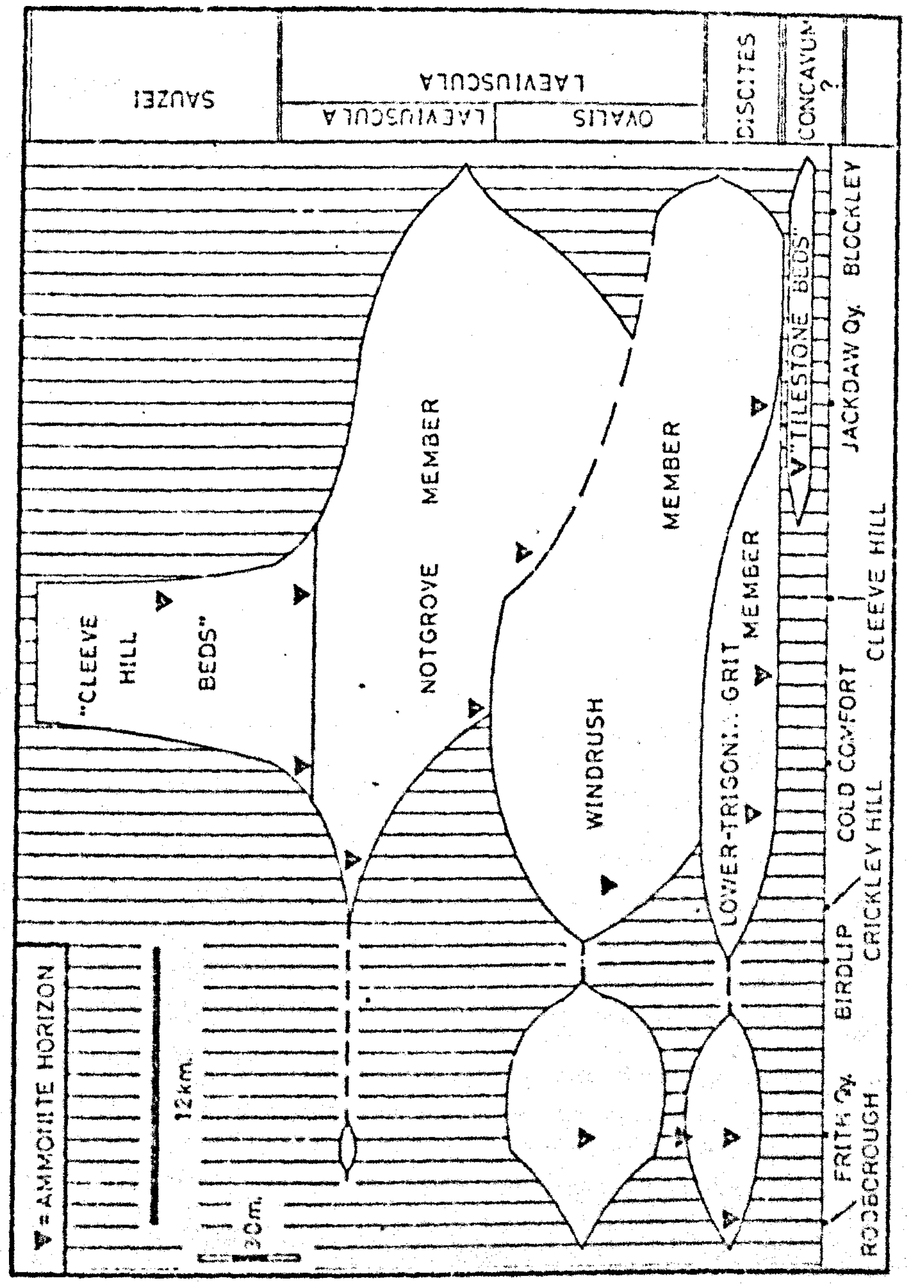



Figure 3.

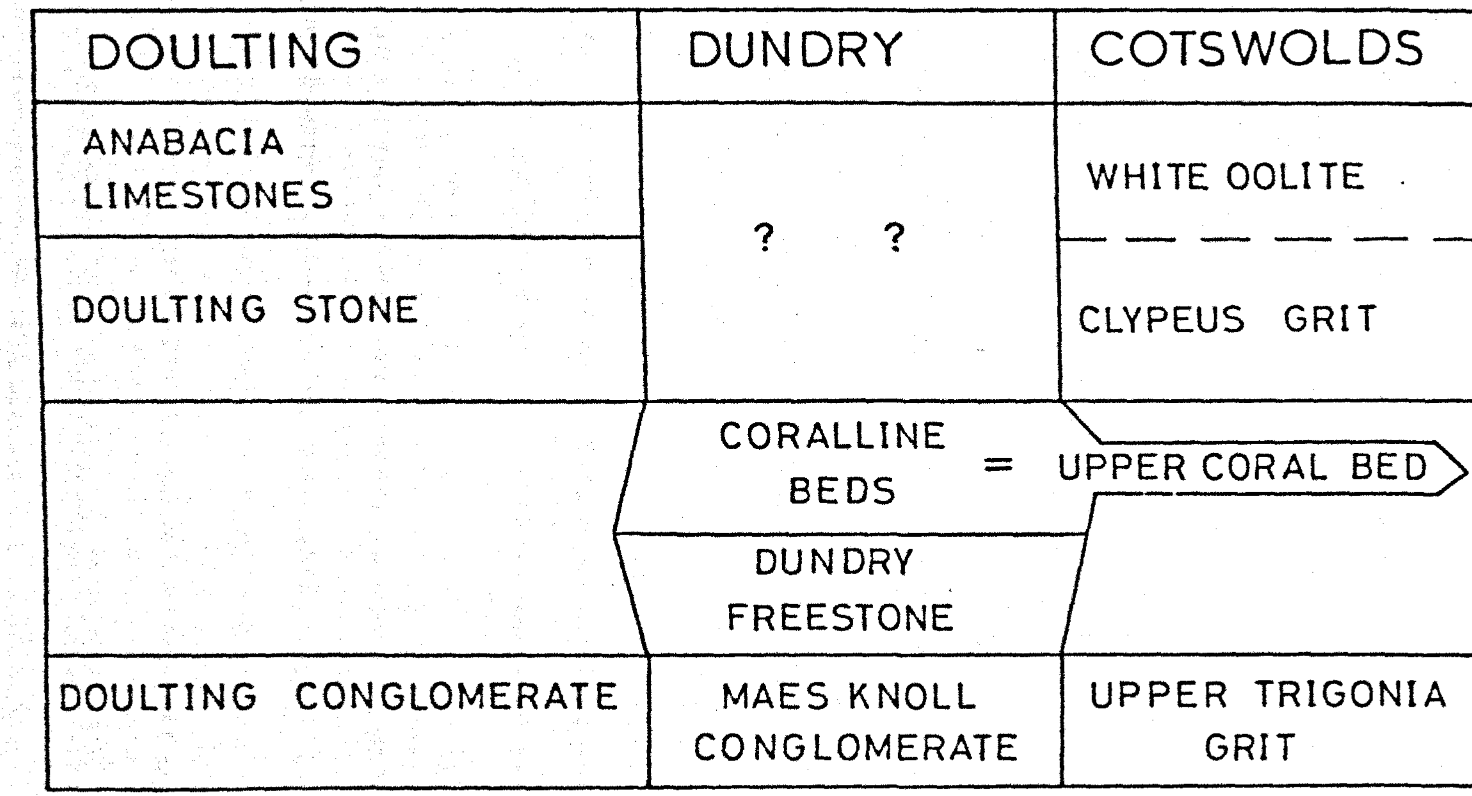
A schematic correlation of the Lower Bajocian, Hartley Hill Formation and the "Tilestone beds" of the Stanway Hill Formation in the mid and north Cotswolds, which is approximately to scale.

## CORRELATION OF THE COTSWOLD BAJOCIAN ROCKS

The correlation of the constituent Members of the Hartley Hill Formation is straightforward. Apart from minor changes in nomenclature, the correlation summarised in figure 3 is essentially the same as that put forward by Buckman (1895 and 1901) and Arkell (1933). There are however, more problems with the correlation of parts of the Stroud Formation in the south Cotswolds. A summary of the correlation suggested here is shown in figure 5. This differs in some important respects from that put forward by Richardson (1907b, pp.386-8 and 420-2, Tab.1 and fig.4; 1916, p.485), who suggested a more complex sequence, see figure 4. Richardson considered the 'Dundry and Doulting Freestones' as distinct deposits and hence recognized the following horizons in the Mendip/south Cotswold district:

| | | |
|---|---|---|
| | | ( Rubbly beds |
| | | ( *Anabacia* Limestones |
| 'Top beds' | = | ( Doulting Stone |
| | | ( Upper Coral bed |
| | | ( Dundry Freestone |
| | | ( Upper *Trigonia* Grit |

Unfortunately this succession is largely artificial, as it is the result of mis-correlation between three different areas (the Doulting district, the Cotswolds and Dundry Hill). No single locality has been described which has shown convincing exposures of all of the above deposits. Whilst there is an area of over-lap between the Cotswold and Mendip districts, which allows a degree of lithostratigraphic correlation, the isolation of Dundry Hill demands the use of biostratigraphic methods, as




Text figure 4.

The lithostratigraphic subdivisions of the 'Upper' Inferior Oolite (Stroud Formation) recognized by Richardson (1907b, 1910a & 1916) in the Mendips and south Cotswolds.

it is impossible to trace the lateral variation of these beds. Unhappily Richardson in the latter case relied heavily on the evidence of facies controlled faunas, such as that from the 'Upper coral bed' (Richardson, 1907b, p.387). This led him to make correlations which are now at variance with the ammonite evidence.

The Doulting district

In the Doulting railway cutting (ST51424), the Inferior Oolite is represented by the '*Anabacia* Limestones', 'Doulting beds' and by a basal conglomerate - the 'Doulting Conglomerate' (Richardson, 1907b, p.390). Richardson (*op. cit.*, p.386), considered that the 'Conglomerate bed' was to be correlated with the 'Upper *Trigonia* Grit' (*garantiana* hemera), the 'Doulting beds' with the '*Clypeus* Grit' (*truellei* hemera) and the '*Anabacia* Limestone' with the 'White Oolite' of Stroud (pre-*zigzag* hemera), although he had little or no ammonite evidence for these assumptions. These correlations made the presence of an unconformity necessary between the 'Doulting beds' and the 'Conglomerate bed', in order to explain the absence of the 'Dundry Freestone' and the 'Upper coral bed' at Doulting - see Fig.4.

Recent work has changed this interpretation. The 'Doulting Conglomerate' is now known to be of *subfurcatum* Zone age, whilst ammonites indicating the presence of the *garantiana* Zone have been found in the 'Ragstone' (Parsons, 1975a), that is the basal part of the 'Doulting beds' (Richardson, 1907b, p.396). More is now also known of the ammonite distribution within the '*Anabacia* Limestones'. It is evident that the *parkinsoni*/*zigzag* Zonal boundary falls within these beds, and that the lower half of the '*Anabacia* Limestones' is to be correlated with the *bomfordi* subzone of the *parkinsoni* Zone (Arkell, 1951-9, p.155; Torrens, 1969, p.B19). Since they fall between rocks of known *garantiana* and upper *parkinsoni* Zone age, it is logical to expect the bulk of the upper 'Doulting beds' to be *parkinsoni* Zone, *truellei* subzone in age. This is partly confirmed by the rare ammonites which are thought to be from this horizon: *Parkinsonia* cf. *dorsetensis* (Wright), Mells station cutting (ST710515, Richardson, 1907b, p.405); *Bigotites* cf. *lanquinei* (Nicolesco), BUGM.3401, Great Elm, Vallis Vale; *Prorsisphinctes* sp., BUGM.13459, Vallis Vale and *Parkinsonia* cf. *pseudoparkinsoni*, Wetzel BUGM.87, Holway.

