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Front cover: Horkstow chain suspension bridge designed by Sir John Rennie and built in 1835 as viewed on the Humberside excursion (see pp. 195–200).

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WAS THERE A GLACIAL LAKE HARRISON
IN THE SOUTH MIDLANDS OF ENGLAND?

by

Doug Harwood

Summary

Glacial Lake Harrison has long been accepted as an example of a pro-glacial lake for which "detailed evidence" is available. Recent work by the British Geological Survey has introduced a refreshing air of controversy into the theory. This paper is a review of current ideas and evidence. It is concluded that, although the geomorphological aspects of the theory seem increasingly problematic, the sedimentary evidence continues to support some form of lake hypothesis. However, there is uncertainty as to whether there was a single extensive lake covering the whole area or a series of smaller, transient lakes on top of, within and in front of an advancing ice sheet. The status of the Lake Harrison sediments (i.e. the Wolstonian) as a separate episode in the British glacial chronology, is also disputed.

Introduction

The period from the late 1950's to the early 1970's witnessed a sustained critique of the use of the model of a pro-glacial lake and its overflow channels as an explanation of drainage anomalies and related landforms (Sissons, 1958; Price, 1973). In particular the process of locating former pro-glacial lakes solely on the basis of the supposed position of meltwater overflow channels is now regarded as totally inadequate. The absence of additional confirmatory evidence in the form of lacustrine deposits and shoreline features has undermined previously 'classic' applications of the theory, such as the Cleveland Hills 'system' (Gregory, 1965; Edwards, 1981) and Lake Lapworth (Shaw 1972). Nevertheless, until recently, Shotton's 1953 theory of glacial Lake Harrison, which explains glacial deposits and landform assemblages of the South Midlands, has remained unquestioned. Indeed, Embleton and King (1968), in their review of the field, included Lake Harrison as an example for which 'detailed evidence' is available.

In his 1953 paper Shotton argued for the existence of a 'Lake Harrison' stretching from Leicester and Birmingham to Moreton-in-Marsh during the Wolstonian or Saale-Riss glaciation (Fig. 1). This water was impounded in the Avon basin between the Jurassic escarpment to the south-east and three ice lobes (western Severn Valley or Welsh Ice, northern ice and north-eastern Chalky Boulder—Clay Ice). Three gaps in the Jurassic escarpment were interpreted as former overflow channels (the Watford or Daventry gap, the Fenny Compton Gap and the Dasset Gap).

The 'detailed evidence' for these ideas has been derived from three major sources:

(*a*) a close examination of the Quaternary sediments
- (i) in the area around Wolston in Warwickshire (Shotton, 1953);
- (ii) along the proposed lake shoreline in South Warwickshire (Bishop, 1958);
- (iii) further north in Leicestershire (Shotton, 1976; Rice, 1968, 1981; Douglas, 1980).

(*b*) the discovery of a 400′ bench, which was interpreted as a wave-cut platform, along the southern margins of the region (Dury, 1951).

(*c*) evidence from boreholes suggested the possible existence of a major valley (the Proto-Soar) beneath the Quaternary deposits, stretching north-east from Moreton-in-Marsh to Leicester. Shotton argued, that the earlier melting of the Welsh ice and the resultant drainage of Lake Harrison to the south-west, led to the development of a south-westerly flowing drainage system, which was the precursor of the present River Avon and thus reversed the drainage of much of the area.

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The persuasiveness of this theory and its accompanying evidence have convinced most geomorphologists of the validity of the Lake Harrison idea. It is usually quoted without question in accounts of the geomorphology of the English Midlands (Straw and Clayton, 1979; Open University, 1980). However, recent work derived from the BGS mapping of the Warwick sheet has introduced a refreshing air of controversy into the topic (Ambrose and Brewster, 1982; Sumbler, 1983a). The time seems right for a reappraisal of the original ideas and evidence. The purpose of this paper is to offer a review of the current arguments. The debate will be dealt with under the following headings: (*a*) depositional evidence, (*b*) the 400' wave-cut bench, (*c*) overflow channels, (*d*) the impounding of Lake Harrison and (*e*) drainage reversal.

Depositional Evidence

In his original 1953 paper, Shotton interpreted the Wolstonian sequence of Quaternary deposits in the South Midlands mainly in terms of alternating lacustrine (i.e. laminated, varved and stoneless clays) and shoreline (i.e. deltaic) conditions. Lake conditions were correlated with periods of ice damming, due to glacial advance, whilst the deltaic environment was associated with phases of ice melting and retreat (Table 1).

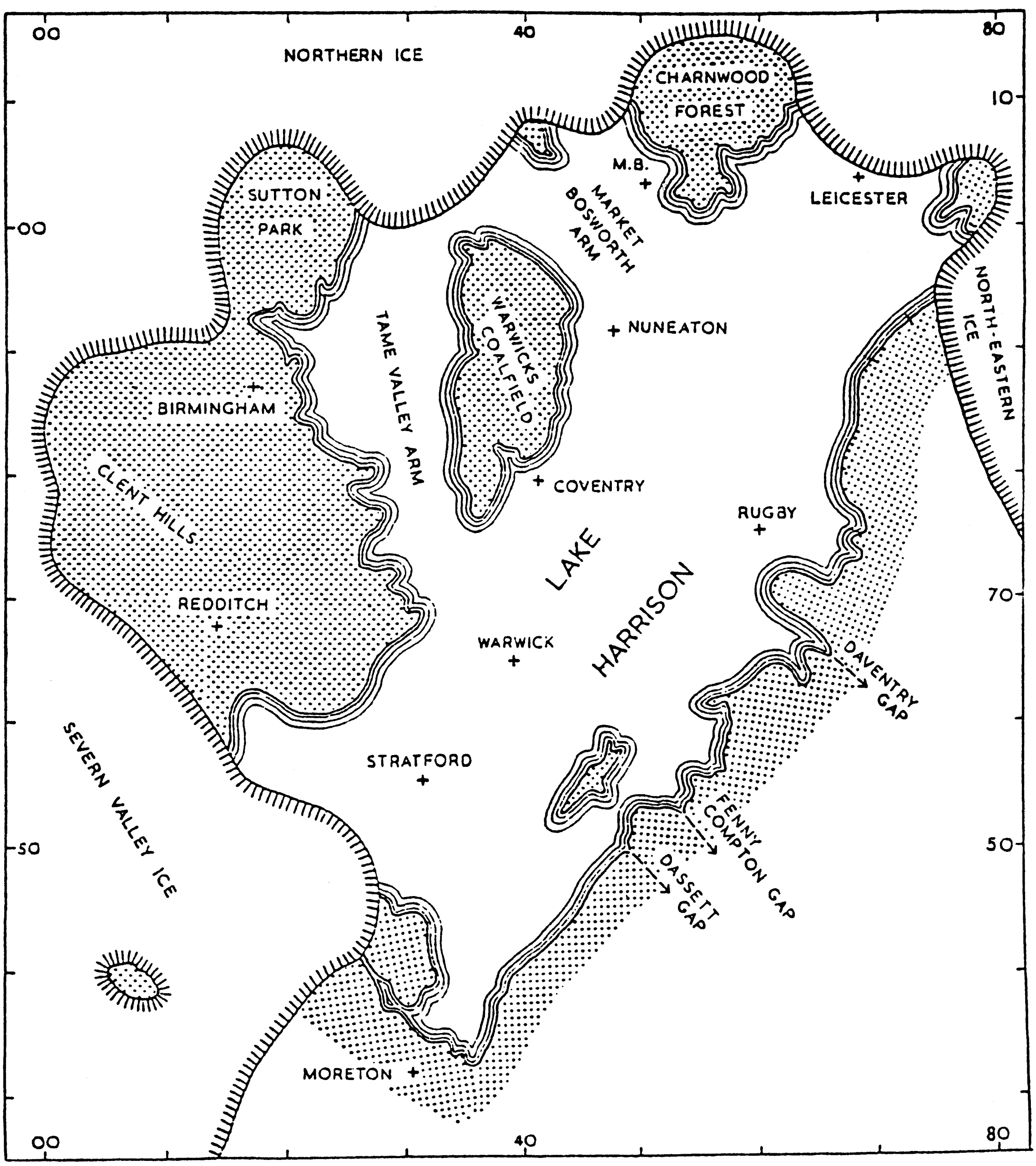

Fig. 1. Possible appearance of Lake Harrison near to its maximum extent, from Shotton, (1953), p. 251.

Research during the last 30 years has gradually eroded confidence in some of Shotton's original ideas, so that a significantly smaller proportion of the Wolstonian sequence is now regarded as lacustrine or deltaic in origin (Table 2). eg.

1. Whereas, in 1953, Shotton argued that the beginnings of lacustrine conditions were already evident in the Baginton-Lillington sands and gravels, there now seems to be general agreement that the series were entirely "cold climate riverine" in origin (Sumbler 1983a, p.24; Shotton 1984, p.262).

2. In 1953 Shotton regarded both the Lower and Upper Wolston Clays as deposits of ponded water. Today his original Lower Wolston Clays have been subdivided into two sections (Table 2). It is now generally agreed that the lower series is not lacustrine but is instead a till derived from Triassic bedrock (Thrussington Till), deposited directly by an overlying ice sheet (Shotton, 1976; Rice, 1981; Sumbler, 1983a). Shotton (1976) has argued for the onset of lake conditions at this time in the south of the region, but has based this judgment upon Tomlinson's (1935) evidence of laminated clays from only one locality, namely Snitterfield. Rose (in preparation) has recently confirmed this interpretation as follows: "At Snitterfield, the top of the Baginton Sands interdigitates with the base of the Lower Wolston Clay (which were formed in a pro-glacial lake), confirming the continuity of sedimentation initially suggested by Shotton 1953, (p.6)". However, recent B.G.S. reports indicate little additional support for this idea of an early Lake Harrison to the south of Leamington Spa. No mention is made of any form of lacustrine deposit in the geological survey of the area around Stratford-upon-Avon (Williams and Whittaker, 1974). In detailed notes on parts of sheets 183 (Redditch) and 184 (Warwick), only brief mention is given to 'bedded clays and sands' and these are described mainly as "pockets within boulder clay" rather than as lacustrine deposits (Ambrose and Strange, 1982). In their memoir of the 'Geology of the Country around Redditch', Old *et al.* (in preparation) describe how the glacial lake deposits of the area "are commonly interbedded with thicker accumulations of sand and gravel and boulder clay". Such depositional assemblages might be better explained as the product of small, localised lake conditions in close proximity to ice, or even sometimes as the remnants of kettle holes, rather than the product of a single lake.

3. The main area of Wolston Sands is now generally interpreted as an outwash plain or sandur stretching as far south west as Wolston rather than as a delta. For example, "the sedimentary structures consistently indicate deposition by moving water rather than into ponded water" (Douglas, 1980, p. 283). Shotton (1983, 1984), concedes this point, although, on the basis of his 1953 observation, he still prefers the lacustrine interpretation for the sands in the south, around Wolston itself.

4. The Upper Wolston Clays are now seen mainly as a till, belonging to the Chalky Boulder Clay series (Oadby Till), with only occasional lacustrine inclusions (Shotton, 1976, 1984; Rice, 1981; Sumbler, 1983a and b). This, rather than as a major Lake Harrison deposit, which was Shotton's preferred interpretation in 1953.

5. There has been long standing general agreement that the Dunsmore Gravels represent the remnants of a former outwash plain marking the final retreat of the Wolstonian ice sheet (Shotton, 1953; Sumbler, 1983a).

6. This leaves only the upper section of the original Lower Wolston Clays as truly lacustrine[1]. Recent research has in fact strengthened the evidence for lake conditions during this phase, especially in the area around Market Bosworth. Here, there has been the discovery of significant thicknesses of fine-grained laminated Quaternary deposits, which can be differentiated from the main till sequences in the area by particle-size analysis. Although "at first sight massive and structureless", (this clay) "is generally finely-laminated" indicating "deposition in standing water" (Old *et al*, 1987, p.53). These sediments now constitute the best available evidence in support of the Lake Harrison theory (Douglas, 1980; Shotton, 1976, 1983, 1984; Sumbler, 1983a; Old *et al*, 1987) and it has been suggested that they indicate the presence of a pro-glacial lake across the area, lasting for some 10,000 years (Shotton, 1976, p.248).

However, there are still some grounds for scepticism. According to Old *et al.* (1987), the Wolston Clay in Warwickshire is rarely entirely free of stones, which again suggests that the lake conditions might have been in close proximity to ice. Evidence from contemporary glaciers suggests that such ponded water could have developed either within a glacier or on top of the ice, as well as in a pro-glacial situation (Embleton and King, 1975; Drewry, 1986). Also there are often beds of sand and gravel within the clay/silt series, which suggest the close proximity of either englacial or proglacial fluvial conditions although small-scale turbidites have been suggested as an alternative explanation by Douglas (1980, p.282). Here, Shotton's use of the idea of alternating glacial advances and retreats is no longer sufficient to explain such clay/sand and gravel sequences (Boulton, 1970, 1972). Despite these reservations, there is general consensus that a lacustrine environment does offer the best explanation for the Lower Wolston Clay.

How far does the current state of understanding of the Quaternary deposits in the South Midlands vindicate Shotton's (1953) theory? At present there are two main views. Sumbler (1983a, p.25) has suggested that instead of "a single, semi-permanent body of water", there may have been "a succession of transient ice-marginal lakes ponded against the higher ground in front of the Oadby Till ice-sheet, as it advanced up the Proto-Soar Valley". It is interesting that Shotton used a similar interpretation to explain otherwise anomalous lacustrine material in 1953 (p.247). Sumbler has elaborated further upon this idea in correspondence with the author, arguing "tentatively" that there was a "soggy and wet ice sheet advancing with pauses over its own deposits so that the whole sequence was laid down in one". This view and its evidence has been summarised in the 'Warwick' memoir, as follows: "The close association between the Wolston Clay and the overlying and underlying tills, coupled with the widespread occurrence of till in the Wolston Clay, suggest the close proximity of ice. Possibly the clays accumulated in transient glacial lakes and ponds formed in front of, upon and even within ice-sheets advancing, intermittently from the north and east" (Old *et al*, 1987, p.53).

Shotton meanwhile continues to prefer the single lake hypothesis, arguing that the evidence of the Bosworth Clays and Silts in the north-east suggest a more extensive lake (Shotton, 1984, p.264). Judging from recent publications Old *et al*, (1987 and in preparation) it seems difficult to resolve the Sumbler-Shotton disagreement on the basis of present Quaternary deposits, except to say that supporting evidence for the single lake hypothesis is very rare outside the Leicestershire survey areas. Sumbler, in correspondence with the author, has suggested that neither theory is either provable or amenable to disproof on the basis of present evidence.

There is one further area of controversy, which could be important to the evaluation of Lake Harrison theory. Until recently, the glacial deposits of the Coventry, Leamington, Rugby area have been used as the type for the Wolstonian Stage, which covers the sediments laid down during the glaciation between Hoxnian and Ipswichian interglacials. Sumbler (1983a) has disputed this interpretation, arguing that, as yet, no Hoxnian or Ipswichian deposits have been found in sequence with the Wolstonian glacial material. Instead, he puts forward the case for interpreting the drifts as Anglian in origin, on the admittedly 'tenuous' grounds that "the Oadby Till is chalk-bearing and the only chalk-bearing tills yet dated with certainty in eastern England are Anglian in age" (Old *et al*, 1987, p.48-9). This view has recently received further support from evidence that "the lower members of the Wolstonian sediments, the Baginton/Lillington Gravels and the Baginton Sands ... can be traced into East Anglia where they underlie Lowestoft Till" (Bowen *et al*, 1986, p.307). Rose (in preparation) therefore recommends that, "the use of the term 'Wolstonian' is misleading" and "should be abandoned". If this alternative chronology is accepted, then an even longer period of time becomes available for post-lacustrine developments. This has important implications for the chances of survival of the geomorphological features associated with the theory. It is to this evidence at and beyond the lake margins that we now turn.

400′ Wave-Cut Bench

At the same time as Shotton was investigating the Quaternary deposits of the Leamington-Rugby area, a 400′ bench was identified by slope profile analysis along the southern margins of the Midlands lowland basin (Dury, 1951). Its close correlation with the uppermost levels of lacustrine deposits known at that time, persuaded Shotton to suggest that the feature was a wave-cut platform marking the upper limit of the former lake shoreline (Shotton, 1953). Since 1953, this interpretation has had to survive a number of empirical difficulties. Bishop (1958), in trying to replicate Dury's work, found that "some of the benches were not located" and some were too high to conform with the original lake-height theory. There were also problems in trying to relate the 400′ bench to local glacial deposits (Bishop, 1958, p.276)[3]. In addition, Bishop (1958) reported discoveries of lake deposits above the presumed lake height of 400′. One might think that this conflicting evidence should have cast serious doubts upon both the validity and significance of any relationship between Dury's bench and the former shoreline of Lake Harrison. Instead, Bishop postulated an elaborate 2-stage theory of glacial advance and retreat, in order to accommodate a Lake Harrison at two different levels (435′ and 410′). Of course, this could be the correct explanation. However, recent work by the B.G.S. has cast fresh light on the controversy in finding a correlation between the bench and an outcrop of the '70-marker' member, a hard bed in the Lower Lias, thus arguing that the feature could have a structural rather than a wave-cut, shoreline origin (Ambrose and Brewster, 1982). In response Shotton (1983) has maintained that this structural bench could still have coincided with a former lake-level. Such a coincidence, although obviously a possibility, would, however, have been remarkable and Ambrose and Brewster (1982) have found no evidence of shoreline deposits along the main Middle Lias escarpment at or around 400′, to support this view. Moreover, if the above suggestion of an 'Anglian' origin for Lake Harrison is accepted, the long period of time available for subsequent weathering and erosion would make the survival of a wave-cut bench highly unlikely (Sumbler, 1983b).

Table 1. The sequence of Pleistocene deposits around Coventry, Rugby and Leamington, including a description of environmental changes during the Wolstonian (based upon Shotton, 1953).

			ENVIRONMENTAL CONDITIONS
NEWER DRIFT	DEVENSIAN	AVON TERRACES	
	IPSWICHIAN INTERGLACIAL		
OLDER DRIFT	WOLSTONIAN i.e. LAKE HARRISON PHASE	DUNSMORE GRAVEL	Outwash zone left by the final retreat of the ice.
		UPPER WOLSTON CLAY	Readvance of the mainly eastern ice causes Lake Harrison to reoccupy the area. Ice eventually advances across the lake as far as Moreton-in-Marsh.
		WOLSTON SAND	Meltwater streams from retreating ice cause delta to be formed across the lake deposits.
		LOWER WOLSTON CLAY	Ice blocks all outlets. Lake Harrison covers the area.
		BAGINTON SAND	Continued ice advance leads to the beginnings of ponding.
		BAGINTON/ LILLINGTON GRAVEL	Outwash zone due to the advance of northern ice.
	HOXNIAN INTERGLACIAL		
	ANGLIAN	BUBBENHALL CLAY	

Table 2. The sequence of the type Wolstonian glacial drift deposits and a description of environmental changes (based upon Shotton, 1976; Rice, 1981; Sumbler, 1983 and Old et al., 1987).

Shotton (1976) Rice (1981)	Sumbler (1983) Old et al. (1987)	Environmental Conditions	Shotton (1953) Equivalents
Dunsmore Gravel	Dunsmore Gravel	Outwash sandur left by final retreat of the ice.	Dunsmore Gravel
Upper Oadby Till Lower Oadby Till	Upper Wolston Clay and Oadby Till	Ice readvances across the whole region from the north-east leaving mainly a Chalky Till with occasional lacustrine beds.	Upper Wolston Clay
Wolston Sand and Gravel	Wolston Sand and Gravel	Outwash sandur from retreating ice.	Wolston Sand
Bosworth Clays and Silts	Lower Wolston Clay	Ice-front retreats to a position in North Leicestershire. EITHER Lake Harrison (Shotton, 1983) OR a series of separate pro-glacial lakes (SUMBLER, 1983), occupy the region.	Lower Wolston Clay
Thrussington Till	Thrussington Till	Ice covers the region (at least as far SW as Leamington). A pro-glacial lake may have occupied the zone between the ice and the Jurassic escarpment.	
Baginton Sand Baginton-Lillington Gravel	Baginton Sand and Gravel	Fluviatile outwash material associated with the advance of northern ice.	Baginton Sand Baginton-Lillington Gravel

Glacial Overflow Channels

We have seen that three overflow channels were originally postulated for Lake Harrison. How far does this aspect of the theory stand up to critical scrutiny? Firstly, it is important to go back to the original roots of the idea. The precise locations of Lake Harrison's overflow channels were initially based upon Shotton's assumption of a lake height at approximately 410′, eg.

> "The possible outflows of Lake Harrison are several, for there are at least three cols across the Jurassic scarp on the south-east side of the Lake, which have a level at least within a few feet of 410′ .... They are the Daventry, Fenny Compton and Dassett gaps" (Shotton, 1953, p.251).

This lake height of 410′ was based upon the coalescence of two lines of evidence:

(a) 'the highest levels of lake clays known at that time'

eg.
"Moreton-in-the-Marsh 404′, Thurlaston 370′, Lutterworth 389′, Sibson 390′, Hinckley 398′ .... (Therefore) .... it seems justifiable to assume a level of just over 400′ for the lake and I shall henceforth use a figure of 410′ without further argument" (Shotton, 1953, p.237).

(b) Dury's 400′ bench.

Certain empirical weaknesses have since come to light. The original evidence was based upon a small sample of lake bottom rather than shoreline deposits, of which only one (Moreton-in-Marsh) was located at the assumed lake margin. It has already been noted that lake clays were subsequently found at heights above 410′ and necessitated a two-stage lake theory (Bishop, 1958). More recent discoveries of lacustrine deposits have, however, been consistent with the 410′ shoreline in the eastern parts of the region (Douglas, 1980; Old *et al.* in preparation), but examples well above the level continue to be found in the west (Old *et al*, in preparation). These height anomalies inevitably create uncertainty about the single lake hypothesis and alongside the doubts already expressed about Dury's 400′ wave-cut platform, the identification of cols suitable as overflow channels begins to look increasingly arbitrary. Research has so far failed to provide supporting evidence of the fluvial deposits which might be expected at the three gaps, nor is there any morphological evidence that would distinguish the features as having an overflow origin.

Shotton (1983) has attempted to use morphological and sedimentary evidence from the Cherwell valley to justify the overflow channel hypothesis, eg.

> "Bishop (1958) demonstrated that Lake Harrison water had escaped through the Fenny Compton gap into the Cherwell .... He traced the morphological flat, which developed at the head of the Cherwell, down river until it carried sediment upon itself, and finally into the Wolvercote Terrace. (p. 34)

Although fashionable during the pre-1960 'Denudation Chronology' phase, this process of extrapolating 'flats' over great distances in order to correlate terrace formations is viewed with scepticism today. It assumes smooth curves of river profiles, which never seem to exist in reality. Bishop (1958, p.283) acknowledged these difficulties and was originally much more tentative in his conclusions than is apparent from Shotton's above statement, eg.

> "The tracing of this level downstream is difficult, but a line approximately parallel to the river is suggested, approaching gradually upstream towards the flood plain. It *appears* to link with the top of the Wolvercote terrace".

On the other hand, the idea of a movement of glacial drift material southwards by meltwater is strongly supported by the evidence of the river terrace material. Tomlinson (1929), Sandford (1932) and Bishop (1958) have all shown that erratics from the Oadby Till were carried across the present drainage divide into the Evenlode and Cherwell valleys, to produce a distinctive change in the terrace lithology with the formation of the Wolvercote Terrace. Also, it is argued that the morphological flats can be closely correlated with this critical sedimentary evidence over quite short distances (Rose, personal correspondence). This all seems to support some form of glacial meltwater process, associated with the Fenny Compton and Moreton cols. However, it is less clear that these meltwaters have to be the product of lake overspill. Direct meltwater from a decaying ice-front situated against the Liassic Scarp face is perhaps the more likely explanation.

Finally, although Sumbler (1983a, p.25) acknowledges that his "marginal lakes" .... "may have found outlets through some of the cols", it would appear from the above discussion that the overflow channels do not represent strong primary evidence for the existence of Lake Harrison as a single extensive sheet of water.

Impounding of Lake Harrison

In order to explain and justify the location of Lake Harrison, Shotton (1953) had to invoke the presence of glacial obstructions at a number of points around its margins:

> "Clearly this lake could not have held water .... if the col below 300′ between Bredon Hill and Church Lench remained open .... it is necessary to invoke the presence of the Second Welsh Glacier in the Severn and Worcestershire Stour Valleys, forming a wall from the Clents to the Cotswold Scarp. The simultaneous existence of the dams at both ends of the ancient valley is essential if it is to hold water."

> "To retain water up to the level of 410′, certain other outlets must be blocked. Ice must have covered the low ground around Kibworth Harcourt (6897), while, on the other side of the valley pre-glacial cols at Snarestone (3508) and Caldecote (3596) cannot have functioned as overflows" (p.250).

As recently as 1980, Douglas has identified yet another potential outlet/overflow channel, at Saddington, which would have required glacial blockage in the context of a single lake hypothesis (p.283).

The problem is that observations of contemporary glaciers have revealed that they do not necessarily form impermeable barriers to meltwater drainage. Nor do they always support extensive long-term lake development, especially in the ice-melt zone of temperate glaciers (Embleton and King, 1975, p.532-5). Moreover, in the case of Lake Harrison, although there is evidence that the blockage areas were glaciated, it is difficult to demonstrate the simultaneous existence of ice at each of the postulated outlet points. Of course, this does not disprove the existence of Lake Harrison. It is equally true that pro-glacial lakes do form and survive for long periods, providing that the topographic position is appropriate or as a result of crustal depression due to ice loading (eg. L. Agassiz). Nevertheless, the full supporting sedimentary evidence for the simultaneous impounding of Lake Harrison at each of its outlet points is not yet available. In its absence, we have to rely upon circular arguments and in the end, it can seem just too convenient for the model that every altitude anomaly should be explained away so easily. In Popperian terms, it constitutes 'weak' theory, in not being sufficiently amenable to tests for falsification.

Drainage Reversal

In the introduction, it was noted that evidence had been found suggesting the existence of a sub-drift valley (Proto-Soar) stretching from Moreton-in-Marsh to Leicester. The line of this valley from south west to north east was also followed by the Baginton Sands and Gravels at the base of the Wolstonian (Shotton, 1953). Rose (in preparation) has used the distribution of Baginton Sands and Gravels to trace this buried Proto-Soar valley into South Lincolnshire and East Anglia, "towards Bury St. Edmunds, Diss and the region of the North Sea". As yet, nobody has disputed either this evidence or the idea of the shift of the Soar-Avon watershed from Moreton-in-Marsh into Leicestershire as a result of the eventual drainage of Lake Harrison towards the end of the Wolstonian. However, in their recent account of 'the Geology of the Country around Warwick', Old, *et al.* (1987) do begin to show some reservations. They argue that "not only are data meagre, but the rock-head contours are the integration of several distinct episodes of subaerial, glacial and possibly sub-glacial drainage, and so are most unlikely to represent the surface topography at any given time" (p.49). However, even if the sub-drift evidence does prove to be valid, it does not follow that the existence of Lake Harrison was an essential pre-requisite for the reversal of drainage in the Soar-Avon. The overriding of the region by ice from the north and north-east would inevitably have disturbed any previously north-east flowing drainage system. The eventual melting and retreat of these glaciers would have encouraged the establishment of a predominantly south-westerly drainage, even if Lake Harrison had not existed.

Conclusion

Shotton's theory of Lake Harrison is an elaborate and imaginative synthesis of the glacial evidence in the South Midlands, which has clearly had a dominant influence upon all subsequent research into the Quaternary history and geomorphology of the region. None of the geomorphological ramifications of the theory seem to offer strong support for Lake Harrison. However, the evidence of lacustrine deposits especially in the north and east of the region (Shotton, 1976; Douglas, 1980; Rice, 1968, 1981) and around Snitterfield, near Stratford- upon-Avon (Rose, personal communication) does suggest some form of lake hypothesis. Nevertheless, the exact nature and extent of this lake environment is still controversial. For some recent writers, a single large Lake Harrison remains the best model available for understanding the glaciation of the area. (Shotton 1983, 1984; Old *et al.*, in preparation; Bowen *et al.*, 1986; Rose, in preparation). Others argue that the presence of lacustrine clays in a number of localities does not prove that they were all deposited simultaneously in the same lake. For them, a transient series of glacial lakes or ponds 'in front of, upon and even within' the ice sheets advancing from the north and east seems a preferable explanation (Sumbler, 1983a; Old *et al.*, 1987). This dispute is not yet resolved and readers will find the dichotomy still reflected in the different approaches to the lacustrine deposits adopted in the forthcoming Warwick and Redditch memoirs.

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Notes

1. These Lower Wolston Clays were renamed the Bosworth Clays and Silts by Shotton (1976), but the recent Warwick Memoir (Old *et al.*, 1987) has reverted to the old name (Lower Wolston Clay).
2. Old, *et al.* (in preparation), attempt to reconstruct an elaborate system of ice-front lakes and overflow channels to explain these lacustrine deposits, but appear not to try to accommodate the different height anomolies explicitly.
3. According to Bishop (1958), the 400′ bench truncates drift ranging from lower to upper Wolstonian in age. Bishop therefore placed the formation of the bench as Late Wolstonian. Otherwise, the bench would have been overrun by the final advance of the Oadby Till ice sheet without being destroyed or obscured. However this Late Wolstonian age for the lake does not correlate with the main phase of lacustrine sedimentation, which, we have seen, was Lower Wolstonian.

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A NEW SPECIES OF THE CARBONIFEROUS TRILOBITE *LINGUAPHILLIPSIA* FROM CUMBRIA, ENGLAND

by

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Summary

Linguaphillipsia mitchelli sp. nov. is described from the Park Limestone, Holkerian stage at Whitbarrow Quarry, Cumbria. *Linguaphillipsia* is rare in the British Dinantian, with only three species previously described from the Arundian to Asbian interval. Further discoveries of *Linguaphillipsia* may prove biostratigraphically significant.

Introduction

Whitbarrow Scar Quarry (NGR, SD 454 847 to 462 855) is an extensive working along the base of White Scar behind Raven's Lodge Farm. Both the limestone and a large area of Pleistocene "cemented" scree have been extracted. Commercial quarrying began in 1946 but operations have now ceased.

