THE CONODONT FAUNAS AND STRATIGRAPHY OF THE YOREDALE SERIES IN THE ASKRIGG AND ALSTON REGIONS

by

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INTRODUCTION TO THE YOREDALE SERIES

CHAPTER I

1. GENERAL INTRODUCTION

The Northern Pennines consist of a dissected plateau of undulating, exposed moorland which rises to a maximum height of 2930 ft. at Cross Fell, on the Alston Block. This report concerns that part of the Pennines which falls between the Stublick and Craven Fault Systems i.e. the "Rigid Blocks", where the Yoredale Series represents the major series of rocks and the Millstone Grit is often represented only by the resistant cappings to many of the hills. Heights do in general increase northwards on to the Alston Block but there is also a general increase in height westwards over the whole of the region, due to the gentle easterly tilt of the strata. Where the flat-bottomed, glacially-modified valleys have been cut more deeply, the massive limestone is exposed beneath the Yoredale Series. In Teesdale the whole of the Lower Carboniferous succession has been breeched to expose part of the Lower Palaeozoic basement, though this is the result of tectonic influences rather than the erosive force of the river.

The process of erosion has also exposed the epigenetic mineral deposits which occur over wide areas of both the Askrigg and Alston Blocks. The most important mineral is galena, though the variety of minerals present is great. Lead-mining began at a very early date and it is reported to have been carried out around Grassington in as early as pre-Roman times (Raistrick 1936). The industry reached its maximum development however during the first half of the 19th Century and resulted in an early knowledge of detailed sections of the strata. It also resulted in a host of mining terms being adopted in the literature since it was around this time that Yoredale stratigraphy received its first systematic study.

In the past there has been a great deal of confusion over the definition of the name "Yoredale Series". Dunham (1948) noted that the term had happily lost any attempt at preciseness and could be employed in a traditional way for the cyclic sequence of strata on top of the Great Scar Limestone. After Phillips (1836) had classified the Yoredale Series as forming an upper division of the Mountain Limestone (Carboniferous Limestone) Formation, sandwiched between the "Lower Limestone Group" and the Millstone Grit Series, the term was widely and often erroneously used and any alternating or varied series of rocks of Carboniferous age was liable to be dubbed "Yoredale Rocks". This was especially apparent in the mapping of the Millstone Grit Series of the Central Pennines, where the Limestone-shale facies below the lowest prominent gritstone was described as "Yoredale Rocks" with complete disregard of lithologic differences and the possibilities of diachronism. Nowadays however, the term has quite rightly ceased to be used south of the Craven Faults.

In the present report the term "Yoredale Series" describes the alternating limestones, shales and sandstones which occur between the massive limestone in the lower part of the Lower Carboniferous and the Millstone Grit facies above. The range in age of the series is greater in the north on the Alston Block than it is on the Askrigg Block since cyclothemic conditions began earlier in the north and also the base of the Millstone Grit rises in that direction. The range of the succession of the present study is that found in or adjacent to the type-area of Wensleydale.

The base of the series for this study is taken at the Girvanella Band, (D_1-D_2 junction) which here occurs in the middle of the Hawes Limestone. The upper limit has been more difficult to define in view of the changing horizon of the Millstone Grit base, which in places in the south of the Askrigg Block cuts out the whole of the Yoredale succession. The upper limit has in fact been taken above the Mirk Fell Beds, which are the highest beds in the region of the type-area and also occupy a critical position with regard to the nature of the base of the Millstone Grit.

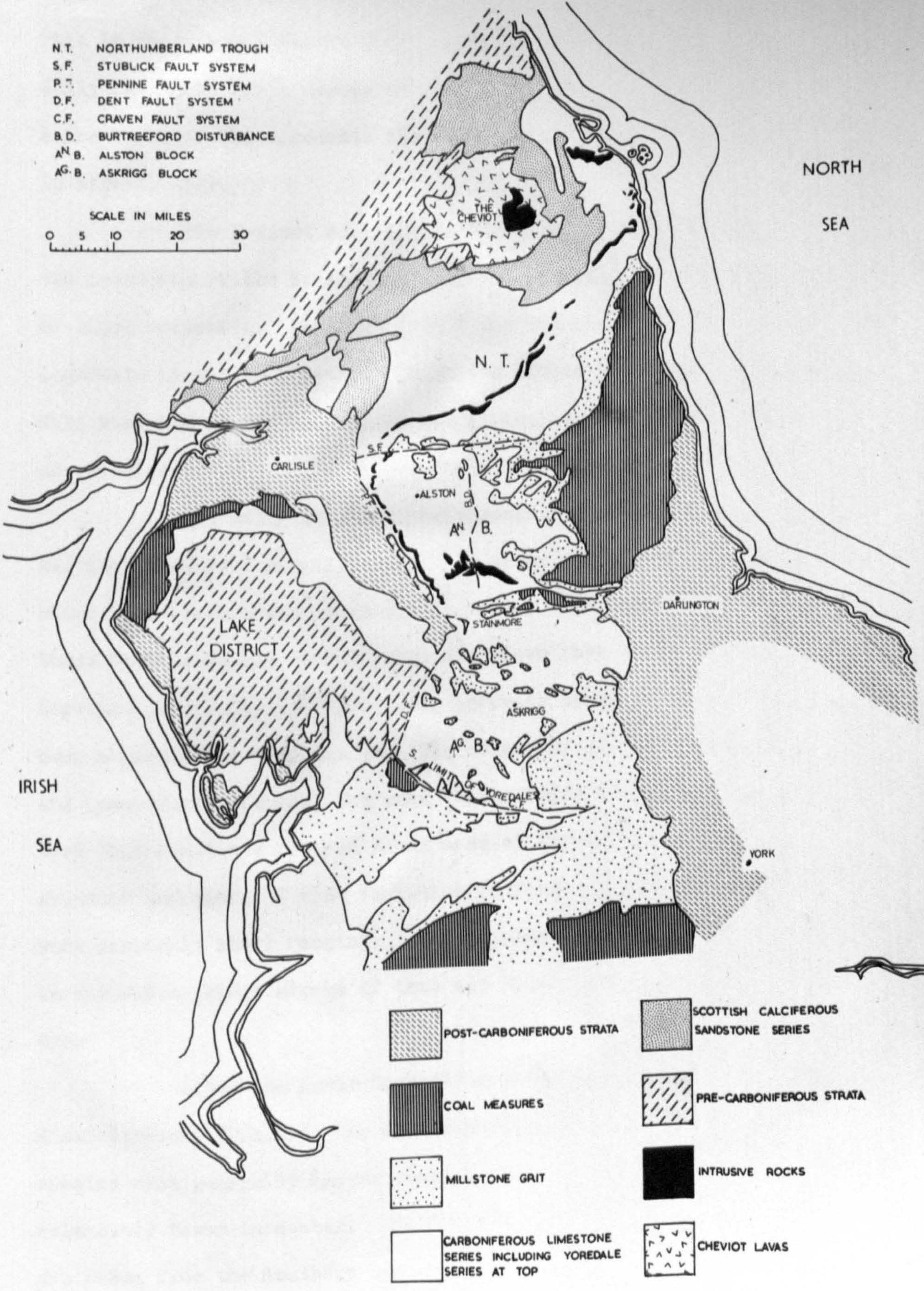


Fig. 1. GEOLOGICAL MAP OF THE NORTH OF ENGLAND

The succession studied therefore ranges in age from the base of D_2 (D_1-D_2 junction, Upper Viséan) to lower E_2 (Lower Namurian). This is therefore a fairly short ranging series of rocks stratigraphically but there are a number of reasons why they are important and why a knowledge of the conodonts they contain has important reperoussions in stratigraphy.

The present work is the first study to be carried out on the conodonts of the Yoredale Series and contains the first descriptions of these conodonts. Johnson (1959) did record that he had found conodonts in the Four Fathom, Great and Little Limestones of the Roman Wall District of Northumberland but he included no identifications or descriptions.

The study of conodonts throughout the geological column has increased very rapidly since 1930 after a long, slow, early period which began with their discovery in 1854. The increased interest in these fossils during recent years has shown them to be stratigraphically important and capable of providing accurate zonal fossils. There has been a particular emphasis upon the conodonts of the Upper Devonian and Lower Carboniferous, the main reason being that it was during this time that conodonts reached their acme of development and were therefore abundant and showed a wide variation in form. Some genera and species were extremely short ranging. This emphasis has been particularly so in the U.S.A. where strata of this age occupy much of the mid-continental area.