The Dundry district

Richardson never published any detailed account of the Dundry Inferior Oolite, and it is evident from his references to Dundry, that he relied heavily on Buckman's work (Buckman and Wilson, 1896). The succession of beds within the Stroud Formation on Dundry is apparently simple, but it has been confused by poor exposures and a high degree of cambering. The beds in question, the 'Coralline beds', the Dundry Free-stone and the basal, Maes Knoll Conglomerate, are poor in ammonites and hence difficult to date. Buckman found sufficient ammonites to indicate a *garantiana* hemera age for the Maes Knoll Conglomerate, but above this any correlation was pure conjecture (Buckman and Wilson, 1896, Tab.IV). Buckman suggested that the Dundry Freestone and 'Coralline beds' might be the equivalent of the '*Clypeus* Grit' and the 'White Oolite' of Stroud respectively (*op. cit.*, Tab.V).

Richardson made several amendments to these suggestions, since he considered that the micro-fauna from the 'Coralline beds', particularly the micro-morphic brachiopods, indicated a correlation with the 'Upper coral bed' of the Cotswolds (Richardson, 1907b, p.387). If this were so, then in a complete succession, the Dundry Freestone would have to be stratigraphically lower than the 'Doulting Freestone', and separated from it by the 'Upper coral bed', or its equivalents, see figure 4. The facies controlled faunas from these coral beds were thus the only evidence for the duplication of the Freestone beds in Richardson's interpretation of the upper Inferior Oolite succession. Unfortunately only a few additional ammonites have subsequently been collected from these Dundry beds. Apart from the specimens of _Garantiana_ recorded from the Maes Knoll Conglomerate (Buckman and Wilson, 1896, Tab.V), the specimens of _Strenoceras_ (_Pseudogarantiana_) aff. _dichotoma_ (Bentz), from Maes Knoll (ST598661), Cb4963, and of _Parkinsonia_ _rarecostata_ from the West End of Dundry Hill (ST553670), BUGM.3397, and Rackledown quarry (ST572654), Cb4962, all confirm that this horizon is to be correlated with the _acris_ subzone of the _garantiana_ Zone (Parsons, 1979). Ammonites are extremely uncommon above this horizon and include; _Parkinsonia_ cf. _parkinsoni_ (Wetzel _non_ Sow.) from 1.0m above the best freestone beds on Dundry Down, BUGM.13458; _Parkinsonia_ _parkinsoni_ (Buckman _non_ Sow.), Cb4961, from Dundry village and _Bigotites_ cf. _tuberculatus_ (Nicolesco), Cb4959, from a freestone quarry at West Dundry. These ammonites suggest a correlation of the Dundry Freestone with the _parkinsoni_ Zone and possibly with the _truellei_ subzone. All that can be said of the 'Coralline beds' is that they are _parkinsoni_ Zone, and probably just post-_truellei_ subzone in age. The two ammonites known from the latter horizon; _Leptosphinctes_ sp., South Main-road quarry (ST567655), Cb4993, and _Cadomites_ (_Polyplectites_) aff. gracile (Westermann), Rackledown quarry, Cb4994; are unfortunately too small and badly preserved to give a precise correlation.

The South Cotswolds

The upper Inferior Oolite exhibits typical Cotswold facies as far south as Chipping Sodbury. South of this point these horizons gradually assume their Mendip characteristics, with a decline in the amount of oolitic limestones present, associated with a marked relative increase in bioclastic material. Richardson (1910a), because of the rarity of ammonites, was forced to use lithostratigraphic methods, supported by the closely related facies controlled faunas of bivalves, brachiopods and echinoderms, to correlate these highly variable beds. He considered that the 'Upper Trigonia Grit' persisted as far as the Mendips, whilst the 'Doulting beds' and 'Anabacia limestones' were the equivalent of the 'Clypeus Grit' and Stroud, 'White Oolite' respectively (Richardson, 1910a, pp.85-7), - see figure 4. Richardson had little or no ammonite evidence to support these correlations, and unfortunately this situation has shown little subsequent improvement. Most of the ammonites which have been found between Bath and the Mendips are either of limited stratigraphic significance, or poorly localized. The most valuable ammonite fauna has come from the brown, crinoidal, ferruginous, slightly de-calcified limestone, which is the undoubted lateral equivalent of the Upper-Trigonia-grit. Specimens from this horizon include: Strenoceras (Garantiana) sp. Dunkerton (ST700589), BUGM.86, (Tutcher and Trueman, 1925, p.624); S. (G.) cf. garantiana, Midford Railway cutting, (Richardson, 1910b, p.98); S. (G.) garantiana, Cb4964, S. (G.) cf. garantiana (Pavia non d'Orb.), Cb4965, S. (G.) sp. Cb4967 and S. (Pseudogarantiana) cf. minima (Wetzel), Cb4966, Limpley Stoke and Murhill, Bath (ST782612-795607); *Parkinsonia rectangularis* (Wetzel), Viaduct quarry, Limpley Stoke, Cb4960 and *S.* (*G.*) sp., Stantonbury Hill, Cb4982: all of which indicate a correlation with the *acris* subzone of the *garantiana* Zone.

Correlation of the Doulting, Dundry and south Cotswold districts

Using the ammonite evidence it is possible to produce a simple interpretation of the Stroud Formation in the south Cotswolds - see figure 5. First the 'Doulting Conglomerate', with its *subfurcatum* Zone fauna is unique, as it has no known Cotswold or Dundry equivalents. Secondly the *garantiana* Zone beds are the most easily correlated, since ammonites of this age have been found in the Cotswold Upper-Trigonia-grit, the Dundry Maes Knoll Conglomerate and in the Doulting 'Ragstone'. The latter record thus totally **discredits Richardson's interpretation (see Text figure 4) of the correlation of these** beds , since the Dundry **Fst. is** unquestionably post-*garantiana* Zone in age. Such evidence as is available would suggest that much of the 'Doulting Freestone' *sensu stricto*, is *truellei* subzone in age. Since the 'Doulting' and Dundry Freestones are thus possibly of the same sub-zonal age, occur in identical stratigraphic positions resting disconformably on *garantiana* Zone rocks, and since no locality has been convincingly recorded at which they are both preserved, it would seem unnecessary to maintain them as distinct stratigraphic units. As the Dundry Stone or Freestone has priority, it has been re-defined as a formal Member of the Stroud Formation (Parsons, 1979) with Dundry Down quarry (ST552666), Dundry as its type locality, where it consists of 4.6m of massive bioclas-

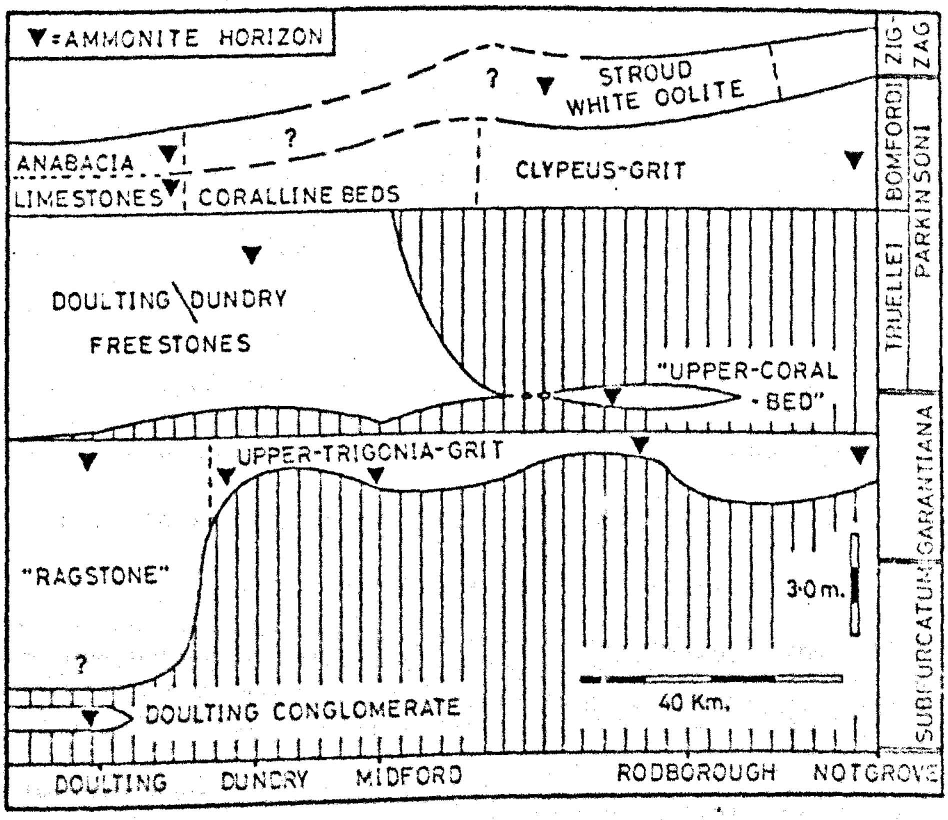



Figure 5.

A schematic correlation of the Upper Bajocian, Stroud Formation in the Mendips and south Cotswolds.

tic limestone.

The Clypeus-grit Member of the Cotswolds can be correlated with a basal part of the '*Anabacia* Limestones', since they both contain *bomfordi* subzone faunas. Taking their relative position into account, it is likely that the 'Coralline beds' are also to be correlated with this subzone, although this needs to be confirmed by the location of further *in situ* ammonites. This latter correlation is partly substantiated by the rare occurrence in the 'Coralline beds' of the characteristic echinoid *Clypeus ploti* Klein (T. Fry, pers. com., 1974). There is thus probably a disconformity over much of the Cotswolds between the Clypeus-grit and Upper-Trigonia-grit Members, which marks the position of the absent Doulting/Dundry Freestones (Parsons, 1979). The so-called 'Upper coral bed' is of limited stratigraphic significance. It is probably of *garantiana* Zone age in the Stroud district, but elsewhere, such as Timsbury Sleight (Richardson, 1907b, p.413), it could be of any age. There is no stratigraphic value to the debris produced by the erosion of corals and their associated facies fauna. These correlations are summarized in figure 5. It must however be stressed that this is still only a provisional interpretation, which must be followed up by further *in situ* ammonite collection.

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# 2C. A STRATIGRAPHIC REVISION OF THE SCARBOROUGH FORMATION, MIDDLE JURASSIC, OF NORTH-EAST YORKSHIRE

CONTENTS

SUMMARY

A resumé of previous work on the stratigraphy of the Scarborough Formation (Bajocian Stage, Middle Jurassic) and an analysis of its ammonite faunas are given. It is shown that the upper part of the Scarborough Formation spans the Romani, Humphriesianum and Blagdeni subzones of the Humphriesianum Zone, whilst the lower part is to be correlated with a lower, but as yet unspecifiable Zone. The Lithostratigraphy of this Formation is described, several new, formal lithostratigraphic units are introduced (the Hundale shale, the Ravenscar Shale and the White Nab 'Iron-stone' Members) and the main coastal exposures of this Formation at Gristhorpe, Scarborough, Cloughton and Ravenscar are described.