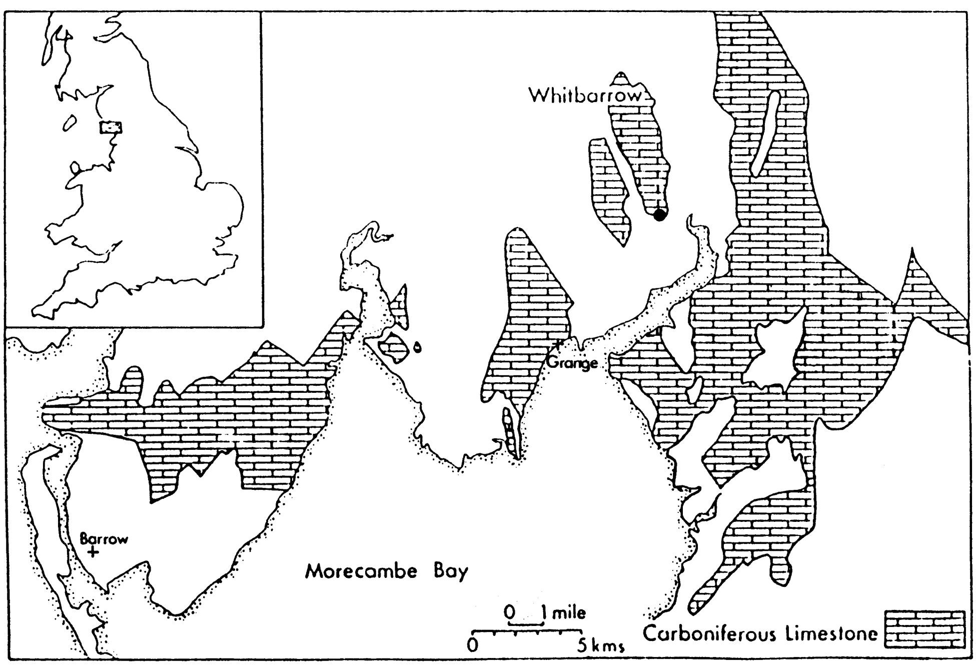

Fig. 1. Location of Whitbarrow Scar Quarry southern Lake District.

Mercian Geologist, Vol. 11, no. 3, 1988, pp. 155–160, plates 1 & 2 (2pp.)

Stratigraphy

In the early Carboniferous, limestones with thin subordinate calcareous mudstone and sandstones were deposited on the southern margin of the Lake District. Mitchell (1980, unpublished) has mapped the outcrop of the Dalton Beds and Park Limestone on the Whitbarrow block (Fig. 1). The Dalton Beds are considered to be of Arundian age, whilst the Park Limestone is referred to the Holkerian (Mitchell, 1978). There are excellent exposures in the upper part of the Dalton Beds and lower part of the Park Limestone in Whitbarrow Scar Quarry at the southern end of White Scar. The Dalton Beds are pale to dark-grey, thick-bedded limestone with a prominent mudstone/sandstone unit at the top which is about 0.3 m thick at Whitbarrow and may be equivalent to the Ashfell Sandstone of the Ravenstonedale area to the east. Ramsbottom (1974, p. 57) considers the Ashfell Sandstone to be a regressive phase at the top of Major Cycle 3. The succeeding Park Limestone comprises massive pale grey limestones, which form the upper parts of the outcrop.

	STAGES	LITHOSTRAT.	CYCLES	SPORE ZONATION		MACROFOSSIL SUBZONES
Visean	Brigantian	Gleaston Formation c 200 m	6	B. nitidus - R. carnosus	NC	D. muirheadi
				T. vetustus - R. fracta	VF	L. floriformis
	Asbian	Urswick Limestone 120 - 160 m	5	R. nigra - T. marginatus	NM	C. murchisoni
	Holkerian	Park Limestone 120 m	4	P. tessellatus - S. campyloptera	TC	N. minus
						C. carbonaria
	Arundian	Dalton Beds 120 m	3	K. triradiatus - K. stephanephorus	TS	Gastropod Beds C. carinata
		Red Hill Oolite 60 m		L. pusilla	Pu	C. isorhyncha
	Chadian	Martin Limestone 50 m	2			S. gregaria
	Courceyan	Basement Beds 0 - 100 m	1	S. clavinger - A. macra	CM	Solenopora

Fig. 2. Visean stratigraphy of the southern Lake District.

Lithostratigraphy after Rose and Dunham (1978), sedimentary cycles after Ramsbottom (1973), spore zonation after Higgs et. al. (in press), local macrofossil zones modified from Garwood (1913) and stages after George et. al. (1976).

Dr. A.E. Adams (pers. comm. 1983) has kindly provided the following petrographical information: "The limestones are pale, medium-grained, bioclastic and peloidal limestones, packstone in texture with some micritic pellets and a diverse suite of bioclasts; algae, foraminifera, calcispheres, echinoderm fragments, molluscs with micritic envelopes, brachiopods, ostracods, tubular problematica and 'ungdarellids'". The new species of *Linguaphillipsia* occurs in the lower part of the Park Limestone, and is associated with a diverse macrofauna that includes brachiopods (*Linoprotonia, Megachonetes, Actinoconchus, Echinoconchus* and *Propriopugnus*), gastropods (*Bellerophon, Straparollus, Naticopsis* and *Pharkidonotus*), corals (*Lithostrotion, Syringopora, Aulopora* and *Clisiophyllum*), bryozoans, fish teeth and bivalves. *Lithostrotion minus* (McCoy) and *Linoprotonia corrugatohemispherica* (Vaughan) are both recorded elsewhere from limestones of Holkerian age Rose & Dunham (1978, p. 36).

Dr. N.J. Riley (B.G.S.) (pers. comm. 1987) has identified the following foraminifera and algae from the trilobite matrix; *Archaediscus* cf *varsanofievae, Archaediscus* stage *concavus, Bogushella ziganensis, Calcisphaeres, Endothyra spp, Endospiroplectammina, Eostaffella* sp, *Forshiinae, Kamaeniids, Koninckopora inflata, Koninckopora minuta, Mediocris* sp, *Nodosarchaediscus* sp, *Palaeotextularia, Pseudolituotuba, Stacheiinae, Tetrataxis* sp and agglutinated single walled palaeo-textulariids. He writes: "The microbiotas are rather illusive, *A. stage concavus* is most useful, although *Holkeria, Pojarkonella* etc. are not present. No Arundian or Asbian guides are present hence the fauna is consistent with a Holkerian age".

Palynological assemblages from Whitbarrow Scar Quarry have been examined by K.J. Dorning, Pallab. Research, Sheffield; the lower part of the Park Limestone typically contains moderately well preserved palynomorphs and sedimentary organic matter, including abundant marine benthonic calcareous algae, a low diversity acritarch microflora and scolecodonts, together with spores of moderate diversity. A diverse spore and acritarch microflora of moderate to excellent preservation was recorded from samples collected from the prominent mudstone/sandstone unit at the top of the Dalton Beds, which include forms indicative of the *K. triradiatus—K. stephanephorus* spore Biozone of Higgs et al. (in press). This assemblage biozone is restricted to the late Arundian—early Holkerian.

Systematic Palaeontology

Family:	*Proetidae*	Hawle & Corda, 1847
Subfamily:	*Linguaphillipsiinae*	G. & R. Hahn, 1972
Genus:	*Linguaphillipsia*	Stubblefield, 1948

Linguaphillipsia scabra (Woodward, 1884)
Plate 2, figs 1–7

1884	*Phillipsia scabra* sp. nov. Woodward, p. 43–44, pl. 9 figs. 5a & 5b.
1926	*Phillipsia scabra* Woodward, Bush, p. 257.
1970	*Linguaphillipsia scabra* (Woodward), Osmólska, p. 48.
1970	*Phillipsia scabra* Woodward Osmólka, p. 49.
1973a	*Linguaphillipsia matthewsi* sp. nov. G. & R. Hahn, p. 551–557, text figs. 1–2, pl. 64, figs. 1–6.
1973b	*Linguaphillipsia matthewsi* G. & R. Hahn, p. 479–509, text fig. 1e.
1975	*Linguaphillipsia matthewsi* G. & R. Hahn, G. & R. Hahn, Leitfossilien: 54.
1982	*Linguaphillipsia matthewsi* G. & R. Hahn, G. & R. Hahn, p. 115–121.
1984	*Linguaphillipsia matthewsi* G. & R. Hahn, Thomas et al., p. 66–67.
1984	*Phillipsia scabra* Woodward, Thomas et al., p. 69.
1984	*Linguaphillipsia matthewsi* G. & R. Hahn, Riley, p. 6–8.
1985	*Linguaphillipsia matthewsi* G. & R. Hahn, Hahn & Amler, p. 72,75.

Description: Woodward described and figured *Phillipsia scabra* from Vallis Vale, Frome, Somerset. Dr. R.M. Owens has examined the type material and states (pers. comm. 1986) "The cephalon figured by Woodward (1884, pl. 9, fig. 5a) has unfortunately been damaged, with most of the central portion of the glabella removed. What remains, as well as the free cheek and pygidium, agree closely with *Linguaphillipsia matthewsi* G. & R. Hahn 1973a". Both these species have identical characteristics (see plate 2, figs. 1–7) therefore *L. matthewsi* may now be regarded as a junior synonym.

Linguaphillipsia mitchelli sp. nov.
Plate 1, figs 1–8

Derivation of name:	After Mr. Murray Mitchell, formerly of the British Geological Survey, for his contributions to Dinantian biostratigraphy.
Holotype:	NMW 86.25G.2109 pygidium.
Paratypes:	NMW 78.1G. 255, 256, 261, 264, 271, 272, 274 86.25G.193, cranidia; 78.1G.265, 86.25G.9, free cheeks; 78.1G. 194, 254, 257–60, 262, 263, 266–70, 273, 275, 276 pygidia.
Type locality:	Whitbarrow Quarry, 22 km. NE of Grange-over-Sands, Cumbria, England. NGR. SD 4600 8530.
Age:	Park Limestone, Holkerian.
Diagnosis:	*Linguaphillipsia* belonging to the "*scabra* group" (=matthewsi group) of G. & R. Hahn 1973b. Frontal lobe of the glabella narrower than across L_1 and with a narrow smooth band of anterior border between frontal lobe and innermost terrace ridge. Posterior margin of pygidum subacuminate in outline. 13–14 axial rings and 10 pairs of pleural ribs.
Description:	The following comparative description is condensed since this species closely resembles *L. scabra* (Woodward, 1884) which was described in detail by Hahn & Hahn (1973a).

The glabella has a slightly more strongly forward taper, and the frontal lobe does not extend as far across the anterior border, leaving a narrow smooth band between it and the innermost terrace ridge. Such a band is not present in *L. scabra* where the glabella extends close to the anterior border (Hahn & Hahn 1973a, pl. 64, figs. 1–2; text 1a, p. 555). The preocular facial sutures are more strongly divergent, and the terrace ridges on the lateral border extend further inwards (see pl. 1, fig. 5 and Hahn & Hahn 1973a, pl. 64, fig. 1a, p. 555). The sculpture is of fewer, coarser granules, of similar distribution to *L. scabra*. The pygidium of *L. scabra* and *L. mitchelli* are very similar, differing only in the subacuminate posterior margin and smaller number of axial rings (13–14 compared with 15–18). Small pygida of *L. mitchelli* (pl. 1, fig. 6) are proportionately less elongated, with a rounded posterior margin.

Remarks: Hahn & Hahn (1973b) recognised four species groups within *Linguaphillipsia*, and all three British species belong to the "*scabra* group". Differences between the British species are small, those between *L mitchelli* and *L scabra* have been discussed. The youngest of them, *L. cumbriensis* Riley from the Asbian, differs in having the frontal lobe of the glabella almost as wide (tr) as it is across L_1 and in having a pair of terrace ridges on the dorsal surface of the pygidial border.

L. scabra livensis G. & R. Hahn 1982 from the Visean of Belgium (V_2b—equivalent to early Holkerian) is very similar to *L. scabra*, differing in a narrower glabella with a greater construction at γ, fewer pygidial axial rings (15–16) and a broader margin. It is distinguished from *L. mitchelli* by similar characters to *L. scabra*.

Few trilobites have so far been described from the Arundian and Holkerian in Britain; the presence of *Linguaphillipsia* species at localities in Somerset, Avon, the Gower and Cumbria suggests that this genus might be more widespread than is currently supposed. It is possible that there exists a succession of closely related species that together with other trilobites may prove of biostratigraphical value. In Britain, *Linguaphillipsia* is unknown in carbonate mound facies, and its distribution might be expected to be more widespread than that of many trilobites that are largely restricted to this biofacies.

Acknowledgments

I thank R.M. Owens of the National Museum of Wales for reading the manuscript and providing the photographs also M. Mitchell, A.E. Adams, N.J. Riley and K.J. Dorning for unpublished information.

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Plate 1. *Linguaphillipsia mitchelli* sp. nov. Whitbarrow Scar Quarry, Grange-over-Sands, Cumbria.

1a,b Holotype, pygidium. ×6. NMW. 86.25G.2109. dorsal and lateral views.

2. Cranidium. ×6. NMW. 78.1G.255.
3. Cranidium. ×4. NMW. 86.25G.193.
4. Free cheek. ×5. NMW. 86.25G.9.
5. Free cheek. ×5. NMW. 78.1G.265.
6. Juvenile pygidium. ×10. NMW. 78.1G.270.
7. Pygidium. × 8. NMW. 78.1G.254.
8. Pygidium. ×5. NMW. 78.1G.263. Latex cast.

Linguaphillipsia cumbriensis Riley, 1984
Chonetes Shale, Yeathouse Quarry, Frizington, Cumbria. (Paratypes)

A. Free cheek. × 4. BGS. Ro 5588. (Photo. N.J. Riley).

B. Pygidium. × 4. BGS. Ro 5506. (Photo N.J. Riley).

NMW = National Museum of Wales.
BGS = British Geological Survey.

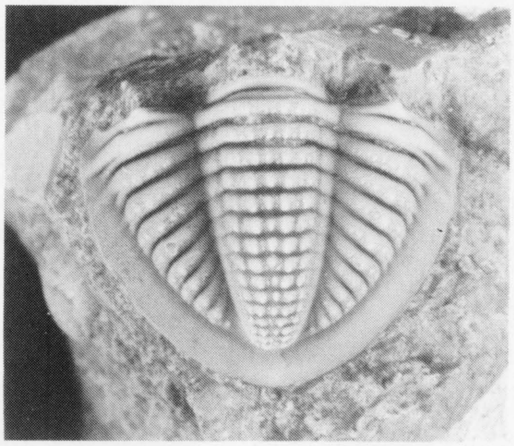
Plate 2. *Linguaphillipsia scabra* (Woodward, 1884).

1. Cranidium. × 4. NMW. 85.34G.1a. Clifton Down Limestone, Holkerian, Whatley Quarry, Frome, Somerset.
2. Cephalon. ×6. GSM. 95321. Figured Woodward 1884, pl. 9, fig. 5a. Vallis Vale, Somerset.
3. Free cheek. ×5. NMW. 85.34G.22. Whatley Quarry.
4. Pygidium. ×5. GSM. 33751. Vallis Vale.
5. Pygidium. ×5. NMW. 85.34G.4. Whatley Quarry.
6. Pygidium. ×5. GSM. 33752. Vallis Vale.
7. Pygidium. ×5. NMW. 85.34G.2. Whatley Quarry.

Linguaphillipsia sp. [aff. *Weberiphillipsia*]

8. Pygidium. ×5. NMW. 20.361.^q. Chadian/Arundian. Black Rocks, Ogmore-by-Sea, Mid Glamorgan, South Wales.

GSM. (ex Geological Survey Museum now at BGS Keyworth).



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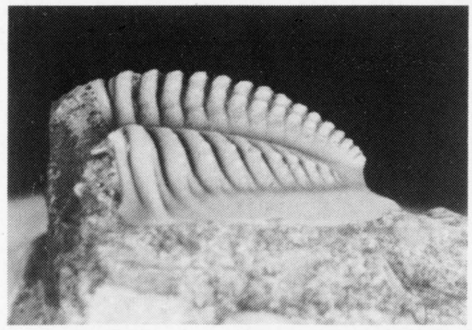

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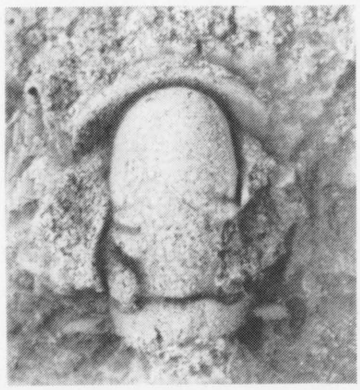

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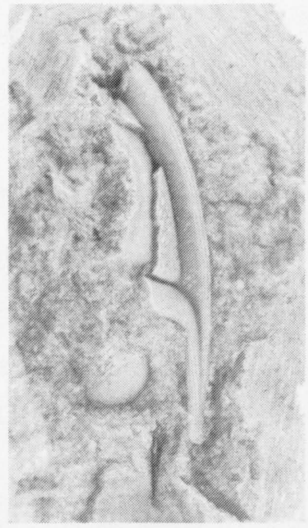

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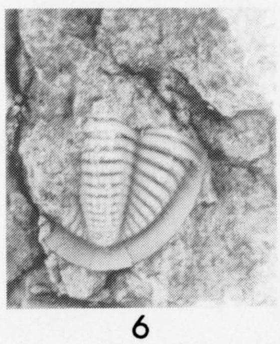

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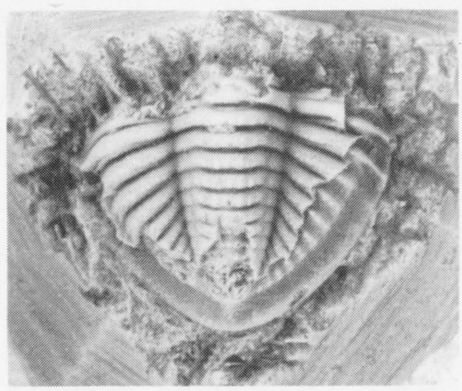

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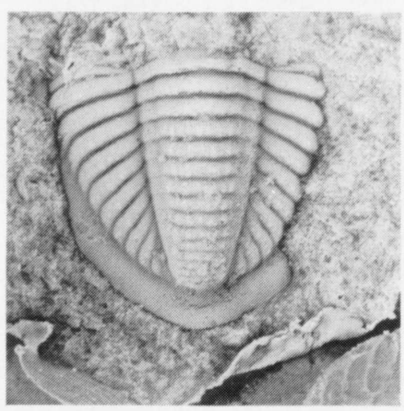

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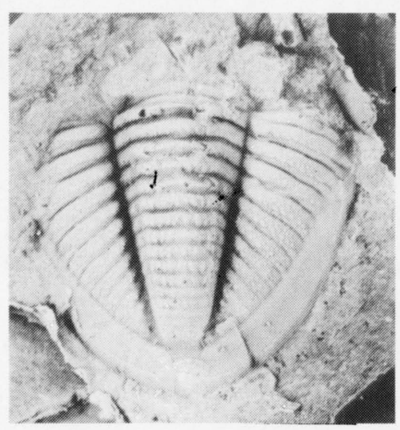

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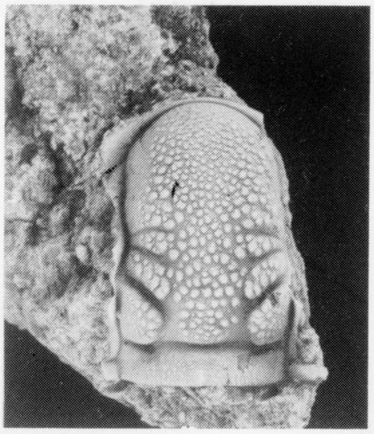

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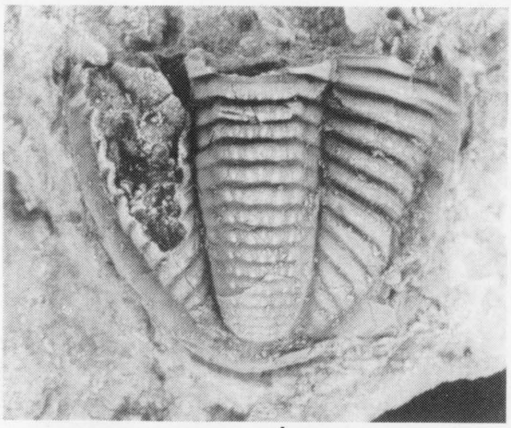

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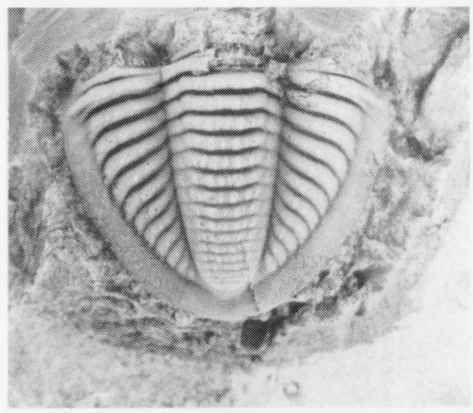

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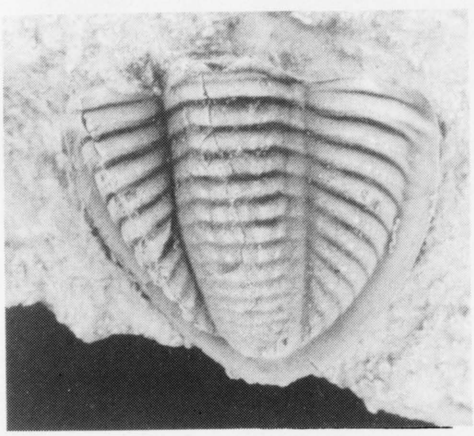

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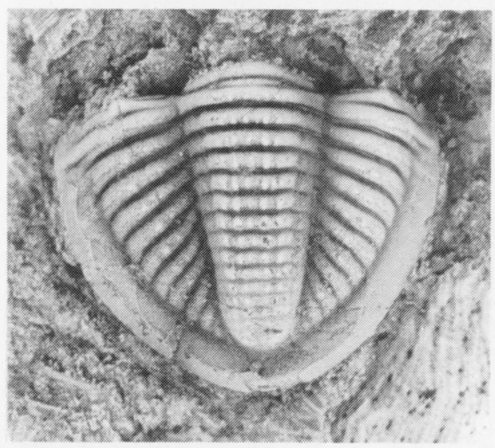

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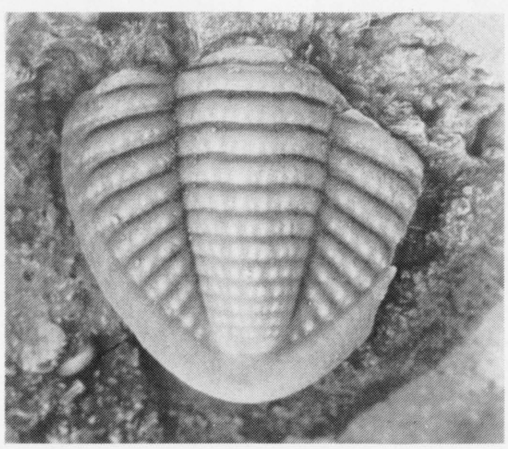

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THE PALAEONTOLOGY AND GEOCHEMISTRY OF THE GASTRIOCERAS CANCELLATUM MARINE BAND, ON THE GLYN NEATH BANK, NORTH CROP OF THE SOUTH WALES COALFIELD

by

L.A. Owen

Summary

The Gastrioceras cancellatum Marine Band in the Namurian of the Glyn Neath Bank, near Glyn Neath on the North Crop of the South Wales Coalfield shows twelve different palaeontological phases and three geochemical phases within 250cm of shale above the thin persistent cancellatum sandstone. The fauna, geochemistry and sedimentology of the marine band can be shown to reflect the palaeoenvironment. Phase 1 to 9 (1. *Planolites* (A); 2. *Lingula*; 3. Coarse ribbed bivalves; 4. Brachiopods and "*Hydrobia*-like" gastropods; 5. *Planolites* (B) and vertical burrows; 6. Mixed bivalves and brachiopod spat; 7. *Glabrocingulum* and *Nuculana*; 8. Solid thick-shelled goniatites, and 9. *Nuculana, Glabrocingulum* and brachiopod. "nests") indicate a gradual deepening of water; phase 10 (fragmented, thin shelled goniatites) represents a sudden deepening to an anoxic environment with slow sedimentation rates and reduced redox potentials. Phase 11 (mixed fauna) represents a rapid shallowing of the water depth to phase 12 (*Planolites* (A). The change in water depth may have been several metres to several tens of metres.

Introduction

(*a*) *Previous Research*

In a major marine band a series of faunal phases, and lithological and geochemical levels can be recognised (Robertson, 1932; Elias, 1938; Craig, 1954; Ferguson, 1962; Heptonstall, 1964; Calver, 1968; Bloxam and Thomas, 1969; Spears and Amin, 1987 and Holdsworth & Collinson, 1987). The principal work on faunal phases was done on Westphalian marine bands by Calver (1968), Namurian marine bands have similar fauna, but have been neglected. Jones (1965) discussed the nature and threefold lithological and fauna development of the Lower Gastrioceras (G1) stage marine bands, but his descriptions lacked detail. Heptonstall's (1964) study of the G. cancellatum Marine Band in Northern England concentrated on taxonomic studies neglecting its geochemistry.

These phases and levels may correspond with environmental changes in terms of cyclically fluctuating salinities, variations in water depth, sedimentation rates and energy regimes, induced by eustatic sea level changes, tectonics or other allocyclic processes (Ramsbottom, *et al.* 1962; Jones, 1963, Holdsworth, 1966; Calver, 1968; Collinson, 1987).

(*b*) *Present Study*

The Gastrioceras cancellatum Marine Band in the Namurian of the North Crop of the South Wales Coalfield is exposed along a road cutting at the "Glyn Neath Bank" (NGR.SN91450772–91510771) near Pont Nedd Fechan (Fig. 1). It was studied in order to determine the relationship between its palaeontology, geochemistry, sedimentology and thereby consider possible sea level changes, energy regimes and palaeoenvironments within a Namurian marine band.

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(*a*) *Field sections and sample collecting*

The shale, above a persistent decimetre bed of quartz wacke locally known as the cancellatum sandstone (Jones, 1965), which contains the G. cancellatum Marine Band was examined. Four 15cm deep, 5m thick vertical excavations were made along strike over an exposure of approximately 100m. The height of any noticable changes in fauna and lithology were recorded. 2kg samples of shale were collected at intervals of 10cm in one section and 1.5kg samples at 20cm in another section.

(*b*) *Laboratory work*

The shale was dried in air and either split by hand or distintegrated using a technique developed by Knights (1951). The fossils were removed from the shale, their relative attitude to fissibility, mode of preservation and fragmentation were recorded, examined and measured under the binocular microscope, and the total number of fossils per species within the shale sample was recorded.

Each sample of shale was powdered using a jaw crusher and passed through a BSS60 (250u) sieve. The colour of each sample was recorded using the United States Geological Survey standards.

(*c*) *Chemical Analysis*

1. Uranium, Thorium and Potassium—A gamma-ray spectrometer was used to measure uranium, thorium and potassium using the method of Strachan (1973).

2. Total Organic Carbon (TOC)—The combustion products of powdered shale samples were analysed using an automatic self-integrating, steady-state, thermal conductivity analyser (Model 240C Elemental Analyser, Perkin-Elmer) to obtain the TOC content.

3. Ca, Ba, Fe, K, Rb, Zn, V, Mg, Mn, Cu, Cr, Ti, Zr, Ni and Sr—The shale samples were fused with lithium metaborate using a technique developed by Imperial College Geochemical Unit and analysed using an I.C.P. to measure major and minor elements.

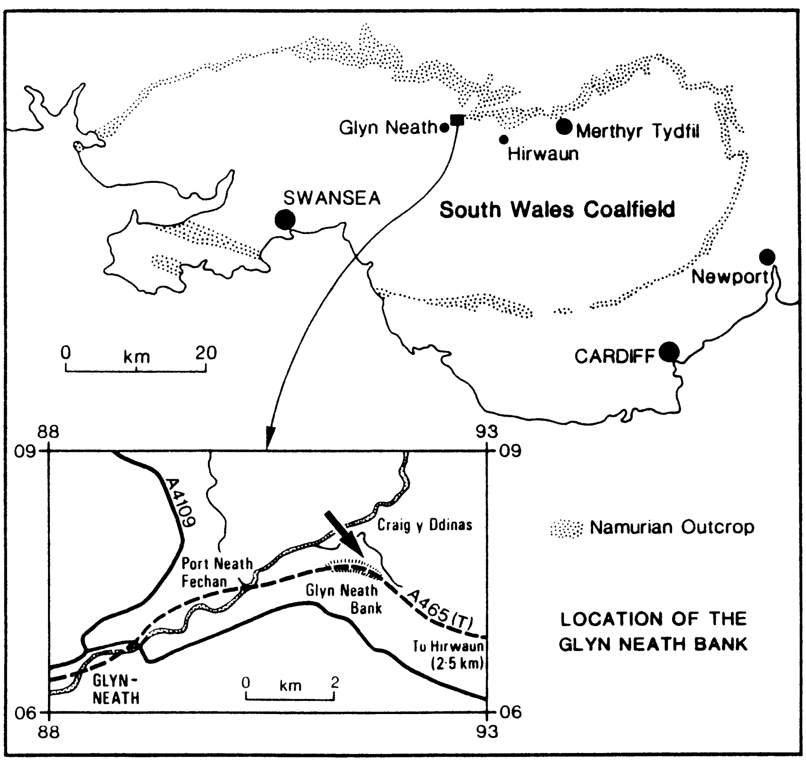

Fig. 1. Location Map.

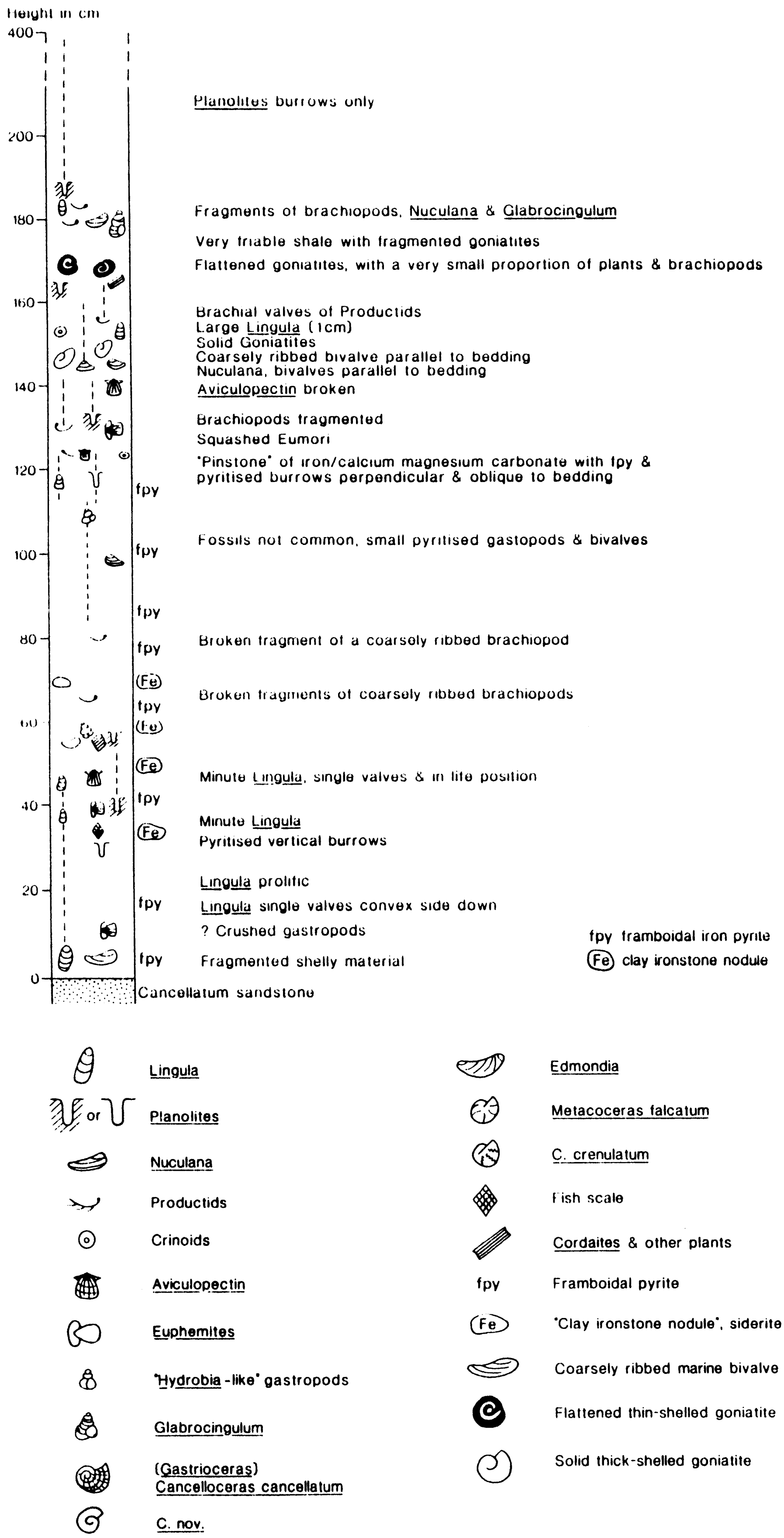

Fig. 2. Field log at (NGR SN91490771) the eastern end of the Glyn Neath Bank.