After the Lower Carboniferous or its equivalent in the Mississippian, (U.S.A.), the faunas showed less variation, genera and species were generally longer ranging and in general the conodonts were relatively fewer in number. In Great Britain the Namurian conodonts are known from the Southern Pennines (Higgins, 1961) and also the Lower and Upper Limestone Group conodonts are known from the Midland Valley of Scotland (Clarke 1960). The conodonts from the Yoredale Series therefore represent a link, both geographically between the Southern Pennines and the Midland Valley of Scotland and stratigraphically between the Lower and Upper Carboniferous. This stratigraphic link is the result of the series extending from the Upper Viséan into the Lower Namurian, though the actual junction is not apparent in the field. This study therefore bridges the gap between the abundant and extremely varied faunas of the Lower Carboniferous or Mississippian on the one hand and the less abundant and less varied, though nevertheless stratigraphically sensitive faunas of the Namurian on the other. Even on a purely stratigraphic basis the Yoredale Series has tended to be regarded as somewhat apart from the general succession because of its unique stratigraphic horizon and the difficulties involved in cyclic sedimentation.

The goniatites of the Namurian have proved to be an extremely successful and delicate means of zonation and correlation and the Namurian conodonts were studied in conjunction with this goniatite zonal scheme. The Yoredale Series contains only rare goniatites but large faunas of conodonts so that the latter represent a means of correlating with the standard goniatite succession through the associated Namurian conodont faunas. This is indeed important to the Yoredale Series stratigraphy since the insensitivity of the coral/brachiopod scheme over such a relatively short period of time and under these conditions, plus the rarity of the goniatites, has resulted in previous attempts of recognition of Yoredale horizons, subdivision of the series and correlation with other areas being only tentative or partly successful.

Similar difficulties have been experienced in the U.S.A. where a thick succession of Mississippian cyclic sediments in the Illinois Basin contains only sparse goniatites. The similarities between certain of the conodont faunas of the Illinois Basin and those of the Yoredale Series are however quite marked thus making correlation on a wide scale possible.

2. HISTORY OF PREVIOUS RESEARCH INTO THE STRATIGRAPHY OF THE YOREDALE SERIES

The study of the rhythmic sediments of the Yoredale Series has had a long and varied history, spanning the time from the beginning of the 19th Century until the present day. During this period a large number of works have been published, and a summary of these is given below. Included in this summary are reports which, though not specifically concerning the Yoredale Series of the Askrigg and Alston Blocks, are indirectly important in a historical survey of this type. Those reports dealing specifically with the geology of the Northumberland Trough, which lies to the north of the Alston Block, have been excluded, since this trough is a well defined tectonic area comprising a complete study in its own right.

Interest in the Yoredale Series has not remained static through this time and there have also been changes in emphasis in the method and type of study carried out. It is therefore convenient to divide the summary into the following sections;-

(a) Pre-1924. A period of sparse publication during which regional studies were carried out by mapping originally based upon lithological correlations, later by the development of zonal fossils.

(b) 1924-1947. A period of prolific publication when very detailed work was carried out on small disconnected areas and much of the stratigraphy of the N. of England was elucidated.

(c) 1948- to Present Day. A period during which there has been a re-development of the regional study, with particular emphasis upon the reconstruction of the palaeogeography of deposition, combined with the earlier methods. Recently there has also been an intensified search for the rare goniatites.

(a) Pre-1924.

Early studies of the rocks of the stable block areas were channelled into two distinct paths by the conflicting sources of information. The naturalist became aware of the influence of geology upon the topography drainage, vegetation, etc. and thought in terms such as "Mountain Limestone". The lead-miner, however saw geology as a vertical succession of rocks of varied character and was able to recognise possible lead-bearing horizons.

One of the early accounts was that on Winch (1817) who divided the Carboniferous System into an upper "Coal Measures" and a lower "Lead Measures". The earliest accurate and valuable work, however, was probably that of Westgarth Forster (1821), whose "Section of the Strata from Newcastle-on- Tyne to the Mountain of Cross-Fell, in Cumberland, with remarks on mineral veins in general" contained many detailed sections and much of the nomenclature of miners for individual beds.

Without doubt the most influential works were those of Sedgwick (1835) and Phillips (1836). It was Sedgwick who coined the name "Great Scar Limestone", but it was in Phillips' classic work, "Illustrations of Yorkshire Geology, Part II The Mountain Limestone", in which many of the early problems of Yoredale Geology were solved. Phillips came to an early appreciation of the facies problem in the Carboniferous and considered Yoredale or Uredale (the old name for Wensleydale) to be most representative of the region. This valley thus became his type-area and the beds were named "Yoredale Beds". Phillips was clearly aware of the repetitive nature of these beds, although he did not describe them as "cyclic" or "rhythmic" and he therefore gave names, most of which are still in use at the present day, to the major limestones. His succession was as follows:-

Main Limestone,

Underset Limestone,

Impure Productal Limestone,

Middle Limestone

Simonside Limestone

Hardra (or Hardrow) Limestone resting on the Mountain Limestone.

Phillips' work proved to be so detailed and concise that little improvement was made until the end of the century. In Yorkshire the only work of note between 1836 and 1895 was the mapping carried out by the officers of the Geological Survey, who produced the 1" sheets with accompanying memoirs. In the Ingleborough Memoir (Dakyns et al, 1890) to sheet 50, New Series, and the Mallerstang Memoir (Dakyns et al., 1891) to sheet 40, New Series, the names used in the numerous detailed sections were a slightly revised version of those used by Phillips. The additional names included the Three Yard, Five Yard, Gayle and Hawes Limestones, whilst "Impure Productal Limestone" was discarded.

Outside of Yorkshire, the only important work at this time was by Hugh Miller in 1887. This work concerned the Calcareous Division (Upper Limestone Group) of Northumberland and Miller was the first person to draw attention to the regular rhythmic character of the sedimentation in beds of this type.

In 1901 Goodchild first demonstrated the disappearance of Yoredale horizons southward beneath the Millstone Grit, due to the unconformable overstep of the latter.

At the turn of the century, the Yoredale Series was therefore known in broad outline and correlation on lithologic grounds had been attempted. The latter had been partly successful but could not be regarded as a completely reliable method. The use of Carboniferous fossils for zonation, dating and correlation was therefore a major advance which was later refined and permitted correlation over much greater distances.

The development of this new method began with various accounts on different aspects of palaeontology and stratigraphy by such writers as Marr (1899), Garwood (1896-1900) and Hind (1900-1907) with the result that a committee on "Life Zones in the Carboniferous" was set up by the British Association.

It was however Vaughan (1905, 1906) who made the "break-through" when he established his zonal succession of the Lower Carboniferous in the Bristol District. He was followed in 1913 by Garwood, who produced, among other works, an extremely important, large, detailed work on the Lower Carboniferous Succession in the North-West of England. Garwood established a zonal scheme through the Lower Carboniferous, based primarily on Brachiopods and Corals, and was able to correlate with Vaughan's zones of the South-West Province (p.544).

The period closed with Woolacott's account (1923) of the deep boring at Roddymoor Colliery, near Crook, Co. Durham. This borehole was the deepest at that time (1921) and passed from Middle Coal Measures, through Lower Coal Measures, Millstone Grit, 1374 ft. 10 ins. of Yoredale Series, Melmerby Scar Limestone Series and Basement Conglomerate into Skiddaw Slates. Woolacott illustrated a gradual thickening of the strata beneath the Fell Top Limestone from Teesdale, northwards to Alston and then a pronounced thickening into the Northumberland Trough. He was able to correlate the latter area with the Roddymoor Section.

This long period therefore saw the gradual elucidation of the general stratigraphy of the Yoredale Series, combined with the development of the basic techniques of the stratigrapher. The latter changed from detailed mapping using local lithologic correlations to mapping based upon a knowledge of the fossil content of the rocks and therefore also a knowledge of the relative age and range of the beds concerned compared with the standard successions of Vaughan and Garwood.

(b) 1924-1947.

1924 saw the beginning of an extremely active period of research when large numbers of geologists worked in great detail on small disconnected areas, over practically the whole of the Northern Pennines. As a result this was the most prolific period for publications.