# I. INTRODUCTION

The Jurassic rocks of North-East Yorkshire were some of the first in the World to be the subject of detailed scientific study. In the early part of the Nineteenth Century notable pioneer geologists such as W. Smith, A. Sedgwick, J. Phillips, W. Williamson, all left their mark on the progress of Jurassic Stratigraphy in Yorkshire. Towards the end of that century however, the focus of Jurassic workers had shifted again towards the South of England, and to the present day this area of the country has been the more intensely studied, often at the expense of other districts. This picture of relative neglect of the Yorkshire Jurassic, is true of the particular horizon which is the subject of this paper; the Scarborough Formation, (Middle Jurassic, Bajocian Stage) - see Table 1. Our knowledge of the stratigraphy of this unit, as based on well localised ammonite collections, has not improved since Williamson's work of 1840. Whilst it is true to say that ammonites are not common in this marine intercalation within the largely non-marine 'Deltaic Series' (Ravenscar Group, Hemingway & Knox, 1973), a careful search of the more extensive exposures of the Scarborough beds, will not usually go unrewarded. Since, as I have said, large areas of exposure are needed, in order to 'shorten the odds' of finding an in situ ammonite, only the coastal exposures are of any real value for stratigraphic work. Of these, the exposures at Ravenscar, Hundale Point (Cloughton), White Nab (Scarborough) and Gristhorpe Bay are the most extensive and accessible (see Text fig. 1) and are described here.

The following account summarises the previous stratigraphic

| | | |
|---|---|---|
| Ravenscar Group | Scalby Formation | |
| | Scarborough Formation | |
| | Cloughton Formation | Gristhorpe Member |
| | | Lebberston Member |
| | | Sycarham Member |
| | Eller Beck Formation | |
| | Saltwick Formation | |

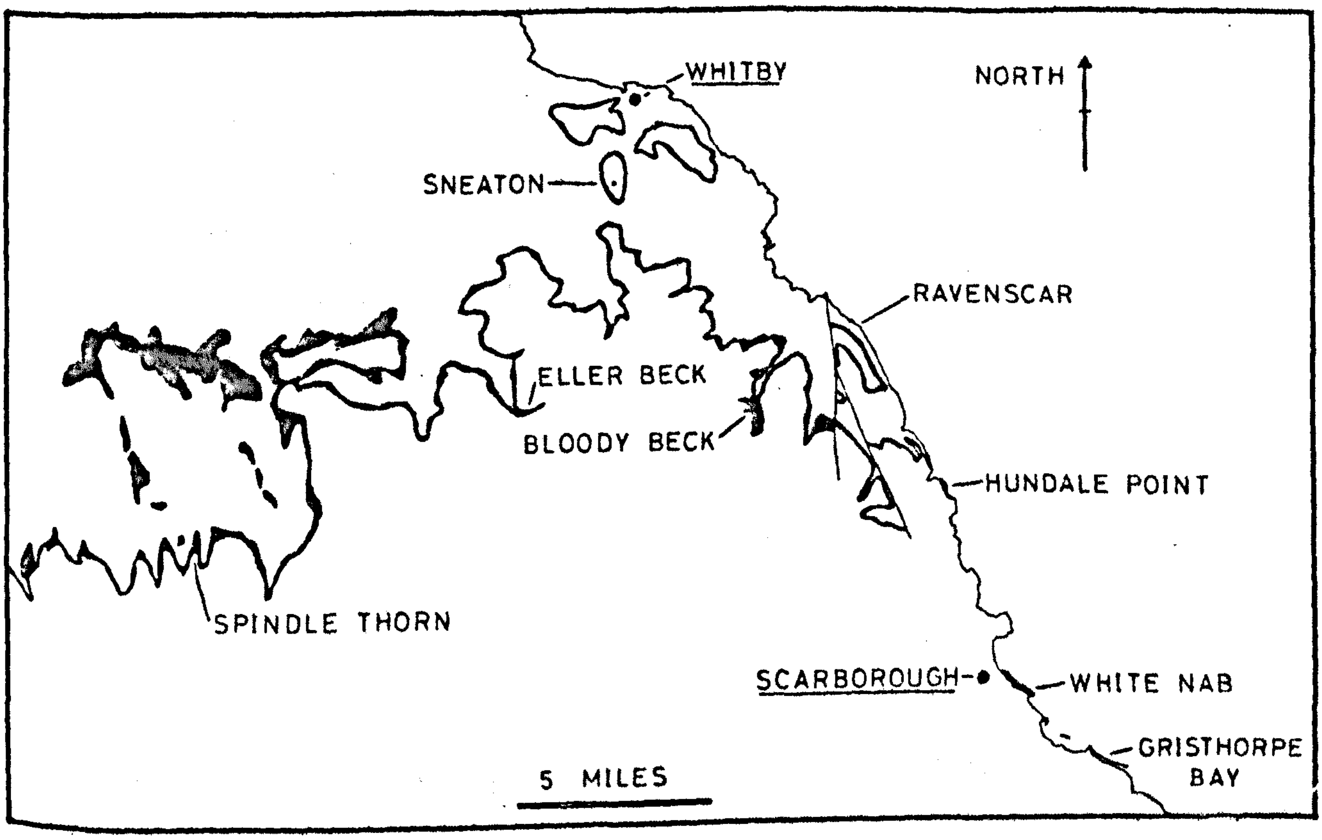
Table 1.

The lithostratigraphic subdivisions of the Ravenscar Group in north-east Yorkshire, after Hemingway and Knox (1973).

work on these beds, as well as giving details of the relevant ammonites in existing Museum collections, my own collections and those of M. Bradshaw, G. Farrow, Professor P.C. Sylvester-Bradley and J.K. Wright. These new ammonite records have enabled a more detailed correlation to be made of the Scarborough Formation and have made the task of lithostratigraphic subdivision that much easier.

## II. HISTORY OF PREVIOUS RESEARCH

The marine horizons within the Ravenscar Group are relatively thin, and escaped the notice of many of the earlier workers, who grouped all of the non-marine sandstones together. Thus Conybeare and Phillips (1822) correlated all of these beds with the Inferior Oolite - Fuller's Earth series and Sedgwick (1826), who recorded specimens of '*Perna*', *Trigonia* and '*Avicula*' from what were later to be known as the Scarborough Beds of White Nab, (Sedgwick, 1826, p.357), included them all within his 'Newer Coal Formation', (*op. cit.* p.353). It was John Phillips who gave the first detailed description of the Scarborough Formation, which he variously called the 'Bath Oolite' or 'Grey Limestones', (Phillips, 1829, p.140), and who recorded the first ammonite from this horizon; '*Ammonites*' (*Teloceras*) *blagdeni* Sowerby, from White Nab, (*op. cit.* p.152). In spite of recording this typical Bajocian ammonite species, Phillips was able to state - "the Grey Limestone of the Yorkshire Coast is equaeval with the Great or Middle Oolite of Bath" (*loc. cit.*). In the second edition of his 'Illustrations of the Geology of Yorkshire', Phillips (1835), gave a few more details of the Scarborough Beds, but recorded no further ammonites.




Text figure 1

A sketch map of the main outcrops of the Scarborough Formation in the north-east Yorkshire Moors, showing the location of the major localities cited in the text.

Williamson (1840) gave a detailed section of what he called the 'Great or Bath Oolite', of White Nab, Scarborough, and also gave the first well localised records of ammonites from this horizon; citing '<u>Ammonites</u>' <u>blagdeni</u> from his bed d. and more rarely from bed f, (Williamson, 1840, pp.231-3). This last account is one of the most important works on the Scarborough beds, and Williamson's section is repeated, in a slightly modified form, by several subsequent authors. Morris and Lycett (1851-5) in their famous monograph continued to include the Scarborough beds within their concept of the Great Oolite, in spite of their comment that they "possess few mineral features which serve to connect them with their supposed equivalent in Gloucestershire" (Morris & Lycett, 1851-5, p.VI). Apart from specimens of <u>Belemnites</u> <u>giganteus</u> and <u>A</u>. <u>blagdeni</u>, Morris and Lycett figure one ammonite of real interest from the Scarborough beds, <u>A</u>. <u>braikenridgi</u>, which was forwarded to them under the manuscript name <u>A</u>. <u>triptolemus</u>, by Bean. This latter specific name was rejected by them, but was subsequently resurrected by Buckman,(1912).

Oppel (1856) was able to anticipate Wright's correlation of the Scarborough beds, with the Inferior Oolite of Southern England, when he stated (<u>op</u>. <u>cit</u>. p.340) - "I am convinced that Phillip's Cave Oolithe (or Bath or Great Oolite) is entirely identical with the <u>A</u>. <u>humphriesianus</u> schicten of other areas" and recorded the following from Scarborough to support this conclusion; '<u>Belemnites</u>' <u>giganteus</u>, <u>A</u>. <u>blagdeni</u> <u>A</u>. <u>humphriesianus</u>, and <u>A</u>. <u>subcoronatus</u> Oppel. Phillips however still stuck to his correlation with the 'Bath Oolite' (Phillips, 1858) and it was not until the publication of Wright's paper (1860), that he was willing to admit his error ....... "Dr. Wright has lately placed before the Society a proposal to assign to the Inferior Oolite a portion of the sandy, shaly, irony and calcareous beds which Professor Morris and myself refer to .... the Great Oolite of Bath. .... In the section referred to, between unequivical Lias and unequivical Cornbrash, there have been gathered very few ammonites...... In addition to '*Ammonites*' *blagdeni*, which was found at Gristhorpe so long ago, the diligent naturalists of Scarborough have collected ..... *A. murchisonae* ..., *A. humphreysianus* and *A. parkinsoni* ..... which makes the palaeontological evidence in favour of the slightly greater antiquity of these Oolitic beds preponderate" (Phillips, 1860, p.xli). At this time Phillips also recorded a specimen of *A. humphriesianus*, which he had found at Gristhorpe in 1855, (*op. cit.* p. xlii). Wright, although finally getting the age of the Scarborough beds correct in fact added very little to our knowledge of these beds, since he merely repeated Williamson's section; with *A. humphriesianus* and *A. braikenridgi* in addition to *A. blagdeni* from White Nab, (Wright, 1860, p.29).

We have now reached a lull in the progress of research on the Scarborough Formation. Hudleston, who introduced the term 'Scarborough limestones', rather than 'Grey limestones', (Hudleston, 1874, p.292) and Fox-Strangways (1892, 1904 & 1915) described many detailed sections, but recorded no new ammonites, except for "*Ammonites laeviusculus*" (= ? *Dorsetensia* sp.), from Hundale, (Hudleston, 1882, p.147).

The honour of recording the first members of the genus *Dorsetensia* from the Scarborough beds must go to Drake (1903), who pre-empted Buckman's identification of material from the Herries collection by four years. In a short, and totally forgotten note in the 'Naturalist', Drake recorded two specimens of Dorsetensia subtecta Buckman from the Scarborough beds of Hundale Point, one from his own collection and the other from that of a friend, G. Sheppard, (Drake, 1908, pp.296-7). In the same paper Drake also mentions two specimens of Normannites braikenridgi macer (Qu.), which he had collected from the fore-shore at Scarborough. It is unfortunate that neither Drake nor Buckman (1912) made any attempt to give an accurate horizon for these specimens of Dorsetensia , and it has taken to the present day, to locate the faunas in situ.