Results

(i) *Palaeontology*

Twelve faunal phases were recognised in the section, listed from the base upwards (Fig. 2 and 3);

1. *Planolites* (A) phase: These horizontal burrows have been described by many workers (Ramsbottom et al. 1962; Calver, 1968; Holdsworth, 1966 and Eager, 1985).

2. *Lingula* phase; *Lingula* is very prolific and at least 25% of the population were found in life position, vertical to the shale fissility. Figure 4 shows the size ranges for *Lingula* samples within the section.

3. Coarse ribbed bivalves phase; *Edmondia sp., Sanguinolites sp., Caneyella sp., Palaedima simplex* and *Aviculopecten losseni* occurred as isolated valves.

4. Brachiopod and "*Hydrobia*-like" gastropods phase; Brachiopods (*Eomarginifra* aff. *frechi*) were found in life position and "*Hydrobia*-like" gastropods (cf. *Loxomena*) were very abundant.

5. *Planolites* (B) and vertical burrows phase; *Planolites* (B) was abundant and mm diametre calcite filled vertical burrows were present. Some of these may have been small foraminifera, other fossils included fragments of brachiopod and *Glabrocingulum* aff. *armstrongi.*

6. Mixed Bivalve and brachiopod spat phase; Numerous bivalves (Edmondia sp.; *Sanguinolites* sp.; *Posidonia* sp. and *Palaeolima simplex*) with brachiopod spat were present.

7. *Glabrocingulum* and *Nuculana* Phase; *Nuculana attenuata* was found in life position with well preserved specimens of *G. armstrongi.*

8. Solid thick-shelled goniatites phase; *Cancelloceras evansi, C.* aff. *crencellatum, C.* cf. *demaneti, Reticuloceras superbilinque, Anthrococeras* sp. and *Agastrioceras* were present as well preserved fossils often forming nuclei for calcareous nodules.

9. *Nuculana. Glabrocingulum* and brachiopod "nests" phase; Brachiopod "Nests" (*Eomarginifera frechi*), which had as many as 100 individual and coquinas were present with occasional *N. attenuata* and *G.* aff. *armstrongi.*

10. Fragmented thin-shelled goniatites phase; C. cancellatum, C. branneroides/C. rurae, C. cf. *crencellatum, C.* sp. nov. aff. *cancellatum* and *Anthracoceras* sp. were present with densities exceeding 100 individual Kg^{-1} and were frequently highly fragmented.

11. Mixed phase; Most of the fauna present in Phase 1 to 9 were present within this phase, but *L. mytiloides* was less common and *Orbiculoldes nitida* was present.

12. *Planolites* (A) phase; This is similar to phase 1 with an absence of marine fauna.

(ii) *Geochemistry*

Geochemically the marine band can be split into three levels (Fig. 5) Level I (0–160 cm) shows little geochemical variation throughout 160 cm of shale and is similar geochemically to Level III (200–250 cm). Level II (160–200 cm) is very distinctive having higher concentrations of TOC, U, P, Ca, Ni, Zn, Cu, U, Cr and Sr and lower concentrations and ratios of Th, Na/K, Th/U, Si/C and Ba.

(iii) *Sedimentology*

The marine band comprises shale which varies from medium dark grey to grey black, the latter being associated with Level II which is rich in organic carbon (Figs. 2 and 5). Horizons of poorly developed black grey "bullion limestone" (Holdsworth, 1966) nodules up to 10 cm thick and 30 cm long were present between 100 and

140 cm above the cancellatum sandstone. These comprise ferroan calcite and ferroan dolomite with subordinate pyrite and fine horizontal laminations were picked out by silt and clay minerals. No microfossils were seen, but well preserved goniatites and productoids with spines were commonly preserved in life position.

Below 1 m (phases 1 to 3) and in phase 12, oblate "clay ironstone" nodules up to 3 cm long were present, comprising siderite and had a high clay mineral content.

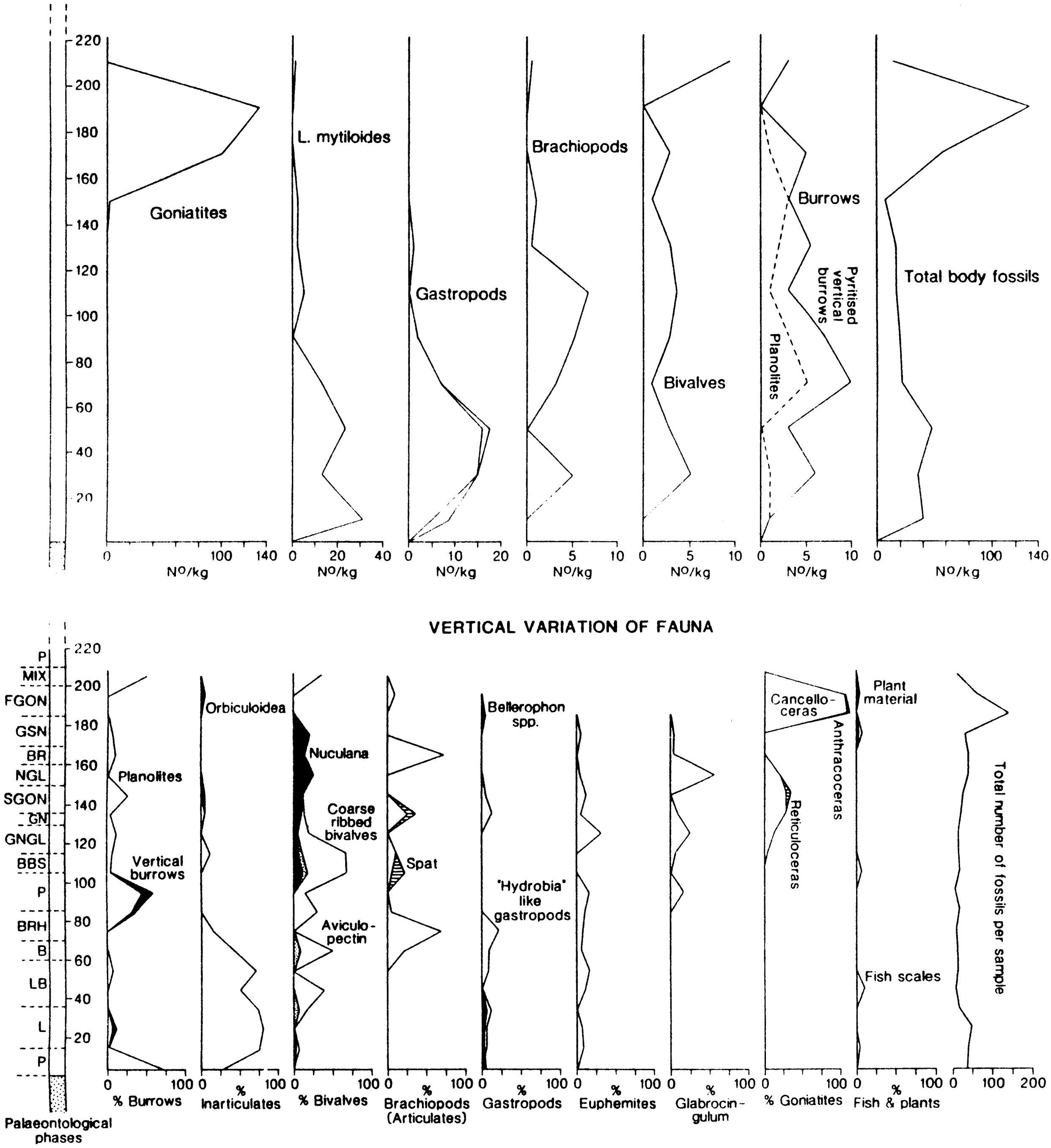

Fig. 3. Vertical distribution of fauna in two sections. P—*Planolites*. MIX—Mixed fauna; FGON—Thin-shelled flattened goniatites; GSN—Goniatites and solid *Nuculana*; BR—Productoid "nests"; NGL—*Nuculana* and *Glabrocingulum*; SGON—Sold thick-shelled goniatites; GN—Goniatites and *Nuculana*; GNGL—Goniatites, *Nuculana* and *Glabrocingulum*; BBS Bivalves and brachiopod spat; BRH, Brachiopods and "*Hydrobia*-like" gastropods, B—bivalve; LB—Bivalves and *Lingula*; L—*Lingula*.

Faunal Phases: 1. *Planolites* A (P); 2. *Lingula* (L); 3. Coarse-ribbed bivalves (LB); 4. Brachiopods and "*Hydrobia*-like" gastropods (BRH and B); 5. *Planolites* B and vertical burrows (P); 6. Mixed bivalve and brachiopod spat (BBS); 7. *Glabrocingulum* and *Nuculana* (GN and GNGL); 8. Solid thick-shelled goniatites (SGON); 9. *Nuculana, blabrocingulum* and brachiopod nests (BR and NGL); Fragmented thin-shelled goniatites (FGON and GSN); 11. Mixed (MIX) and 12. Planolites A (P).

Discussion

Various authors (Elias, 1938; Craig, 1954; Ferguson, 1962; Heptonstall, 1964; Calver, 1968, and Spears and Amin, 1981) have shown how faunal phases relate to palaeoenvironment. Similarly the fauna in Gastrioceras cancellatum Marine Band reflects changes in the palaeoenvironment, plus the geochemistry can be related to these changes.

The geochemistry of phases 1 to 9 (Level I) changes little and possibly indicates a geochemical environment which had little influence on the faunal development and was controlled little by water depth (Fig. 5). The fauna however does indicate a slight progressive deepening of water up section (Fig. 6) *Planolites* (A) phase (1) represents brackish water burrows (Ramsbottom *et al.*, 1962; Holdsworth, 1966; Calver, 1968; Eager et al., 1985 and Pollard, 1986). The presence of siderite rich clay ironstone nodules within phases 1 to 3 (Fig. 2) indicate shallow water environments such as are present on contemporary deltas and lakes (Pye, 1984).

Lingula Phase (2) probably indicates a quasi-marine environment, though living species e.g. *L. unguis* can tolerate a wide-range of conditions from intertidal zones, tidal channels, shallow marine environments and flourish near outlets of major rivers (Ferguson, 1963 and Craig, 1952). A gradual decrease in the size of individuals in samples taken from up the section to a height of 80 cm where larger forms with smaller populations take over may be a function of deepening of water and increased salinites producing environmental stunting and giantism (Hallam, 1965) (Fig. 4). The width and length histograms are skewed towards smaller individuals (Fig. 4). The frequent numbers of *Lingula* preserved in life position indicates that this does not represent a death assemblage (Boucot, 1957). It may represent a high infant mortality, but the vertical differentiation in size of individuals up the section suggests that this is not the case and may represent two populations. Although four species of *Lingula* have been recovered from the Namurian of Western Europe (viz. *L. parallela. L. squamiformis, L. credneri* and *L. mytiloides*) each distinguished by characteristic length/width ratios in the Gastrioceras subcrenatum Marine Band on the North Crop. Therefore it is likely that there are two populations of *Lingula* within the section and size changes of samples may be a function of water depth.

The coarse ribbed bivalve phase (3) suggests an environment with slightly higher energies than the two preceding, because *Edmondia* sp. *Sanguinolites* sp. and *Caneyella* sp. were likely to have been byssally attached and their strong heavy shells would be more resistant to higher energies.

The presence of brachiopods in Phase 4 is the first real evidence for normal marine salinities. This Phase is followed by a second *Planolites* phase (Phase 5) with vertical burrowers. *Planolites* in Phase 5 may have been a different organism and need not be associated with the brackish water forms in phase 1 (Crimes, 1976). Mixed bivalves dominate in Phase 6 suggesting a distinct community. Phase 7 contains *N. attenuata* preserved in life position suggesting deeper water than the preceding phases (Fig. 6) (Calver, 1968).

Namurian goniatites can be divided into two broad types, "thick-shelled" and "thin-shelled" (Calver, 1968). Ramsbottom *et al* (1962) suggested that thin-shelled goniatites are deeper water forms than the thick-shelled goniatites and Swan (pers. comm.) believes that many of the thick-shelled forms were benthonic. The difference between the goniatites in Phase 8 and those in Phase 10, maybe that Phase 10 represents the deeper water thin-shelled free living forms. A phase, rich in brachiopod nests (Phase 9) separates the thick shelled benthonic goniatite community from deeper water forms of Phase 10.

Phase 10 marks a major change in the geochemistry of the shales and the introduction of deep water forms (Ramsbottom *et al* 1962 and Calver, 1968) (Figs. 5 and 6). The ratio of thorium/uranium is lowest in this Level (II) which serves as a good indicator of a reduced redox potential (Adams and Weaver, 1958) possibly below a stable thermocline within anoxic sediments. The increase in uranium, TOC, phosphorous and calcium within Level II has been observed by previous workers (Ponsford, 1955; Bloxom and Thomas, 1969 and Spears, 1964). The correlation with phosphorous is probably due to the fixation of uranium in phosphates (Clarke and Young, 1958). The correlation with calcium suggest uranium is present in carbonate-fluorapatite (collophane). A decrease in potassium with an increase in uranium has also been shown by Bloxom and Thomas (1969), they suggest that uranium is not held in illite as Beer and Goodman (1944) seem to indicate (Fig. 5).

Hirst (in Jones, 1965) suggested that sodium/potassium ratios may reflect changes in sedimentation rates. The low ratios in Level II (Fig. 5) may indicate low sedimentation rates which would have allowed larger quantities of degraded illite to lose sodium due to cation exchange near surface waters before becoming deeply buried. These slow sedimentation rates help to explain the very high concentration of goniatites found in this level.

Degens *et al* (1957 and 1958) and Spears and Amins (1981) showed that certain trace elements may be characteristics of specific environments of deposition. Table 1 compares Spears' and Amin's (1981) results with the increase in nickel, zinc, copper, vanadium, chromium and strontium in level II. The trace element concentration in Level II have more "marine-like" values than those in Levels I and III. This indicates deeper waters for Level II than I and III. The coincidence of high TOC in this layer indicates that trace elements may be concentrated in the organic fraction of the shales (Degens *et al* 1957).

Phase 11 has a mixed fauna comprising a condensed regression sequence of phase 1 to 9. *Orbiculoides nitida* is present and seems to have replaced *Lingula* which is less common suggesting that the two were mutually exclusive. However, Calver (1968) in Westphalian marine bands often found them together. Phase 12 (Planolites (A)) indicates a continued regression to shallow brackish water sediments similar to phase 1. The geochemistries of Phases 11 and 12 (Level III) also indicate a shallowing of water depth and a return to redox potential similar to those of Level I.

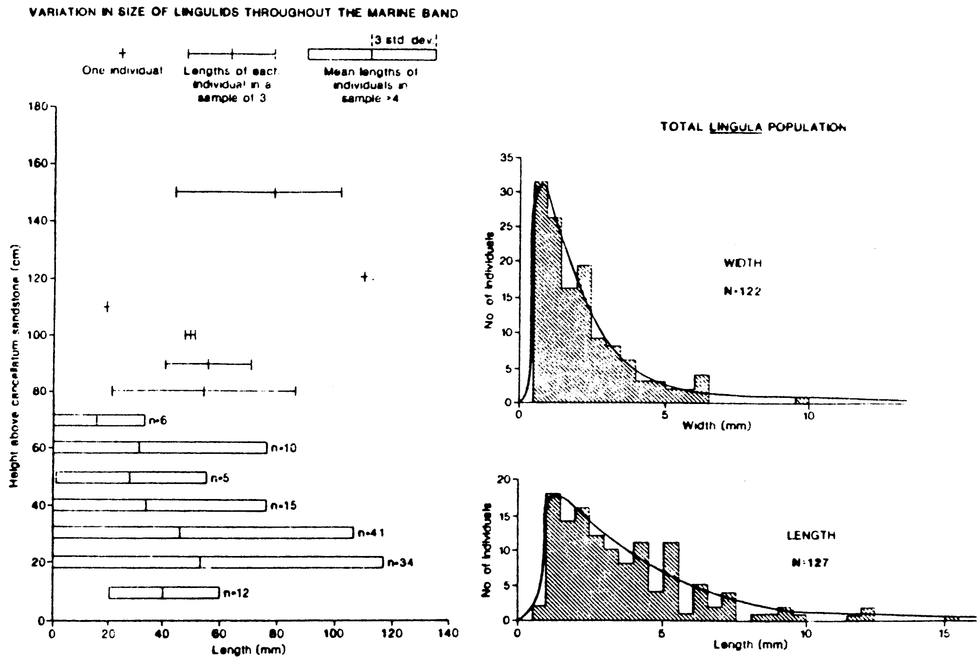

Fig. 4. Variation in size of lingulids throughout the marine band.

Table 1. Comparison of trace elements average and standard deviation from the Glyn Neath Bank and data calculated from eleven samples from different environments taken from Degens *et al.* (1957).

	Degens *et al* (1957)						This study	
	Fresh water		Brackish water		Marine		Glyn Neath Bank	
	Mean (ppm)	Std Dev.	Mean (ppm)	Std Dev.	Mean (ppm)	Std Dev.	Mean (ppm)	Std Dev.
Ba	577	254	545	82	455	121	535	48
Cr	110	47	67	11	62	20	103	18
Cu	77	22	74	21	74	19	23	20
Ni	26	7	22	11	50	25	62	12
Sr	363	128	500	148	445	93	122	14
V	50	16	35	13	45	14	128	22
Z	-	-	1500	-	550	31	81	19

Conclusions

The G. cancellatum Marine Band is more complex than Jones' (1965) three-fold division for G1 marine bands. The fauna contrasts markedly with the G. cancellatum Marine Band in Northern England which had a less varied fauna comprising *Caneyella, Dunbarella, Cancelloceras* and *Reticuloceras* (Heptonstall, 1964) and shows a greater similarity to Belgium faunas (Swan, pers. comm.). This is because during Carboniferous times Southern Britain, Belgium and France were small interconnecting basins and were a distinct faunal province, whilst the Central Pennine Basin was separated from this province by the Wales Brabant massif.

The faunal phases compared favourably with Calver's (1968) Westphalian marine bands, which indicated progressively deeper water facies with a marine incursion and a return to shallow water facies with a marine regression. However, the G. cancellatum Marine Band in South Wales is asymmetric, Phases 1 to 9 represent progressively deeper water faunas and a sudden deepening from Phase 9 to Phase 10 with a condensed Phase 11 containing fauna present in Phase 1 to 9 returning to shallow water fauna of Phase 12 (Fig. 6).

The three-fold geochemical division indicates a large change of water depth probably in the order of tens of metres in Level II corresponding to Phase 10. This represents a change from an environment (Level I) in which sediments have low TOC and low uranium levels to an environment in which sediments were anoxic with reduced redox potentials and therefore higher TOC and uranium levels. This was also reflected in the increase of the trace elements nickel, zinc, copper, vanadium, chromium and strontium and a decrease in barium in Level II. Level III (Phases 11 and 12) had sediments with geochemistries similar to Level I indicating a return to geochemical environments of shallower waters.

Acknowledgments

Mr D.E. Evans for introducting me to the Namurian of the North Crop and drawing my attention to this section. Dr J. Ferguson for encouraging this work at Imperial College. Dr. T. Ford and Dr. D. Siveter at the University of Leicester for their help and constructive criticism of the manuscript. Mrs C. Deacon for typing the manuscript, and Mrs K. Moore and Mrs R. Pollington for draughting the figures.

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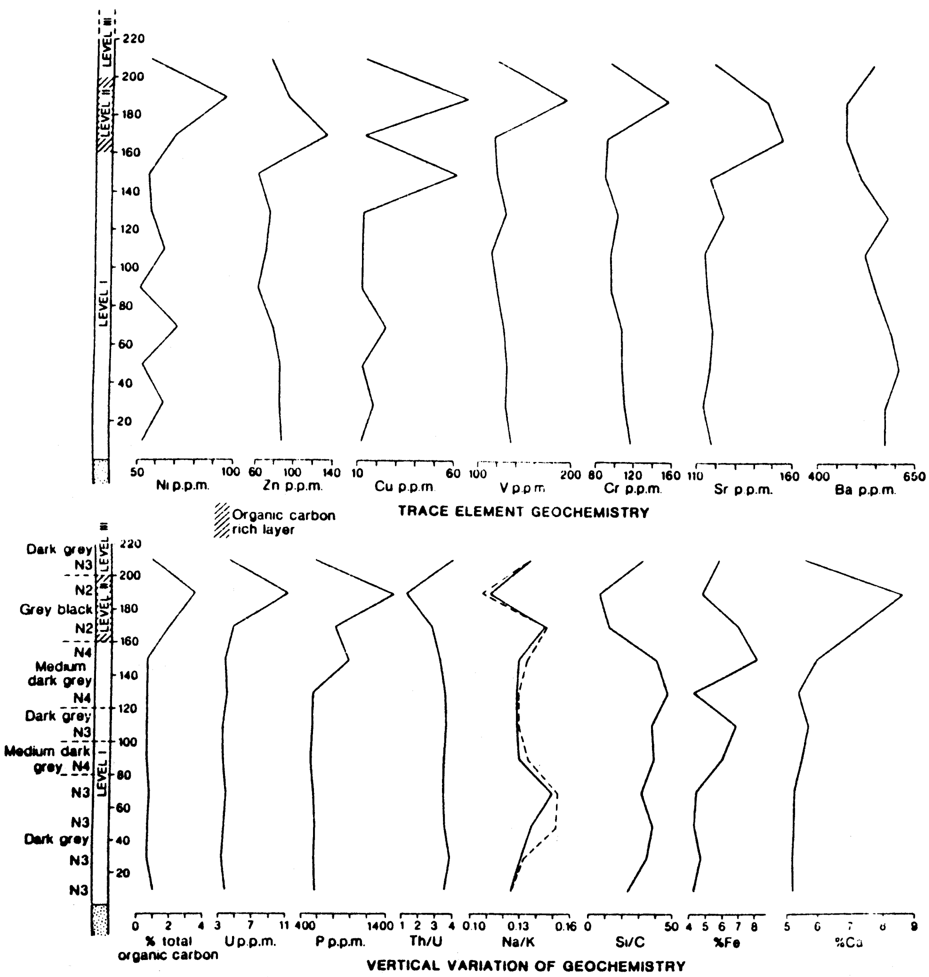

Fig. 5. Vertical variation of geochemistry throughout the marine band.

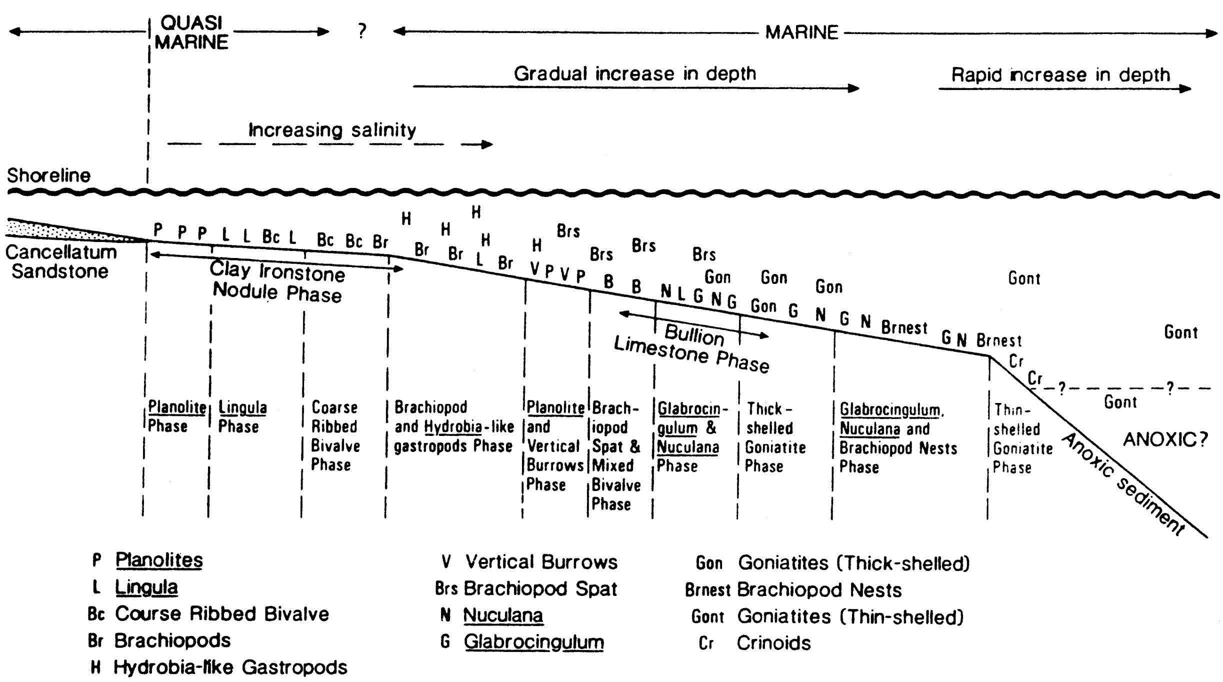

Fig. 6. Model for the environment and faunal phase of the Gastrioceras cancellatum Marine Band.

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A REVIEW OF THE TERRESTRIAL VERTEBRATE FOSSILS OF THE OXFORD CLAY (CALLOVIAN-OXFORDIAN) OF ENGLAND

by

David M. Martill

Summary

Dinosaurians form a rare but important part of the allochthonous fauna of the Oxford Clay of Central England. Their stratigraphic and geographical distribution is assessed. Comparisons of the English Oxford Clay dinosaur fauna are made between slightly younger faunas from Africa and North America. English Callovian dinosaur faunas are shown to have affinities with North America and African faunas, but it is assumed that local "islands" in North West Europe were populated by dinosaurs and that the Oxford Clay dinosaur fauna was locally derived. The history of dinosaur palaeontology in the Oxford Clay is reviewed. This paper is the first attempt to discuss the various Oxford Clay dinosaurs as a composite assemblage.

Introduction

The Oxford Clay of Southern and Eastern England has yielded a few incomplete skeletons of dinosaurs and pterosaurs, including the presence of a varied terrestrial vertebrate fauna on nearby land during the Callovian and Lower Oxfordian. The remains include representatives of most of the major dinosaur orders known to occur in the Jurassic. Sauropods, theropods, ornithopods, anklyosaurs and stegosaurs have all been reported. Rhamphorhynchoid pterosaurs are represented by fragmentary material only, which is nevertheless important for palaeobiogeographical and palaeoecological interpretations.

The distribution of dinosaur skeletons within the Oxford Clay does not appear to be restricted geographically or stratigraphically. Initially it would seem that dinosaurs are more abundant in the Peterborough district where they are restricted to the Lower Oxford Clay, but this is most likely an effect of collector bias, as the early collectors concentrated their efforts in the local brick pits. There is also more exposure of the Lower Oxford Clay than the Middle and Upper Oxford Clays and this too will have biased the data set.

Most of the dinosaurian material held in museums was collected during the latter half of the last century and the early part of this century, almost certainly reflecting the non-mechanical methods used for winning the clay from the pits where the discoveries were made. The widespread introduction of mechanical excavators at the turn of the century led to the destruction of many of the large Oxford Clay vertebrate fossils. The reduction in the size of the labour force in the pits also meant that fewer people were available to collect the fossils. Recent discoveries have been made of Callovian and Oxfordian marine reptiles and fishes (Charig & Horell 1971, Martill 1985, 1987), but vertebrate fossils, though still abundant in the brick pits, are usually very fragmentary. The only dinosaurian specimen to come to light in recent years is a small ornithopod phalanx of uncertain provenance (Martil 1984).

Material examined for this review is held in the following institutions:

SMC, Sedgwick Museum, Cambridge; BMNH, British Museum (Natural History); PCM, Peterborough City Museum, Peterborough, Cambridgeshire; OUM, Oxford University Museum, Oxford.

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History of Discovery of Oxford Clay Dinosauria

A number of early discoveries of fragmentary dinosaur material from the Oxford Clay of Weymouth, Dorset, and the coeval Arigle de Dives, of Normandy, France, were made in the 1850's, although this material was not noticed until 1888 (Lydekker 1888, p. 163, 180). None of this material can be identified satisfactorily to a generic level, and must remain indeterminate. The earliest written account of an English dinosaur referred to the Oxford Clay was by Seeley, who drew attention to a fragment of a femur named *Cryptosaurus eumerus* in a footnote (Seeley 1869, p. 93). The femur was more fully described in 1875 (Seeley 1875, p. 149) and was considered to have affinities with the iguanodonts of the Lower Cretaceous. There is some doubt about the stratigraphic origin of this specimen and Galton (1980) has demonstrated that it probably came from the Ampthill Clay (Upper Oxfordian). It is thought to belong to the ankylosaur family *Nodosauridae*. This specimen need not be considered further here as it clearly does not belong in the Oxford Clay biota.

During 1874, Seeley visited the now famous, but at that time almost unknown, collection of Mr. Alfred Leeds of Eyebury, Peterborough. A detailed account of the visit is given by Leeds (1956, p. 6), and briefly by Seeley himself (1889). The collection, which consisted chiefly of marine reptiles and fishes, also included a few dinosaur bones.

Seeley notified J.W. Hulke at the British Museum (Natural History) of the presence of dinosaurian remains in the collection, but it was not until May 1886 that Hulke visited Alfred Leeds to view the material for himself. Hulke was accompanied by Arthur Smith Woodward, who became a regular visitor to the collection at Eyebury and a good friend of Alred Leeds and his family. The following year Hulke paid a repeat visit to Eyebury to describe the contained dinosaur material (Hulke 1887), but it is interesting to note that Hulke believed the Leeds specimens were collected from the Kimmeridge Clay, despite it being well known that most of the Leeds collection was obtained from the Oxford Clay. There are no local exposures of the Kimmeridge Clay in the Peterborough area. It is possible that Hulke confused the name Kimmeridge with Kellaways, as the Kellaways beds are frequently exposed in the bottoms of the brick pits, and that the confusion found its way into the literature. Woodward described many of the fish from the collection, and one of the more spectacular dinosaur discoveries (Woodward 1905).