The four articles published during 1924 set the pattern of the later works. A faunal sequence in the Carboniferous rocks met in the Roddymoor Boring was published by Lee and the account of the Lower Carboniferous succession in the Settle District and along the Line of the Craven Faults, by Garwood and Goodyear, was a comprehensive work. The most influential work on Carboniferous Palaeontology since Vaughan, was however, Bisat's description of Carboniferous Goniatites on the North of England and their Zones. This work enabled the shale-facies to be sub-divided as well as the calcareous facies and was therefore of profound effect generally, though it had little effect upon the study of the Yoredale Series where Goniatites are rare. It was thus the work of Hudson, in his account of the Yoredale Series of Wensleydale, which had the greatest effect upon later work and set the pattern for the next quarter of a century.

Hudson described the lithology and faunal phases from the whole of the Yoredale Succession in Phillips' type-area, from the upper leaf of the Great Scar Limestone (the Hawes Limestone of the Geological Survey) up to the Fell Top Limestone. He illustrated the shallow-water nature of the sediments, while dealing in detail with the general rhythmic sequence of a single cyclothem and concluded that Hind's explanation for the development of a cyclothem (1902) i.e. variations in the rate of subsidence of the sea-floor, did not entirely fit the facts. He believed that, "the main sequence of shale, sandstone and limestone, was due to change of material transferred from land to sea and in the case of the limestone, to a cessation of this transference".

Of the accounts published after 1924, the majority concerned the stratigraphy of small, local areas and included:- Nidderdale (Tonks, 1925): Skyreholme Anticline, Yorkshire (Anderson, 1928); Dent Fault and Shap District (Miller and Turner, 1931); North West Yorkshire (Hudson, 1933); Stainmore (Turner, 1935); Alston Moor to Botany and Tan Hill (Carruthers, 1938); Simonseat Anticline (Hudson, 1939) and the Greenhaw Mining area (Dunham and Stubblefield, 1945).

Works of wider interest covered such fields as the Fauna of the Lower Carboniferous (Hudson, 1925); the Junction between the Lower Carboniferous and Millstone Grit (Chubb and Hudson, 1925); Lower Carboniferous Rocks (Hudson, 1927); The Alston Block (Trotter and Hollingworth, 1928) and the Structural Features of the Alston Block (Dunham, 1933).

It was also during this period that the Geological Survey Memoir for the Brampton Sheet (No. 18) appeared (Trotter and Hollingworth, 1932). This memoir described beds varying in age from Tuedian up to Lower Coal Measures and the classification used included all those beds between the Main Limestone and the Lower Coal Measures into the Upper Limestone Group. The term "Millstone Grit" was therefore forfeited. The authors made a direct correlation between the Askrigg and Alston Block cycles and their equivalents in the Lower, Middle and Upper Limestone Groups of the Northumberland Trough.

The period from 1924 to 1947 was therefore one of great advances in stratigraphic knowledge, not only of the Yoredale Series, but of Carboniferous geology in general. However, the sudden burst of interest at the beginning of the period led to great confusion in classification and as a result a committee of the British Association for the Advancement of Science was appointed, a report being issued at the Southampton meeting in 1925. The status and meaning of the term "Yoredalian" was among the numerous subjects considered in this report, but unfortunately there was still no measure of agreement.

In his address to the British Association (1926) on Progress in the Study of the Lower Carboniferous (Avonian) rocks of England and Wales, Reynolds considered the use of the term "Yoredale Series" or Cosmo John's variant "Yoredalian" desirable in Yorkshire. The upper limit of the series was to be taken at the entry of the Lancastrian Fauna of the Upper Carboniferous type as described by Bisat, but the lower limit he considered more difficult to define because of the uncertainty of such terms as "top of D_2" etc. Reynolds' own suggestion was to commence the Yoredalian at the base of the

Orionastraea level and to include all between that level and the Girvanella Band in D_2. There would then be no need to use the term D_3 in Yorkshire or the North West Province.

Numerous terms, some of which were of dubious definition, were used in a classification by Allan, in his address to the Heerlen Carboniferous Congress, on the Stratigraphy of the British Carboniferous. In this classification Yoredalian consisted of the E and P zones and bridged the junction between the Viséan and the Lancastrian.

There was also much confusion about the term "Millstone Grit" during the beginning of this period, since rocks alluded to by this name were known to be the most difficult of all the members of the Carboniferous to reduce to any systematic agreement.

The standardisation of terms and the classification of the Carboniferous System into time stages, which were brought about at the Heerlen Carboniferous Congress of 1927, was therefore of fundamental importance to Carboniferous stratigraphy. These stages were based upon the fossil content of the rocks, particularly the goniatites, made possible primarily by the work of Bisat. The upper limit of the Viséan was put at the top of the zone of Glyphioceras spirale (granosum) and the base of the Upper Carboniferous was marked by the appearance of Eumorphoceras pseudobilingue. Originally the Upper Carboniferous had consisted of Westphalian (Lower) and Stephanian (Upper) but at this congress it was decided to distinguish three divisions. The new division was named Namurian (created by Purves in 1883) and consisted of the Eumorphoceras, Homoceras and Reticuloceras zones, with its upper limit coinciding with the horizon of Gastrioceras subcrenatum, thus placing it between the Viséan and Westphalian. The Namurian was later further subdivided on Goniatites (Hudson, 1945).

By the end of the 1924-1947 period, the detailed stratigraphy of the Yoredale Series was therefore fairly well known, so it is not surprising that the trend which followed was to utilise all the previously gained knowledge, combined with new techniques, and return once more to the regional study.

(c) 1948 to the Present day

This final period is one of sustained interest and conflicting trends. Papers more typical of the previous period continued to be published but were associated with aspects such as the Palaeogeography of Yoredale times, the mode of deposition of the Series, the junction between the Viséan and Namurian and a systematic search for goniatites.

The period began with the publication of the Geological Survey Memoir covering the Northern Pennine Orefield (Dunham, 1948), the greater part of which consisted of detailed descriptions of individual mineral veins and a discussion on the type of deposits present, their origin and age.

Descriptions of the geology of localised areas covered such areas as Grassington (Black, 1950); The Cotherstone Syncline (Reading, 1957); Coverdale (Wilson, 1960) and the Nature Reserve of Moor House (Johnson and Dunham, 1962). Of slightly wider field was the description of the Namurian of the North West Corner of the Askrigg Block (Rowell and Scanlon, 1957) in which facies changes were described between the "Yoredale Limestone Facies," the "Yoredale Grit Facies" and the "Millstone Grit Facies".

Moore (1958), "The Yoredale Series of Upper Wensleydale and adjacent parts of north-west Yorkshire", considered the variable sediments of the Yoredales to be very similar to those accumulating at the present day on the Mississippi Delta. Several sedimentary facies have been recognised within a relatively limited area of the Mississippi Delta (Fisk 1954) and Moore reviewed the Middle Limestone Group in terms of this modern example.

Other authors who have been concerned with the palaeogeography of the Yoredale Series include Dunham (1950) and Johnson (1960, 1962). Dunham suggested the changes in conditions which must be represented by a single cyclothem, whereas Johnson (1960) reconstructed the palaeogeography of the rigid block area. In his 1962 paper (read 1958) Johnson described the lateral variations which occur when tracing these cyclothems from the Alston Block into the Northumberland Trough.