The most important stratigraphic work on the Scarborough beds is undoubtedly that of Richardson (1912), who, in the company of E.T. Paris, had studied in detail the outcrop of these beds. Richardson introduced several new, named lithostratigraphic units, proposed a new name for the whole series; the Scarborough beds rather than 'Scarborough limestone', since there is in fact very little limestone present; as well as recording several species of ammonites. Within the main body of his paper Richardson (1912, p.195) recorded Teloceras coronatum (Qu., non Brugière), Stepheoceras subcoronatum (Oppel) and Parkinsonia sp. from White Nab; whilst in an Appendix, Buckman discussed the following species Skirroceras ? triptolemus (Bean m.s.), Teloceras sp. nov. (= T. blagdeniformis (Roche)), T. coronatum (Qu.), Stemmatoceras subcoronatum (Oppel), Stepheoceras cf. zieteni (Qu.), S. cf. pyritosum (Qu.), Dorsetensia romani and D. liostraca S.B., which were either re-interpretations of material previously recorded from the Scarborough beds, or new records from the Herries collection, (Buckman, 1912, pp.205-8).

Buckman used the Zonal divisions of the Bajocian established by Mascke in North Germany, and from the previously cited specimens, concluded that the Scarborough beds spanned Mascke's Stemmatoceras, Stephanoceras, Stepheoceras and possibly the basal Teloceras Zones, (op. cit. p.208). These Zones all fall within Buckman's Blagdeni hemera, (Buckman, 1910).

Arkell's well known synopsis of the British Jurassic, (Arkell, 1933), is positively misleading as far as the Scarborough beds are concerned. Arkell quoted Buckman's above mentioned ammonite identifications, and correctly inferred a Blagdeni **zone** date for this fauna, (op. cit., p.221). However, Arkell made the serious mistake of following Richardson's generalised division of the Scarborough beds into three main sections; an upper shale division, a middle sandstone division and a lower limestone division, and solely on this basis, made the assumption that all the ammonites found had come from the lower limestone division. It was not until 1965, that Bate, pointed out that the opposite is in fact true, and that most ammonites come from the upper portion of the sequence, (Bate, 1965, p.93). In the forty years subsequent to the publication of Richardson's paper, there has been very little progress in elucidating the stratigraphy of these beds. In 1951, Sylvester-Bradley recorded a single specimen of Dorsetensia pulchra S.B. from Monk's Walk Wood, Sneaton, (Hemmingway, 1951, p.119), and since that time there have been various other records of Dorsetensia from the coast. Rare specimens of Dorsetensia have been recorded from Ravenscar, (Hemmingway, et al., 1969, p.C18), and from Hundale point, (Hemingway et al., 1963, p.19).

In 1953, Sylvester-Bradley gave a useful summary of the best exposures of the Scarborough beds, and cited Teloceras blagdeniformis (Roche) as a typical ammonite, following Cox and Arkell's (1948-50) re-identification of the Teloceras blagdeni Sow., figured by Morris and Lycett, (1851-5, Pl. xiv. fig 3). Other recent publications, covering the Scarborough Formation include, Farrow's work on the trace-fossils, where several unspecified ammonite horizons are recorded in a text figure, (Farrow, 1966, text fig. 3); Bate's work on the Ostracod faunas, where, as well as giving numerous highly detailed, measured sections, he divided the Scarborough Formation between two Ostracod zones; an upper zone of Glyptocythere scitula Bate and a lower of G. polita Bate, (Bate, 1965), and Hemingway's general and sedimentological description of these beds, where he unfortunately assigned them to the Bathonian Stage (Hemingway in Rayner & Hemingway, 1974, p.185).

This then has been the progress of stratigraphic research on the Scarborough Formation, and it is sad to note that there have been no records of ammonites accurately collected in situ, from measured sections, since Williamson's work of 1840.

## III. BIO-STRATIGRAPHY OF THE SCARBOROUGH FORMATION

The ammonite faunas to be described below and summarised in text fig. 3, may all be included within the Humphriesianum Zone of the Lower Bajocian. A three-fold subzonal division of this Zone is adopted here -

| | |
|---|---|
| | Blagdeni subzone |
| Humphriesianum Zone | Humphriesianum subzone |
| | Romani subzone |

This follows a similar subdivision of the Humphriesianum Zone described from the Basse Alpes of South-East France, (Pavia & Sturani, 1968), but uses pre-existing subzonal indices, rather than any new terminology; thus the Romani subzone (Haug, 1891) = the Cycloides subzone, (Sturani, 1971).

The stratigraphy of the North German Bajocian, of which the Yorkshire rocks are merely a continuation, mirrors these subdivisions.

| Subzones used here | Zones of Mascke 1907 | | Zones of Kumm, 1952 |
|---|---|---|---|
| Blagdeni | Teloceras | = | Blagdeni |
| Humphriesianum | Stepheoceras | = | Humphriesi |
| Romani | ( Stephanoceras | = | Umbilicum |
| | ( Stemmatoceras | = | Coronatum |

NOTE:

In the following section specimen numbers prefixed by CP. refer to specimens in the author's collection, and by G. to specimens in the Scarborough Natural History Museum. Secondly any bed numbers quoted from the Gristhorpe, White Nab and Hundale Point exposures refer to the sections which are re-described here, whilst bed numbers quoted from any other sections are mainly those used by Bate (1965).

(a) The subzone of Dorsetensia romani (Oppel)

The lowest ammonite collected in situ during the course of this work was a specimen of Stephanoceras (Skirroceras) sp. from the lower part of the Spindle-Thorn Limestone (bed 14), Hundale Point (National Grid Reference, TA025948), some 0.43m. above the top of the Crinoid Grit. This specimen (CP.3094), which is too squashed and fragmentary for positive identification, probably belongs to the S. (S.) nodosum

(Hyatt) - macrum (Qu. emend. Renz) group, which is typical of the middle Humphriesianum Zone in south Germany, but which also occurs as low as the Romani subzone. From further up in the Spindle-thorn limestone a single specimen of Dorsetensia sp. has been observed in bed 18d, but it was too squashed and distorted to facilitate extraction. Directly above this horizon, in the base of the Ravenscar Shale, specimens of Dorsetensia become relatively abundant. In the small cliff in the Ravenscar shale, just to the south of the actual point at Hundale, specimens of Dorsetensia have been found at the following heights above the base of bed 20 : D. cf. deltafalcata (Qu.), + 0.70m. (CP3067); D. cf. liostraca S. Buckman, + 1.7 & + 2.9m. (CP2645); D. cf. romani, + 0.70, + 2.80 & + 2.90m. (CP.2223, 2723, 2728 & 9), and D. spp. + 1.1 + 2.80m. (CP.2730 & 3064). Similarly on the fore-shore, three, large specimens of D. liostraca (CP.2681, 2964 & 2987) were found in the shale reefs at a similar horizon to those specimens found in the cliff.

This locality at Hundale Point has in the past been the source of numerous specimens of Dorsetensia. Apart from those ammonites mentioned by Drake (1908), which were destroyed, along with the Hull Museum in the last war, the Herries collection, now in the York museum, contains several specimens of Dorsetensia from Hundale. The three specimens identified by S. Buckman from this collection, have been located, since they still bear L. Richardson's labels. I have cleaned and developed these specimens and they can now be more confidently identified as D. aff. romani (Oppel), D. cf. liostraca and D. cf. subtecta S. Buckman, which is in full accord with Buckman's opinions (S. Buckman, 1912, p.207). There are several other specimens, mainly fragmentary, of Dorsetensia in the Herries collection, which look as though they came from the tidal reefs at Hundale and a single specimen of D. liostraca in the Scarborough museum (G.63) also from this locality.

There are no exposures in the Ravenscar Shale south of Hundale and it is significant that no specimens of Dorsetensia have been found south of this point either. To the north at Ravenscar, G. Farrow informs me (pers. com.) that the ammonite recorded by him (Farrow, 1966, p.127), from the basal 3.0m. of his bed SB 27 at Beast Cliff (OV993006), was probably a specimen of Dorsetensia. Similarly J. Wright has found a calcareous nodule, containing a specimen of Dorsetensia, at Ravenscar some 3-4.0m. above the base of the same bed (Wright, pers. com. in lit.). These records are confirmed by the occurrence of a specimen of D. aff. liostraca (CP.2747) immediately above the horizon rich in Isognomon (Farrow, 1966, p.127, bed SB 27), which is 3.5m. above the top of the Crinoid Grit. The specimen of D. pulchra S. Buckman, found by P.C. Sylvester-Bradley is now in the Institute of Geological Sciences' collections (83873). This specimen, in a clay-stone matrix rich in Meleagrinella, was found in a freshly slipped mass of shale at Monk's Walk Wood, Sneaton, (NZ896086), and it was identified by W.J. Arkell. It is perhaps a little fragmentary for positive identification, but it must have come from the thick shale which here, as at Ravenscar, rests on the Crinoid Grit (Fox-Strangways, 1915, p.43).

No other genera of ammonites have been found within the Ravenscar Shale at present. This contrasts strongly with the Romani subzone faunas of Dorset (Whicher & Palmer, 1972) and the Hebrides (Morton, 1965), where Stephanoceratid ammonites are abundant. However, in the north German successions there are horizons which are rich in Dorsetensia, often to the exclusion of other ammonite groups (Westermann, 1954, p.23), there is thus no difficulty in correlating this Ravenscar shale fauna with the Romani subzone.

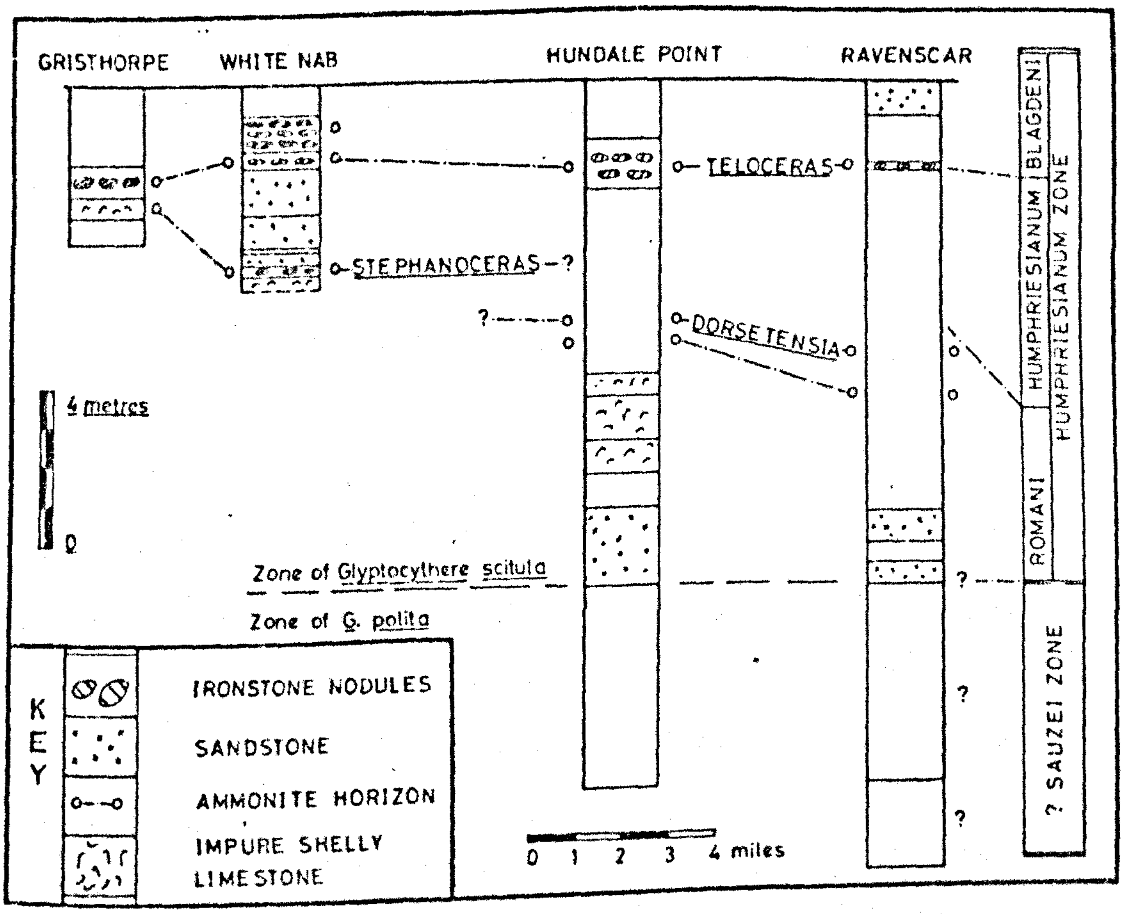
(b) The subzone of Stephanoceras humphriesianum (J. de C. Sow.)