Hulke's 1887 paper described the first sauropod remains found in the Callovian of Britain, *Ornithopsis leedsi*. The specimen consisted of parts of an incomplete pelvic girdle, ribs and vertebrae, and was found during the sinking of a well on the east side of Peterborough on the site of the old gas works. Seeley (1889) gave a detailed account of the discovery and described the succession in the well, which if compared with present knowledge of the stratigraphy of this area indicates that the specimen was discovered at the junction between the Kellaways clay and Kellaways sand. The specimen is therefore of Lower Callovian age, probably from the *M. macrocephalus Zone.*

A second dinosaur from the Oxford Clay in Hulke's paper of 1887 was assigned to *Omosaurus*, (= *Dacentrurus*), an armourless stegosaur known from the Kimmeridge Clay of Swindon, Wiltshire. This assignation was probably made because of the confusion of formation names as outlined above. This was the most complete skeleton of a dinosaur to come from the Oxford Clay at that date. The specimen consists of a pelvic girdle, limb bones and parts of the axial skeleton. Described with the specimen were large plate-like bones, then thought to be part of the dermal armour, but which are now known to be from the giant fish *Leedsichthys problematicus* Woodward. However, later discoveries of this dinosaur by Leeds, did indicate the presence of dermal armour including large spines. It was unfortunate that the first specimen did not possess dermal armour including large spines (presumably lost due to taphonomic processes), and even more unfortunate that the specimen was mixed up with *Leedsichthys* bones. This might have been a result of indiscriminate collecting by pit workers rather than by Alfred Leeds, who was almost certainly a meticulous collector.

Alfred Leeds' second stegosaur from Fletton, was undoubtedly a true stegosaur. Described by Nopsca (1911) as *Stegosaurus priscus*, this specimen possessed dermal armour distinct from the material assinged to *Leedsichthys*, and also distinct from the dermal armour of the well known North American *Stegosaurus* from the slightly younger Morrison Formation.

The historical confusion over the Oxford Clay stegosaurs, although complex is less confusing than that of a single limb bone (BMNH R1933) of an ornithopod dinosaur, also from the Leeds collection. A full account of the synonymy of the specimen is given by Galton (1980), but it is interesting to note that after being first described by Lydekker (1889) as *Camptosaurus leedsi*, this specimen has been placed in two different genera and three different families in six papers by three authors. It is now known as *Callovosaurus leedsi*.

Since much of the early material collected by Leeds and other collectors in the Peterborough area was described without comparative material being available for study, it is hardly surprising that the relationships of the specimens has been difficult to establish. The following list indicates all of the valid dinosaur taxa from the English Oxford Clay (see appendix for systematics):

Dinosauria
Saurischia
Cetiosauriscus stewarti Charig
"Ornithopsis" leedsi Hulke
Metriacanthosaurus parkeri (von Huene)
Eustreptospondylus oxoniensis Walker

Ornithischia
Sarcolestes leedsi Lydekker
Lexovisaurus durobrivensis (Hulke)
Callovosaurus leedsi (Lydekker)
Dryosaurus sp.

Origin of the Oxford Clay dinosaur remains

Throughout its outcrop in England, the Oxford Clay is a fully marine deposit as indicated by a super-abundance of marine bivalves and cephalopods. Although some dinosaurs are known to have occasionally entered freshwater, and some forms may have lived much of their lives in or near water, most were terrestrial (Bakker 1971). Moreover the Oxford Clay sea was too deep to allow wading to take place, and land was probably in excess of 50 km from the present outcrop (Ziegler 1982). The dinosaur fossils are therefore allochthonous and their derivation requires explanation.

Terrestrial vertebrate fossils are unusual in marine deposits; most dinosaur remains being found in fluviatile or lacustrine deposits. Dinosaur remains found in the English Oxford Clay probably did not enter the sea directly from land, but were transported into the sea *via* large river systems. Evidence for this is indicted by vast quantities of fossil wood in the Lower and Middle Oxford Clays. The wood was either washed down rivers or drifted from "mangrove" type swamps bordering the sea. Some of the wood is worn indicating prolonged transport with abrasion.

Dinosaurs may have entered rivers to drink and been drowned accidentally, or more likely, became the prey of large crocodiles. Crocodiles are abundant in the Lower Oxford Clay and although adapted for a marine environment (Tresman, 1987), it is quite likely that they also inhabited local river systems (Martill 1984). Two forms of crocodile were abundant in the English Callovian and Oxfordian, *Steneosaurus* which had a long narrow snout typical of many fish eaters, and *Metriorhynchus* which was more massive, and was a cephalopod feeder, but may have been able to take large prey (Martill 1986).

On becoming the prey of a crocodile the dinosaur would be mutilated. Limbs and neck may have been removed from the carcase, and in most cases it is likely that very little of the kill would remain, but it is known that some crocodiles store caches of foód under roots in river banks (Taylor 1987). Occasionally portions of the kill may drift downstream, especially during periods of flood, and may have avoided being scavanged until they reached the sea. Bloated carcases may drift for many days (Schafer, 1972), and many kilometres out to sea. The drifting carcases would be subjected to intense scavenging by marine animals and, as a consequence, only very incomplete skeletons would arrive on the sea floor. During transport scavenging may take place and isolated bones would fall to the sea floor; for this reason terrestrial animals in marine deposits are usually represented by isolated bones or incomplete skeletons.

Only very rarely has a complete articulated dinosaur been found in the Oxford Clay. An almost complete skeleton of *Eustreptospondylus oxoniensis*, a slender carnosaur, was discovered in the Middle Oxford Clay at Wolvercote, Oxfordshire. This specimen clearly entered the sea as a complete, presumably bloated carcase. It is difficult to see how it avoided attack by scavengers, but possibly fewer scavengers were available since marine reptile bones are significantly less abundant in the Middle Oxford Clay than in the Lower Oxford Clay (Martill 1985). If the abundance of bones is representative of the fauna, then the chances of arrival on the sea floor undamaged may have been greater during this period, but the abundance may also have been controlled by the flow regimes of the source rivers.

The drifting process can cause wide dispersal of carcases and the introduction of endemic fauna to foreign areas. The time taken from entering the sea to arrival on the sea floor is dependent on a variety of factors including the size of the carcase and the degree of post-mortem attack. Schafer (1972) has shown seal carcases can drift for more than fifty days. A larger animal may well drift for longer.. During the drifting period a carcase is broken down by bacterial processes, by its own gastric juices and by scavengers, but provided the body wall is not punctured, the build up of decomposition gasses will keep it afloat. In a strong current a carcase may drift for hundreds of kilometres, perhaps even thousands. The English Callovian dinosaur fauna may therefore not be derived from a local land mass, but may be a composite fauna derived from a variety of sources.

Table 1 shows the stratigraphic distribution of Callovian and Lower Oxfordian dinosaurs from England and France. The map in Fig. 1 shows that dinosaurs have been found over most of the outcrop of the Lower Oxford Clay.

Comparisons with other Callovian dinosaur faunas

Although there are no records of European Callovian dinosaur species being found outside Europe, at the generic level there are taxa in common with younger faunas (Late Upper Jurassic) from North America and Africa. Bonaparte (1979) has announced the discovery of Callovian dinosaur faunas in South America, but these are not fully described, and their relationship to the European faunas is as yet unknown.

The stegosaur *Lexovisaurus* from England and France is similar to, and regarded by some authors as a subgenus of *Kentrosaurus* from the Tendaguru Shale (Kimmeridgian) of East Africa (Lavocat 1955; Steel 1969). The ornithopod *Dryosaurus*, well known from both the Morrison Formation (Kimmeridgian) of North America and the Tendagaru Shales (probably Kimmeridgian), has also been reported from the Oxford Clay of Peterborough (Galton 1977a and b). Since the English Callovian specimen is an isolated limb bone the generic assignation may be in doubt. The faunas which contain taxa in common with the Peterborough fauna have been dated as Kimmeridgian, and are hence some thirteen million years younger.

The presence of inter-continental dinosaur genera shows that land links between major continents existed during the Jurassic (Charig 1973; Colbert 1973; Galton 1977a), even during major transgressive episodes such as the Kimmeridgian, and also in the Cretaceous (Suess 1979; Anderton et al. 1980) when the two super continents of Laurasia and Gondwana were undergoing rifting. Even before plate tectonics and continental drift was accepted, the world wide distribution of sauropod dinosaurs prompted Osborn (1931) to discuss the existence of land-bridges between the major continents.

It is possible to examine the similarities between faunas at different taxonomic levels using similarity coefficients. Theoretically there should be a correlation between the level of similarity and the difference in age of the faunas, or if both faunas are of the same age there should be a decrease in similarity with effective distance as evolution takes a different direction in each fauna. If a succession of faunas on different continents is examined there should be a decrease in similarity with time. This approach has been used by a number of authors using Simpson's coefficient of similarity:

$$\frac{c}{n^1} \times 100$$

where c = number of taxa common to both faunas, and n^1 = number of taxa in the smaller of the two faunas.

This simple approach has been used by Charig (1973) and Cox (1973), but Galton (1977a) has further considered the coefficient of difference:

$$1 - \frac{c}{n^2} \times 100$$

where n^2 = number of taxa in larger of two faunas.

Charig (1980) suggests that with the present state of the science and the limited amount of material available comparisons at anything higher than the familiar level are unreliable. The results may also be affected by the classification system used.

I have followed the classification used by Galton (1977b) to compare the English fauna with the Tendaguru and Morrison faunas, but I must stress that the English fauna is very poorly known compared to the two continental faunas. The results can only be used in the most general terms. The Tendaguru and Morrison faunas are taken from Galton (1977b).

Table 1.

AGE	STAGE	BIOZONE	LITHOSTRATIGRAPHY	DINOSAUR SPECIES
UPPER JURASSSIC	LOWER OXFORDIAN	*Cardioceras cordatum*	Upper Oxford Clay	*Eustreptospondylus divesensis* *Metriacanthosaurus parkeri*
		Quenstedtoceras mariae		
MIDDLE JURASSIC	UPPER CALLOVIAN	*Q. Lamberti*	Middle Oxford Clay	*Eustreptospondylus oxoniensis*
		Peltoceras athleta		
	MIDDLE CALLOVIAN	*Erymnoceras coronatum*	Lower Oxford Clay	
		Kosmoceras jason		*Callovosaurus leedsi* *Dryosaurus sp.* *Lexovisaurus durobrivensis* *Sarcolestes leedsi* *Cetiosauriscus stewarti*
	LOWER CALLOVIAN	*Sigaloceras calloviense*	Kellaways Sand	*Ornithopsis leedsi*
		Macrocephalites macrocephalus	Kellaways Clay	
			Upper Cornbrash	

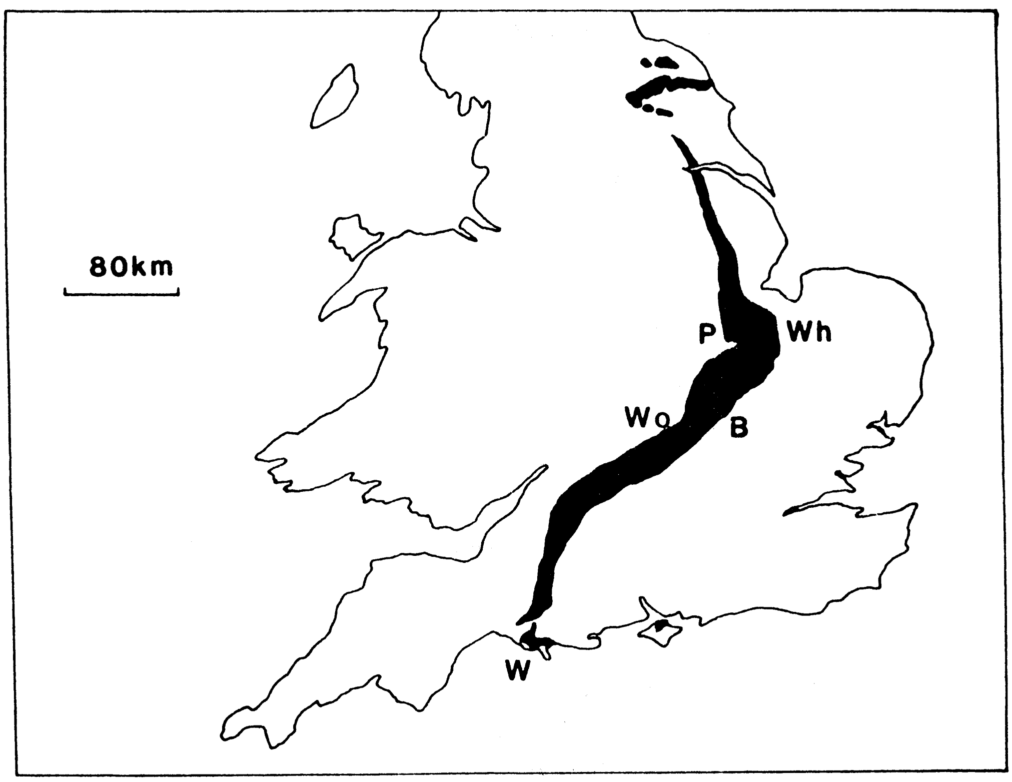

Fig. 1. Outcrop of the Oxford Clay with dinosaur sites indicated. P. Peterborough, B. Bedford, W. Weymouth, Wo. Wolvercote, Wh. Whittlesey.

Morrison Fauna (after Galton 1977b)

Cetiosauridae	*Haplocanthosaurus sp.*
Brachiosauridae	*Brachiosaurus altithorax*
Camarosauridae	*Camarosaurus sp.*
Apatosauridae	*Apatosaurus ajax*
Diplodocidae	*Barosaurus lentus*
	Diplodocus carnegei
Coeluridae	*Coelurus sp.*
	Ornitholestes sp.
Megalosauridae	*Ceratosaurus nasicornis*
	+ a new genus and species
Allosauridae	*Allosaurus fragilis*
Incertae sedis	*Iliosuchus sp.*
	Marshosaurus sp.
Stegosauridae	*Stegosaurus sp.*
Fabrosauridae	*Nanosaurus sp.*
Hypsilophodontidae	*Dryosaurus altus*
	Othnielia
Camptosauridae	*Camptosaurus sp.*

Tendaguru Fauna (after Galton 1977b)

Brachiosauridae	*Brachiosaurus brancas*
Diplodocidea	*Barosaurus africanus*
Dicraeosauridae	*Dicraeosurus*
Titanosauridae	*Torniera*
Coeluridae	*Elaphrosaurus*
Megalaosuridae	*Ceratosaurus (?) roechlingi*
	Megalosaurus (?)
Stegosauridae	*Kentrosaurus*
Hypsilophodontidae	*Dryosaurus lettow-vorbecki*

European Callovian Fauna (after various authors)

Cetiosauridae	*Ornithopsis (?) leedsi*
Diplodocidae	*Cetiosaursicus stewarti*
Megalosauridae	*Eustreptospondylus oxoniensis*
	Metriacanthosaurus parkeri
Stegosauridae	*Lexovisaurus (Kentrosaurus) durobrivensis*
Nodosauridae	*Sarcolestes leedsi*
Hypsilophodontidae	*? Dryosaurus sp.*
Camptosauridae	*Callovosaurus leedsi*

Morrison/European

	Families	*Genera*
European Fauna N_1	7	8
Morrison Fauna, N. America N_2	12	18
Taxa in common C	6	1
Coefficient of similarity	85.7%	12.5%
Coefficient of difference	57.1%	94.4%

Tendaguru/European

	Families	*Genera*
European Fauna N_1	7	8
Tendaguru Fauna, E. Africa N_2	8	9
Taxa in common C	4	2
Coefficient of similarity	57.1%	25%
Coefficient of difference	55.5%	81.1%

Similarity coefficients at the family level between the continental dinosaur faunas of the Morrison Formation and the Tendaguru Shales with the European Oxford Clay allochthonous fauna show that there are stronger affinities between the North America Morrison fauna (app. 85%) than with the African Tendaguru fauna (app. 57%). Galton (1980) has suggested that the strong similarity between Morrison and Tendaguru faunas indicates that the African and North American continents were connected during the Middle and Upper Jurassic, but that the connection was probably through South America. Palaeogeographic reconstructions of the continental positions during the Middle and Upper Jurassic show the Oxford Clay epicontinental sea to be approximately mid-way between the two continents. It is likely that dinosaur carcases could have drifted from rivers draining either continent, but the greater similarity between the Oxford Clay fauna and the North American fauna favours derivation from North America. European massifs were presumably populated by dinosaurs, so it is not unlikely that the Oxford Clay fauna may be locally derived, (figure 2). If European massifs were populated with dinosaur faunas then connections must have existed with either Africa or North America at times of world wide marine regression.

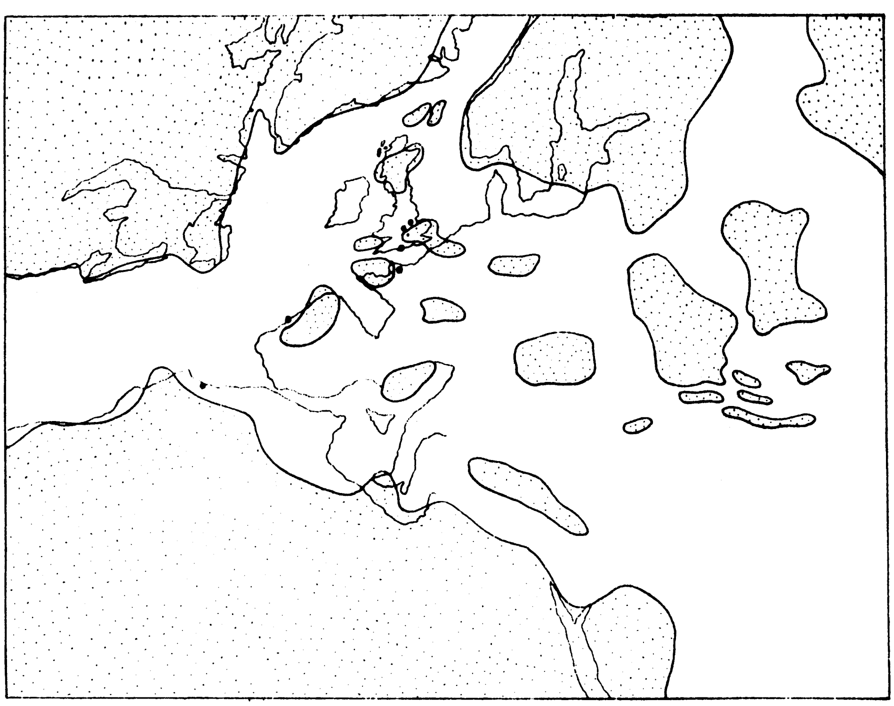

Fig. 2. Palaeogeographic reconstruction of North Africa and Europe during Callovian times. Dots indicate dinosaur localities.

Callovian dinosaur faunas world-wide

Several isolated dinosaur discoveries have been made in Normandy, France, from beds coeval with and in similar facies to the Oxford Clay. The marine reptile fauna of these beds does not differ from that recorded from the Lower Oxford Clay of England (Hoffstetter & Brun 1958, p. 70), and the dinosaur fauna contains some similar elements, including the stegosaur *Lexovisaurus durobrivensis*. But there are differences; no sauropods have been recorded, and a theropod, although closely related, belongs to distinct genus and species, *Piveteausaurus divesensis*.

Worldwide there are very few dinosaur sites that can be definitely dated as Callovian. Thulborn (1972) indicated the presence of a small ornithischian dinosaur *Alcodon kuehnei*, in the Upper Callovian of Pedrogoa, Portugal. But this animal is only known by its teeth, and its relationship with other Callovian dinosaurs is uncertain.

Isolated sauropod vertebrae from the North of Morocco have been dated as Middle Callovian (Lapparent & Lucas 1957). The poorly dated dinosaur faunas from the High and Middle Atlas mountains of central Morocco may also be of Callovian age, in contradiction to recent workers (Monbaron 1980, Monbaron & Taquet 1981) who used the dinosaurs as evidence for a Bathonian age for these beds. The great thickness of fluvio-deltaic red beds in the High Atlas, especially in the Tilouguit basin (600–700 m) may indicate that the Callovian is also included within the sequence.

Dinosaurs have also been reported from the Callovian of Patagonia, Argentina (Bonaparte 1981). There are no genera common to the European Callovian dinosaur faunas, but Bonaparte (1981) has suggested some similarities between the Argentinian sauropod *Patagosaurus fariasi* and *Cetiosaurus leedsi* (= *Cetiosauriscus leedsi*, Bonaparte *pers. com.*)

The Xiaoshaximiao Formation of the Sichuan basin, China, is dated as Bathonian to Callovian, and has yielded a rich fauna of sauropods, *Datousaurus* and *Shunosaurus*, and the stegosaur *Huayangosaurus*. Benton (1985) has indicated that there are similarities between the Chinese sauropods and the English *Cetiosaurus*, but *Cetiosaurus* is not well known. A small ornithopod, *Xiaosaurus*, and a carnosaur, *Xuanhanosaurus*, have also been reported.

Pterosauria

Pterosaur remains are extremely rare in the Oxford Clay and have been reported on only three occasions. The earliest record is that of Phillips who figures a phalanx and a femur of *Rhamphorhynchus bucklandi* (Phillips 1871, plate 12, Figs. 29–33). These specimens, OUM J28533 and J28534 were found at St. Clements, Oxford, probably in the Middle Oxford clay.

Lydekker (1890) recorded the second occurrence of a pterosaur from the Oxford Clay of St. Ives, Huntingdonshire, now Cambridgeshire, which he assigned to the genus *Rhamphorhynchus* under the new name of *R. Jessoni*. This specimen, BMNH R.4759 (Wellnhofer 1978), is almost certainly from the Middle Oxford Clay. Lydekker believed this represented the first pterosaur to be discovered in the Oxford Clay, but he was evidently unaware of Phillips (1871) earlier discovery. The material includes two cervical vertebrae, a dorsal vertebrae, left innominate and left femur. Lydekker's figure of the femur (Lydekker 1890, p. 430, Fig. 3) appears to be very similar to that figured by Phillips (1871, plate 12, Fig. 32), and the two are probably conspecific.

In an address to the Ealing Naturalist and Microscopists Society, Andrews (1911) notes the presence of *Rhamphorhynchus* in the Oxford Clay of Peterborough. He was referring to specimens later mentioned by Leeds (1956, p. 76), which were described as being "some insignificant wing-bones". Two individuals are represented; BMNH R.1995 comprising a complete right ulna 10 cm long and broken left and right humeri; and R.4759 a single complete wing bone 14 cm long.

Discussion

Although the Oxford Clay is a fully marine deposit, yielding an abundant fauna of belemnites, ammonities and comparatively abundant marine reptiles, it is clear from the occasional discovery of dinosaur bones and the superabundance of fossil wood that nearby land was populated by abundant and diverse dinosaur faunas.

The dinosaur remains so far discovered in the Oxford Clay are likely to be the remains of prey of large crocodiles or carnivorous dinosaurs. Large crocodiles drag their prey into water to drown and such a process would introduce terrestrial elements into the aquatic environment enabling at least a few mutilated carcases to reach the Oxford Clay basin. Crocodiles are an abundant element of the Peterborough fauna, although the forms *Steneosaurus* and *Metriorhynchus* were fully adapted to the marine environment (Tresman 1987a & b) more terrestrially adapted crocodiles may have inhabited local rivers and estuaries.

Acknowledgments

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Appendix

Systematics of valid dinosaur taxa from the English Oxford Clay

Class DINOSAURIA Bakker & Galton 1974
Subclass ORNITHISCHIA (Seeley 1888)
Order STEGOSAURIA (Marsh 1877)
Family STEGOSAURIDAE Marsh 1880
Subfamily STEGOSAURINAE Nopsca 1917
Genus *LEXOVISAURUS* Hoffstetter 1957
Lexovisaurus durobrivensis (Hulke 1887)

1887	*Omosaurus durobrivensis* Hulke, p. 699, Fig. 2
1901	*Omosaurus leedsi* Seeley, Huene, *nomen nudem* p. 718
1911	*Stegosaurus priscus* Nopcsa, p. 109–114, 145–153 Figs. 1–9
1911	*Stegosaurus durobrivensis* (Hulke), Nopcsa, p. 148, 153
1933	*Omosaurus durobrivensis* Hulke, Arkell, p. 358
1956	*Omosaurus durobrivensis* Hulke, Leeds, p. 104
1957	*Lexovisaurus durobrivensis* (Hulke), Hoffstetter, p. 537–547
1958	*Lexovisaurus durobrivensis* (Hulke), Hoffstetter & Brun, p. 76
1969	*Lexovisaurus durobrivensis* (Hulke), Steel, p. 49
1973	*Lexovisaurus durobrivensis* (Hulke), White, p. 138
1980	*Lexovisaurus durobrivensis* (Hulke), Galton, p. 825 Fig. 1Q–U
1980	*Lexovisaurus durobrivensis* (Hulke), Galton, et. al. p. 39, Plate 1 Figs. 1–5
1981	*Lexovisaurus* (Nopcsa, 1911 as *Stegosaurus priscus*) Galton, p. 40
1983	*Lexovisaurus durobrivensis* (Hulke), Galton, p. 142
1983	*Lexovisaurus durobrivensis* (Hulke), Galton & Powell, p. 221, Plate 1, Figs. 22–24

Holotype BMNH R. 1989

Other material. BMNH R. 584, R. 1989–92, R, 3167; PCM R. 177; SMC J. 46875, J. 46879.

Diagnosis Armoured stegosaur in which the dorsal armour consists of alternating plates along the back and spines towards the tail. There is a pair of parasacral spines. The femur exceeds the ilium in length. The skull is not known.

Discussion Stegosaurs known only by fragmentary skeletons and isolated spines. The genus has close affinities with the East African *kentrosaurus* Hennig, and possibly with the Chinese *Huayangosaurus*.

Early confusion over the name *Omosaurus*, and the referring of British stegosaurs to both *Omosaurus, Dacentrurus* and *Stegosaurus* has resulted in a long synonymy. Marsh (1889) showed that *Omosaurus* was almost indestinguishable from *Stegosaurus*, and pointing out that *Omosaurus* was pre-occupied by a phytosaur (Leidy 1856), suggested that all British *Omosaurus* material be referred temporarily to *Stegosaurus*.

A second "Stegosaur" obtained by Henry Keeping was described as *Stegosaurus sp.* by Huene (1901), but in his discussion he suggests that material had been referred to *Omosaurus leedsi* by Seeley. In the Sedgwick Museum catalogue (unpublished) it is pointed out that Huene made this assumption on a museum label in Seeley's handwriting. *O. leedsi* is therefore a *nomen nudum.*

The problem of the name *Omosaurus* occurred again, when Lucas (1902) considered the type material of *Omosaurus* from the Kimmeridge Clay of Swindon to be distinct from the North American *Stegosaurus* because it lacked dermal armour. Lucas proposed the new name of *Dacentrurus* for stegosaurs without dermal armour. This new name was never used for Oxford Clay stegosaurs as the third specimen was found with dermal armour. Had this specimen not been found, the first specimen may well have been referred to *Dacentrurus*. The first specimen, although its so called dermal armour was shown to be from a fish, was considered to be conspecific with the third specimen. Later however, Hoffstetter (1957), considered the dermal armour described by Huene (1901) in the second specimen also to be from the giant fish *Leedsichthys*. I have examined this material and agree with Hoffstetter, but it is not possible with present knowledge of *Leedsichthys* to positively identify the bones.

The differences in the structure of the dermal armour mentioned above were not used to separate Oxford Clay stegosaurs from their North American cousins until 1957. Hoffstetter reviewed both English and French Callovian stegosaur material and synonymised *S. priscus* Nopsca with O. *durobrivensis* Hulke. He erected for their inclusion the new genus *Lexovisaurus* (Hoffstetter, 1957), (*Figs. 3 + 4 this paper*).

Locality Peterborough, Cambridgeshire, Bedford, Bedfordshire, doubtfully from Weymouth, Dorset. Aslo known from Argence, France.

Horizon Lower Oxford Clay, Middle Callovian, of England. Most likely Jason zone. Lower Callovian of France, Calloviense zone.

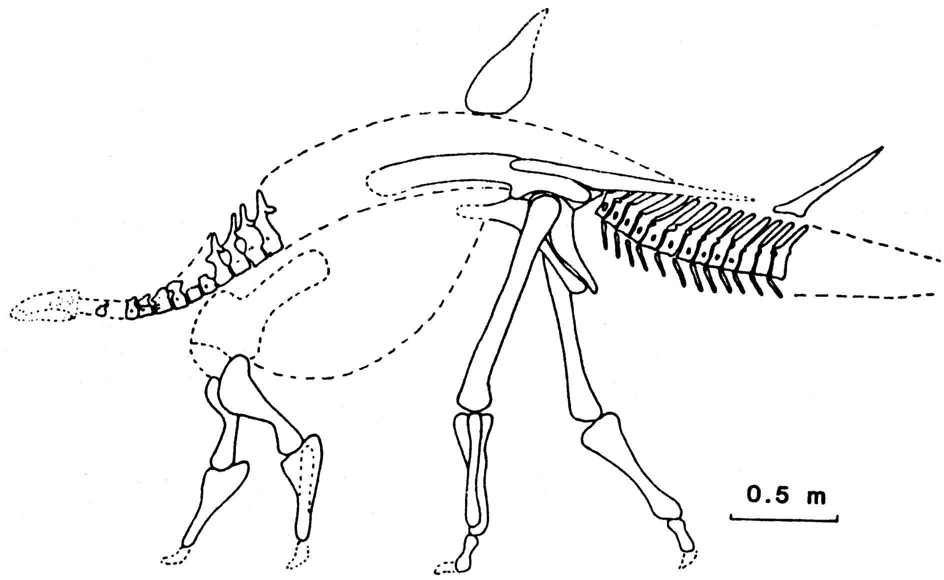

Fig. 3. *Lexovisaurus durobrivensis*. After Galton 1983.

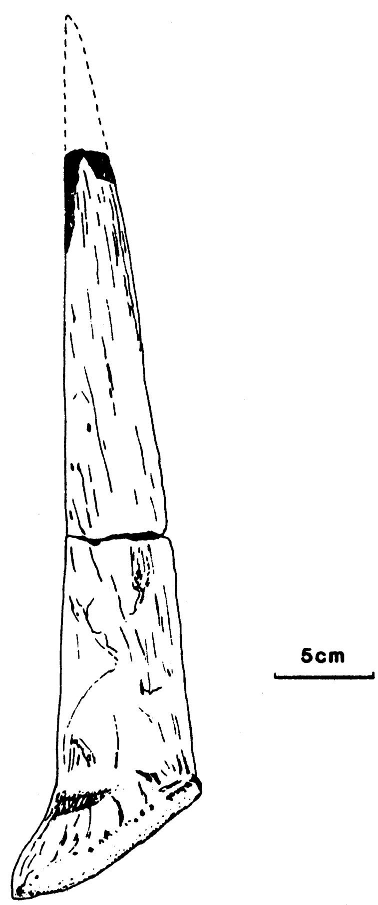

Fig. 4. ?Caudel spine of *Lesovisaurus cf. durobrivensis* drawn from a photograph of PCM R177.