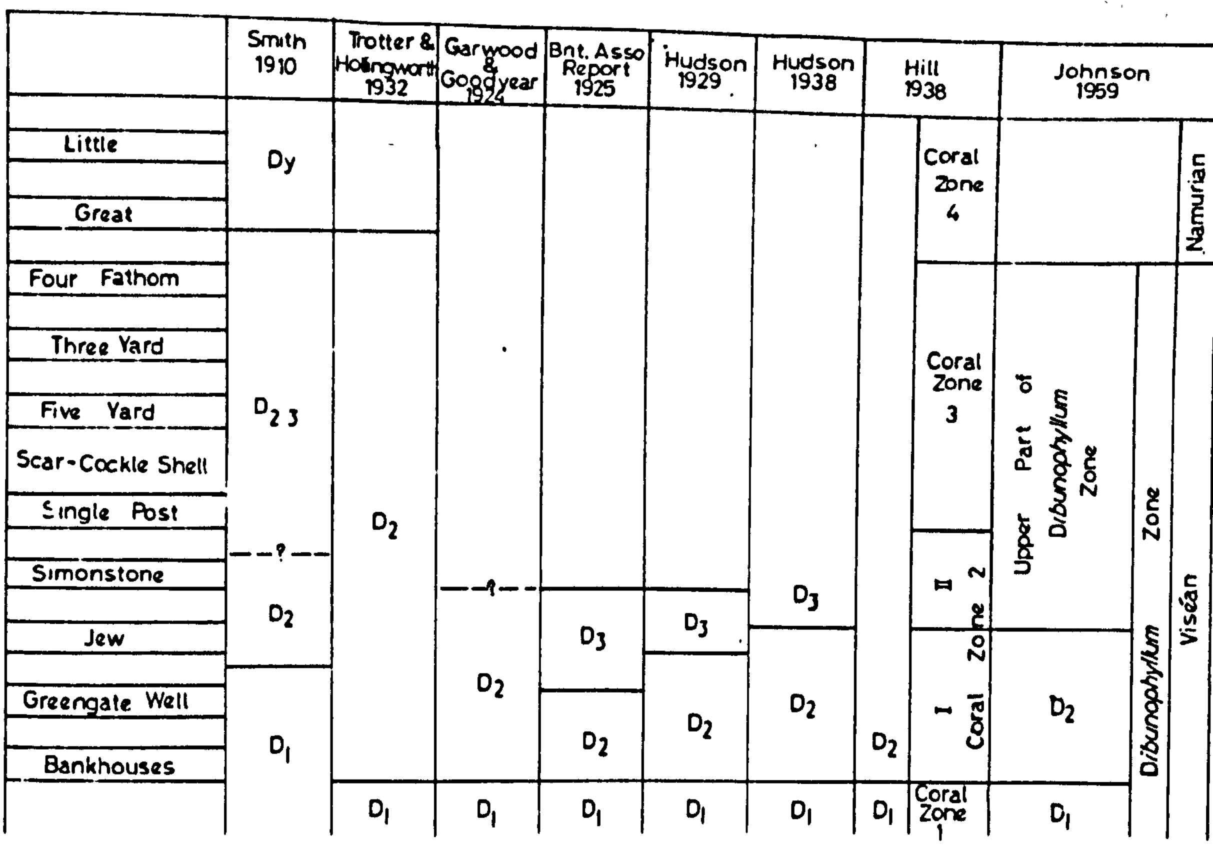


Fig. 2a. THE SUBDIVISION OF THE DIBUNOPHYLLUM ZONE IN NORTHERN ENGLAND

(Mainly After Johnson 1959)

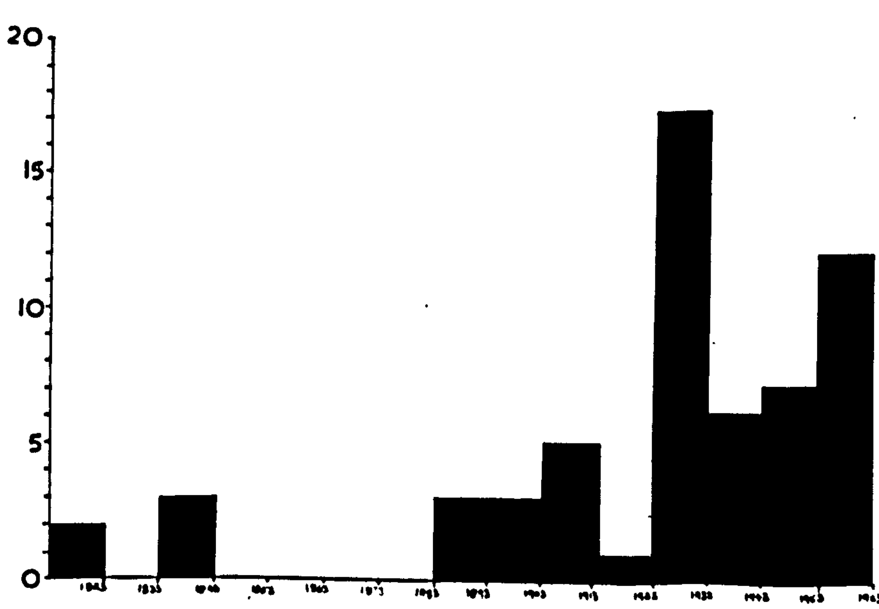


Fig. 2b HISTOGRAM OF PUBLICATIONS DIRECTLY OR INDIRECTLY CONCERNING THE YOREDALE SERIES

One final trend has been the study of the Viséan-Namurian junction. Bisat (1950) described the junction goniatite faunas, but this was not directed towards the Yoredale Series, where a concentrated effort to find these fossils has only taken place in recent years. Rayner (1953) in her Review of the Lower Carboniferous Rocks of the North of England, listed all the Yoredale specimens and concluded that the Viséan-Namurian Junction lay between the Underset and Main Limestones. Since 1953 further goniatites have been found and are reported in Johnson, Hodge and Fairbairn (1962). These authors state that the base of the Namurian almost certainly lies in the clastic sediments beneath the Great (=Main) Limestone.

Very recent work shows a trend towards the study of the Geochemistry and Micropalaeontology of the Yoredale Series. Work which has been published especially concerns the palaeosalinity of tho environment of deposition, e.g. Departure Curves for computing Palaeosalinity from Boron in Illites and Shales (Walker and Price, 1963).

The Yoredale Series has thus been subjected to a long history of research. In spite of the changes in interest which have taken place certain topics have remained active for long periods, most prominent of which is the question of the mechanism of deposition of these rhythmic deposits. This has been a vexed question, not only in the North of England but also in the U.S.A. where the Chester Series is in many ways comparable to the Yoredale Series and many authors have considered the origin of this series in their work.

Reference to text fig.(2b), which is a histogram illustrating the number of reports published relating to the Yoredale Series since 1814, shows that over three times as many have been published during the last 40 years than there were during the previous 100 years. The year 1924, the year of Hudson's "Rhythmic Succession of the Yoredale Series" was the turning point in the history of research, indeed the ten years from 1924 to 1933 saw the publication of more accounts than any other such period before or after.

3. THE STRATIGRAPHY AND STRUCTURE OF THE YOREDALE SERIES

STRATIGRAPHY

(a) Introduction

The Yoredale Series form a distinct facies of rhythmic shallow-water sediments within the Carboniferous System, occuring between the Great-Scar Limestone and the Millstone Grit. The major part occurs within the Upper Viséan but the series also extends into the Namurian. There are a number of problems concerning the Yoredale Series which are directly related to the Stratigraphy. Not the least of these is the problem of the actual definition of the series and its correlation with the internationally agreed time divisions. Correlation within the series itself is in effect virtually the same problem as the latter. The difficulties are mainly the result of the sequence being highly varied and containing a large proportion of non-marine strata. Faunas which are present therefore tend to be essentially local benthonic faunas and are of little use in long-range correlation or sub-division. Moore (1958) however pointed out that, with reference to the Coral/Brachiopod scheme the basal part of the Yoredale Series falls on the boundary between the Lower and Upper Dibunophyllum subzones and he took the Girvanella Band, which in Wensleydale lies in the middle of the Hawes Limestone, as a convenient boundary between the two subzones and as the base of the series. The latter was also the practice of Hudson (1924) and is continued in the present account.