The majority of the rest of the ammonites to be recorded here originate from this subzone.

(i) The 'Lower Belemnite Bed' of White Nab

This, one of the lowest beds visible at White Nab (TA059865) during low tides, takes its name from the common specimens of Megateuthis elliptica (Miller) to be found (Hudleston, 1874, p.315). Stephanoceratid ammonites are relatively common at this horizon (bed 3) and include Stephanoceras aff. gibbosum (S. Buckman), (CP.2410); S. aff. crassicostatum (Qu. emend. Renz), (CP.2975, ex. M. Bradshaw, & CP.2834); S. cf. zieteni (Qu. emend. Renz), (CP.3095) and S. aff. triptolemus (Bean m.s. emend. S. Buckman), (CP.2215). A single, very large specimen of S. pseudohumphriesi Maubeuge (CP.2725), has been found loose at the very base of the exposure at White Nab. Examination of the matrix of this specimen, including comparisons with the aid of thin sections, shows that this specimen came from a lower horizon still, that is bed 2. More collection is required from this horizon, which is only exposed at the very lowest tides. All of the above ammonites would suggest a correlation with the Humphriesianum subzone s. str., since they are identical to the forms commonly found at the type horizon of S. humphriesianum in north Dorset (Whicher & Palmer, 1971, p.113, middle of bed 4).

The 'Lower Belemnite bed' has been correlated in Text figure 2, with bed 3 at Gristhorpe Bay, since the latter is the probable source




Text figure 2

A correlation of the main ammonite horizons recognised within the Scarborough Formation, in the coastal exposures between Gristhorpe and Ravenscar.

of a specimen of S. humphriesianum. This specimen, which is one of the closest I have seen to the lectotype, was collected by J. Phillips in 1855 (cited, Phillips, 1860, p.xlii), and it is now in the Oxford University Museum (J.16200). Examination of the matrix of this ammonite, which is a dark grey, calcareous, highly fossiliferous shale, with a yellow bloom on the weathered surface of shell fragments, would suggest a provenance from bed 3, which has an identical lithology.

(ii) The 'Black Rock Nodule Bed'

At Black Rock, Scarborough (TA051870), there are extensive exposures of this layer of siderite rich clay-stone nodules, from which previous authors have recorded (Teloceras) 'Ammonites' blagdeni (Williamson, 1840; Wright, 1860, & Hudleston, 1874). This layer of nodules (bed 7) does yield relatively common specimens of Teloceras. However, none of those which I have collected, or examined in other collections, from this horizon are at all close to T. blagdeni, since they all show finer ribs, a higher primary rib density, a more rounded venter and a thinner whorl section, than is typical of T. blagdeni. Specimens from this horizon at Black Rock include; T. cf. acuticostatum Weisert, (CP.1267); T. aff. frechi (Renz), (CP.1268), and T. aff. acuticostatum, (G.73). This bed has also produced specimens of Stephanoceras crassicostatum (CP.2680), which together with the Teloceras, accord with a position high up in the Humphriesianum subzone for this bed, as with the middle part of the Oborne Road-stone of north Dorset (Whicher & Palmer, 1971).

Species of Teloceras with a high primary rib density, similar to those recorded above, have been found at Hundale Point. These include; T. cf. lotharingicum Maubeuge, (G.72), from 2.0m. below the top of the Scarborough Formation, that is approximately bed 22, with which there is a close match in matrix, and _T._ cf. _acuticostatum_ Weisert (G74), which was found loose on the beach, but which shows a similar chocolate-brown, mud-stone matrix, rich in _Meleagrinella_, to that of the previous specimen.

Specimens of _Teloceras_ have also been found in siderite rich nodules at other localities. The ammonites recorded by Farrow (1966, Text fig. 3), from Gristhorpe Bay and Red Cliff are of this genus (Farrow, pers. com.). J. Wright has recently found a specimen of _Teloceras_ in a siderite nodule, at the bottom of the cliff at Ravenscar (Wright, pers. com., _in lit._). This must have come from the top 5.0m. of the Scarborough Formation, where there are layers of siderite rich nodules (Bate, 1965, p.85, bed 14) - see Text fig. 2.

(c) The subzone of _Teloceras blagdeni_ (J. Sow.)

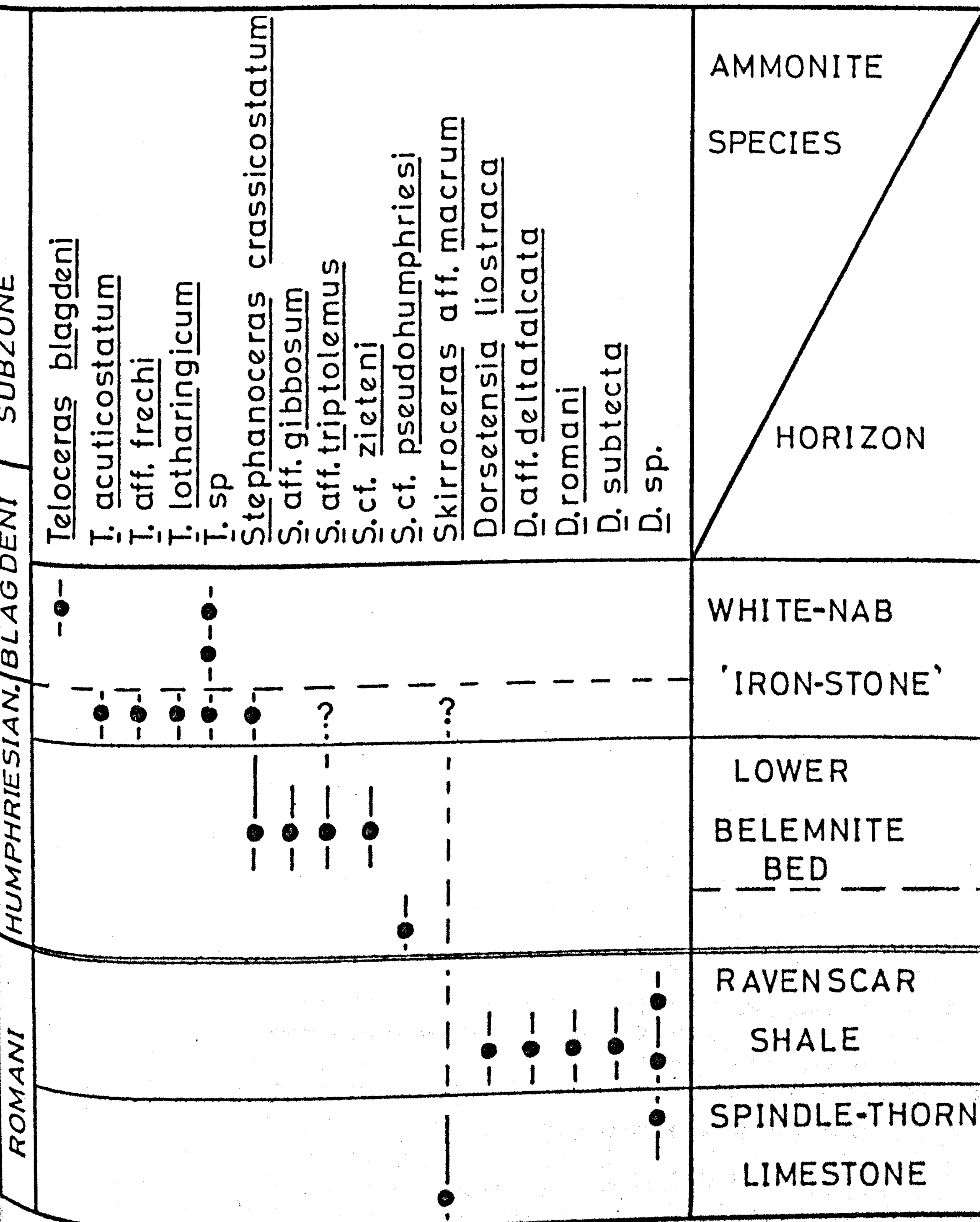
The upper part of the White Nab 'Iron-stones' at Scarborough is of this age, as it yields relatively common specimens of _Teloceras_, including _T. blagdeni s. str._ An impression of the venter of a specimen of _T._ aff. _blagdeni_ has been seen in bed 8 at White Nab, whilst in the suprajacent bed 9 at Black Rock, specimens of _T. blagdeni_ (CP.2933) and _T._ sp. (CP.3133) have been collected. This latter horizon is the undoubted source of the numerous, often squashed, specimens of _Teloceras_ to be seen in various museum collections, including a fine fragment of the body-chamber of _T. blagdeni_, from the Williamson collection in the Manchester Museum (L9561). A single specimen of _T._ aff. _blagdeni_ in the Scarborough Museum (G.71) has a hard, rust-red coloured matrix, which would suggest a provenance from bed 8 at White Nab. These ammonites thus substantiate Williamson's record of '*Ammonites*' *blagdeni* from his bed f. (Williamson, 1840, p.232).

(d) Stratigraphically unlocalised Ammonites.

The most important ammonite from the Scarborough Formation, is undoubtedly the recently re-discovered type specimen of *Stephanoceras triptolemus* (Bean m.s. in Morris & Lycett), (British Museum, - 46553). This specimen will be described and refigured at a later date, and all that need be said of it at present, is that its matrix, a dark grey mud-stone, weathered to a red colour, and with a Belemnite and several specimens of *Meleagrinella* imbedded; would suggest a provenance from the'Black Rock nodule bed'; it is undoubtedly Humphriesianum Subzone in age.

There are large numbers of Scarborough Formation ammonites in various museums throughout the country. The Sedgwick Museum has an excellent selection of material from this horizon, especially that in the Leckenby collection, which includes a fine specimen of *Dorsetensia deltafalcata* (J 1457), very similar to that recorded here from Hundale. Whilst the Geological Survey have several specimens of *Teloceras* from the Lycett collection, mainly of the *T. lugdenensis* group, which probably originated from bed 9 at Black Rock; the best collection of Scarborough beds material is in the Scarborough Natural History Museum. The following specimens are all from the Scarborough district, and most probably from the 'Black Rock nodule Bed'; *Skirroceras* cf. *macrum* (Qu. emend. Renz.), (G.75); *Stephanoceras* cf. *crassicostatum* (Qu. emend. Renz), (G.70), and *Teloceras lugdenensis* (G.67). Again a Humphriesianum subzone age is indicated for this bed.