Order ANKYLOSAURIA (Osborn 1923)
Family NODOSAURIDAE Marsh 1980
Genus *Sarcolestes* Lydekker 1893

Sarcolestes leedsi Lydekker 1893

1893	*Sarcolestes leedsi* Lydekker, p. 286
1933	*Sarcolestes leedsi* Lydekker, Arkell, p. 358
1955	*Sarcolestes leedsi* Lydekker, Lapparent & Lavocat, p. 785–962
1956	*Sarcolestes leedsi* Lydekker, Leeds, p. 35
1969	*Sarcolestes leedsi* Lydekker, Steel, p. 44, Figs. 15, 4
1973	*Sarcolestes leedsi* Lydekker, White, p. 148
1980	*Sarcolestes leedsi* Lydekker, Galton, p. 825, Figs. 1a, b
1980a	*Sarcolestes leedsi* Lydekker, Galton, p. 486
1983	*Sarcolestes leedsi* Lydekker, Galton, p. 141, Figs. 1, 2

Holotype BMNH R. 2682. An incomplete left mandible with replacement teeth is the only known specimen of this taxon.

Diagnosis Small teeth extend to anterior end of dentary, short medially projecting process bears symphysis, mechelian canal open, coronoid eminence low. Crown of first dentary tooth laterally compressed with fine denticles on anterior edge, other teeth simple with regular marginal denticles, crowns smooth labially and lingually. There is a dermal plate fused to the lateral surface of the mandible.

Discussion Galton also refers to *Sarcolestes* ? a dermal scute SMC J. 46884, but this specimen was not found associated with the type material and cannot be satisfactorily referred to *Sarcolestes*.

Horizon Lower Oxford Clay, Middle Callovian, probably Jason zone.

Locality Fletton, near Peterborough, Cambridgeshire. White (1973, p. 148) lists Oxford as a locality but this is incorrect.

Order ORNITHOPODA Marsh (1871)
Family CAMPTOSAURIDAE Marsh 1885
Genus *Callovosaurus* Galton 1980

Callovosaurus leedsi (Lydekker 1889)

1889	*Camptosaurus leedsi* Lydekker, p. 47
1890	*Camptosaurus leedsi* Lydekker, p. 258, Fig. 61
1901	*Camptosaurus leedsi* Lydekker, Huene, p. 716
1909	*Camptosaurus leedsi* Lydekker, Gilmore
1933	*Camptosaurus leedsi* Lydekker, Arkell, p. 358
1956	*Camptosaurus leedsi* Lydekker, Leeds, p. 35
1969	*Camptosaurus leedsi* Lydekker, Steel, p. 16, Figs. 8, 12
1972	*Camptosaurus leedsi* Lydekker, Galton, p. 466
1975	*Camptosaurus (?) leedsi* Lydekker, Galton, p. 741, Fig. 2
1980	*Camptosaurus leedsi* Lydekker, Galton & Powell, p. 418, Fig. 2g
1980	*Callovosaurus leedsi* Lydekker, Galton, p. 73, Figs. 2, 3
1983	*Callovosaurus leedsi* (Lydekker), Galton, p. 142

Holotype BMNH R. 1993 A right femur. This is the only known specimen referable to this taxon.

Diagnosis Femur in which the greater trochanter is proportionally narrow, lesser trochanter expanded antero-posteriorly and flattened transversely, distal and unexpanded with shallow anterior intercondylar groove.

Discussion A full summary of the synonymy of *C. leedsi* is given by Galton (1980). Lydekker in referring this specimen to *Camptosaurus* noted that the assignation may be temporary, and pointed out that it was difficult to distinguish from *Camptosaurus* or *Iguanodon prestwichii*, a Kimmeridgian dinosaur which Lydekker placed in the genus *Camptosaurus* later that year (Lydekker 1889, p. 259). Gilmore (1909) considered that *C. leedsi* might be closely allied to the Hypsilophodontidae, and in particular to the genus *Dryosaurus*, a dinosaur which has been tentatively recorded from the Oxford Clay (see below). Galton (1972, 1973) also considered *C. leedsi* to be allied to the Hypsilophodontidae, and also questioned its inclusion in the genus *Camptosaurus*. Galton (1975) and Galton & Powell (1980) referred *C. leedsi* to the ornithopod family Iguanodontidae, but one month later *C. leedsi* was referred to the re-erected family Camptosauridae in the new genus *Callovosaurus* (Galton, 1980).

Horizon Known only from the Lower Oxford Clay, Middle Callovian, probably Jason zone.

Locality Recorded as Peterborough, Cambridgeshire.

Family HYPSILOPHODONTIDAE Dollo 1882
Genus *Dryosaurus* Marsh 1894

Discussion A slender tibia from the Oxford Clay of Fletton, SMC J. 46889, was referred by Galton (1977a) to *Dryosaurus sp.* but later (Galton 1977b, 1980) referred to the same specimen as hypsilophodontid *incertae sedis*. It is clear that a slender built ornithopod dinosaur is represented in the Oxford Clay dinosaur fauna, but the material is inadequate for positive generic assignation.

Subclass SAURISCHIA (Seeley 1888)
Order SAUROPODOMORPHA (Huene 1932)
Infraorder SAUROPODA Marsh 1878
Family DIPLODOCIDAE Marsh 1884
Genus *Cetiosauriscus* Huene 1927

Cetiosauriscus stewarti Charig 1980

1905	*Cetiosaurus leedsi* (Hulke), Woodward, p. 232, Figs. 39–49
1922	*Cetiosaurus leedsi* (Hulke), Huene, p. 86
1922	*Cetiosaurus leedsi* (Hulke), Anon, Plate III
1927	*Cetiosauriscus leedsi* (Hulke), Huene, p. 444
1927	*Cetiosauriscus leedsi* (Hulke), Huene, p. 122
1933	*Cetiosaur[isc]us leedsi* (Hulke), Arkell, p. 358
1956	*Cetiosaurus leedsi* (Hulke), Leeds, p. 36–8, 104
1973	*Cetiosaurus leedsi* (Hulke), White, p. 125
1979	*Cetiosaurus leedsi* (Hulke), Bonaparte, p. 1378
1979	*Cetiosauriscus stewarti* Charig, p. 231, Figs. 13.1, 13.3
1981	*Cetiosauriscus leedsi* (Hulke), Monbaron & Taquet, p. 244

Holotype BMNH R. 3078. A partial skeleton including portions of four dorsal vertebrae, neural spines of the sacrum, four anterior caudal vertebrae, a continuous series of twenty seven middle caudal vertebrae, numerous chevrons, a right scapulo-coracoid, right humerus, right radius and ulna, portions of left and right ilia, left femur, left tibia and fibula, left pes. Three sauropod teeth BMNH R. 3377, may also belong to this individual (see Leeds 1959, p. 38). Woodward (1905) also assigns a series of proximal caudal vertebrae BMNH R. 1967, to this specimen.

Diagnosis Sauropod dinosaur in which the dorsal centra are antero-posteriorly compressed. Caudal vertebrae with straight chevrons anteriorly, becoming boat shaped posteriorly. Humerus relatively short, with thick deltoid crest. Femur long and slender. Teeth spatulate. (*See figures 5 + 6 in this paper*).

Discussion BMNH R. 3078 is perhaps the most important dinosaur discovery to have been made in the Peterborough district. Until 1968 this was the most complete sauropod skeleton known in the British Isles, and contributed much to our knowledge of Middle Jurassic sauropod anatomy. It was erronously assigned to

Cetiosaurus leedsi by Woodward (1905), when it was considered to be conspecific with material described by Hulke (1887) as *Ornithopsis leedsi*. Charig (1981) has demonstrated that R. 3078 cannot be compared with *O. leedsi* as there are no elements common to both specimens. Unfortunately, this point was not recognised by Huene (1927) when he made R. 3078 the type of a new genus *Cetiosauriscus*. This meant that the type specimen of *Cetiosauriscus* was misidentified and was in need of a new specific name. Charig (1981) proposed the name of *C. stewarti*, after the former chairman of the London Brick Company, from whose pits many of the Oxford Clay vertebrates have come.

Berman & McIntosh (1978) and Charig (1981) show that *Cetiosauriscus* is allied to the North American *Diplodocus*, for which they re-erect the family Diplodocidae Marsh 1884 to contain these two and five other sauropod genera. Of the genera within the family Diplodocidae-*Apatosaurus, Barosaurus, Cetiosauriscus, Dicraeosaurus, Diplodocus, Mamenchisaurus* and *Nemegtosaurus:– Cetiosauriscus* is the oldest and considered to be a rather primitive member.

Locality Discovered in 1898 at the New Peterborough Brick Company, No. 1 yard, (Leeds 1956), near Peterborough, Cambridgeshire.

Horizon Lower Oxford Clay, Middle Callovian, Jason or Coronatum zone.

Family CAMARASAURIDAE Cope 1877
Genus *ornithopsis* Seeley 1870

Ornithopsis leedsi Hulke 1877

1887	*Ornithopsis leedsi* Hulke, p. 695, Fig. 1
1888	*Ornithopsis leedsi* Hulke, Lydekker, p. 57
1888	*Pelerosaurus leedsi* (Hulke), Lydekker, p. 242
1888	*Ornithopsis leedsi* Lydekker, Mansel-Pleydell, p. 39
1889	*(Ornithopsis) leedsi* Hulke, Seeley, p. 391–397, Fig. 3
1905	*Cetiosaurus leedsi* (Hulke), Woodward, p. 323
1956	*Ornithopsis leedsi* Hulke, Leeds, p. 35
1980	*Ornithopsis leedsi* Hulke, Charig, p. 242

Holotype BMNH R. 1985–8. Associated pelvic bones and vertebrae. A plaster cast believed to be of one of the type vertebrae is BMNH R. 1716.

Diagnosis Ischium long and slender with long antero-ventral projection. Pubis massive, becoming thickened towards distal end, foramen present proximally.

Locality Site of old gas works, East of Peterborough, Cambridgeshire.

Horizon Almost certainly at the junction of the Kellaways Clay with the overlying Kellaways sand. See Seeley (1889) and Woodward & Thompson (1909).

Discussion There has been much confusion over the nomenclautre of Oxford Clay sauropods. It appears that there are two taxa, based on two specimens, with a number of other isolated bones being referred to one or other of these taxa. If a complete specimen were ever found it may show the two to be congeneric and even conspecific. The following list indicates the whereabouts of all known Oxford Clay sauropod specimens.

Specimen	**Source**	**Institute**
4 caudal vertebrae	Lower Oxford Clay	BMNH R. 1984
Partial skeleton	Lower Oxford Clay	BMNH R. 3078
Pelvic girdle & vertebrae	Base of Kellaways Sand	BMNH R. 1988
Distal caudal vertebrae	Lower Oxford Clay	BMNH R. 1967
3 sauropod teeth	Lower Oxford Clay	BMNH R. 3377
2 dorsal vertebrae (probably pliosaurian)	Lower Oxford Clay	PCM R. 85
worn dorsal centrum	Kellaways Sand	PCM R. 242

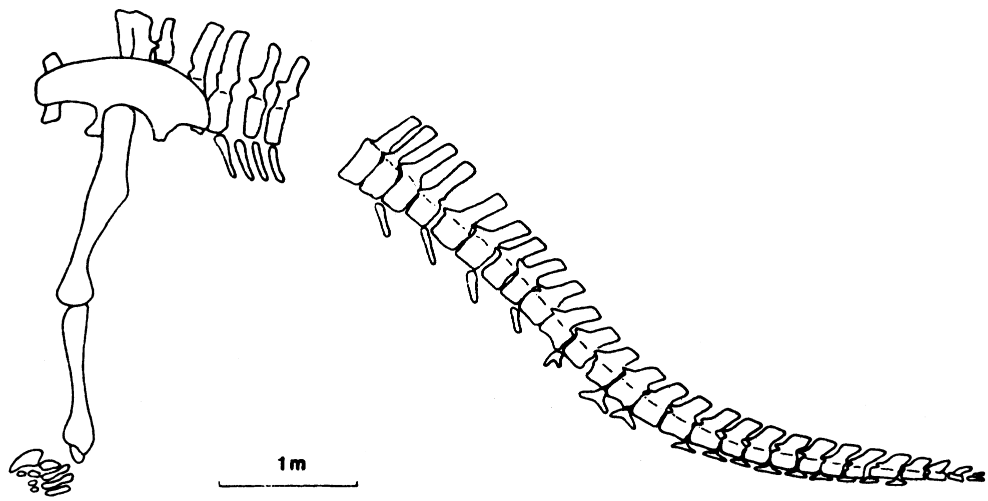

Fig. 5. Rear portion of skeleton of *Cetiosauriscus stewarti*. Based on Woodward (1905).

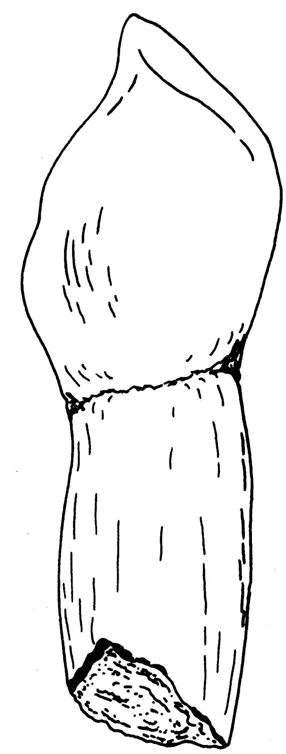

Fig. 6. Spatulate tooth of sauropod dinosaur. Probably referrable to *Cetiosauriscus stewarti* Charig. Lower Oxford Clay, Peterborough. Specimen BMNH R3377. Lingual view. X 2.5.

Order THEROPODA (Marsh 1881)
Infraorder CARNOSAURIA Huene 1920
Superfamily MEGALOSAUROIDEA Walker
Family MEGALOSAURIDAE Huxley 1869
Genus *Eustreptospondylus* Walker 1964

Eustreptospondylus oxoniensis Walker 1964

1871	*Streptopondylus cuvieri* Owen, Phillips, p. 319, Fig. 74
1905	*Streptopondylus cuvieri* Owen, Nopcsa
1905	*Streptopondylus cuvieri* H.V. Meyer, Nopcsa, p. 81
1923	*Streptopondylus cuvieri* Pivetaeu, p. 114
1926	*Megalosaurus cuvieri* (Owen), Huene, p. 35
1932	*Megalosaurus cuvieri* (Owen), Huene, p. ??
1952	*Streptopondylus cuvieri* Owen, Swinton, p. 130
1964	*Eustreptospondylus oxoniensis* Walker, p. 120, Fig. 17e
1970	*Eustreptospondylus oxoniensis* Walker, Steel, p. 32, Fig. 10
1977	*Eustreptospondylus oxoniensis* Walker, Taquet & Welles, p. 191

Holotype OUM J. 13558. An almost complete skeleton, with imperfect skull and teeth.

Diagnosis A large (up to seven metres long), but lightly built carnivorous dinosaur. Vertebrae elongate, cervicals and anterior dorsals strongly opisthocoelus, scapula small, humerus slender, pubis straight and rod-like with terminal expansion. Teeth laterally compressed, keeled with small serrations. See figure 7.

Discussion Confusion over the use of the generic name *Streptospondylus*, and the general fragmentary nature and rarity of megalosaur material, has led to a complicated synonymy for Callovian carnosaurian dinosaurs. A detailed account of the synonymy of *Eustreptospondylus*, and the background to the confusion is given by Walker (1964) and more concisely by Steel (1970).

Locality Summertown Brick Pit, near Oxford, Oxfordshire.

Horizon Middle Oxford Clay, Upper Callovian, Athleta Zone.

Genus *Metriacanthosaurus Walker 1964*

Metriacanthosaurus parkeri (von Huene 1926)

1922	*Megalosaurus parkeri* von Huene, p. 453
1926	*Megalosaurus parkeri* von Huene, p. 477
1926	*Megalosaurus parkeri* von Huene, p. 35–167, Figs. 51–53
1959	*Megalosaurus parkeri* von Huene, Delair, p. 78
1964	*Metriacanthosaurus parkeri* (von Huene), Walker, p. 109, Fig. 16
1970	*Metriacanthosaurus parkeri* (von Huene), Steel, p. 36
1973	*Metriacanthosaurus parkeri* (von Huene), White, p. 150

Holotype OUM J. 12144. Three dorsal vertebrae, four proximal caudal vertebrae, right ilium, portions of left and right ischia, left and right pubes, right femur and proximal part of left femur. The holotype is the only known specimen.

Diagnosis Megalosauridae with neural spines elongate, femur slender with lesser trochanter placed proximally, pubes with expanded foot, cnemial process of tibia with strong upward projection.

Discussion The relationship of *Metriacanthosaurus* is in some doubt. Whilst most workers (Walker 1964, Steel 1970) assign it to the Megalosauridae, the height of the neural spines indicated to von Huene (1926) that it could be an early member of the Spinosauridae. This has not been entirely ruled out by Walker (1964).

Locality Weymouth, Dorset.

Horizon There is doubt as to the exact stratigraphic position of this specimen. It is certainly from the Oxford Clay. An oyster, *Gryphaea dilatata* found adhering to one of the vertebrae has been taken to indicate an Upper Oxford Clay (Lower Oxfordian) age for the specimen.

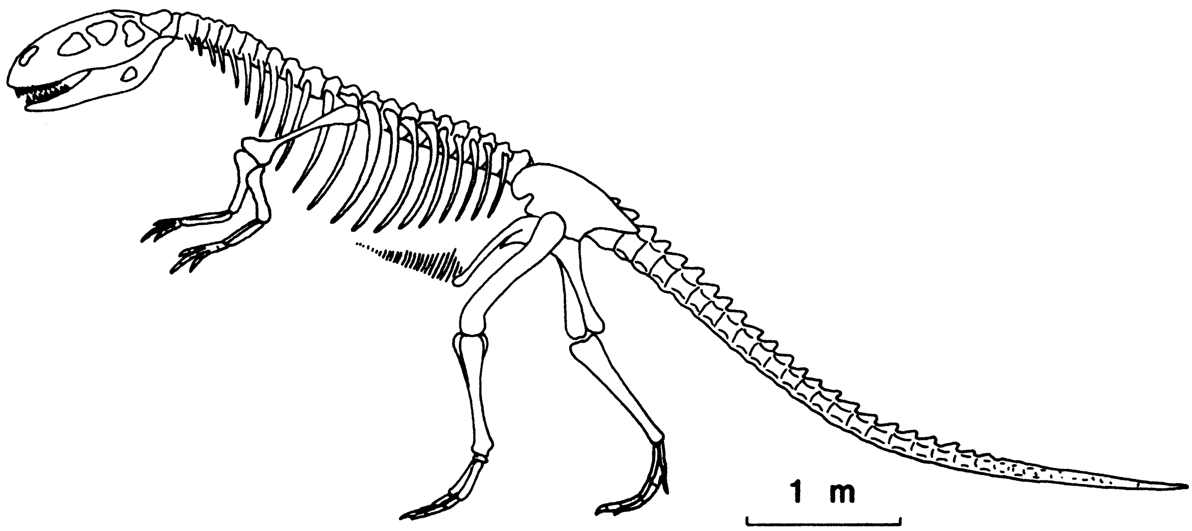

Fig. 7. Skeleton reconstruction of *Eustreptospondylus oxoniensis*. After Steel (1970).

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DAY EXCURSION TO SHROPSHIRE

Leader: I.D. Sutton 15th June 1986

The purpose of this excursion was to examine the sedimentary sequence and faunas of the Wenlock and Ludlow series in the classic areas close to Much Wenlock and Ludlow.

A party of thirty-seven members travelled by coach via Wolverhampton and Bridgnorth to Ludlow. The journey to Bridgnorth was largely across the low ground of the Permo-Triassic with very little exposure. However, at Bridgnorth, the party were able to see the excellent exposures of the dune-bedded Permian aeolian sandstone in the river cliffs of the Severn. The leader pointed out that there is only tentative evidence for the age of the sandstones, but they do underlie the transgressive base of the Sherwood Sandstone and have been tentatively correlated with the Penrith Sandstone. Since the latter is in places overlain by a thin conformable cover of Magnesian Limestone, a Lower Permian age is possible for the Bridgnorth sandstone.

From Bridgnorth, the party travelled to Ludlow, passing between Brown Clee Hill to the north and Titterstone Clee to the south, both largely formed of Old Red Sandstone, but with a capping of Carboniferous sediments and resistant dolerites.

From Ludlow, the party travelled southwestwards along the Wigmore Road for a distance of about 4 km to the Forestry Commission carpark and picnic site (SO473732). A short walk in bright sunshine took the group to a small quarry on the north side of the road (SO472730), where the leader pointed out that this was one of the localities on the Mortimer Forest Geological Trail which traverses the Wenlock and Ludlow succession along the Wigmore Road anticline. With the aid of the 1:25,000 Geological Survey Leintwardine and Ludlow special sheet, the northeast to southwest axis of an anticline with a northeasterly plunge was demonstrated (see Fig. 1). In this area round Ludlow, the Silurian sediments are of shelf facies, but not far to the west, there is a sudden transition to the deep water facies of the Welsh Basin. These basinal deposits are much thicker and include turbidites and slumped beds. To the west of the area being visited, a number of submarine channels of Ludlow (Leintwardine) age, in the transitional zone between shelf and basin, have been identified (Whitaker 1962).

At this first locality, 4.5 m of the highest horizons within the Much Wenlock Limestone Formation are exposed. A few brachiopods, crinoids and bryozoans were found, but generally, the limestone is nothing like as fossiliferous as the Much Wenlock Limestone Formation around Much Wenlock, perhaps because the Much Wenlock Limestones on the Wigmore Road section were deposited further out on the shelf in deeper water, in conditions not anywhere near so favourable for bottom dwelling organisms. Slickensiding is very apparent along a number of surfaces, indicating faulting along the axis of the anticline.

Led by the secretary, no doubt anxious for her lunch, the party progressed to a small quarry just on the opposite side of the road a few yards into a wood (SO472730). This is the type locality for the boundary between the Wenlock and Ludlow series (see Fig. 2). The lower 2 m or so of the section consists of massive nodular limestone with little bedding, from the scree debris of which the party collected specimens of *Favosites, Heliolites, Halysites, Atrypa, Leptaena* and numerous bryozoans and crinoid fragments. Above the limestone is a distinctive thin clay horizon which has been selectively weathered out, followed by about 2.5 m of similar massive, poorly-bedded, limestone before a very distinctive and fairly sudden change to brownish siltstones occurs. This change marks the boundary between the Wenlock and Ludlow series and is the type section (boundary stratotype) for this stratigraphical horizon.

Everyone then enjoyed a picnic lunch at the Forestry Commission Picnic Site before setting off along one of the Forestry tracks to exposures of the Middle Elton Beds in a low bank on the side of the track about 800 m from the road (SO480730). The exposures extended for 100 m or so, and the party diligently searched the loose debris for the wide range of fossils to be found, of which monograptids, dalmanitid trilobites, straight nautiloids and taxodont bivalves were the most plentiful.

Having returned to the coach, the party were then transported to Gorsty (SO478736) where exposures of the Upper Elton Beds were seen in another Forestry Commission trackway.

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Vol. 11, no. 3, pp. 191–194.

Lack of time, however, prevented any serious examination of these strata. The party walked along the road to Mary Knoll House and then along a foot path to the pine topped hill of Mary Knoll (SO486736). This is an excellent viewpoint and despite the haze created by the heat of the day, the short walk was well worthwhile to view features both close at hand and in the misty distance (see Fig. 3). Looking towards the southwest, the hills of Radnor Forest with the distinct hill of the Whimble could just be seen. These are composed of basinal Ludlovian deposits. Further round to the west, the basinal Ludlovian hills of Clun Forest, are followed by the laccolith intrusion of Corndon Hill, the Precambrian of the Longmynd, and Caer Caradoc. Further round to the east of north, the ridge of Wenlock Edge and the largely Precambrian Wrekin were obscured by trees, but beyond the trees and almost due east, Brown Clee and Titterstone Clee, formed of Devonian strata, with cappings of Carboniferous could be well seen. To the southeast just about visible, was Worcester Beacon on the north end of the Malvern Ridge. Completing the full 360 degrees, the ground nearer to Mary Knoll showed the structure of the Wigmore Road anticline very well. In the immediate foreground to the southwest was a depression carved out in the fairly easily eroded Elton Beds flanked on either side by the distinctive hills of High Vinnals to the south and Bringewood Chase further round to the west indicating the outcrop of the Bringewood Beds. The wooded ridge beyond the Elton Beds is the outcrop of the Much Wenlock Limestone. Slightly further away to the west were the dip slopes of the Ludlow beds. On the descent from Mary Knoll, a short stop was made at a small quarry in the Bringewood Beds with poor specimens of the distinctive *Kirkidium knightii*. From Mary Knoll, the coach took the party back to Ludlow crossing the Bringewood, Leintwardine and Whitcliffe Beds in the process with the very distinctive man-made recess at the end of Wigmore Road marking the original presence of the Ludlow Bone Bed. This at one time was the type locality for the boundary between the Silurian and Devonian. The journey from Ludlow took us along Corvedale with Brown Clee to the south and the dip slopes of the Upper Ludlovian to the north. At Much Wenlock, we headed westwards along Wenlock Edge towards The Plough Inn. As we progressed along the Edge, to the southeast, the Much Wenlock Limestone Formation could be seen dipping away underneath the Elton Beds occupying low ground and then the distinctive ridge of the Upper Bringewood Beds.

From The Plough Inn carpark, a short walk across a meadow took the party to an excellent vantage point on the edge. The leader first of all pointed out the geological and landscape features to the northwest. Immediately in the foreground was the boulder clay covered vale of the Wenlock and Llandovery shales with the higher ground of the basal Llandovery Kenley Grit in the neighbourhood of Church Preen. Beyond this ridge, were the outcrops of the Caradocian near Chatwall, and further to the west and northwest, the Precambrian hills of Ragleth, Caer Caradoc and the Lawley. The bare outcrop of limestone on which the party was standing could be seen to be massive with no obvious bedding and represented one of the many small lenticular masses of reef-limestone described as "ballstones" by Crosfield and Johnson (1914). The reef structures consist of a framework of corals and stromatoporoids, often in growth position, and with a fine grained calcite mud matrix.

On returning to Much Wenlock, the party made their last stop of the day in the large working Shadwell Quarry on the outskirts of the village. The quarry faces showed clearly the bedded and reef limestones. Much of the time was spent collecting the wealth of fossil material from the weathered tip heaps. A wide range of fossils were found and included brachopods of which *Atrypa reticularis* was exceedingly abundant, along with *Meristina, Camarotoechia, Leptaena, Sphaerirhynchia* and *Strophonella*. Tabulate corals including *Favosites, Heliolites, Syringopora* and *Halysites* and also other faunas including trilobites (*Calymene* and *Encrinurus*), gastropods (*Poleumita*), straight nautiloids, crinoids and bryozoans were found.

With plastic bags filled, the odd large tabulate coral colony under the arm, the party made their way back to the coach and then via the gorge and bridge at Ironbridge to Telford and by using the M54 motorway, a fairly fast return to Nottingham was made.

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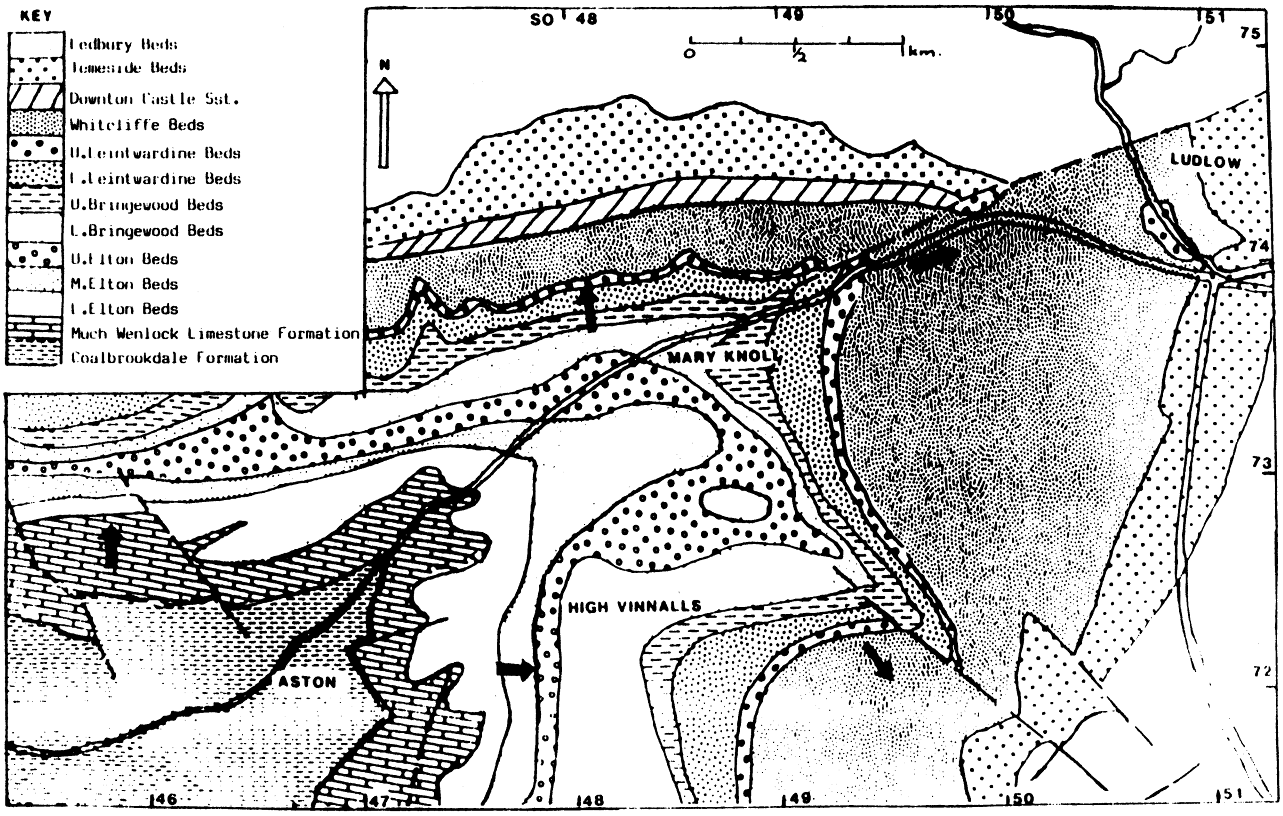

Fig. 1. Geological sketch map of the Wigmore Road anticline S.W. of Ludlow.