(b) The Succession and Nature of the Cyclothems

The sediments comprising the Yoredale Series are varied but occur in a standard sequence, known as the cyclothem which, with a certain amount of variation, is repeated several times to make up the full succession of strata. Dunham (1950) described an ideal cyclothem as consisting of:- (i) Marine Limestone; (2) Marine Shale; (3) Unfossiliferous (?non-marine) ferruginous shale; (4) Sandy Shale, shaley sandstone or "grey-beds" (interbedded shales, siltstones and

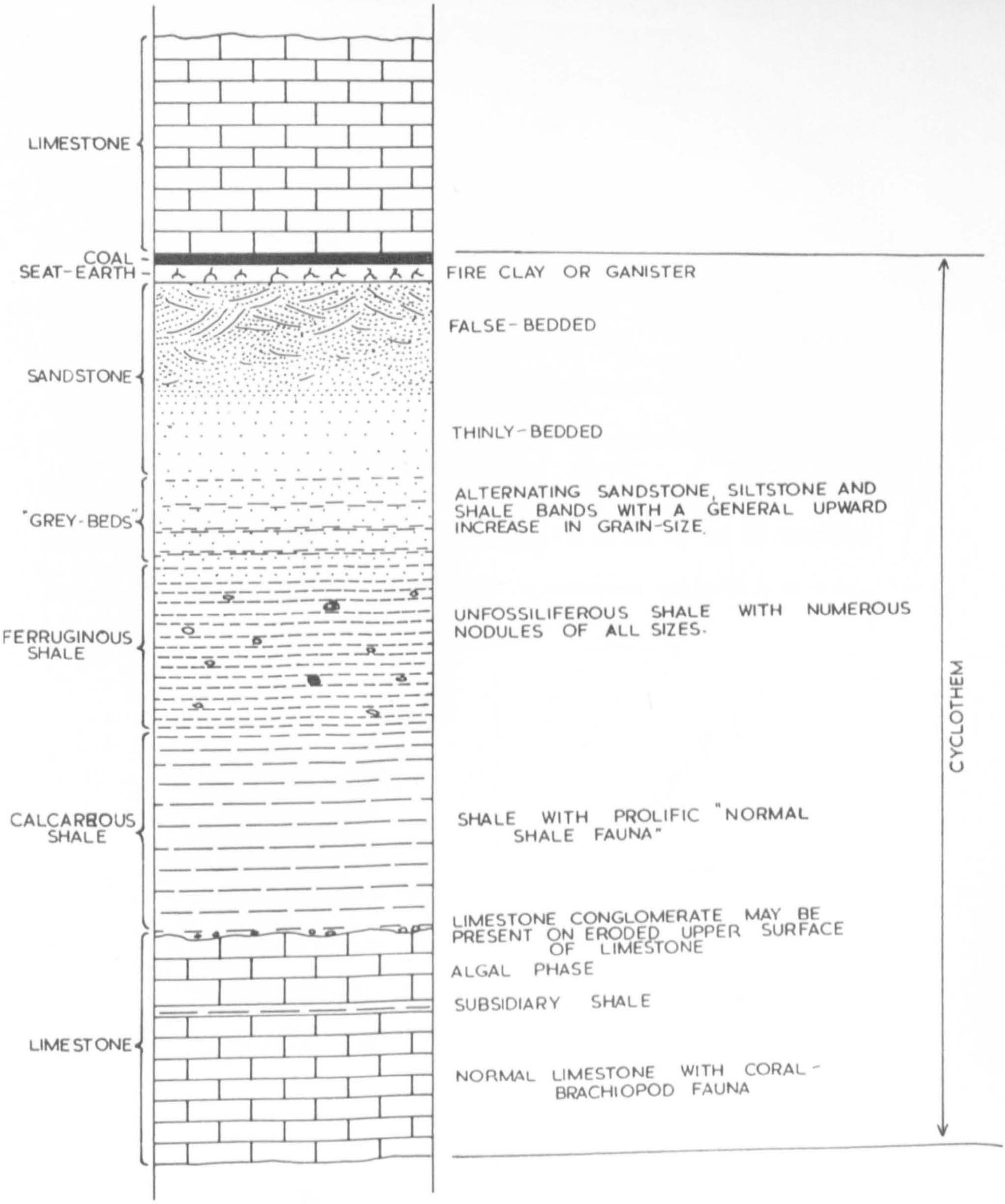


FIG. 3.

DIAGRAMMATIC SECTION THROUGH A "STANDARD YOREDALE CYCLOTHEM"

PARTLY AFTER HUDSON 1924

sandstones); (5) Sandstone; (6) Ganister or Underclay; (7) Coal. Except for the limestone, any of these lithologies may be absent or duplicated. The limestones, however, are persistant over a large area of the Northern Pennines, Individual cyclothems are named after the limestone which they contain at their base.

The succession of limestones described by Hudson (1924) was elaborated by Moore (1958) when he added the minor, un-named limestones which occur within several of the cyclothems. Moore also resurrected the name "Hawes Limestone", used by the Geological Survey but not used by Hudson, for the limestone beneath the Gayle Limestone and occuring between the Thorney Force Sandstone and Gayle Shale. The succession used in the present study is a combination of those of Hudson and Moore and is as follows. The minor limestones are not included, but the Iron Post Limestone is included.

Mirk Fell
Crow Limestone
Little Limestone
Main Limestone
Iron Post Limestone
Underset Limestone
Three Yard Limestone
Five Yard Limestone
Middle Limestone
Simonstone Limestone
Hardraw Scar Limestone
Gayle Limestone
Hawes Limestone
\- - - - - -
Hawes Limestone

(c) <u>Lithologies and Faunal Content of a Yoredale Cyclothem</u>

Fig.(3) represents a diagrammatic section through a "standard Yoredale cyclothem" as seen in the type-area. The lithologies represented are very variable.

(i) Yoredale Shales:-

Yoredale Shales are of two types, Calcareous and Ferruginous.

The calcareous shale rests with a distinct break upon the upper surface of a limestone. Even where this surface does not show signs of actual erosion, in the form of in-filled pot-holes, there is usually evidence of the limestone having been completely lithified prior to the deposition of the shale. The calcareous shales are dark-grey, poorly laminated and grade up into the ferruginous shale without a break. Their fauna is the richest and most diverse to be found in the Yoredale Series. Hudson (1924) described the "Normal Shale Fauna" as consisting of Bryozoa, Trilobites, Spiriferids, Productids, Lamellibranchs and rare Corals. In some cases the shale contains a "Modified Limestone Fauna", which is essentially a coral-phase combined with various elements of the normal shale fauna. Hudson was able to emphasise the limestone-shale break, when he described that in passage from a limestone fauna to a normal shale fauna the modified limestone fauna, which might have been expected, is in almost all cases absent.

The ferruginous shale is darker coloured and has better lamination than the calcareous shale. It is also quite often micaceous and usually contains abundant reddish-brown ironstone nodules of all sizes. In marked contrast to the calcareous shale, the ferruginous shale is barren of any fauna.

(ii) Yoredale Sandstones:-

The ferruginous shale grades up into laminated flaggy sandstones by way of the "grey-beds", which are interbedded shales, siltstones and sandstones. In passage up through the "grey-beds" the proportion of sandstone increases at the expense of first the shale and secondly the siltstone, until the bed is eventually a thinly-bedded sandstone. Moore (1958) recognised two types in these lower sandstones, the ripple-marked, and the truly-laminated sandstones, which are interbedded. Trails and borings are common at this horizon.

The beds of sandstone thicken upwards and develop into massive and false-bedded sandstones which are, nevertheless, still relatively fine-grained (angular quartz-grains less than 0·2 mms. in diameter - Dunham, 1950). Moore also recognised an extremely coarse, false-bedded sandstone of local extent and with abrupt contact with other lithologies, which he interpreted as channel-fillings.

The above sequence of shale, siltstone and sandstone, may be repeated several times within a single cyclothem and may even have associated thin limestones, thus making up the minor cyclothems mentioned earlier.

There may be a ganister or fire-clay on top of any of the sandstone members. The thickness of the seat-earth varies and is in no way related to the thickness of the coal above it. Thin coals occur at several horizons in the Yoredale Series, but they are more commonly absent.

(iii) Yoredale Limestones:-

Although the limestones of the Yoredale Servies are by far the most persistant bands, there is nevertheless a large amount of variation in lithology, both between different limestone bands and between different localities of the same limestone.

The limestones are commonly coarsely crystalline with varying proportions of crinoidal debris. Detrital grains such as quartz and mica are rare. All the limestones are divided into regular beds or "posts" varying in thickness from a few inches to many feet. The colour of fresh rock varies from light-grey through blue-grey to very dark-grey, depending upon the proportion of carbonaceous material present, which acts as the pigment. The weathered surface may show, in addition, colours from yellow to brown, as a result of oxidation of iron compounds contained in the rock.

Several types of fossil community are present. The normal type is the coral/brachiopod assemblage which is chiefly composed of Productids, Clissiophyllids and Lithostrotionidae but this may be replaced by any one of a number of types of community, thus giving rise to a wide range of faunal limestone types. These include algal limestone, bryozoan limestone, coral limestones, etc.