A search through the material in the Scarborough Museum showed




Text figure 3

The stratigraphic distribution of the major ammonite groups in the Scarborough Formation.

no sign of the specimen of '*Parkinsonia*' recorded by Wright (1860, p. 29) as being in this collection. I have considerable doubts over the identification of this specimen, which was supposedly from White Nab. As noted by Buckman (1912, p.208) the matrix of some specimens from the Kellaways Rock is very similar to that of the Scarborough Formation, and this '*Parkinsonia*' may well have been a misplaced specimen from this former horizon. The specimen of '*Parkinsonia*' identified from White Nab by Richardson, (1912, p.195), is still in the Herries collection at York, and it proves to be a squashed fragment of *Teloceras*. There is *no* evidence for the Parkinsoni Zone in the Scarborough Formation, similarly there is no ammonite evidence for any horizon lower than the Romani subzone of the Humphriesianum Zone. However, as at Hundale Point for example, there is almost ½ of the Scarborough Formation below the lowest specimen of *Dorsetensia*, the occurrence of lower stratigraphic horizons, such as the Sauzei Zone, could not be ruled out. The distribution of ammonites, as known to the present, is summarised in text fig. 3.

## IV. THE LITHO-STRATIGRAPHY OF THE SCARBOROUGH FORMATION OF THE NORTH-EAST YORKSHIRE MOORS.

The three-fold lithological subdivision of the Scarborough Formation suggested by Richardson, into shale, sandstone and limestone divisions, is a gross over-simplification. Many of the litho-stratigraphic units discussed here (see Table 2) are highly lenticular, and quickly disappear when traced laterally. When attempting a broad interpretation of rapidly changing lithologies, such as those of the Scarborough Formation, it is essential to have a bio-

| | |
|---|---|
| The Scalby Formation | |
| The Scarborough Formation | The 'Transition Shales' (0.0-3.5m.) |
| | The White Nab 'Iron-stone' member (0.0-2.0m.) |
| | The Lambfold-hill Grit member (0.0-3.0m.) |
| | The Ravenscar Shale member (0.0-36m.) |
| | The Spindle-Thorn Limestone member (0.0-4.0m.) |
| | The Crinoid Grit member (0.0-3.5m.) |
| | The Hundale Shale member (0.0-5.0m.) |
| The Gristhorpe member | |

Table 2

The constituent members of the Scarborough Formation in the north-east Yorkshire Moors.

stratigraphic framework against which to correlate the various beds. A step in this direction was made by Bate, whose two ostracod zones demonstrated the essentially isochronous nature of the 'Crinoid Grit', (Bate, 1965, text figs. 2 & 3). A study of existing ammonite horizons would indicate that there are two other isochronous beds, the units here called the Ravenscar Shale Member and the White Nab 'Ironstone' Member. Using these three horizons it is possible to produce a slightly more accurate picture of the variations in litho-facies - see text fig. 4. The lithostratigraphic divisions described below are only of any value to the east of Rye Dale and Rievaulx, since elsewhere there is more limited biostratigraphic control and far greater variation in lithology. It is to be noted that the lithostratigraphic scheme suggested here is still only provisional, as more work, particularly on the inland sections, is needed.

The Scarborough beds have recently been elevated to the formal rank of a Formation within the Ravenscar Group (Hemingway & Knox, 1973, p.533). Following the recommendations of the Geological Society of London (Harland _et al._, 1972), formal subdivision of these beds is thus here undertaken at the level of 'member'.

(a) The Hundale Shale Member.

The lowest marine horizon within the Scarborough Formation seen on the coast, consists of a series of sandy shales and calcareous mud-stones, rich in _Gervillia_, lying beneath the 'Crinoid Grit', and best exposed at Hundale point, the type locality for this new litho-stratigraphic unit (beds 7-2). The age of these beds is doubtful, since no ammonites have been found, but it must be pre-Humphriesianum Zone, and is most likely Sauzei Zone in age. These beds are often absent inland, but where present, such as at Bogmire Gill (Bate, 1965, p.91, bed 1), they tend to be more calcareous, and nearer to a pure limestone. This unit is some 5m. thick at Hundale, and has a very similar thickness at Ravenscar, where there are some thin sandstone beds present. The occurrence of these sandstones is not unusual, since around the edge of the basin of deposition of the Scarborough Formation sandstones are predominant at almost all horizons, (Bate, 1965, p.96).

(b) The Crinoid Grit Member.

This term was used by Richardson (1912, p.195) to describe the sandstone, rich in comminuted crinoid debris, which occurs towards the middle of the Scarborough beds. Whilst it is most typically developed inland, as around Helmsley Moor, (Bogmire Gill, the type locality, Bate, 1965, p.91, bed 2, - 3.5m. thick) there is a good thickness of the Crinoid Grit on the Coast at Ravenscar and Hundale point. At the latter locality it is some 2m. thick, with many crinoid ossicles in the upper part, and with prominent ripple marked surfaces towards the middle (beds 12-8).

(c) The Spindle-Thorn Limestone Member.

This limestone overlies the 'Crinoid Grit' in the main part of the Yorkshire Moors, around Spaunton and East Moors, and it was once well seen in an old quarry at Spindle-Thorn, the type locality, (SE 717928 - Richardson, 1912, p.197), where it is about 2m. thick. Although Richardson introduced this term for the inland limestone occurrences (loc. cit.), there are shaly limestones and highly calcareous mud-stones at the same horizon on the coast, (Hundale, beds 13-19).

(d) The Ravenscar Shale Member

This term is introduced here for the thick shale unit with highly fossiliferous nodules, which is so well seen on the coast at Hundale point and Ravenscar cliffs. Although it is probably best exposed at these two localities, where it has yielded diagnostic ammonites, proving it to be Romani subzone, Humphriesianum Zone in age the Ravenscar Shale is at its thickest in the region of Harland Beck and Farndale, where the survey recorded over 36m. of shale, (Fox-Strangways, Reid & Barrow, 1885, p.40). Although thicker at inland localities, exposures are not good, and the most complete exposures are at Hundale and Ravenscar, and the latter, where there are some 13.5m. of Ravenscar Shale, may be taken as the type locality - see Bate 1965, p.85, beds 12 & 13.

(e) The Lambfold-Hill Grit Member

This name was introduced by Richardson (1912, p.197) for a sandstone in the upper part of the Scarborough Formation, at Lambfold Hill, Pockley Moor, (SE 615945), where it forms an important topographic feature. This unit is well exposed in Bogmire Gill, near the type locality, where it is 3.0 m. thick, (Bate, 1965, p.91, bed 5) and may be traced intermittently eastwards as far as Bloody Beck (SE 945981), where beds 13-15 (Bate, 1965) probably represent a 'feather edge'.

(f) The White Nab 'Ironstone' Member

At White Nab and Black Rock Scarborough there are extensive exposures of a series of gritty shales, ironstained, sandy, limestones and siderite rich mud-stone nodules, here called the White Nab 'Ironstone' Member. The term 'iron-stone', in this case is perhaps a mis-nomer, since the siderite content of the beds is low, however, weathering produces a characteristic deep red colour to these rocks. At White Nab, the type locality, this unit is 1.75 m. thick and comprises beds 7-16. The siderite rich nodules of this member, yielding Teloceras, have been traced the full length of the coast, there is thus every reason to believe that this horizon in the upper part of the Scarborough Formation is isochronous over most of the eastern part of this district. The particular bed of siderite rich nodules, yielding most of the specimens of Teloceras at Scarborough is here separated informally as the 'Black Rock Nodule bed' (bed 7).

(g) The 'Transition Shales'

No formal name is given to this unit, since it is impossible to be certain that we are dealing with the same Member at different localities. A series of sandy, ironstained, sulphurous, shales are often present in the upper part of the Scarborough Formation, forming a gradual transition to the non-marine sandstones of the Scalby Formation. Thus at Hundale Point there are approximately 2.0 m. of these shales, which are progressively sandier and less fossiliferous up towards the junction with the over-lying Scalby Formation. These shales are often absent, mainly due to 'wash-outs' coming down from the base of the Moor Grit (= basal Scalby beds). Thus at Gristhorpe, in some parts of the cliffs, up to 1.5 m. of these sandy shales have been cut out. These shales are sometimes sufficiently arenaceous to form a soft, poorly cemented sandstone; as in the top of the cliff at Ravenscar, (Bate, 1965, p.85, bed 16).

## V. DESCRIPTION OF COASTAL EXPOSURES

As already noted in the Introduction, the coastal exposures of the Scarborough Formation are the only ones to show a large enough area of outcrop for the collection of ammonites. Thus those at Ravenscar, Hundale, Scarborough and Gristhorpe are described here, starting with the most northerly and working south.

### (a) Ravenscar

Sections at Ravenscar have been described by Fox-Strangways (1915, p.39), Bate (1965, p.85) and Farrow (1966, p.116). The most accessible and complete exposures are in an old quarry on the cliff-face (NZ991009), but even these are becoming increasingly obscured by talus and vegetation. Thus in the last few years it has become difficult to make out the finer details of this section. Taking this into account, this exposure is only described here in the most general terms and for fuller details earlier works should be consulted (Bate, 1965, p.85).

SCARBOROUGH FORMATION

6/ A series of flaggy sandstones, which are more shaly towards the base. 4.0–4.5m.

White Nab 'Ironstones'

5/ A series of sandy, calcareous shales, with sideritic, clay-stone nodules.

*Teloceras* sp. (by matrix) 1.0–1.5m.

Ravenscar Shale

4/ A series of grey shales, which are more sandy towards the top. These beds are very fossiliferous, particularly 3.5 m. from the base, where there is a layer of Isognomon, surmounted by a horizon rich in crinoid debris.

Dorsetensia aff. liostraca S. Buckman 10.5 - 13.5m.

The Crinoid Grit

3/ A massive, sphaeroidally weathered, sandstone, with comminuted crinoid debris towards its top. 1.4m.

The Hundale Shales (2)

2/ A poorly exposed sequence of inter-bedded limestones, mudstones, sandy shales and sandstones, with a prominent horizon rich in Gervillia towards the base. 3.4-4.5m.

1/ A series of thinly bedded, flaggy sandstones. 3.0-4.5m.

(b) Hundale Point, Cloughton

This is the best exposed coastal section (TA026948), which shows one of the thickest developments of the Scarborough beds. Although it has been previously described, (Hudleston, 1874; Fox-Strangways, 1915; Bate 1965), this section has never been given the attention which its abundant faunas warrant. Apart from the term 'Isognomon bed' which is new, all the other informal bed names used here originate from Hudleston (1874).

26/ 'The Moor Grit'

A massive, cross-bedded sandstone, which is more thinly bedded towards the base. seen to 2.0m.

THE SCARBOROUGH FORMATION (25-2)

25/ 'The Transition Shales' (25-24)

A laminated, yellow-grey coloured, sandy shale, with brown, sandy layers some 2.5 cm. thick.

0.46-
0.67m.

24/ A series of grey, sulphurus shales, which are more sandy towards the top.

0.84m.

The White Nab 'Ironstones' (23-22)

23/ A series of sulphurous, grey, sandy shales, with two layers of unfossiliferous, very iron rich nodules (c.0.20m. thick), one at the top and the other towards the middle of the bed.

0.90m.

22/ A hard, calcareous, grey-brown mudstone, which weathers to a rusty colour, and which contains numerous well preserved fossils.

<u>Teloceras</u> cf. <u>acuticostatum</u> (from here by matrix)

<u>T.</u> aff. <u>lotharingicum</u> Maubeuge

<u>Meleagrinella</u> <u>lycetti</u>

0.15-
0.30m.