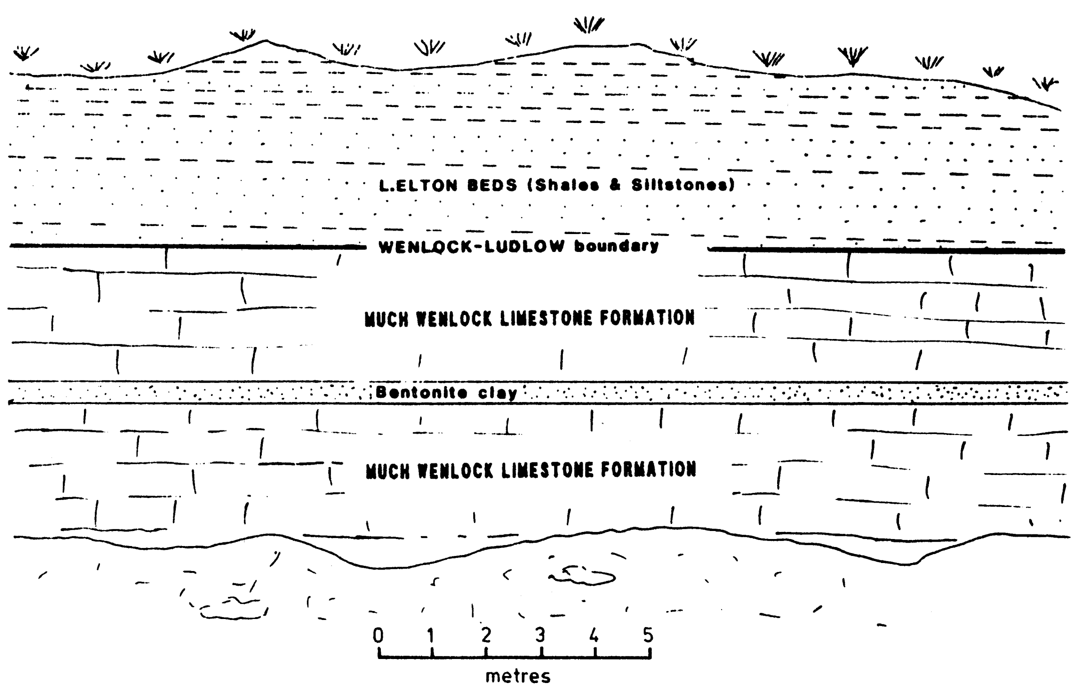

Fig. 2. Sketch section of the quarry face at S0472730, the type locality of the Wenlock-Ludlow Boundary

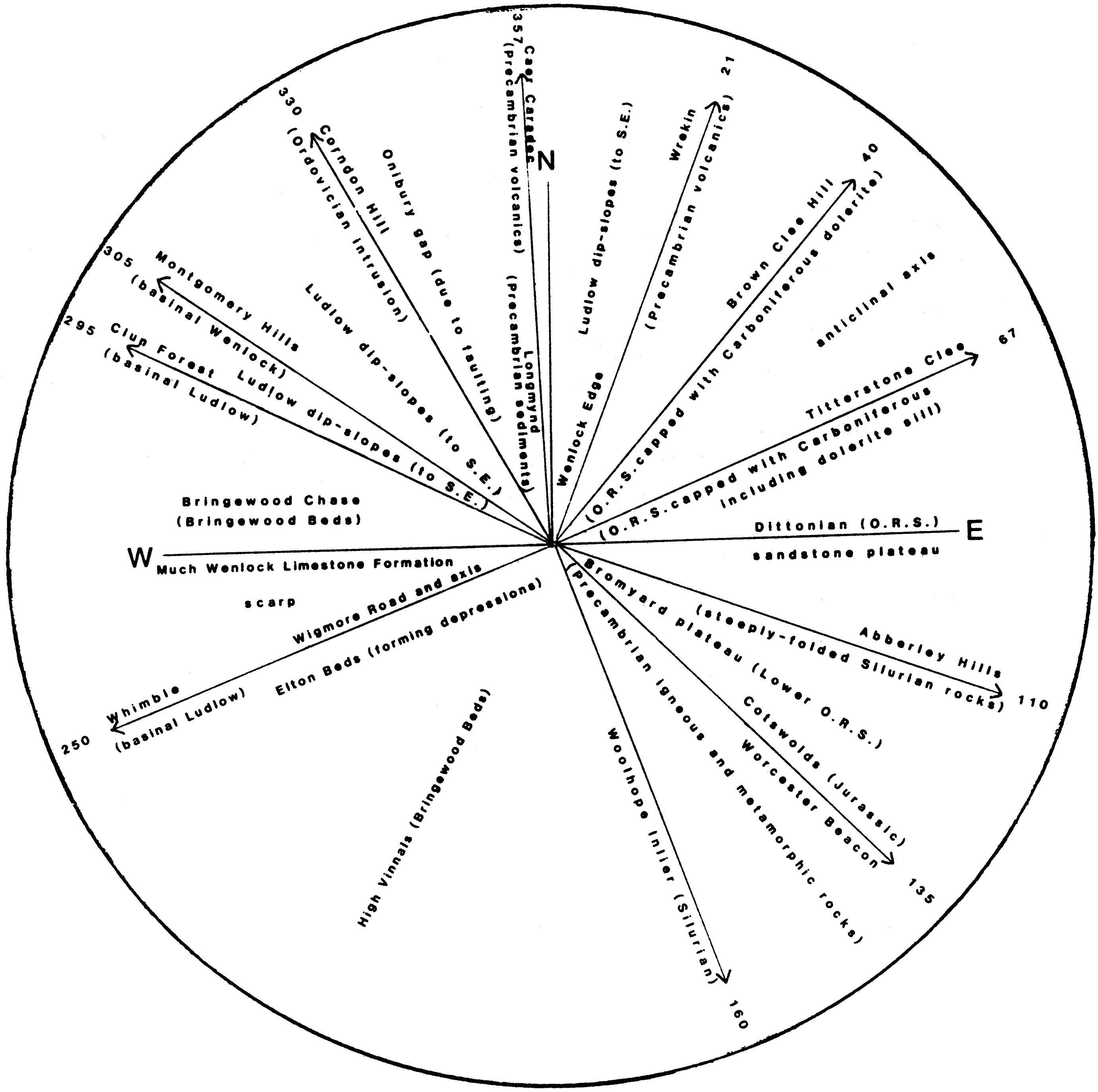

Fig. 3. The Panorama from Mary Knoll at S0486736

WEEKEND EXCURSION TO HUMBERSIDE

DAY 1—GEOLOGY AND SCENERY TRAVERSE OF NORTH LINCOLNSHIRE (SOUTH HUMBERSIDE)

Leader: D N Robinson — Saturday 27 September 1986

The purpose of this excursion (the first part of a weekend) was to demonstrate features of the gology and scenery of North Lincolnshire (South Humberside) adjacent to the Humber bank by a traverse eastwards from the River Trent. This crossed three cuestas of Jurassic and Cretaceous strata and included some key glacial features. The route can be followed on OS 1:50,000 sheets 112 and 113, and the Geological Survey 1:50,000 sheets 80 drift (Kingston upon Hull) and 89 drift (Brigg).

After meeting at Normanby Hall Country Park north of Scunthorpe, we proceeded to the Burton on Trent Cliff. This 200ft feature overlooking the lower Trent extends from Burton Stather to Alkborough. Exposures are few and very difficult of access along the partly wooded slope, but we were fortunate in that a new storm water channel (SE 868187) was under construction down the face of the Cliff. Here beds dip east at 3°. The sequence is:

Blown Sand

Frodingham Ironstone (or ferruginous limestone with abundant gryphaea) which forms much of the dip slope, with considerable local use as building stone

Lower Lias—Scunthorpe Mudstones, with thin, hard limestones; makes up central and upper part of slope

Upper Penarth (Rhaetic) beds - brownish shale and clay (some brick red) to 27ft (8m) thick.

Lower Penarth (Rhaetic) Beds—grey/black shales, up to 36ft (11m) thick. The Penarth Beds form the lower part of the slope, part covered with blown sand and esturarine alluvium; only exposed in landslips.

Excavation of the storm water channel gave access to the Lower Lias clays and limestones, and in the latter we were able to find shiny brown limonite oolite grains (forerunners of ironstone deposition to follow).

We then moved to Alkborough where the Cliff is at 150ft (45m) and overlooks Trent Falls—the confluence of the Trent and Ouse. There is a fine viewpoint at the 13th century Julian Bower turf maze (SE 880217). A number of nearby houses and garden walls were of the gryphaea-rich ferruginous limestone.

The route east followed the dip slope of the Cliff across patches of Frodingham Ironstone via West Halton, and crossing the valley of the north-flowing Winterton Beck. To the south is the large gullet of a disused opencast ironstone quarry now a landfill site, with no access to any remaning exposure. The overburden is of Coleby Mudstones of the Middle Lias, and the lower part of the slope is covered by head deposits. The narrow 150ft scarp is capped with Lincolnshire Limestone. On the ridge crest the route joins the A1077 and proceeds east.

At the crossroads at SE 933204 the route crossed on to morainic topography—glacial sands and gravels with Skipsea Till—of the Winteringham-Horkstow terminal moraine. A few enclosed hollows may be kettle holes. At a disused sand and gravel quarry (950213) we were able to examine the coarse, mainly flint gravels, but also with sands and well defined patches of varved clays (indicating former pools within the moraine). The light scatter of erratic pebbles showed the usual assemblage of Scottish granites, porphyritic lavas and occasional schist, Carboniferous grits from North England, the fossiliferous Lias limestone and septarian nodules from the Jurassic of north-east Yorkshire, and more unusually Red Chalk (only transported a short distance from the north end of the Lincolnshire Wolds).

The route continued along the A1077, where it is liable to flooding along the Humber bank, across the Ancholme valley, floored with estuarine alluvium (Humber 'warp'). The first New Cut to improve drainage was in 1637, and the final system including catchwater drains was completed by Sir John Rennie in 1844. Lunch was taken at the Hope & Anchor inn by his sluice, with views of Read's Island just offshore.

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The major quarry visited was at South Ferriby, SE 990225 (by permission Rugby Portland Cement plc). The quarry has been excavated from the top of the 250ft (75m) Wold scarp, and to about that depth through chalk into clay to supply both to the cement works at Ferriby Sluice by overhead conveyor. Before excavation reached the clay, the supply was from the Humber warp of Winteringham Ings in the Ancholme valley adjacent to the works. The sequence exhibited in the quarry is:

Lower Chalk—Ferriby and Welton
Red Chalk
Upper Carstone
unconformity
Kimmeridge/Ampthill (Ancholme Group) Clays

As virtually all the Lower Cretaceous sequence is missing, the exposure in this quarry demonstrates the result of progressive truncation towards the Market Weighton block of Late Jurassic and Lower Cretaceous strata as pre-Albian uplift and erosion of the northern part of the East Midlands shelf proceeded. The clays at the bottom of the quarry contain the so-called Kimmeridge 'logs'—fossilised timber trunk sections c.1ft in diameter, about which little appears to be known. No examples were found on this occasion, but the clays did yield ammonities, particularly quite large near smooth outer sections of *Pictonia*, with some flattened bivalves (largely *Ostrea*), the occasional *Pinna*, as well as the disappointing cemented nodules, most of which proved barren.

From the village we took an unmetalled track to the Humber bank to examine the south Ferriby Cliff sections (SE 993218—997225). The Humber gap is of late Tertiary consequent drainage origin, possibly exploiting fault line weakness. Before the Last (Devensian) Glaciation (which penetrated the gap to the Winteringham-Horkstow line) the Humber flowed direct east, until diverted by the tills of Holderness.

The river cliff section examined has late Devensian (Skipsea) till and periglacial deposits resting on a planed surface of disturbed and contorted chalk. Pebbles and sand between the chalk and the till indicate the margin of an ice-dammed lake when the ice margin still lay to the east. The till is up to 25ft thick, and reddened by Flandrian weathering.

South-west of this section is a terrace of unstratified sandy chalk gravel over the till—probably solifluction of frost-shattered chalk from a dry valley in the chalk slope. Nearby is the unusual sight of raised saltmarsh on a beach of discoid chalk pebbles.

Leaving South Ferriby we travelled south on the B1204, on sand and gravel along the foot of the Wold scarp, and turned off along an unmetalled road to Horkstow Bridge (SE 973190). This unique 232ft (70m) chain suspension bridge with rusticated Yorkshire stone towers was designed by Sir John Rennie and built in 1835.

The Horkstow morainic 'ridge' restricted the Humber and warp was laid down in the embayment to the north. On the west side of the river are the remains of recently demolished brick kilns used to burn clay from the straightening and deepening of the river. A search of one of the sites showed vitrified bricks where the flue holes were situated, and bricks were found where one of the through holes was in the shape of the letter F; the brickmaker here in the 1880s and 1890s was John Frank.

Returning towards the main road we could see the parallel periglacial rills on the Wold scarp, with a closer view when ascending the scarp to a minor ridge-top road at 300ft (90m). This gave superb views of the Ancholme valley and to the west over the lower limestone cuesta to the Scunthorpe steel works; to the south of the simple Wold escarpment and in the distance the Wrawby-Brigg ridge; and from Saxby Wolds east down the dip slope to the refineries and factories of the Humber bank (Grimsby-Immingham).

Near Elsham the route passed disused chalk quarries and the water treatment works of Anglian Water's Trent-Witham-Ancholme transfer scheme on the old airfield. Descending gently and under the M180 we joined the A18 to pass through the high level Barnetby gap which was exploited by west flowing Weischel (late Devensian) meltwaters, and past the huge Melton Ross chalk quarry.

Turning off near the Humberside Airport, the last site visit was a small long disused quarry at Kirmington (TA 105117). This is a SSSI and one of the most important Quaternary sites in Eastern England. The complex sequence of glacial and interglacial deposits up to 90ft (27m) thick occupies the west end of the buried Kirmington 'fjord'. Estuarine clays and peat lie beneath 3–10ft (1–3m) of coarse marine shingle (strongly cryoturbated) of clatter-marked cobbles, capped by 6ft of Devensian till. Only the shingle and overlying till can be seen in two small trench exposures.

The marine shingle suggests an interglacial sea level of 70ft OD. Stratigraphical and geomorphological circumstances support an Ipswichian age for the shingle, but an earlier Hoxnian age has been suggested as it has yielded artifacts of Clactonian type. However, if the shingle is Penultimate rather than Last Interglacial—how has it managed to survive?

The party then travelled north, crossing the Humber Bridge for the second day in North Humberside.

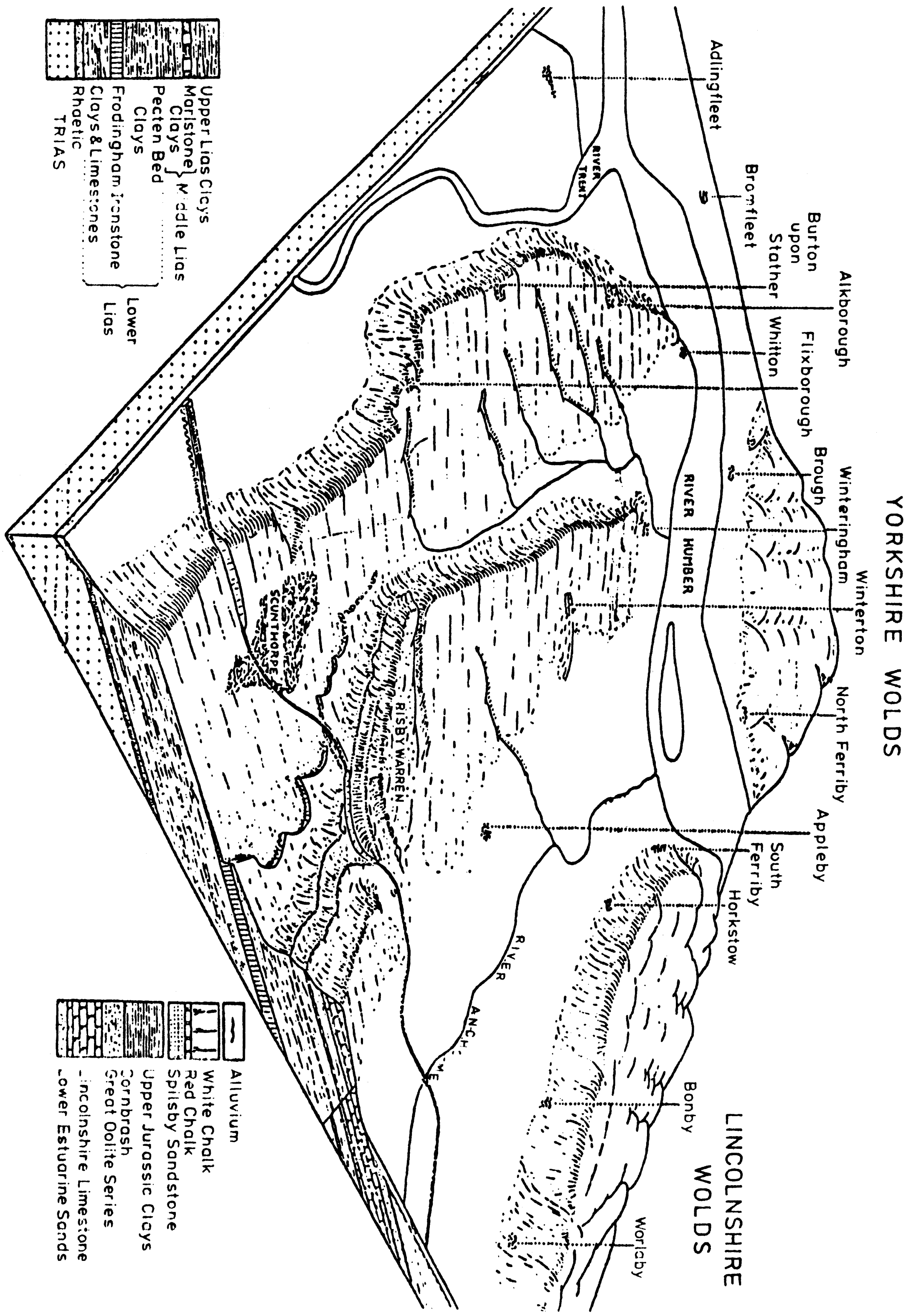

Fig. 1. The relationship between physical features and solid geology in north Lincolnshire.

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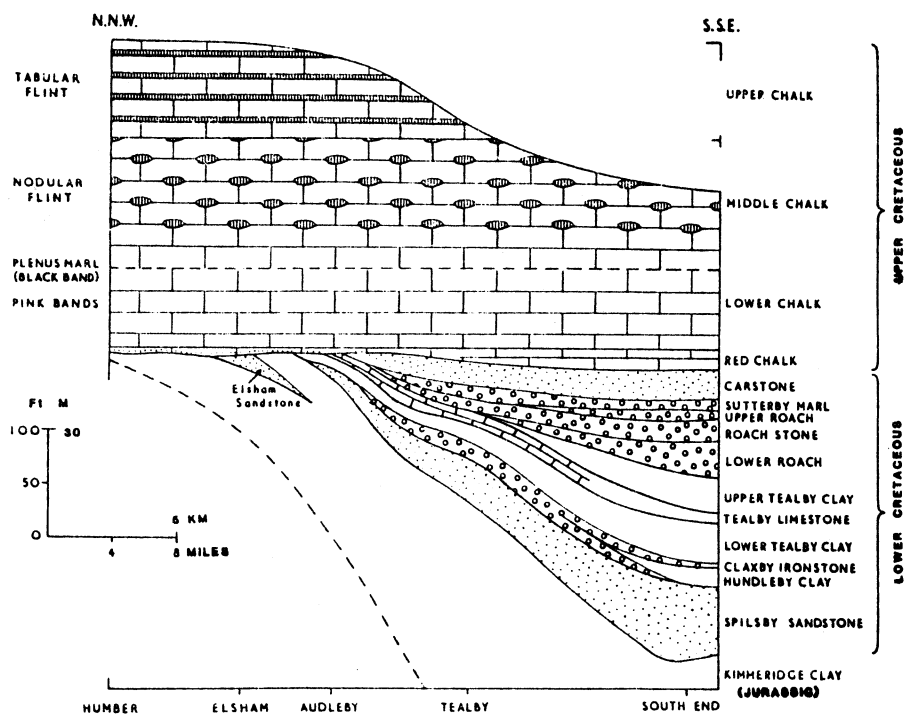

Fig. 2. Diagrammatic cross-section.

DAY 2—FLAMBOROUGH HEAD AND THE YORKSHIRE WOLDS

Leader: Rosalynde Grum B.A.

Our aim was to study the coastal geomorphology of Flamborough Head, and when driven inland by the rising tide, to examine the late Devensian ice marginal features of the Yorkshire Wolds. The party set out in good spirits thanks to the fine weather and an excellent (though rather early) breakfast at the Monarch Hotel, Bridlington.

Locality 1 Sewerby Beach G.R.202686

We examined the famous Ipswichian Cliff and raised beach with its associated glacial, aeolian and fluvioglacial deposits. These were still recognisable from the description in earlier guides in spite of the Drab Clay changing its name to the more distinguished title of Skipsea Till. The processes of weathering and erosion affecting the chalk and boulder clay cliffs were pointed out; then we turned our attention to the present day beach materials. After the leader had commented on the scarcity of macrofossils in the chalk the party found numerous fossil bivalves, sponges and trace fossils in the chalk boulders! A hunt for glacial erratics turned up a whole range of foreign and local rock types incluing a boulder of Norwegian larvikite nicely confirming the source of the ice sheet.

Locality 2 Flamborough Head G.R. 2570

Here the chalk has been fashioned into caves, arches, stacks and a blow hole by marine erosion along planes of weakness in the rock. At Selwicks Bay G.R. 255709 we climbed down to the beach to examine the faults, folds and joints of the east-west orientated Flamborough Head shatter zones which has controlled the development of the land forms. The incoming tide prevented us from walking behind the arches, slightly to the relief of the leader, who on a previous visit had witnessed a helicopter rescue exercise from this precise point. The party had to be content with photographing the landform from the end of the headland G.R. 258707.

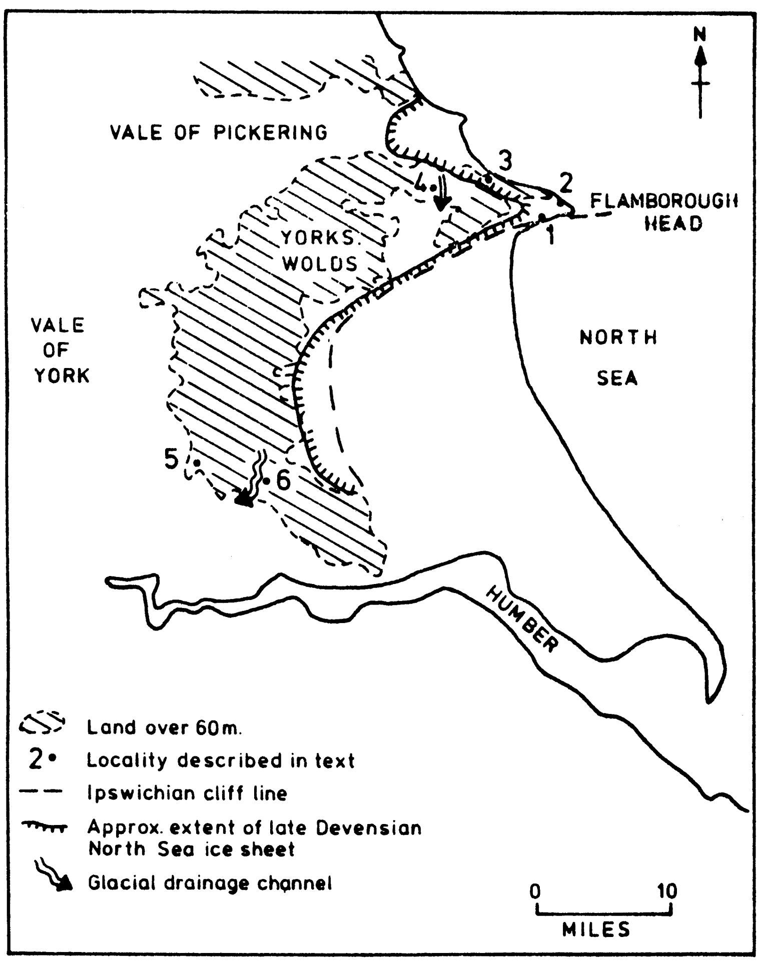

Fig. 3. Locality map.

The glacial deposits were examined where landsliding around the blow hole provided fresh sections. These were seen to be a mixture of till and fluvioglacial gravels.

From Flamborough Head the party travelled northwards along the B1229 towards Speeton. Several circular depressions were observed in the fields. Theories advanced as to the formation of these features ranged from solution hollows in the chalk to bomb craters from the war!

Locality 3 The Speeton Moraine

Before reaching Speeton the late Devensian terminal moraine showed up clearly on the skyline. A transect on foot from the church at G.R. 172747 towards the cliffs enabled us to observe the steep 'ice contact' slope on the north side.

Locality 4 The Hunmanby Overflow Channel G.R. 100766–107745

South of Hunmanby the overflow channel from a temporary lake, dammed between the ice front and the Wolds, overflowed southwards towards Rudston. The flat floor of the valley of the Gypsy Race stream near Rudston led earlier geomorphologists to postulate the existence of a glacial lake Rudston. The leader wondered if this has suffered the same fate as Kendal's lakes around the North York Moors which have now evaporated from the literature.

Heading homewards across the Wolds, the position of the late Devensian ice margin could be plotted by the presences or absence of till in the ploughed fields. The boundary occurred at a height of about 60 metres. The rather featureless shallow valleys on the till were in marked contrast to the very deeply incised 'ice free' valleys such as that of Millington Beck G.R. 844565 to 830510 (*Locality 5* on the map). From the road at 830535 there was a good view of the deeply incised edge of the Wolds and the flat floor of the Vale of York into which valleys drained.

Locality 6 Glacial drainage system near Market Weighton

From Middleton on the Wolds G.R. 947496 southwards to South Dalton Wold G.R. 940440 a shallow depression crossing the spurs of higher ground was identified as a subglacial drainage channel draining southwards andwestward into the Market Weighton spillway G.R. 940440 to 890425. The channel shows up clearly on the Market Weighton Geological Survey sheet. Members of the party argued that the channel was unlikely to date from the last glacial advance because of the absence of till in the surrounding fields.

The party followed the path of the glacial drainage to Market Weighton and then dispersed.

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FIELD EXCURSION TO EXAMINE THE DEEP WATER MUD-MOUND COMPLEX AT DOVEDALE

Leader: Paul H Bridges

May 16th 1987

Introduction

A number of carbonate mud-mound complexes formed in the deep water to the SW of the developing Derbyshire Platform in late Tournaisian—early Viséan times. The largest of these is located at Dovedale in the Peak District where it occupies an outcrop of approximately 4 × 1.5 km. The rocks are quite well exposed in the valley of the southward flowing Dove. The field party, comprising members of East Midlands Geological Society and the North Staffordshire Geologists' Association, set off to examine features recording the growth of the complex and evidence relating to the origin of the mounds (Fig. 1).

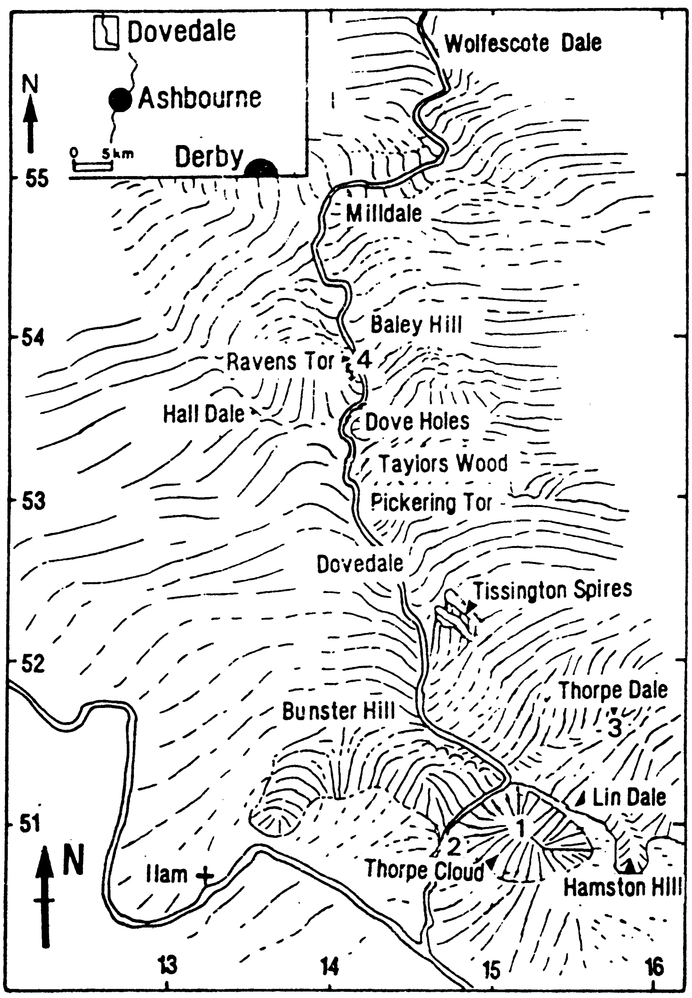

Fig. 1. Map of Dovedale showing the location of the principal sites (1–4) visited during the field excursion.

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Vol. 11, no. 3, pp. 201–203.

1. The party alighted from the coach at the short-stay car park at Thorpe (SK 155 505) and ascended the moderately inclined SE facing slope of Thorpe Cloud. At the top the party examined the mound core facies which locally displays a hummocky lamination. In photomicrographs members of the field party could see that the lamination is sometimes crinkled indicating a cryptalgal origin. The lamination is composed of poorly-defined, small peloids, micrite and comminuted skeletal debris. It was suggested that these peloids were precipitated around bacteria in a similar way to Recent peloids which have been described from the fills of borings in the reefs of Belize. The absence of micritization of shells and the burrows of soft-bodied infauna supports this view. Thus micro-organisms, bacteria and algae, are regarded as having had an important role in the accretion of the sediment in the mounds. Other organisms including sponges, bryozoans, crinoids, echinoids, foraminifera, ostracodes and algae (releasing calcispheres) also colonized the mound complex (Fig. 2) (Bridges & Chapman, in press).