Chert is often found associated with the higher limestones. It first appears in the Middle Limestone as nodules or thin bands and in general increases up the sequence, though not necessarily being present in every limestone. The Crow Limestone is often entirely represented by a bed of Chert.

The highest beds studied are the Mirk Fell beds of Tan Hill, Yorkshire. These beds, of E_2 age, are atypical of the Yoredale Series, since they consist predominantly of a shale sequence and are also atypical in their macrofauna, as well as in their conodont content. They nevertheless occur at the top of the Yoredales, immediately below the Millstone Grit. They begin with the Mirk Fell Ganister and are capped by the Kettlepot Ganister and consist of about 145 ft. of beds, (see fig. 9)

(d) Lateral Variations in the Cyclothems

Cyclothems of the type already described persist throughout the Northern Pennines, over an area of 1600 sq. miles. The number present in any one particular area however, depends upon the location of that area, since there is both a tendency for limestones to split when traced towards the north, and for cyclothems to be replaced by massive limestone to the south.

Probably the best example of a limestone splitting is the Middle Limestone of Wensleydale, which appears to be the joint equivalent of the Scar, Cockle Shell and Single Post limestones of the Alston Block. This would imply a southward extinction of all but the limestone members of the Cockle Shell and Single Post Cyclothems. Further splitting affects these individual bands in the Northumberland Trough. At Greenhaw, in the South East of the Askrigg Block, the Gayle and Hardraw Scar cyclothems appear to be represented by a massive limestone

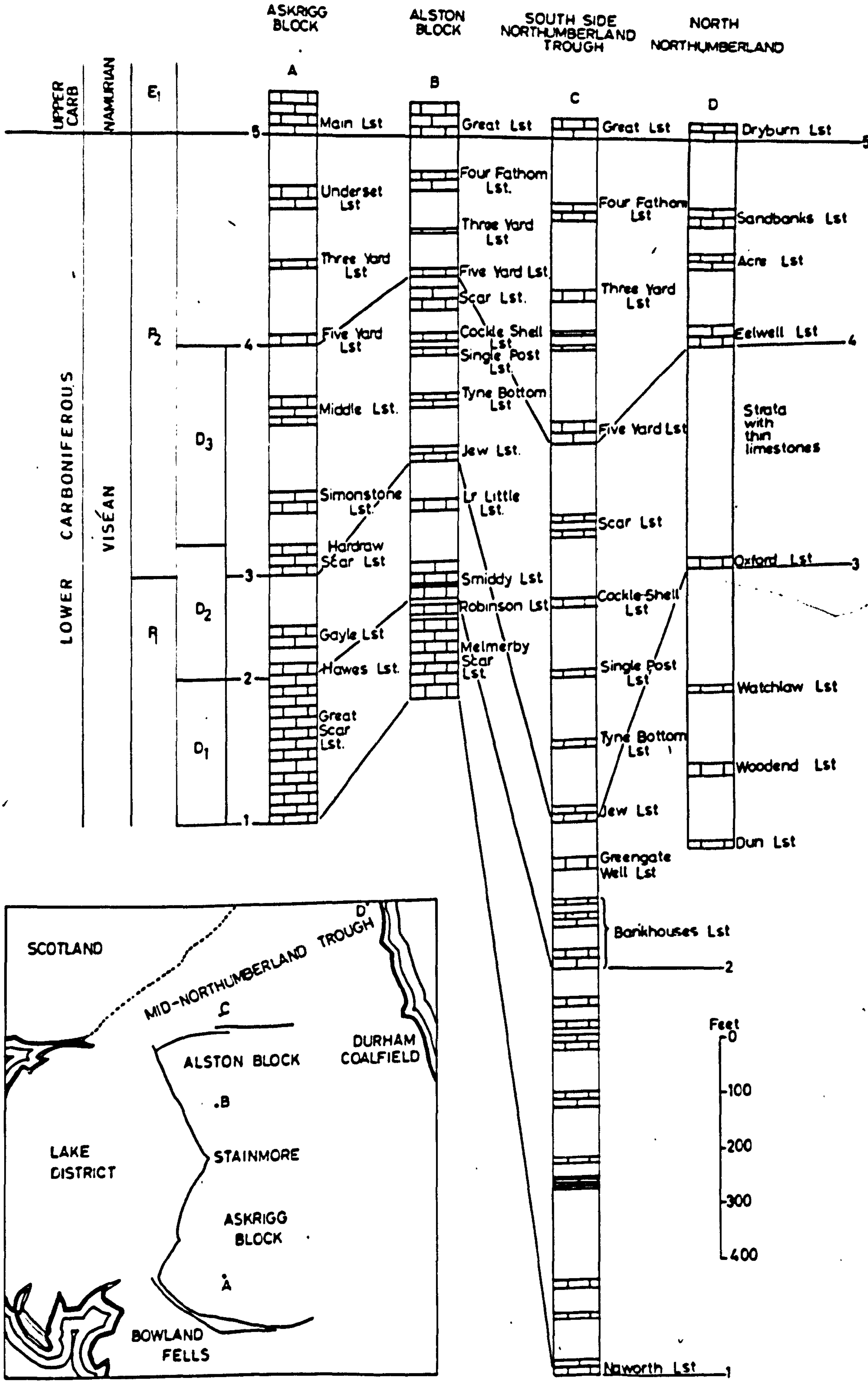


Fig. 4. COMPARATIVE GENERALISED SECTIONS SHOWING THE LIMESTONE MEMBERS FROM THE MAIN LIMESTONE DOWNWARDS WITH THEIR LATERAL EQUIVALENTS. CORRELATION OF THE SUCCESSION AND SKETCH DIAGRAM SHOWING THE LOCATION OF THE FOUR SECTIONS

(Mainly after Johnson 1960)

sequence, the Coldstone Beds, whilst above these there is the Toft Gate Limestone representing the Simonstone and Middle cyclothems (Dunham and Stubblefield 1945). Therefore below the Scar limestone, the shale and sandstone members die out southwards and the merging of the limestone bands gives rise to the marine limestone sequence.

Above the Middle or Scar Limestone there is no evidence of any regional changes of this sort, and as a result of their regional constancy the Five Yard, Three Yard, Underset and Main cyclothems have been termed the "major cyclothems" (Johnson, 1959).

In view of the regional changes which take place, the disjointed history of research and the early difficulties of correlation, it is not surprising that numerous local names exist for the limestone bands. Fig.4 correlates the limestones from the Askrigg Block, through the Alston Block and into the Northumberland Trough. This figure not only indicates the local limestone names, but also shows the variation in thickness of the whole succession in these different areas. It will be noticed that the succession greatly thickens into the Northumberland Trough and this is mainly the result of an increase in clastic sediment since Dunham (1950) showed that the amount of variation in thickness of a particular limestone is small, even if its associated cyclothem varies greatly in thickness.

(e) <u>The Viséan-Namurian Junction</u>

The line chosen by Phillips (1836) as the junction between the Carboniferous Limestone Series and the Millstone Grit Series, i.e., the top of the Main Limestone, was noted by Edwards (1957) to be the nearest mappable horizon to the faunal division between the Lower and Upper Carboniferous and hence also between the Viséan and Namurian. Much confusion has concerned the use of the terms "Millstone Grit" and Namurian. In the present account, the junction between the Yoredale Series and the Millstone Grit is considered to be a facies junction which changes in horizon, and is not to be confused with the Viséan-