The Ravenscar Shales (21-20)

21c/ A grey, fissile, relatively unfossiliferous shale.

1.5m.

21b/ A dark grey coloured shale, which is slightly softer than the adjacent beds, hence it tends to be weathered back.

<u>Megateuthis</u> sp.

<u>Liostrea</u> sp.

<u>Pseudomelania</u> <u>lonsdalei</u>

0.23m.

21a/ A very dark grey coloured shale, which is highly fossiliferous, especially towards the base. There are numerous small, round concretions present, some of which contain uncrushed fossils.

Dorsetensia liostraca S.B.

D. subtecta S.B.

D. cf. romani (Oppel)

D. aff. deltafalcata (Qu.)

Megateuthis sp.

Cenoceras sp.

Meleagrinella lycetti

6.25m.

20/ A dark grey, very fossiliferous shale.

Meleagrinella lycetti 0.30m.

The Spindle Thorn Limestone (19-13)

19/ A hard, grey, sandy, impure limestone, which contains the same fossils as the bed below, only more sparsely. Material from this bed has been piped down, via burrows, into the bed below.

Meleagrinella lycetti etc. etc.

0.22m.

18d/ A highly fossiliferous, grey, sandy, calcareous shale, with some Thalassinoides style burrows, particularly towards the top.

Dorsetensia sp.

Camptonectes sp.

Catinula ampulla (d'Archiac)

*Gervillia scarburgensis*

*Meleagrinella lycetti*

*Modiola* sp.

*Liostrea* sp.

*Lopha marshi*

*Pinna cuneata* Phillips (in an upright position)

*Platymya scarburgensis* (Phillips)

*Pseudolima* aff. *duplicata*

*Trigonia costata*

*T.* (*Myophorella*) *signata* (Agass.)

*Pentacrinus* ossicles

*Pseudodiadema depressum* (Agass.)

*Rhabdocidaris maxima* (Munst.)

*Serpula* aff. *plicatilis* Goldfuss.

0.82m.

18c/ A layer of hard, grey, calcareous nodules, with sparse, but well preserved and uncrushed fossils, similar to those in the bed above.

0.0–
0.35m.

18b/ A grey, sandy, calcareous shale, slightly softer than bed 18d, and with sparser fossils.

*Cenoceras* sp.

*Pernostrea* sp.

*Pleuromya uniformis* (J. Sow.) (in life position)

0.28m.

18a/ A grey, gritty, highly bioturbated shale, with common *Thalassinoides* burrows. *Pentacrinus* ossicles are common, as are burrowing bivalves, particularly towards the base of the bed.

_Pleuromya uniformis_

_Pholadomya lirata_ 0.50m.

17/ A grey, unfossiliferous, gritty shale, which is distinctly mottled, mainly due to intense bioturbation.

0.36m.

16/ A grey, sandy, calcareous shale, with a similar lithology and fauna, as that of bed 18d.

_Meleagrinella lycetti_

_Lopha marshi_ etc. etc.

0.43m.

15/ A grey, mottled, sandy, highly bioturbated shale, very similar to bed 17. 0.65m.

'The _Isognomon_ bed'

14/ A grey, sandy, calcareous, highly fossiliferous shale, very similar to bed 18d. Occasional calcareous nodules, containing well preserved fossils are found scattered throughout the middle of the bed. Disarticulated valves of _Isognomon_ are common.

_Stephanoceras_ (_Skirroceras_) sp. (0.43m. above 12)

_Catinula ampulla_ (d'Archiac)

?_Gryphaea_ sp.

_Exogyra_ sp. (attached to the ammonite)

_Isognomon isognomonoides_ (Stahl.)

_Lopha marshi_

_Pinna_ sp. (very large and flat lying).

_Trigonia costata_

0.46m.

13/ A grey, bioturbated and mottled shale, with sparse oysters towards the base. The basal 9 cm. is softer, browner coloured and is often packed with serpulid tubes.

Lopha marshi

Pernostrea sp.

Serpula sp.

0.25-
0.30m.

The Crinoid Grit (12-8)

- - - - - - - - An oyster-encrusted 'hard-ground' - - - - - - - - - -

12c/ A hard, crystalline, sandy limestone, with a very flat top, and containing a large quantity of comminuted crinoid debris.

Rhabdocidaris maxima (Munst.)

Pentacrinus sp.

0.05m.

12b/ A hard, massive, highly bioturbated, calcareous sandstone. Trace fossils, particularly Arenicolites, Teichichnus, Rhizocorallium and Thalassinoides are very common.

0.9m.

12a/ A hard, massive calcareous sandstone, with fine parallel laminations, which is cemented to the base of the bed above. Body fossils are rare, except for a few poorly preserved bivalves towards the base, where there is also some bioturbation.

0.70m.

11/ A dark grey coloured, gritty shale, which grades up into the bed above.

0.33m.

'The Upper Iron Scar' (10b)

10b/ A hard, grey mudstone, which weathers to a rust red colour.

0.25m.

10a/ Two, and sometimes three, layers of hard, calcareous sandstones, with ripple marked surfaces.

0.63m.

9/ A hard, calcareous, parallel laminated grit, which grades down into a softer, bioturbated, sandy marl.

*Pentacrinus* sp.

0.61-
0.67m.

8/ A grey coloured, mottled and bioturbated sandy shale.

0.66-
0.68m.

The Hundale Shales (7-2)

7/ A dark grey, 'coaly' shale.

0.09m.

'The Lower Iron Scar' (6b)

6b/ A hard, fine grained, dark grey, calcareous siltstone, which weathers to a red colour. Fossils are common towards the top of the bed, but are very difficult to extract, and are best seen on weathered surfaces. This horizon has yielded the most varied Gastropod fauna, of any bed within the Scarborough Formation. Towards the base this bed becomes softer and more shaly, and here fossils are easier to extract.

*Cucullaea cancellata*

*Astarte minima*

*Gervillia scarburgensis*

_Meleagrinella_ _lycetti_

_Cloughtonia_ _cincta_ (Phillips)

_Pseudomelania_ _laevigata_ (Mor. & Lyc.)

0.33-
0.40m.

6a/ A rubbly, ironstained, grey, calcareous shale, which becomes harder towards the top, where it grades into the bed above.

_Cloughtonia_ _cincta_ (Phillips)

0.20-
0.30m.

5/ A highly fossiliferous, grey, calcareous shale, which is packed full of bivalves, and which has sparse patches of pseudo-ooliths.

_Pleuromya_ _uniformis_

_Pholadomya_ _lirata_

'_Modiola_' _leckenbyi_ Mor. & Lyc.

0.13-
0.21m.

4/ A shaly and slightly calcareous, fine sandstone, which has a concentration of _Gervillia_ towards the middle and some sparse and poorly preserved fossils towards the top.

0.84-
0.95m.

3/ An iron-stained, grey, calcareous, sandy, highly bioturbated shale.

0.41m.

- - - - - - - - dark shale parting 0.01m. thick - - - - - - - - - -

2/ A dark grey, carbonaceous shale, with poorly preserved bivalves and plant and wood fragments.

0.66m.

THE GRISTHORPE BEDS

1/ A massive cross-bedded sandstone.

3.5m.

(c) White Nab and Black Rock, Scarborough

This section was measured from both the small anticline exposed at Black Rock (TA050870), just to the south of the bathing pool and from the headland of White Nab (TA060865). Whilst the greatest thickness of beds is exposed at the latter locality, the former shows wider areas of outcrop, more suitable for the search for ammonites. This section is perhaps the most frequently described of all the Scarborough Formation localities having been the subject of work by Phillips (1829), Williamson (1840), Wright (1860), Hudleston (1874), Fox-Strangways (1904), Bate (1965) and Farrow (1966). However the discovery of several ammonite horizons within these beds made their re-description worthwhile. Two of the informal bed names, 'Black Rock nodule bed' and '*Gervillia* bed' are new. The rest originate from Hudleston (1874).

18/ 'The Moor Grit'

A massive, cross-bedded sandstone.

3.0m. +

THE SCARBOROUGH FORMATION (17-1)

17/ 'The Transition Shales'

A yellow-grey coloured, sandy shale, containing poorly preserved fossils.

0.35m.

The White Nab 'Ironstones' (16-7)

16/ A dark, brown-grey coloured, shale, with mudstone nodules full of well preserved fossils.

*Pernostrea* sp.

*Meleagrinella lycetti* (Rollier)

0.23m.

15/ A hard, nodular, argillaceous limestone, weathering a rust red.

0.20m.

14/ A purple-grey coloured shale, with numerous well preserved fossils, which have a white powdery preservation, and with frequent patches of pseudo-ooliths.

*Meleagrinella lycetti*

0.20m.

13/ A brown-grey coloured shale, which grades up into a hard, nodular mudstone.

0.33m.

12/ 'The *Gervillia* bed'

A hard, crystalline, impure limestone, which weathers to a deep pink colour, and which is packed full of *Gervillia scarburgensis* Paris.

0.15-
0.23m.

11/ A thin, gritty shale.

0.0-
0.08m.

10/ A hard, pink-grey coloured calcareous mudstone, full of broken shell debris.

0.15-
0.26m.

9/ A grey, gritty shale, which weathers to a mottled red/brown - grey colour, mainly due to the presence, particularly towards the top of the bed, of numerous *Thalassinoides* burrows. These burrows pipe down a darker shale, full of broken shell debris.

*Teloceras blagdeni* (Sow.)

*T.* sp.

*Megateuthis quinquesulcatus* (Blain.)

*Pernostrea* sp.

0.28m.

8/ A nodular and irregular, grey mudstone, which weathers to a dark red colour.

*Teloceras* aff. *blagdeni*

0.15-
0.20m.

7/ 'The Black Rock Nodule bed'

A grey-brown coloured, gritty shale, full of comminuted shell debris and squashed fossils. The basal half of the bed is a darker grey colour and contains common oysters, whilst along the middle of the bed there are scattered irregular clay-stone nodules. These nodules, up to 0.60m. in diameter, are hard, splintery, dark grey in colour and weather to a light pink-grey colour, which is in direct contrast to the rust red of the beds above. Well exposed at Black Rock, where the nodules are scattered over the fore-shore, this bed is at its thickest, and has yielded most ammonites from this point.

*Teloceras* cf. *acuticostatum* Weisert

*T.* aff. *frechi* (Renz)

*T.* aff. *blagdeniformis* (Roche)

*Stephanoceras crassicostatum* (Qu. emend. Renz)

*Gervillia scarburgensis*

*Meleagrinella lycetti*

*Pernostrea* sp.

*Pseudomelania lonsdalei* Mor. & Lyc.

*Megateuthis quinquesulcatus*

0.30-
0.60m.

? The Lambfold-Hill Grit (6-4)

6/ 'The *Chemnitzia* Limestone'

A hard, crystalline, grey, sandy limestone, which is iron-stained, massive and divided into two blocks by a parting 1.0m. from the base, the upper course being the more coarsely sandy. *Pseudomelania lonsdalei* ('*Chemnitzia*' *auctt.*) is very common, particularly on the upper surfaces.

1.95m.

5/ 'The Upper Belemnite bed'

A thin, gritty, grey shale, which thickens to the north and which contains sporadic Belemnites.

0.9-
0.30m.

4b/ A hard, sandy, limestone, similar to bed 4a, which thickens to the north.

0.0-
0.25m.