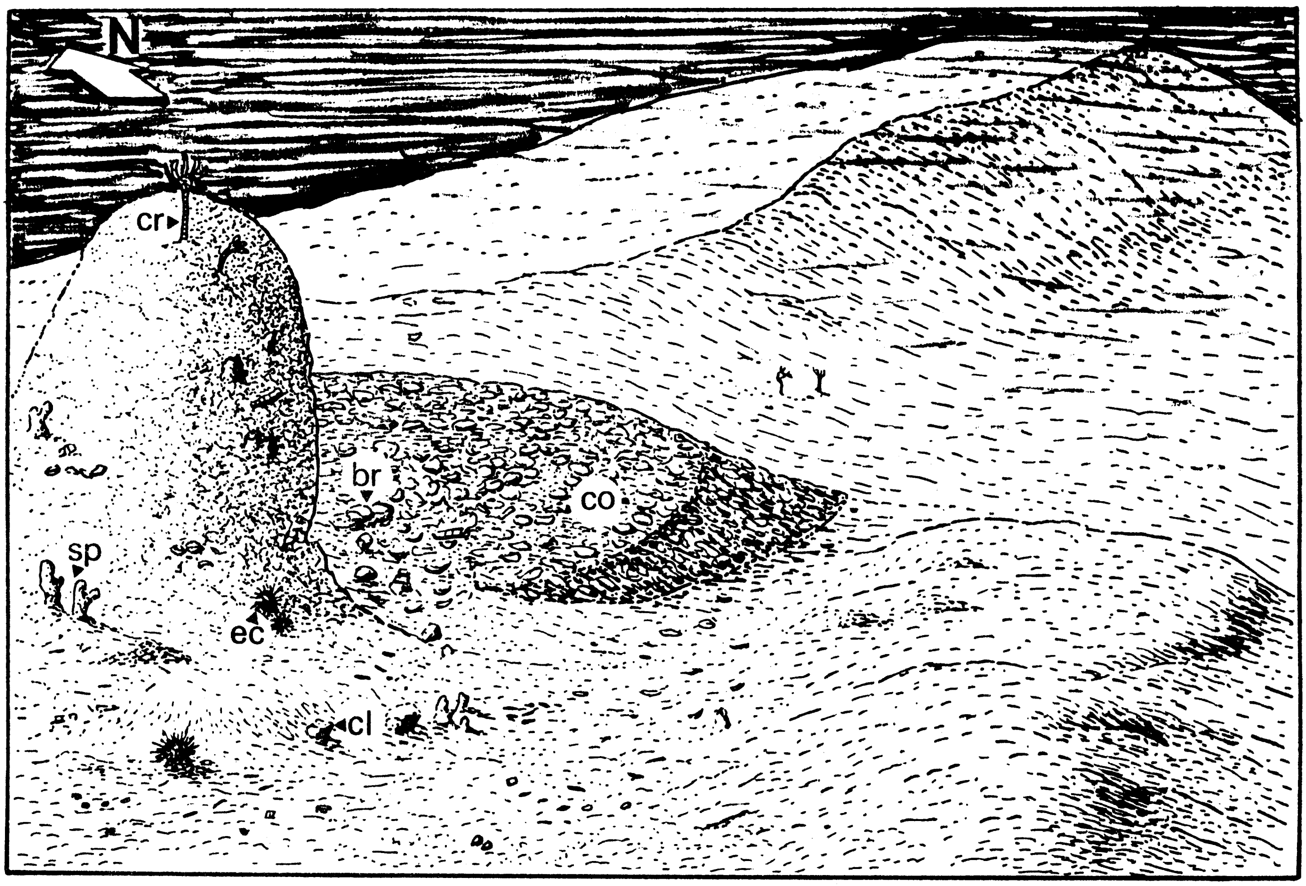

Fig. 2. Reconstruction of the mound surface at the top of Thorpe Cloud. The surface was consolidated and gelatinous with heterotrophic bacteria and cyanobacteria which induced precipitation of calcium carbonate. Macrofauna included sponges (sp), echinoids (ec), crinoids (cr) and brachiopods (br). cl-clasts; co-coquina.

2. The party descended the SW spur of Thorpe Cloud and examined fissure fills near the base (SK 1478 5103). Two kinds of fill were identified. Firstly there is a series of narrow sigmoidal cracks filled by crinoid debris which formed at an early stage when the sediment was consolidated. Secondly there are wider fissures filled with lithoclasts of cemented mound core sediment, crinoids and haematitic carbonate mud, which formed during a later stage of diagenesis.

3. The party then followed a path along the eastern side of the river Dove to the stepping stones (SK 1515 5135) and ascended a dry valley herein named Thorpe Dale to a point where two walls intersect (SK 1543 5166). Mound and intermound facies intercalate and provide evidence of a submarine valley which formerly extended to the SW between Thorpe Cloud and Bunster Hill. Thus the mound at Thorpe Cloud had been separate from the rest of the complex.

4. After lunch the party followed the main valley path past Tissington Spires and Pickering Tor. By mid-afternoon the party reached the foot of Baley Hill on the northern margin of the complex. The party gained a good view across the river Dove to Ravens Tor where the unbedded mound core facies can be seen passing laterally into moderately inclined (10–20°) mound flank facies. Photomicrographs illustrated the micritized lithoclasts and crinoid debris which are characteristic of the flanks. These sediments pass laterally into the intermound facies which varies from fine-grained, dark and bituminous to coarse-grained and generally light coloured. The coarse intermound sediments contain dasycladacean algae, coarse peloids and lithoclasts in clear contrast to the mound core facies. Comparisons with the Waulsortian mud-mounds of Dinant in Belgium, where Lees *et al.* (1985) have proposed bathymetric phases, suggest water depths of between 120 and 280 m. Finally, the party continued along the path of Milldale and rejoined the coach at Shining Tor (SK 1460 5510).

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WEEK-END EXCURSION TO THE CARTMEL PENINSULA, CUMBRIA

Leader: Murray Mitchell September 11–13th 1987

For the twelve members arriving at Castle Head Field Centre, the rain was quickly forgotten in the warmth of their reception; a welcoming cup of tea and the blazing log fire in the library gave the impression of a country house week-end rather than a geological field excursion, an impression that was further enhanced by the excellence of the accommodation and the abundance of the dining table.

The leader, however, was anxious to remind us of the purpose of our visit, and, after allowing time for the four non-resident members of the party to join us, he proceeded to introduce the group to the geology of the area. He began with a review of Lake District geology and continued with a more detailed examination of the Carboniferous Limestone succession in the Cartmel Peninsula (Table 1) and its structural relationships with the underlying Bannisdale Slates, of Silurian age. In this area of the Southern Lake District the Lower Carboniferous limestones rest unconformably on the folded and eroded Bannisdale Slates and dip gently eastwards; north-south faults, associated with the early stages of the opening of the North Atlantic, in Tertiary times, downthrow to the west, and the limestone fells have steep west-facing scarp faces. (Figs. 1 & 2).

This introduction, well illustrated with slides, was enlivened by the speaker's obvious wider interests in the relationships between the geology and the landscape, natural history, and the history of man in the area. A comprehensive set of hand-outs was issued and discussed, and the programme for the week-end was outlined.

On Saturday morning, the party assembled on the east lawn of Castle Head, where the leader, supported by Frank Dawson, one of the Directors of the Centre, explained the view in front of us and its associations with Castle Head. An expanse of very flat grazing marsh, about 1 km wide at this point, is backed by the wooded ridge of Meathop Fell, rising abruptly from the marsh, with Meathop Quarry at its southern tip. The marsh, which is underlain by at least 30 m of post-glacial marine deposits, was the former Lindale Pool, a tidal marsh extending for over 2 km inland until the late 18th century, when John Wilkinson, a noted English ironmaster, built an east-west bank to protect the inland area to the north, an act of benevolence that enabled him to purchase the land and build Castle Head, on its island of higher ground, in 1780. Wilkinson had learnt his trade in his father's foundry at Blackbarrow, and by the age of 20 he was establishing ironworks in Shropshire and Staffordshire. In 1774 he invented a machine which made possible the accurate boring of cylinders, an advance that contributed much to the success of Watt's steam engine. He died in 1808 and was buried, in an iron coffin, in the grounds of Castle Head, with his grave marked by an iron monument.

The remnants of Wilkinson's bank can still be seen, but it became obsolete with the construction of the Ulverston and Lancaster Railway in 1857, when the new railway embankment made an effective barrier against the tides for the whole area of the Pool.

A short walk to the south of the Centre led to an exposure of the Lindale Fault, where a cliff marks the faulted junction of the Bannisdale Slates with the Park Limestones, of Dinantian age; it was pointed out that the undercutting here does not indicate a relative softness of the Slates, but results from the brecciation caused by the movement of the fault. From the dip of the limestones, and their reappearance on Hampsfell to the west, it was demonstrated that there must be at least one other fault between this outcrop of Park Limestone and the Urswick Limestone on Hampsfell. (Fig. 2).

By this time the leader's discussion was being disrupted by the rustling of waterproofs, and the group retreated to the shelter of the Castle Head verandah, where the hospitality of the Centre was further demonstrated with coffee being brought out to us. With the rain becoming a downpour, a change of plan was indicated and the group headed for Cartmel Priory.

In the shelter of the south porch of the Priory, with its beautiful Late Norman doorway, the leader discussed the history of the building and its geological relationships; three different sandstones were used in the early building, all from the Gleaston Formation (Table 1) quarried from the grounds of Holker Hall some 3 km to the south-west; the practical skills shown by the stonemasons in choosing each sandstone for its own particular use in

Mercian Geologist, 1988,
Vol. 11, no. 3, pp. 205–210,
plates 1 & 2 (1p.)

the building was demonstrated. The poorer quality of the stonework of the 15th century additions was speculated on, as were the possible reasons for moving the cloisters from the south side to the north, and the diagonal setting of the upper stage of the tower. The Priory is sited on a glacial 'crag and tail' structure, and was originally surrounded on three sides by a post-glacial lake; glacial till is draped around the crag of Bannisdale Slate, particularly on the south side, and this may have led to the differential settlement indicated by the curve in the drip course at the east end of the structure.

With the clouds lifting, the excursion continued to Humphrey Head (SD 391739) where, after walking a short distance over the Urswick Limestone, we were able to enjoy our lunch in bright sunshine, comfortably seated on the limestone pavement. Visibility had improved considerably by this time, and, from the triangulation point on the summit of the headland, the geological features of the landscape were described; a group of drumlins to the north was pointed out, and in the distance the Lancashire Fells, the Howgills, and Ingleborough showed up clearly.

At Humphrey Head Point it was possible to examine the Urswick Limestone in more detail; the pseudobrecciation (Table 1) is clearly displayed, and this was attributed to burrowing by worm-like animals, a view supported by the fossil forms of these burrows demonstrated in the limestone. The cyclic depositional sequences were also demonstrated here; each shallow-water master bedding plane and shale is succeeded by thinly bedded limestones passing upwards into massive-bedded limestones to the next master bedding plane (Table 1). The shales frequently include volcanic dust deposits. Along the eastern shoreline of the Head, the thin-bedded dark grey limestones, forming the lower part of the Gleaston Formation, were seen to contain abundant corals, and the leader was able to demonstrate his classification system for the identification of Carboniferous corals. For the botanists in the party, the walk back through Humphrey Head Wood was an added bonus.

The final exposure of the day was an outcrop of Permo-Triassic brockrams at Rougholme Point (SD 385740) (fig. 1) on the shore west of Humphrey Head. The brockrams are coarse breccia, deposited by flash floods, with mainly locally-derived limestone pebbles and thin, inter-bedded layers and lenses of red sandstone forming the matrix. A curious feature, which aroused much discussion, is that many of the pebbles show a hardened skin surrounding a hollow or rotted core. This is most apparent on the eroded surfaces, where the skin has been partly eroded away but it was demonstrated that pebbles which retained an intact outer skin may also show a hollow centre. Precise dating of this exposure is uncertain, but Arthurton *et al.* (1978, p. 198) suggested a position high in the Permian sequence. A borehole has shown the brockrams here to have a thickness of 257 m and to overlie strata of probable Namurian age; together with the estimated thickness of 250 m of Lower Carboniferous Urswick Limestone and Gleaston Formation rocks on Humphrey Head, this implies a minimum westerly downthrow well in excess of 500 m on the fault separating Humphrey Head and Rougholme Point.

Sunday morning dawned bright and clear, and the indications of a fine day were confirmed by the local weather forecast. At breakfast, Mrs. Fev Dawson and her colleagues were thanked for the excellent domestic arrangements of the week-end.

The group headed first for Meathop Quarry (SD 432792) where the lowest formation of the Lower Carboniferous present in the area, the Martin Limestone, is exposed. The fine-grained, even-bedded limestone makes an excellent building stone and the quarry was exploited by the builders of the Ulverston and Lancaster Railway, although it probably has a much longer history. It was pointed out that prior to the building of the railway it was possible for stone to be loaded directly into boats moored at the foot of the face.

Evidence for shallow-water deposition for part of the Martin Limestone was demonstrated, including 'birds-eye' structures (fenestral fabric), algal mats and a pavement of dessication polygons, the latter being unfortunately in danger of destruction by over-zealous hammering and collecting.

In the view westwards to Hampsfell, the line of the fault separating the Urswick Limestone, on the south side, from the Bannisdale Slates exposed in the road cuttings and on the Fell to the north (Fig. 1) was clearly shown by the topography and by the differences in vegetation.

The rest of the day was to be spent on a traverse of part of Whitbarrow, starting from Witherslack Hall (SD 437859) some of the cars being parked at North Lodge to avoid a weary trek back along the road at the end of the day. The Hall is sited on a narrow outcrop of Martin Limestone, resting unconformably on Bannisdale Slates; a short distance to the west, a north-south trending fault separates the Martin Limestone and Bannisdale Slates of Whitbarrow from the Dalton Beds of Yewbarrow (Fig. 2).

Walking eastwards from the Hall, an area of flat low-lying meadow, referred to as Witherslack Tarn, was noted to the south and described by the leader as a former glacial lake, now infilled with some 15 m of post-glacial deposits. A small outcrop of Red Hill Oolite to the north of the path was examined; despite its name, this

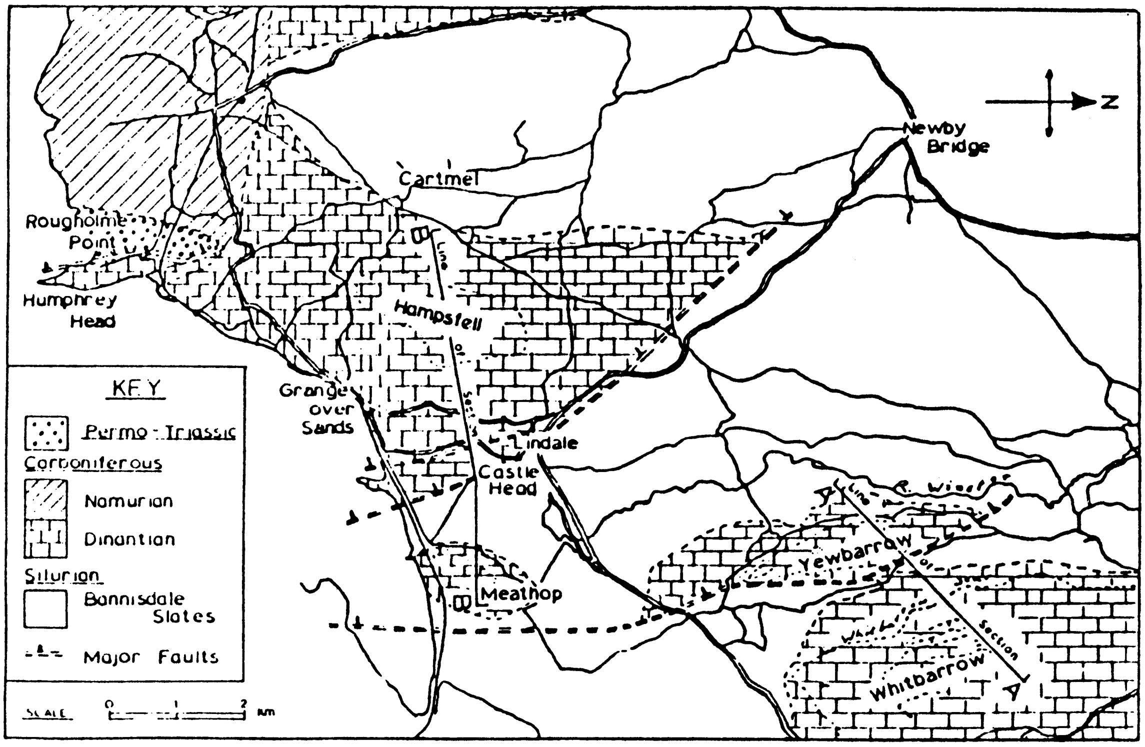


Fig. 1. Location Plan, with geological boundaries (after M. Mitchell).

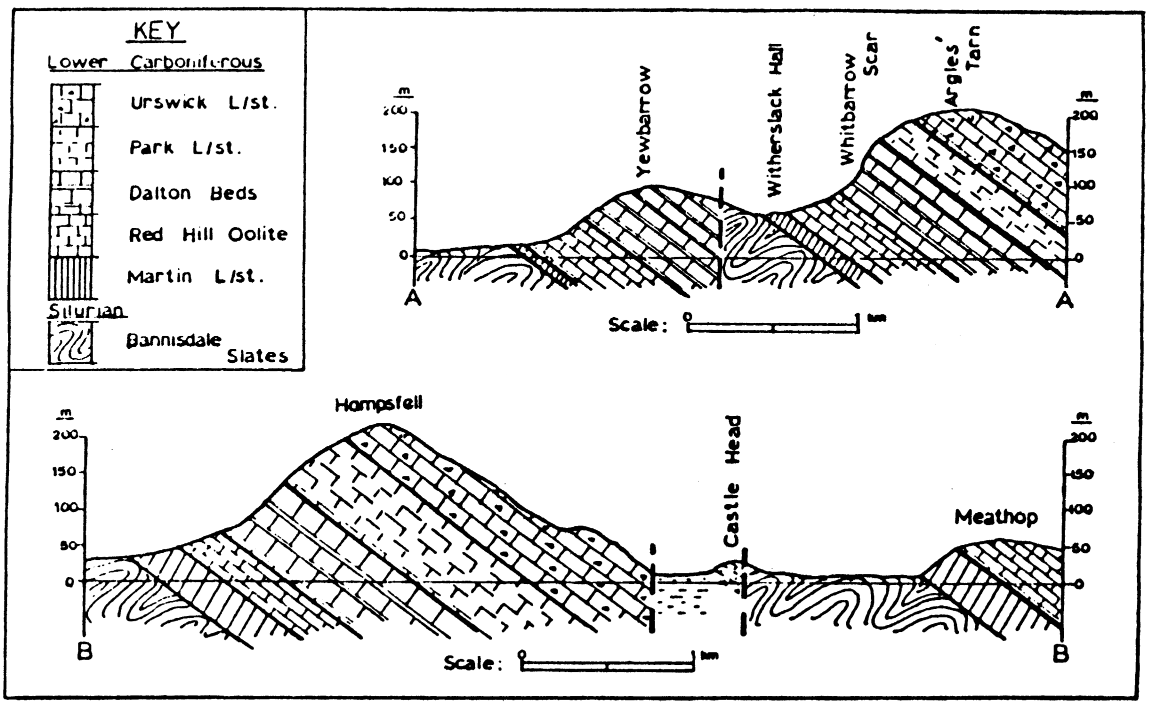


Fig. 2. Geological cross-sections (after M. Mitchell).
AA - Yewbarrow and Whitbarrow
BB - Hampsfell and Meathop

limestone is not an oolite but contains small rounded pellets of carbonate sand. In contrast to the Martin Limestone the rock is poorly bedded and the absence of shale partings made it an excellent stone for lime-burning.

The three divisions of the Dalton Beds were crossed, with the thicker shale partings of the middle division emphasised by springs and wet ground on the lower slopes of Whitbarrow, and the massive-bedded upper division forming the prominent Whitbarrow Scar. The path up the Scar was less steep than it had appeared from below and was further relieved by the need for occasional halts for the leader to point out the geological features of the landscape as they came into view. The progression to the succeeding formation, the Park Limestones, was evident from the well-displayed 'ridge-and-furrow' topography, a succession of outcrop ridges separated by loess-filled hollows covered by grass and heather. A band with the cerioid corals, *Lithostrotion* sp., was seen some 20 m above the base of the Park Limestones, providing another opportunity for the leader to demonstrate the value of his identification key. At the top of the formation shallow-water deposition was indicated by the presenceof 'birds-eye' structures (fenestral fabric) as seen earlier in the day in the Martin Limestone.

The limestone pavements of the Urswick Limestone, forming the top of Whitbarrow, are developed to a much greater extent than at Humphrey Head, and help to accentuate the depositional cycles of this formation; the pavements, formed on the master bedding planes of each cycle, dip eastwards at about 10°, passing up into a low cliff formed by the shales and thinner-bedded units of the next cycle and capped by the massive-bedded limestone on which the next pavement with well-formed clints, grikes, and runnels is developed. Nine or ten of these cycles are present in the Urswick Limestone, forming a distinctive stepped topography, with each cycle representing a period of some 0.5 my, deposition taking place, however, for probably only a third of that time.

The massive-bedded limestone units can be cut out in large blocks, and made excellent gate-posts; a more unusual application, in the past, was for grinding wheels for use in the Sedgwick gun-powder works, where the sparks common to more traditional grinding media would have been a decided disadvantage; another gun-powder works was near Chapel Stile (R.J. Firman, personal comm.).

Much interest was aroused by Argles' Tarn (SD 443871) as much by its distinctive fauna as by its actual existence, apparently sitting on a limestone pavement. Named after the Argles family, former owners of the area, it is fed by a spring and maintains an almost constant level throughout the year. The leader suggested, in explanation, that the shale unit at the base of this particular cycle was thicker than in other cycles, and pointed to the adjacent cliff which also seemed to indicate a thicker sequence in this cycle. As we turned to continue our traverse northward, he pointed out a slight depression crossing the hill-top and trending towards the Tarn, which might possibly indicate a small fault and have some bearing on the origin of the Tarn.

A large erratic block, perched on top of the limestone, provided evidence that, at some stage in the Pleistocene glacial period, ice had covered Whitbarrow; of equal interest was the block itself, an agglomerate from the Borrowdale Volcanics, north of Kentmere.

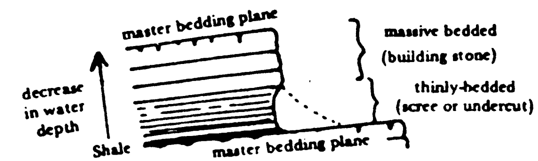
Descending the slope northwestwards from the summit, some small parallel-sided excavations were noted, marking the line of an unproductive mineral vein; a short distance downslope a small adit again showed little sign of productive mineral extraction, specimens in the spoil heaps showing calcite and barytes but only thin stringers of haematite.

The track to North Lodge continued through woodland, crossing the Dalton Beds and the Red Hill Oolite, but with few exposures. At the foot of the slope, a short detour was made to Fairies' Cave, a narrow entrance in the lowest beds of the Martin Limestone. Previous exploration had shown that it leads to a water-filled siphon and on into a large chamber. Flood-flow debris downslope from the cave entrance indicated that the heavy rain of the previous day had caused the siphon to overflow. Along the slope, the cave system had been exploited for a local water supply, still in use, by means of pipes driven into the hill-side, and there was some speculation as to how the locals had determined the right places to insert their pipes.

The junction with the Bannisdale Slates is not exposed, but the presence of slates in the nearby stream was pointed out, thus fixing the position of the junction to within a few metres. The leader stressed that the upper surface of the Bannisdale Slates is very irregular, and this feature is well displayed by the switchback nature of the road from North Lodge to Witherslack Hall.

This completed a very enjoyable excursion, and the members unanimously expressed their thanks and appreciation to Murray Mitchell for a most interesting and informative week-end; also to Frank Dawson, whose contributions and experience in his own fields had added a great deal of extra interest.

Table 1. (prepared by M. Mitchell).

STAGES	LITHOLOGICAL FORMATION	CARBONIFEROUS LIMESTONE OF SOUTHERN LAKE DISTRICT		
			LITHOLOGICAL CHARACTERISTICS	FEATURES OF INTEREST IN GRANGE AREA
BRIGANTIAN	GLEASTON FORMATION (c.200m)		Limestones, shales and sandstones: limestones, dark grey, medium grained, crinoidal, thinly-bedded; prominent algal band (Girvanella Nodular Bed) c8 above base.	Exposures in grounds of Holker Hall. Basal 15 m of limestone well exposed on eastern flank of Humphrey Head.
ASBIAN	URSWICK LIMESTONE (150m)		Limestone, pale grey, medium grained, abundant shell debris, well-bedded, part massive-bedded, part thinly-bedded, regularly jointed. Much pseudobrecciation with irregular dark patches in a paler grey matrix, probably resulting from burrowing of worm like animals. Strongly cyclic (8-9 units).	Major source of Grange building stone (Eden Mount Quarries). Fine stepped dip and scarp topography on Hampsfell and Whitbarrow with clints and grikes on limestone pavements. Cycles  Pseudobreccias well seen at Blawith Point and on Chapel Island.
HOLKERIAN	PARK LIMESTONE (120m)		Limestones, pale grey, medium grained, some pellety fragments, dark crinoidal debris, massive, poorly-bedded or unbedded, occasional partings, closely jointed, blocky and platy weathering.	Stratotype (type section) for Holkerian Stage is taken at the base of the Park Limestone at Barker Scar on the eastern shore of the Levens Estuary. Poorly exposed on Hampsfell – grassy slope below summit. Exposed on Whitbarrow between Lord's Seat and cliff top – cyclic; stony/scree covered ridges and grassy hollows.
ARUNDIAN	DALTON BEDS (120m)		Limestone, medium to dark grey, medium grained, crinoidal, well-bedded with partings of calcareous shale. In 3 parts upper: massive-bedded, sandy, dolomitic middle: shaly partings thicker lower: thick bedded, medium grey.	Upper massive part: forms cliffs of Yewbarrow and Whitbarrow blocks and limestone pavement on summit of Yewbarrow. Middle part: small quarry opposite Witherslack Church. Lower part: seen in crags east of Reake Foot Quarry; base taken at first darker limestone, also more bedded than R.H.O.
	RED HILL OOLITE (60m)		Limestone, pale grey, medium grained, carbonate sand, well sorted, pellety, massive, poorly-bedded.	Caps Meathop hillside and forms broad shelf on west side of Yewbarrow Block to south of Witherslack Church. Used for lime burning (no shale partings) see Catcrag Quarry.
CHADIAN	MARTIN LIMESTONE (50m)		Limestone, medium grey or grey brown, fine grained, laminated algal layers, well-bedded, hard and compact with thin calcareous shale partings.	Well exposed in Meathop Quarry, much used as building stone especially by Furness Railway. See Grange railway station – larger blocks are mostly Urswick Limestone, smaller blocks are Martin Limestone.
TOURNAISIAN	BASEMENT BEDS (0-100m)		Conglomerates, sandstones and shales reddish brown in colour.	not present in Grange area.

Acknowledgements

The author acknowledges the assistance of Murray Mitchell in reading the manuscript and correcting the factual errors; also for permission to reproduce Table 1 in full. Figs. 1 & 2 are adapted from his excursions hand-outs, again with his permission. Grateful acknowledgement is made to Mrs. Judith Small and Mrs. Inga Filmer, who read the first draft and made a number of important contributions.

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Photo by Phillip Small.

Plate 1. View of Humphrey Head from Rougholme Point, with brockrams on shore in foreground.

Photo by Phillip Small.

Plate 2. Urswick Limestone surface on Whitbarrow. Standing figure indicates dip of pavement.

BOOK REVIEWS

BLÈS, J.L. and FEUGA, B., 1986. *The fracture of rocks.* North Oxford Academic Publishers Limited. Translated from French by J. Wanklyn. 131 pages of text and figures. £15.50 hardback. ISBN 0 946536 45 7.

There are many books dealing with rocks and their behaviour in engineering, but relatively few aimed at providing an in-depth understanding of fracture in rocks which embraces field observation and interpretation. This new book fills an important gap between theoretical rock mechanics and engineering geology, and will provide an important addition to texts dealing with rock mechanics.

Appreciation of the fracture of rocks requires an understanding of the parameters governing failure conditions, stress environment and mechanisms of failure. This is recognised by the authors who in the first section of the book provide the reader with a fairly concise treatment of rock mechanics concepts and thereby lays a solid foundation for the second part which is concerned with observation and interpretation of natural fractures.

There are nine chapters in the book, the first three dealing: review of solid mechanics; stress and behaviour; and rock failure. Chapters four, five and six cover: fracturing in geology; types of fractures; and interpretation of fracture mechanisms. The remaining three chapters are concerned with: fracture models; inter-relationship of fractures; and relationships between fractures and folds.

The first part of the book provides a useful insight into stress and strain concepts and the conditions governing fracture in rocks. There are several equations and diagrams supporting the text which allow rapid grasp of the fundamental principles.

The second part of the book discusses the various types of fracture observed in rock structures, and comments on the general conditions favouring their occurrence. The authors use ample illustrations to demonstrate the observed characteristics of rock fractures. Additionally the association of small fractures with major fracture development is clearly presented, as is the role of folding in inducing tension fractures and shearing between bedding planes.

This book provides a useful works of reference on the general character of fractures in rocks masses, and is recommended to geologists and engineers with interests in rock mechanics and engineering geology.

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GUILBERT, J.M. and PARK, C.F. Jr., 1986. *The geology of ore deposits.* W.H. Freeman and Company, New York, New York 10010. 985pp., 661 illustrations, £29.95 hardback. ISBN 0 7167 1456 6.

This new text book on ore deposit geology constitutes a major revision of the third edition of *Ore Deposits* by Park and MacDirimid. The book starts with eight chapters on principles which are only slightly changed from the last edition of *Ore Deposits*. These eight chapters, however, provide an adequate introduction to the principles behind the study of ore deposits although they are somewhat lacking in references to recent work. The authors assume that the reader has a good background in chemistry, physics and particularly in mineralogy. Without this several sections of the text will be virtually incomprehensible.

The main part of the text describes ore deposits, the basis of the subdivision of the major ore deposits in this text has changed from that in earlier editions of *Ore Deposits* from a 'Lingren-type' classification towards a "process-related, kindred group" type of classification. This has resulted in a much better classification than in its precursor texts but one which may cause confusion to the casual reader used to a more environmental classification system. This is particularly apparent with Banded Iron Formations which are classified as volcanic related in this text but sedimentary in many alternative texts. This main section of the book contains many examples, mainly from North America, and is therefore a very useful text, however, there is an almost total absence of information relating to the global distribution of the ore deposit types and also of theories related to the mechanism of formation of many of these deposits.

This text is more a compilation of 'case-studies' than an undergraduate text on ore deposits. To this end it is a worthwhile text but is, to the reviewer at least, spoilt by the lack of consideration of plate tectonic theory in relation to ore deposit genesis and also by the predominance of North American examples. Many of the diagrams and plates in the book are too detailed for the size of reproduction or of poor reproductive quality. There is also, in several places in the book, the annoying features that a diagram will appear before it is referred to in the text, in some cases by several pages. The general typographic quality of the text is good with very few errors.

In summary I feel that this book is a worthwhile addition to any library or individuals collection, its major 'selling point' being the wealth of information relating to specific deposits, but I have reservations as to its use as an undergraduate text outside North America.

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Proceedings 4th International Congress, International Association of Engineering Geology, New Delhi, 10–15 December 1982. A.A. Balkema, Rotterdam 1982. Volumes 1–9, £217.

This record of the 4th International Congress of the International Association of Engineering Geology constitutes a series of 9 volumes covering the presentations, panel reports and sessional reports of the six-day meeting. There is a total of pages in excess of 2800, covering every aspect of engineering geology, there being no single theme to the conference other than the subject of its parent association.

Volumes 1 to 8 include some 270 scientific and technical papers from 33 countries; about one third are representative of engineering geology activity in India. These papers are subdivided into 7 themes;

I. Engineering geological studies for environmental evaluation and development (volumes 1, 2, & 3).
II. Engineering geological problems of tunnelling and excavation of cavities (volumes 4 & 5).
III. Soil and rock as construction material (volume 6).
IV. Engineering geological problems of natural and man-made lakes (part volume 7).
V. Engineering geological problems of sea-cost and shelf areas (part volume 7).
VI. Seismic and seismo-tectonic investigations of engineering projects (part volume 8).
VII. History and development of engineering geology (part volume 8).

Each major theme is subdivided so as to focus attention on specific problems or studies. This is both a help, and, at times, hindrance. There is no doubt that the total Congress Proceedings cover a vast wealth of topics pertinent to modern engineering geology. It is quite exhilarating to browse through the volumes in search of general topics of interest, for they occur in the most obvious of places, and also jump out from the most unexpected; it must have been a mammoth and most unenviable task to sort the papers into their respective groups, because given this amount of material there are, inevitably, substantial overlaps of subject, and consequently the pigeon-holing of material becomes most complicated and difficult. Having said that, the volumes are an excellent record of what appears to have been a most exciting and far-reaching meeting.