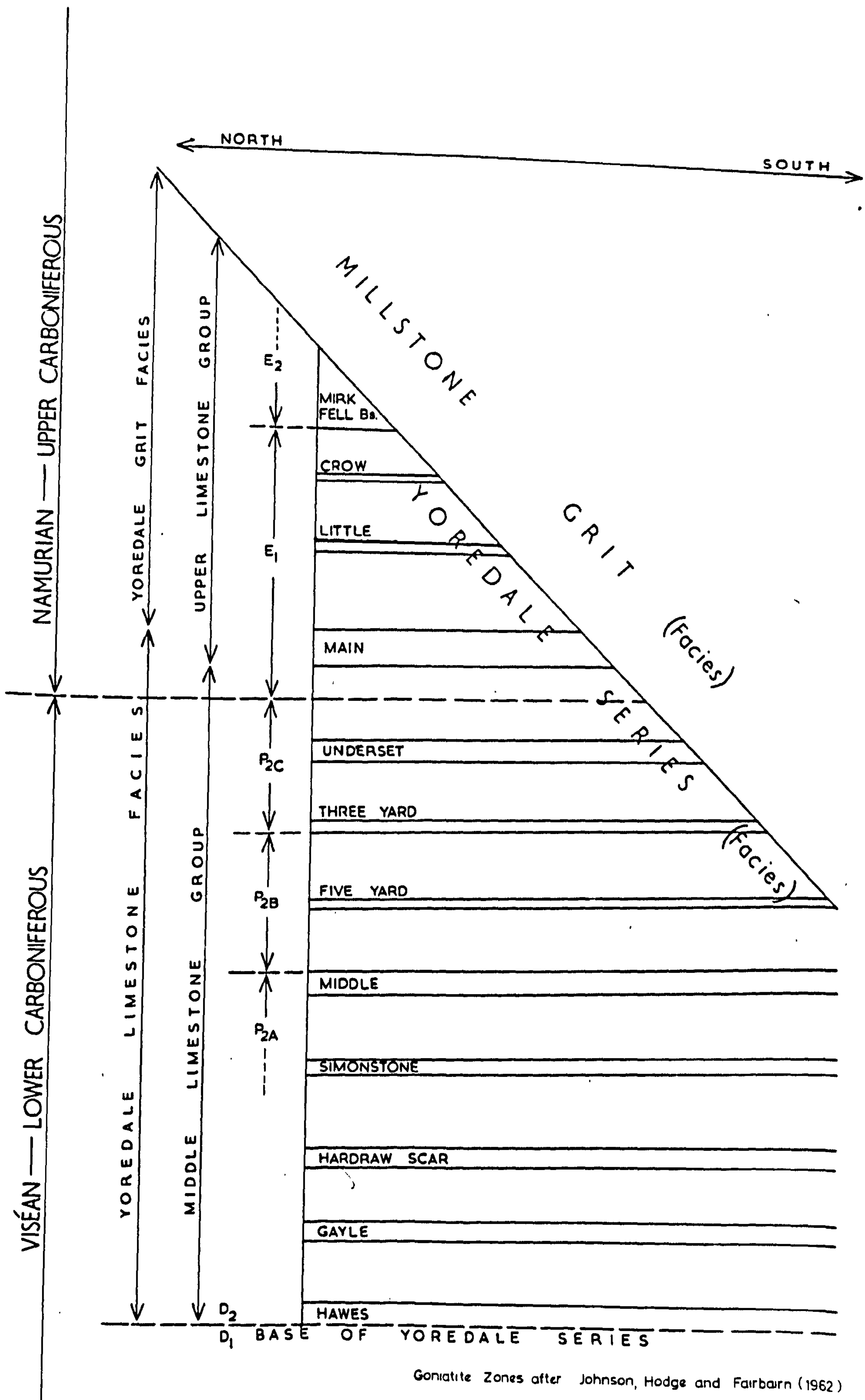


Fig. 5. DIAGRAMMATIC REPRESENTATION OF THE STRATIGRAPHIC TERMINOLOGY USED IN THE PRESENT REPORT

Namurian time division, which is an internationally agreed junction based upon goniatites (see fig. 5). Hence, although all the Yoredale Series is of Yoredale Facies, part of it is of Namurian or Upper Carboniferous age, whilst the remainder is of Viséan or Lower Carboniferous age. The application of the terms is primarily based upon Rowell and Scanlon (1957).

As already stated goniatites are very rare in the Yoredale Series and it was only in 1962 that Johnson, Hodge and Fairbairn substantiated the conclusion of Rayner (1953) that the Viséan-Namurian junction lies between the Underset and Main Limestones. Johnson, Hodge and Fairbairn concluded that the junction almost certainly lies in the clastic sequence just below the Main Limestone, the base of which is taken as its nearest mapping-line.

This line is also taken as the junction between the Middle and Upper Limestone Groups. That part of the Yoredale Series above and including the Main Limestone is known as the Upper Limestone Group, whilst the Viséan Yoredales belong to the Middle Limestone Group. The Lower Limestone Group is not involved since its upper limit is the Girvanella Band, which is taken as the base of the Yoredale Series in Wensleydale.

The Middle Limestone Group is the typical Yoredale series, much less variable than those above. Though the Main Limestone is the basal bed of the Upper Limestone Group, it bears closer affinities to the group below and was therefore named by Trotter (1952) as the top bed of his "Yoredale Limestone Facies". The remainder of the Upper Limestone Group he called "Yoredale Grit Facies".

The Upper Limestone Group differs from the more typical Yoredale Series below in its greater proportion of shale and sandstone and, except for the Main Limestone, in its thin, impure limestones. Cyclothems are discernible, but are somewhat irregular, with the frequent appearance of more than one sandstone and the place of the limestone being taken by a marine shale or sandstone. Hence the Yoredale cyclothem changes upwards into units more typical of the Millstone Grit, where the sandstones are often thick and transgressive and marine bands are less frequent.

(f) The Nature of the Yoredale Series - Millstone Grit Contact

Conflicting opinions have existed as to the nature of the base of the Millstone Grit. For many years the majority of workers considered that the Millstone Grit overstepped the Yoredale Series from south to north. Edwards and Trotter (1954) considered the Grassington Grit (Millstone Grit) to rest unconformably on beds up to the Main Limestone, but to pass laterally into the higher Yoredale beds. Rowell and Scanlon (1957) however, suggested what they considered to be a modification of both these views.

They considered the Mirk Fell Ganister to be unconformable on the beds beneath it and to be separated from its Millstone Grit equivalent, the Lower Howgate Edge Grit, which is also unconformable, by a transition zone, where the two facies interdigitate. They also considered that the Lower Howgate Edge Grit must be correlated with at least the upper part of the Grassington Grit (also unconformable) to the south. Since the Mirk Fell Ganister and Grassington Grit are both overlain by a marine horizon containing *Cravenoceras cowlingense* they must be of the same horizon and age and there is therefore no evidence of any large-scale overstep. Unfortunately this picture is complicated northwards of Tan Hill, where although the pre-Millstone Grit unconformity is present (at the base of the Mirk Fell Ganister) it is less distinct and the Yoredale Facies extends above it up to the base of the Kettlepot Ganister. Rowell and Scanlon therefore considered the relationship to be unconformable below the Mirk Fell Ganister, but above and including this horizon they suggested a lateral change from Millstone Grit Facies through a "transitional facies" into the Yoredale Facies