4a/ A hard, sandy, blue 'hearted', crystalline limestone, which weathers rust-red and which contains numerous badly preserved and broken fossils. The top surface of the bed, which forms an extensive shelf at low tide, is covered with *Thallassinoides*.

0.33m.

3/ 'The Lower Belemnite bed'

A grey, fossiliferous shale, with abundant slightly squashed

*Meleagrinella* and large Belemnites. The calcareous mud-stone nodules, up to 0.45m. in diameter, found at the middle of the bed, contain well preserved fossils and weather to a light pink colour, similar to that of the nodules from bed 7, from which they are distinguished by their softer and less splintery nature.

*Stephanoceras* aff. *crassicostatum*

*S.* aff. *gibbosum*

*S.* cf. *zieteni* (Qu. emend. Renz)

*S.* aff. *triptolemus* (Bean in Mor. & Lyc.)

*Gresslya* sp.

*Meleagrinella lycetti*

*Pernostrea* sp.

*Pentacrinus* ossicles

0.40–
0.48m.

2/ A hard, grey, sandy, calcareous, shelly mud-stone, which weathers to a rust red colour and which is full of broken shell debris.

*Stephanoceras* cf. *pseudohumphriesi* Maubeuge.

(from here by matrix) 0.20–
0.35m.

1/ A blocky, bioturbated, marly shale.

seen to 0.30m.

---

Section incomplete, perhaps a further 3.0m. + below low tide line.

(d) Gristhorpe Bay

This section which was taken from the south side of the Yons Nab headland (TA084841), has been previously described by Phillips (1835), Wright (1860) and Bate (1965).

Base of the SCALBY FORMATION

9/ A hard, yellow-grey coloured sandstone, with carbonaceous layers, and which grades down into the bed below.

seen to 0.30m.

THE SCARBOROUGH FORMATION (8-2)

8b/ A grey, sandy shale, mottled with patches of yellow sandy material.

0.66m.

8a/ A soft, well bedded, grey sandy shale.

0.34-
0.43m.

(A channel cuts down from bed 9 to the top of bed 7b).

7b/ A compact, very sandy shale, which is grey-brown in colour, and which has a softer, dark grey coloured shale fill to the numerous burrows present. This bed weathers to a yellow-brown colour.

0.82m.

7a/ A grey, silty shale, which has a gradational contact with the bed above. There are occasional claystone nodules towards the top of the bed, full of shell debris.

*Pleuromya uniformis*

*Megateuthis quinquesulcatus*

*Rhabdocidaris maxima*

0.36m.

6/ A hard, silty, very impure limestone, which has a splintery fracture, weathers to a bright red colour and which forms a small reef on the beach at low tide.

<u>Meleagrinella</u> <u>lycetti</u>

<u>Trigonia</u> cf. <u>costata</u>

<u>Teloceras</u> sp. (<u>Teste</u> G. Farrow)

0.22–
0.38m.

5/ A grey, gritty, ironstained, relatively unfossiliferous shale, with a layer of impersistent clay-stone nodules, towards the top of the bed, full of shell debris.

0.28–
0.50m.

4/ A hard, grey, silty shale.

0.12–
0.15m.

3/ A light grey, calcareous, highly fossiliferous shale, which is divided by a parting into two, approximately equal courses. The bottom course is darker, softer and less fossiliferous than the top. This bed forms a prominent reef, well out into the bay at low tide, the upper surface of which is covered with shells and shell fragments, which have weathered to a yellow colour.

<u>Meleagrinella</u> <u>lycetti</u>

<u>Pholadomya</u> <u>lirata</u>

<u>Pseudolima</u> aff. <u>duplicata</u>

<u>Trigonia</u> <u>costata</u>

<u>Lopha</u> <u>marshi</u>

<u>Pernostrea</u> sp.

_Pseudomelania_ _lonsdalei_

_Stephanoceras_ _humphriesianum_ (J. Sow.) - Phillip's collection, University of Oxford, from here by matrix.

0.64m.

2c/ A grey, laminated, sandy, highly bioturbated, fossiliferous shale.

0.11m.

2b/ A grey, laminated, sandy shale, with only sparse fossils.

0.31m.

2a/ A laminated sandy shale, with a dark charcoal grey colour, which weathers to a streaky brown and yellow colour. There is a lumachelle of oysters towards the middle of this bed, which has a gradational contact with the bed below.

_Liostrea_ sp.

0.26m.

- - - - - - - - - - - - - gradational contact - - - - - - - - - - - -

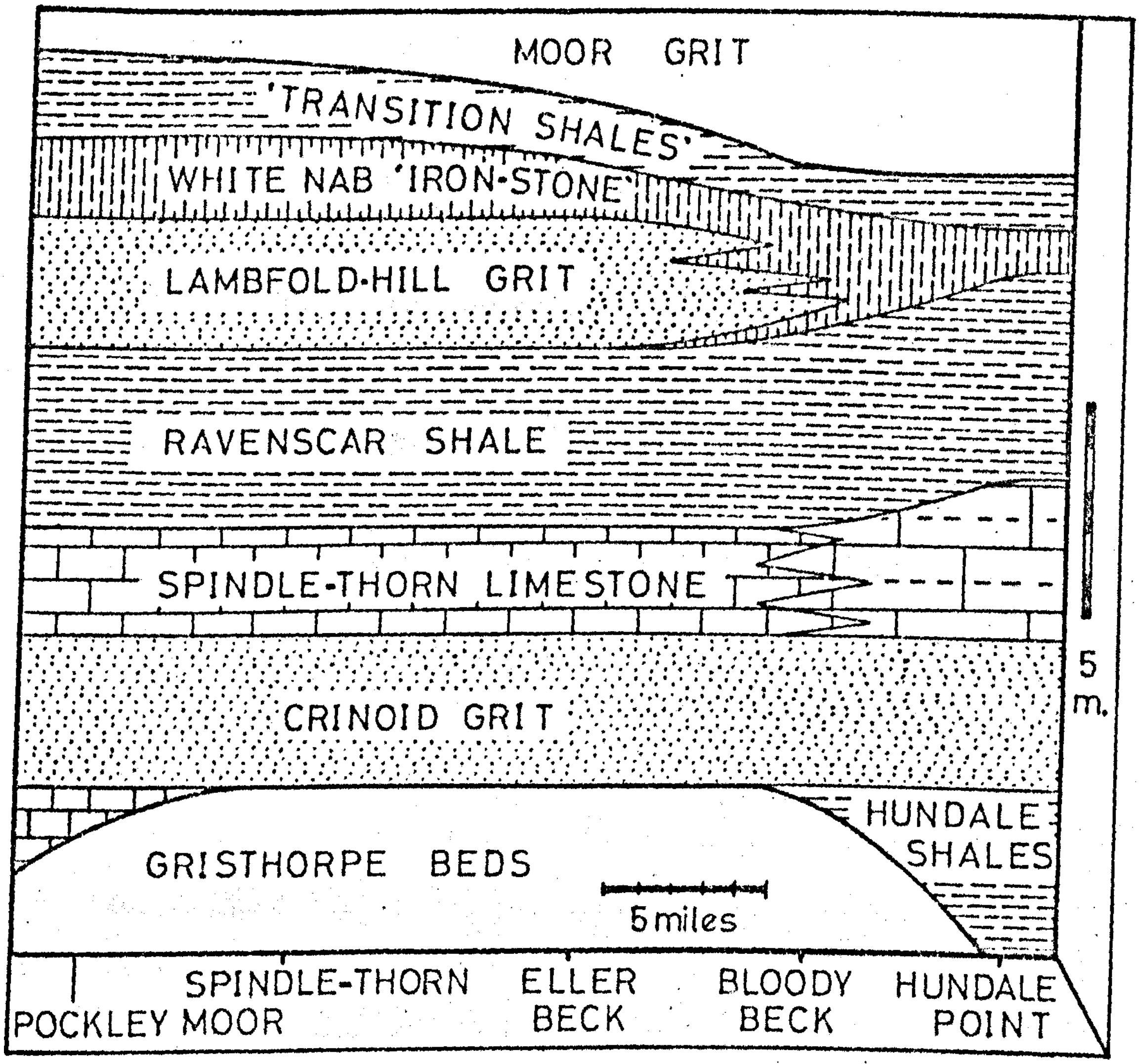
THE GRISTHORPE BEDS

1/ A massive sandstone, with laminated carbonaceous layers, and grading up into the above.

seen to 0.5m.

## VI. STRATIGRAPHIC SUMMARY

The ammonite evidence for the correlation of the Scarborough Formation is summarised in text figs. 2 and 3, and it would indicate that only the top half of the beds, as exposed at Hundale Point, belong to the Humphriesianum Zone. It is probable that the base of this ammonite Zone coincides with the base of Bate's zone of _Glyptocythere_ _scitula_. The horizons below this are pre-Romani sub-




Text figure 4

The lithostratigraphic subdivisions of the Scarborough Formation between Rye Dale and the coast at Cloughton.

zone in age, and most likely to be correlated with the late Sauzei Zone. These new ammonite records have enabled a more detailed correlation of the coastal exposures of the Scarborough Formation to be made. The Ravenscar Shale, where present, would appear to be isochronous, as is the 'Black Rock nodule bed' of the White Nab Member. All of the beds exposed below this latter horizon at White Nab are lower Humphriesianum subzone in age. These beds include the horizons equated with the Lambfold-Hill Member (beds 6-4). It is thus clear that these sandstones cannot possibly be correlated with the Crinoid Grit, as has been suggested by Bate (1965, p.98) and Farrow (1966, fig. 3), as they have an entirely different stratigraphic position. Allowing for the unfossiliferous nature of the top of the Ravenscar Shale at Hundale, there are strong reasons for suspecting the presence of an unconformity between the base of bed 22 and the top of the shales at that section. This would account for the lack of ammonites at Hundale, which are characteristic of beds 1-6 at White Nab. This idea is supported by the nature of the surface upon which the 'Black Rock nodule bed' (7) rests at Scarborough; it has all the characteristics of a 'hard-ground'.

The litho-stratigraphic picture is more complex and is summarised in text fig. 4. Bate's concept of a shallow marine basin, opening to the east, and with a peripheral area of sandstone deposition, (Bate, 1965, p.96, fig. 4), would appear to be essentially correct for the Scarborough Formation; thus the thickest deposits of these beds exist along the axis of the basin - the Ravenscar/Blea Wyke district. This totally contradicts Farrow's thesis of a bathometric gradient from Ravenscar to Scarborough, with the deeper water, at the southern end. This contradiction can easily be explained, since in his work on the trace-fossils, Farrow did not compare stratigraphically equivalent horizons. Thus at White Nab, the siderite rich nodules with relatively common ammonites are not the deep water facies equivalent to all the beds exposed at Ravenscar, as suggested by Farrow, but are the direct equivalent solely to some thin beds at the very top of this latter section, (see fig. 2). Re-interpreting Farrow's work in the light of this evidence, it would seem that the Scarborough Formation was first laid down in a shallow and relatively small basin, centred on the Ravenscar area, where sandstones rich in _Thallassinoides_ and _Rhizocorallium_ were deposited. With the deepening of the basin, marine influences were increased and the greatest abundance of ammonites coincides with the greatest areal extent of these beds, which are represented only by the upper part of the sequence at Ravenscar, and by all of the beds at White Nab and Gristhorpe; the earlier shallow water facies being absent at the two latter localities. Thus, there is not a lateral, but a vertical 'bathymetric gradient', upwards through the Scarborough Formation, with the progressive overstepping of younger, but deeper water beds.

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