Volume 9 contains Panelists' and Sessional Reports summarising the main themes covered by the scientific and technical papers, together with written versions of the Special Lectures delivered during the Congress. Again the range of topics covered is enormous. Volume 10 is not included in this review, it was due for publication at a later date and has by now presumably been published. Its content should be a record of the Technical Sessions and the discussions that ensued. Consequently it is probably one of the most valuable of the series, since it is often only in the discussion sessions that the important issues surface and the more recent developments are aired.

At £217 the set of 9 volumes represents reasonable value for money at todays prices, always assuming the broad content is to your liking. Unfortunately this breadth combined with the large total cost is likely to place the Proceedings within the reach of only libraries and professionals, and, whilst, I was personally converted to them, I cannot recommend them otherwise.

Proceedings 5th International Congress, International Association of Engineering Geology, Buenos Aires, 20–25 October 1986. A.A. Balkema, Rotterdam, 1986. Volumes 1–3, £165.

The 5th International Congress of the International Association of Engineering Geology is recorded in a series of 3 volumes which contain some 263 scientific papers on a wide range of engineering geology topics. The scientific papers are divided into six themes:

Volume 1:

I. Engineering geological investigations of rock masses for civil engineering projects and mining operations.

II. Engineering geological problems related to foundations and excavations in weak rocks.

Volume 2:

III. Engineering geological aspects of foundations in soils.

IV. Engineering geological problems related to hydraulic and hydroelectric developments.

Volume 3:

V. Engineering geology in the new development of road, railroad, coastal and offshore projects.

VI. Engineering geological aspects in environmental planning and urban areas.

In addition, two colloquia were held and these have been published separately in Bulletin NO. 34 of the IAEG. The first was on engineering geology in geothermal energy projects, and the second on engineering geology related to nuclear waste disposal projects. A further volume (4) to the three reviewed here is due to be published at a later date. As with the 4th Congress described above it will contain a record of the discussions arising from the technical sessions, together with the inevitable late papers which missed the deadline (!) and special reports. The importance of the recorded discussion is highlighted in the review of the 4th Congress (above) and the same comments are equally applicable here.

The broad range of topics covered is again highly commendable; it really does make for avid browsing on a dark cold winter's night in front of the fire. Unfortunately it naturally restricts the number of people likely to consider giving it shelf room, for at the price it represents a substantial investment. It will no doubt feature highly on library and institutional lists; I recommend anyone with a passing interest to seek a copy out there.

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YOUNG, B. *Glossary of the minerals of the Lake District and adjoining areas.* 1987 Newcastle upon Tyne: British Geological Survey published HMSO, 104pp., £8.50, paperback. ISBN 0 85272 099 8.

Seventy five years ago Postlethwaite (1913) listed 108 minerals from the Lake District and adjoining areas. By 1940, due principally to petrographical and heavy mineral studies and indefatigable mineral collectors such as Sir John Russell, the total known minerals had increased to about 175 valid species. The post-war advent of X-ray powder photographs, reflected light microscopy and, more recently, X-ray diffraction spectromety and microprobe techniques facilitated the identification of many more mineral phases so that this present glossary lists about 300 valid species. Identification of rare, often minute, minerals became easier than reporting their presence in the scientific literature! Not the least of the virtues of this glossary is that the author has, by working through collections in the British Museum (Natural History), the Geological Museum and the National Museum of Wales, brought to light several minerals either, hitherto unknown in the Lake District, or from new localities therein. In addition, he has collated published data from diverse sources and by well chosen quotations and personal commentary has compiled, not only a glossary, but descriptions of individual varieties, their geographical distribution and their geological settings.

Unlike other lists which were often restricted to well crystallised minerals (e.g. Davidson and Thomson, 1951) this glossary encompasses both vein and rock forming minerals irrespective of their crystallinity. Moreover, it is more useful to geologists and mineral collectors in that it is not confined, as many glossaries are, to a mere list of minerals with references to their first published occurrences. In fact one of my minor criticisms is that it is often impossible from this text to discover who first recorded a particular mineral. For instance the reader is referred to Firman 1978 for a reference to anorthite "in altered calcareous rocks in the granite aureole" [at Shap] whereas much more detailed and localised descriptions were published by Harker and Marr (1891 and 1893). These minor criticisms are, however, offset by the impressive comprehensiveness of both the list and the accounts of the geographical distribution of individual minerals. A summary in bold print is given when the occurrences are so numerous that they cannot all be quoted; nevertheless sufficient extracts from published papers (supplemented by the author's own comments) ensurethat examples of most varieties and parageneses are adequately covered. For instance more than two A4 size pages each are devoted baryte, chalcopyrite, the chlorite group, galena, hematite (5.5pp) and quartz, and more than one page to arsenopyrite, calcite, cerussite, dolomite, epidote, fluorite, garnets, gypsum, malachite, muscovite, pyrite, pyromorphite, sphalerite and tourmaline. Thus in welcome contrast to many glossaries most space is devoted to the commoner or more widespread minerals the most notable exception being gold. The A4 equivalent page allocated to this very rare mineral is, however, fully justified since it has been reported, albeit in exceedingly small quantities, from no less than 25 localities. This glossary, therefore, is a most useful compendium, strongly recommended to both amateur and professional mineralogists.

Like most lists of minerals it must, however, be regarded as an interim rather than a definitive statement. Some of the older records, which have not been verified by subsequent research, such as kyanite from the Shap aureole, need to be reconsidered and if possible the original material re-examined. Also in spite of the considerable acceleration in discovery, identification and reporting (Fig 1) many minerals remain to be discovered. Indeed Brian Young and his co-workers (Young, Fortey and Nancarrow, 1986; Young, Firman and Starkey, 1988) have already added 5 more minerals since he compiled his glossary. The re-examination of collections such as the Harker collection at Cambridge may yield information which was unavailable to petrographers before the development of X-ray analysis and microproble techniques. Moreover, although the latter technique has been applied to vein materials in the Lake District, it is only just beginning to be used for the systematic study of inclusions and the alteration products of rock forming minerals. Similarly X-ray diffraction studies of clay minerals in the many and varied sediments and comprehensive studies of such common, but neglected groups, as the chlorites are bound to yield new mineral species. Thus the next decade is likely to produce about 50 new minerals from the Lake District and adjoining areas if research continues at its present pace. Incomplete as it inevitably is, this publication contains abundant information which will form the basis for much subsequent fundamental research. For the first time we have a comprehensive description of both the nature and distribution of Lake District minerals which will allow such questions as why some areas have a wide variety of minerals and other areas a very restricted range to be addressed. The glossary is, therefore, not only intrinsically interesting but is a potentially valuable research data base.

As the author states in his introduction, "a detailed and accurate knowledge of which minerals occur in an area and where precisely they have been found is a pre-requisite for detailed studies on many aspects of the geology, mineralogy and economic potential of that area". He contrasts the paucity of mineralogical information available to geologists with that on plants available to botanists through the excellent series of county floras. This glossary goes a long way to correct this information imbalance by giving the raw data from which something analogous to botanical distribution maps could be produced. Even without these maps some remarkable facts emerge from an analysis of the data. For example of the 300 or so valid mineral species listed almost two thirds occur within 6 kilometres of Grainsgill Mine and of these about 70 minerals are found nowhere else in the Lake District. The uniqueness of the Caldbeck Fells mineralogy has long been known but the full extent of its diversity is revealed only in this glossary. Were a map of mineral species per unit area to be constructed by any reckoning the Caldbeck Fells would have the greatest diversity of minerals in northern England, rivalling, if not exceeding, any other area of comparable size in Britain. What causes this astonishing diversity? Whilst it is true that the rock types range from ultrabasic to acid igneous rocks and include a variety of metamorphosed and unmetamorphosed sediments, comparable ranges of rock types occur elsewhere without such a unique range of minerals. In part the diversity can be explained by the fact that, in addition to a wide range of rock types the area has been subject to several periods of epigenetic mineralisation followed by deep weathering which oxidised many of the earlier epigenetic mineral deposits. But why should this sequence have occurred here and not elsewhere? Thus the fundamental causes of the Caldbeck Fells unique mineral assemblages still remain enigmatic.

Spectacular as the Caldbeck Fells 'mineral anomaly' is, this glossary also highlights that other areas, neglected until recently, also have unique, though less diverse, mineral assemblages notably in the Coniston and Causey Pike areas. Also more recent research (Young, Fortey and Nancarrow, 1986) has located another unique assemblage of minerals (including four minerals new to the Lake District) in the Eskdale Granodiorite. Each mineral assemblage is spacially associated with a specific part of the Lake District batholith and it is tempting to suggest, following Firman (1978 B), that each component part of the batholith (? separate pluton) has its own distinct associated epigenetic mineral assemblage. In addition the role of the country rocks in controlling epigenetic mineral assemblages needs to be evaluated. For example Redfern (1979) showed that in the Silurian meta-sediments south of the Shap Granite a mineral assemblage occurs which is similar to, but more impoverished in iron, than the metasomatised fissure veins in the meta-volcanics thus, clinozoisite instead of iron-rich epidote, grossularite instead of andradrite and tremolite instead of actinolite occur in the meta-Silurian sediments and even

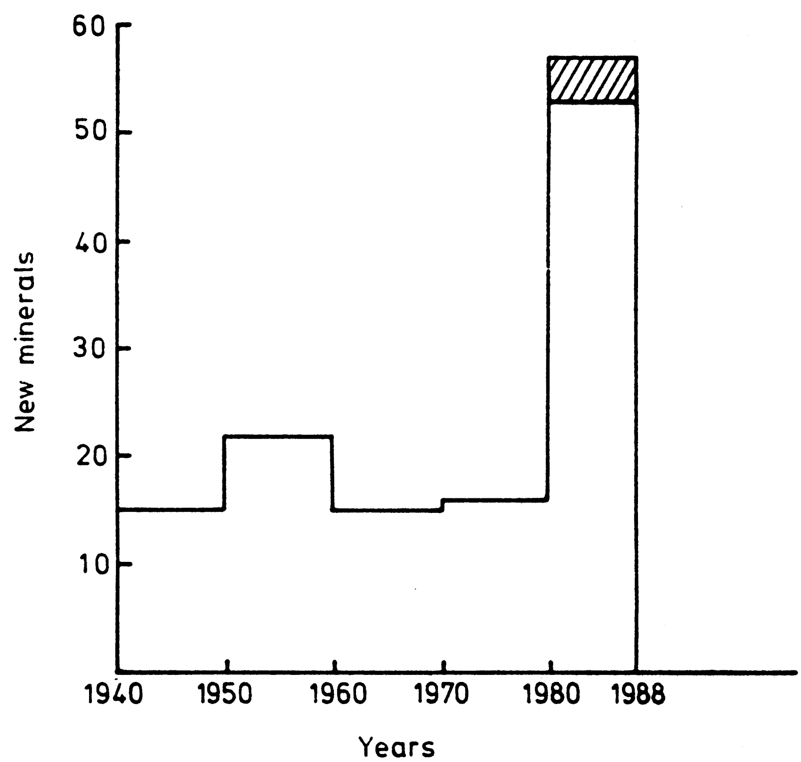

Fig. 1. Number of minerals new to the Lake district and adjoining as reported in the literature per decade since 1940. Data based on information in the glossary, the shaded area indicates new minerals reported since the glossary was published. Note that due to a time lag between discovery and publication the 'upsurge' in recent years is not wholly due to research since 1980.

baryte is white rather than pink as it is elsewhere in the Shap aureole. Similar effects of wall-rock mineralogy and geochemistry affecting the composition of minerals resulting from metasomatism are likely elsewhere. Similarly leaching of the country rocks by circulating brines, whether of juvenile, connate or meteoric origin, is likely to change the composition of the circulating fluids and hence the mineral phases which precipitate. The quantitative effects of such leaching have yet to be evaluated as have the contributions of juvenile and connate fluids.

If we are ever to produce a predictive model for mineralisation which can be used to forecast the likely location of the unexposed mineral deposits we have to thoroughly understand all aspects of the known geology and geochemistry of a given area. Not least is a detailed knowledge of what minerals are present and how they are distributed. Brian Young is to be congratulated for having done this so admirably for the Lake District and adjoining areas. Hopefully he will be able to publish supplements from time to time but in the meantime this glossary provides invaluable information to all interested in Lake District mineralogy and is strongly recommended as a reference for libraries, mineralogists and all interested in Lake District geology.

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EAST MIDLANDS GEOLOGICAL SOCIETY
SECRETARY'S REPORT FOR 1985/86

The Society had now celebrated its 22nd year having put on a programme of 12 meetings consisting of 7 indoor, 4 day field excursions, and 1 week-end excursion. The speakers and leaders provided a variety of subjects making this another successful year.

The Annual General Meeting, always held in early March, took place in the Lecture Hall at Nottingham University with the Officers on Council reporting on the previous year's business, and outlining future plans. Dr Firman had taken over as Editor from Dr Bryant, and Council had decided that Full-time Students should be eligible for concessionary subscription of half the Ordinary Membership rate—at this time £3.00—and would be entitled to receive all publications including the Mercian Geologist.

After the meeting Dr A J Wadge of the British Geological Survey, Keyworth, talked on the "Geology of the Lake District" demonstrating his work in that area, and putting forward an accretionary prism model with repeated sequences of old/young rocks at around 30kms intervals.

The following week Mr Jim Rose, Department of Geography, Birkbeck College, London, gave a preview of his forthcoming week-end in southern East Anglia, thus whetting the appetite of those members who intended joining the excursion.

During April Mr A M Clark, originally of the National Coal Board in London, talked of the economics involved in National Coal Resources.

In early May Jim Rose led about 25 members to the southern East Anglia area for the week-end staying at Graham Court Hotel in Ipswich. He proved an excellent leader and in spite of cold, windy and damp conditions, held the party's interest throughout the whole week-end.

The first day field trip was led by Dr Lloyd Boardman of the National Coal Board, Chatterley Whitfield, Tunstall, to the North Staffordshire Coalfield. Mow Cop Folly gave a marvellous vantage point from which he mapped out the area we were to visit and explained their significance. Evidence of faulting was found there and the Red Rock Fault has a throw of certainly 1500ft and possibly 9000ft. The Bateswood Opencast Site exhibited nearly vertical seams, fine for exposing a considerable part of the North Staffordshire succession, but making it difficult to extract the coal.

The Vice-President, Dr T D Ford, took a party to the classic Castleton area in July. He gave a brief history of the geology and mining at Odin lead vein before walking up the road to Mam Tor. The very obvious landslip seemed to have worsened since the previous visit in 1982. The weather in Nottingham had been fine, warm and sunny, but on reaching Castleton proved to be rather chillier, especially for those optimists wearing shorts as they found to their cost.

September's field excursion was to the Quaternary of the Cheshire/Shropshire Plain and led by Professor P Worsley, Geography Department at Nottingham University. He had kindly organized 2 mini-buses for the 21 members of the party to minimise the cost of hiring a coach. From a point above Congleton the area to be visited was plainly seen giving a splended view, and enabling Professor Worsley to describe the sequence of events which had created the Plain. But it was not a plain sailing day—at Ellesmere a car had inadvisably entered the gate to the quarry and on returning found it firmly closed. Luckily an emergency telephone number was found and ½hr later the released family gave a sigh of relief. It was a very full day and we were found to be running late, one member hoping to catch a train to Sheffield from Nottingham decided to stay again overnight with the Secretary. Also one of the mini-buses was running short of fuel, and Sunday is not a good evening to find petrol stations open. Luckily one was found eventually but by this time the other vehicle had disappeared completely. Party and vehicle did re-emerge at last, the arrival back in Nottingham was at 9.00 pm. A thoroughly enjoyable if eventful day.

Mr J Kerr of Nene College, Northampton led the last field trip of 1985 on a fossil hunting foray to Ketton Quarry, Stamford and Buntings Lane Pit, Peterborough. The 28 members and friends coming happily away with ammonites, belamnites and bivalves.

The November meeting was an amusing and entertaining talk given by Dr G R Coope, Department of Geological Sciences, Birmingham University. His subject was the "Giant Deer of Ireland, not fabulous but make-believe". The antlers of this deer are some 4ft across and can weigh 100lbs but designed to be finely balanced, they are shed and regrown every year.

The Geology of Derbyshire Country Houses was the subject of the December lecture given by Mr M F Stanley, Deputy County Museum Officer at Matlock. He described the stone, most of it quarried locally, used in building many of Derbyshire's famous houses, starting with Haddon Hall. The number, many now demolished, was much greater than we realised. Afterwards at the Social Occasion 2 books written by Maxwell Craven and Mr Stanley were available for sale. The fare for the occasion was in the Derbyshire tradition, the centrepiece being a splendid cake made into Chatsworth House by Dawn Marriott - she excels herself every year.

Before the January meeting began an Extra-ordinary General Meeting was held, as with the death of the Lord Energlyn it was necessary to appoint another Trustee to administer the Society Trust Fund, 3 being the minimum number required. It had therefore been decided by Council that 4 would be a more realistic number, and it was proposed and agreed that both Professors Baker and Worsley should join Sir P E Kent and Dr F M Taylor as Trustees.

Dr C A Boulter, Department of Geology, Nottingham University then gave a lecture on the "Pilbara of Western Australia". The area is only a small part of the country but is, nevertheless, almost the size of England. It is made up of extremely old spectacular volcanics and sediments and has a wealth of flora and fauna equally exotic.

The indoor meetings have been so very well supported with a full Lecture Hall on all but one occasion, and the Presidential Address in February was no exception. So much so that the Secretary was unable to get in the door or hear much of Dr Sutton's Address on "Recent Volcanic Activity in the Bay of Naples", this being almost constant during the last 50,000 years. The AD 79 eruption which destroyed Pompeii and Herculaneum, and the tectonic activity at present around the port of Pozzuoli were discussed.

So ended the Society year with this splendid response from members. We also wish to thank the speakers, Dr A J Wadge, Mr J Rose, Mr A M Clark, Dr G R Coope, Mr M F Stanley, Dr C A Boulter and the President, and the leaders, Mr J Rose again, Dr Lloyd Boardman, Dr T D Ford, Professor P Worsley and Mr J Kerr. All had willingly given their time to provide the society with a very varied programme.

During 1985, 6 Council Meetings were held to arrange Society business. Donations to the Society Trust Fund had been discussed and ways to use it it to the best advantage for everyone. Council had decided that excursion coaches should be subsidied where necessary keeping the fares low. A concessionary rate for Full-time students already mentioned at the AGM, an Annual Merit Award, and money available for Gelological Conservation work. To this end a donation of £200 had been given to the Staffordshire Conservation Trust towards the purchase of Brown End Quarry at Waterhouses.

Eleven circulars were produced during 1985 with announcements of the Society programme, new members, items of geoglogical interest and news. As in other years we express our gratitude to members who kindly deliver circulars and also the Mercian Geologist to those in their vicinity. A few stalwarts made a great contribution by checking, enveloping and helping in the distribution of the Journal and it was hoped that eventually a Distribution Team could be organised, with a supervizor to co-ordinate the task.

Warning was given of the Date Protection Act which would be coming into force the following Spring 1986. We would be able to claim exemption from registration if all members were asked by notice if they objected to having their name, address and postcode on computer file. Assurance was given that this information was all we held on file, and that only officials of the Society had access to that file.

Although membership had dropped slightly to 450, several full-time students had taken advantage of the Concessionary rate which had been encouraging. All who worked and taught students were urged to bring this to their notice. Membership was as follows:-

Honorary	Ordinary	Joint	Junior	Institutional
2	227	116	1	104

One of our eldest members, Mr N Leiter, had become blind and regretfully resigned from the Society, but had generously donated polished pebbles of every hue, specimens and copies of the Mercian Geologist, the money from the sale being put into the Trust Fund.

Finally, your help and support in running the Society throughout the year was very much appreciated, as were the facilities allowed us by Professor Baker and the University of Nottingham. The President, Dr Sutton, the Vice-President Dr Ford and the Treasurer, Mr Fryer were always available for advise and information when needed, so making my task an easier and certainly an enjoyable one. My thanks to you all for making this another memorable year in the Society's history.

W. Madge Wright

SECRETARY'S REPORT FOR 1986/87

The Society, now in its 23rd year, continued to be a great success with its publications and activities. The Indoor Meetings, of which there were 8, were held to capacity audiences, whereas the 8 Field Events had attracted less support on most occasions, in spite of excellent leaders and attractive programmes.

The first meeting of the Society year in March is the Annual General Meeting, attended this time by the Officers and 40 members. There were no problems at the meeting which went very smoothly. This occasion was the first on which the Society Merit Award was given. The Awards Committee had selected Dr Chris Salisbury for his paper on "Flandrian courses of the River Trent at Colwick, Nottingham" which had been published in the Mercian Geologist in 1985.

Following the AGM, Norman Lewis, Conservation Officer for the Notts Trust for Nature Conservation, and a Society Member, gave an insight into the work of the Trust and its relevance to Geology entitled "Just Scratching the Surface".

Preceding the April Meeting, Dr Chris Salisbury was presented with his Annual Merit Award which he said he had been surprised and honoured to receive. Peter F Jones then presented his lecture on Ice Age Derbyshire south of the Peak District talking on the river systems, which had developed during the Ice Age, and which seemed contrary to the movement of the ice.

On a Saturday in May Mick F Stanley escorted a group of members to various Derbyshire Country Houses to look at the stone used in their construction, just 9 were either visited or talked of in passing, and these and many more appear in two Volumes of Derbyshire Country Houses written by Mick Stanley and Maxwell Craven.

The June Excursion visited Shropshire and was led by the President, Dr Ian D Sutton. The promise of a hot day was fulfilled the excursion being made in brilliant sunshine. It was to be a long day and therefore the Mortimer Forest Trail was visited first. During the day some excellent examples of fossils were found here and later at Shadwell Quarry as steps were retraced to Nottingham.

In July a visit was made to British Gypsum workings at Newark in the morning with Ed Moczarski of British Gypsum, explaining the method of extracting the different levels of gypsum at Banticock Pit, the party being fully conscious of the larger dumper trucks constantly on the move and ready to mow down the unwary. The Rhaetic is exposed at a higher level and the bone bed yielded the vertibra and adjacent parts of a Plesiosaur. After lunch Mr Moczarski left the party and Alan Dawn took the coach up the succession. Past Ironstone extraction was easily seen as many roads stood proud of the fields either side. The quarry at Great Ponton was the last stop before returning to Nottingham.

Dr Eric Robinson, editor of the Geological Association Newsletter, had suggested we look at the Church (Rock) Cemetery on Mansfield Road, Nottingham as this contained a wealth of different rocks used for headstones. Dr Robinson joined us at 7 pm—this was the first evening walk to be held—numerous granites, marble, limestone and a very good imitation limestone was noted, but with the cemetery closing at 7.45 pm, it was rather a hurried look—noone relished being locked in for the night! This generated a project to identify the rocks involved and the fashions of the various periods.

Cornwall was the venue for the week excursion in August led by Dr Alan Bromley of Camborne School of Mines. Only 8 members attended Dr Bromley's cross section of the geology of the area, but found the small number had its compensations—the ground was covered much more quickly. The headquarters hotel was the Grove in Falmouth.

In early September Dr Neil Aitkenhead, Dr N J Riley, both of the British Geological Survey, and Mr J Tilsley led a party to Carsington for a 20 minute stop to review the geological features and the failure of the dam in 1984. The Tissington Trail was walked to Crake Low Quarry to assess the evidence for a Carboniferous submarine volcano followed later by a walk over Wetton Hill to study the knoll-reef limestones.

A week-end was spent in North Lincolnshire and Flamborough at the end of September. David N Robinson led a geological and scenic traverse of North Lincolnshire adjacent to the Humber Bank on the Saturday. The party then crossed the Humber Bridge and stayed overnight at the Monarch Hotel in Bridlington. Mrs Roz Grum then led the group on Sunday visiting classical coastal landforms and inland for typical chalk scenery.

The British Geological Survey at Keyworth opened its doors in mid-October and 20 members joined numerous other Societies and groups on the Friday. There is never enough time on these occasions and a few departments only could be visited and those superficially. The Sunday was even more crowded we were told.

The first winter session indoor meeting was in mid-October—a very topical subject especially at that time. Dr N Chapman of British Geological Survey, Keyworth spoke on "Geological Disposal of Radioactive Waste". He discussed the Survey's involvement with the nuclear industry and NIREX in particular. A model of the type of glass containing high level waste was passed round the audience and measured 2 inches in diameter×1 inch deep. Several people from Fulbeck were able to talk to Dr Chapman after the meeting.

A Joint Meeting with Yorkshire Geological Survey was arranged for a full day in Mid-November—the subject being "The Deep Geology of Eastern England". This was held in the larger Lecture Hall in the Department of Geography, University of Nottingham, Professor Worsley kindly arranging this for the Society. Around 280 people arrived compared with the 150 expected. A Society team provided pre-meeting coffee, lunchtime drinks and afternoon tea, with outside caterers providing a cold salad lunch for those having ordered on previously. A complaint heard during and after the meeting was that most speakers were difficult to hear and in future on such occasions a microphone should be available. Dr Frank M Taylor had provided a bargain offer of the complete set of Journals, 39 parts, + membership fee for £11, and 11 people took up the offer.

Dr Tony C. Waltham promised that the December meeting would be entertaining rather than academic. His talk on the "Incredible Limestone Country of South China" was all limestone and caves, the geological aspect was kept to a minimum and instead he described trying to train the Chinese to descend caves and to swim. He did though put forward a reason for the spectacular features found in the area, climate and uplift of the land being unique there and giving rise to almost vertically sided hills. Their civilisation he claimed, is about 200 years behind our own and some of their habits leave much to be desired. A Social Gaterhing on a Chinese Theme followed the meeting and was provided by the following members:– Pauline Hatton, Emily Ramsell, Inga Flmer, Judy Small, Edna Colthorpe, Jean Brayne, Nancy Mulholland and Margaret Boneham. This time Dawn Marriott provided part of the Great Wall of China in sponge and icing.

The British Sedimentology Research Group Conference was held the week before Christmas in the Jesse Boot Centre, University of Nottingham. A stall was organised by Dr Frank M Taylor to display the Mercian Geologist and boost membership. A package deal was again offered of 39 journals for £5 if enrolling as an Ordinary member for £6. This was so successful that 35 people from Great Britain and Europe joined the Society and each staggered away with 39 journals. The Secretary covered the Wednesday morning, Mrs Dorothy M. Morrow the afternoon, Mrs Inga Filmer, Thursday AM, H.G. (Jack) Fryer PM with Drs Firman and Taylor filling in as required.

The first meeting in January 1987 was "Beetles and Beasts of the Ice Age" when Dr Brian J. Taylor, British Geological Survey, Keyworth talked to around 80 members of the work he had done with a not too serious look at beetles of the Ice Age. He assured the assembly that those found in the glacial tills of East Anglia were at present only found in far north latitudes and none have been found here to herald a return to the Ice Age.

The final meeting of this Society year was as usual the Presidential Address. Dr Sutton spoke to 70 members on "Chains and Honeycombs in the Silurian". Illustrating the extent of the Silurian seas, he described the tropical conditions which corals need to flourish, and explained their structure. Wenlock Edge in the Shropshire landscape was a good example of a coral reef and the occasional knoll. Mr Colin Bagshaw gave the Presdient a vote of thanks for his Address.

We thank the speakers, Norman Lewis, Peter Jones, Neil Chapman, Tony Waltham, Brian Taylor and the President for providing us with such interesting talks on so many subjects. Also the leaders, Mick Stanley, Ed Moczarksi, Alan Dawn, Eric Robinson, Alan Bromley, Neil Aitkenhead, Dr N.J. Riley, J. Tilsley, David Robinson and Roz Grum for their varied programme of field visits. So ended another successful year and the above speakers and leaders efforts were much appreciated.

In response to a suggestion at a previous AGM, an additional picking up point was now included for excursions and especially for a Saturday. The South entrance bus stop at the University had proved very popular as parking in Nottingham was both expensive and almost impossible on a Saturday.

During the year 5 Council Meetings had been held and 1 cancelled because of snow. Society affairs are discussed and members suggestions are always welcome and considered. It was pointed out that the Conservation and Countryside Code should always be observed and one or two other points should also be emphasised in particular, during excursions when the leader was addressing the general assembly, it was most distracting if members either talked or hammered in the background. In fact we now advocate the use of a hand lens and no hammering on most occasions.

Sadly 2 deaths had occurred, firstly that of Bob Gratton, and later in the year Sir Peter Kent. Sir Peter's death necessitated an Extra-ordinary General meeting being held to appoint a fourth Trustee. This took place before Brian Taylor's lecture in January 1987, when in addition to the two previously nominated trustees, namely Professors Baker and Worsley, and the existing trustee, Dr F.M. Taylor it was agreed that whoever held the office of President should be a fourth Trustee. Mrs Sue Miles had kindly agreed to draw up the Trust Deed for us.

Ten circulars were produced during the year, the transition from foolscap to A4 being made with a little difficulty in setting out to start with. Those who hand delivered circulars and of course journals too, continued to save the Society many points over the year.

A Society Logo was called for, one which was appropriate to the East Midlands, but there had been a disappointing response up to the end of the year.

Membership had increased from 450 previously to 509—most of the increase due to the splendid effort made by Frank Taylor. We now had:-

Honorary	Ordinary	Joint	Full-time Students	UK Institutional	Overseas Inst
2	258	130	12	80	27

The Society bought during the year a Directory of Lapidary and Geological Societies which was available for consulting should anyone wish to make use of it. Also, Eric Robinson had sent a large batch of GA Guides, which had been reduced in price, for sale at our meetings.

During 1986 as usual I had excellent support from Council and members, and not forgetting the marvellous facilities allowed us by Professor Baker and the University of Nottingham. My thanks to all of you as another successful year was completed.

W. Madge Wright

ERRATA

Cover and plate in Vol. 11 nos. 1 & 2

Although Mr D. Jones developed and printed the photograph of Nottingham Castle which was used for the front cover of the last issue it was Dr F.M. Taylor who took the photograph. David Jones, however, was responsible for the photograph of the author which appeared as a frontispiece to the lexicon.

THE MERCIAN GEOLOGIST

Journal of the East Midlands Geological Society

The jøurnal first appeared in December 1964 and since that time 42 parts, comprising 10 volumes have been issued; the last, Vol. 11 Nos. 1 & 2 in Jan., 1988. The Mercian Geologist publishes articles especially on the geology of the Midlands of England, but other articles have been published which are of current interest to geology generally. Contents include original papers, review articles, biographies, bibliographies, excursion reports, book reviews and the Secretary's report on Society activities.

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Text-figs. normally occupy a full page of the journal, but part diagrams can be fitted into the typed page. Double page diagrams have been published with a single fold but each printed page has to be folded by hand. The standard reduction by our present printing process is approximately $\times 0.75$. Thus the optimum size for the original diagram, including space for caption, index and explanation if required on the diagram, should be 285×190 mm (285×380 mm with a single fold). Greater reduction is possible but care must be taken with the original to ensure that at the final reduced size (230×155 mm; or 230×310 mm) the smallest letters are no smaller than 1 mm and that there is a similar minimum spacing between letters and lines. Bar scales (metric) should be provided as the exact reduction cannot be guaranteed.

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If there are any points of difficulty, please do not hesitate to contact the editor during the production of the manuscript. The editor's sole concern is to produce excellent quality papers to be enjoyed by all readers. Please send completed manuscripts to the editor.

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Year 1988

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