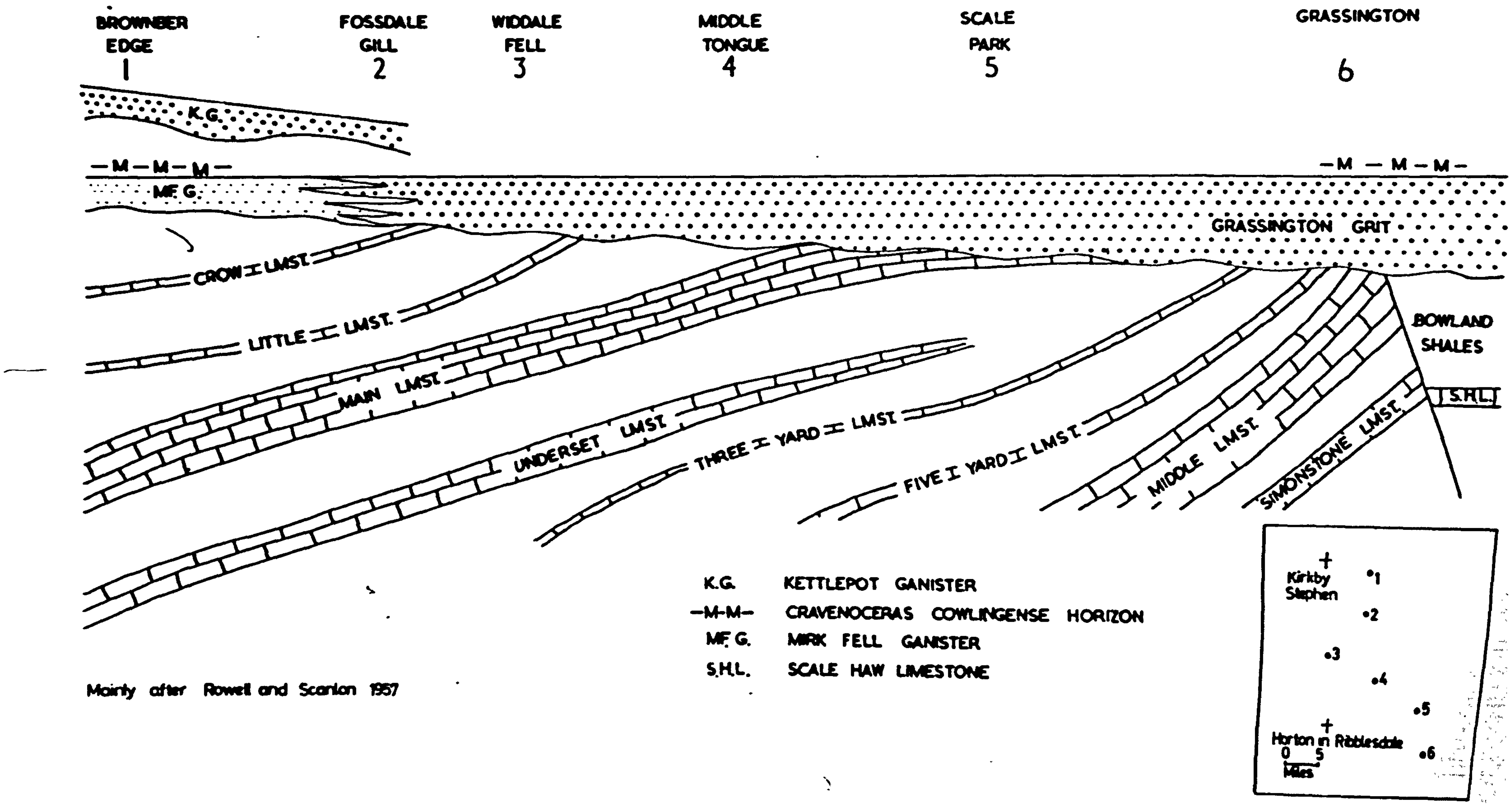


Fig. 6. DIAGRAMMATIC REPRESENTATION OF THE RELATION OF THE MILLSTONE GRIT AND YOREDALE SERIES ON THE ASKRIGG BLOCK AS ENVISAGED BY ROWELL AND SCANLON

(g) Conclusions

The Stratigraphy of the Yoredale Series is therefore complex with great variations in lithology combined with regional changes and junctions about which there has been or still is great confusion. Even the base of the series, must change in horizon if the term Yoredale Series describes a rhythmic facies, since cyclothems occur below the Smiddy Limestone, the lateral equivalent of the Hawes Limestone as indicated by the presence of the Girvanella Band, on the Alston Block. The upper boundary as has been described, is open to conflictions of opinion as far as details are concerned but no matter which is correct, beds of Millstone Grit facies dorest on progressively higher Yoredale Beds as they are traced northward. The factor which could have solved most of the problems outlined in this section would have been an accurate zonation based on goniatites, but so far this has been impossible. The present study indicates that conodonts can take the place of the goniatites and they have the added advantage that they have been retrieved from every major limestone, in many cases abundantly.

STRUCTURE

In a palaeontologic and stratigraphic work it is necessary to be absolutely certain of the succession and therefore structurally simple areas are studied. Fortunately the Carboniferous sediments of the Askrigg and Alston Blocks are relatively undisturbed compared with the surrounding basin sediments and a brief summary of their structural features is given below.

(a) The "Rigid-Block" Concept

The concept of the Northern Pennines occurring as a "rigid-block" dates from Kendall (1911) and Marr (1921). This stable unit is divided into a northern or Alston Block (Trotter and Hollingworth 1928) and a southern or Askrigg Block (Hudson 1938) by the Stainmore Syncline.

As already stated, the deposits on these blocks are relatively thin and undisturbed, and dip uniformly to the east where they disappear beneath the Durham Coalfield.

The blocks themselves are primarily composed of Lower Palaeozoic rocks which were highly deformed during the Caledonian Orogeny and in consequence bear the east-north-easterly "Caledonian Grain". These Lower Palaeozoics are exposed in the Cross-Fell & Teesdale Inliers, were penetrated in the Roddymoor Boring, and are also seen, along with some probably pre-Cambrian rocks, in inliers along the southern margin of the Askrigg Block.

The "Caledonian Grain" has had a considerable influence upon the subsequent behaviour of the region, particularly in its fracturing.

(b) Faulting Associated with the Block Systems.

The majority of the fault-systems developed approximately along hinge-areas which separated a basin-type of sedimentation from the shelf-areas in Carboniferous times and developed as a result of the relatively more rapid subsidence of the basins.

The Stublick Fault System, forming the northern margin of the Alston Block, downthrows 500 to 1750 ft. to the north and extends from the Pennine Fault System to a point a few miles east of Hexham, close to the western extremity of the Ninety Fathom Dyke. The latter forms the northern limit of the block in the east.

The Pennine Fault System, forming the western boundary of the Alston Block, was shown by Shotton (1935) to consist of (a) the Inner Fault, downthrowing to the east, (b) a series of faults thrusting to the east-north-east and (c) the Outer Fault, with a large downthrow to the west. The inner fault and thrust faults are Hercynian resulting in a depression of the block along this line. The outer fault is Tertiary and is related to the general eastward tilting of the Northern Pennines.

The Dent Fault System, forming the western margin of the

Askrigg Block, is associated with a rather complex belt of folding and fracturing known as the Dent Line. This system extends from Stainmore, where it joins the Pennine Fault System via the Dent Line, down the east side of Ravenstonedale to the western limit of the Craven Fault System in the south.

This latter system, which forms the southern limit of the block system, is a complex system consisting of the North, Mid and South Craven Faults. Wager (1931) has shown that the jointing in the Great Scar Limestone is related to the movements which have occurred in the history of this system.

Many of the other faults on these rigid blocks are mineralised, the majority of veins occupying fissures with throws of less than 40 ft. Also the majority are of Hercynian age though they were doubtless reactivated in Tertiary times when the blocks were uplifted by normal faulting along their margins.

(c) Folding

The most important fold of the Northern Pennines is the Burtreeford Disturbance which, in its 22 miles from Elphagreen in East Allendale to Hargill Beck in Lunedale, consists of an east-facing monocline, the downthrow of which is 250 ft. at Cowshill. The main compressional movements which produced this fold occurred slightly earlier than or contemporaneously with the emplacement of the Whin Sill, which was in turn earlier than the mineralisation. Apart from this disturbance there is a remarkable lack of folding on the Alston Block.

The Stainmore Syncline, which occurs between the Alston and Askrigg Blocks is an asymmetric "flat-bottomed" structural and topographic depression with its trough running E.N.E. and a maximum amplitude of 1600 ft. This syncline may correspond with an earlier Lower Carboniferous trough of sedimentation lying between the Alston and Askrigg Blocks.

Folding does occur on the Askrigg Block but it is generally of little importance. The more complicated structure of the southern margin at Greenhow, is tectonically related to the basin south of the block (Dunham and Stubblefield 1945)

(d) Igneous Intrusions

The Whin Sill, intruded during Hercynian times, is exposed on both sides of the Pennines and may be traced from Teesdale northwards in an arc to the Northumberland coast. It varies greatly in horizon, being at its lowest 88 ft below the Melmerby Scar Limestone and rises over 1000 ft. northwards. There are also great variations in thickness from a few feet to over 240 ft.

Tertiary intrusions occur sparsely in the Northern Pennines and originate from the Mull Dyke Swarm.

4. THE PALAEOGEOGRAPHY OF THE YOREDALE SERIES

(a) Pre-Yoredale Palaeogeography

During the early part of Lower Carboniferous times the area covering the north of England was divided into the following regions. To the south there was the main basin of deposition, bounded on its south side by St. George's Land and on its north side by an upland region, the shoreline of which must have roughly coincided with the Craven area. A narrow off-shoot of this main basin, known as the Ravenstonedale Gulf, ran northwards up the western margin of the upland area.

To the north there was the tectonic basic of the Northumberland Trough, the axis of which ran roughly W.S.W.-E.N.E. The southern limit of this trough was marked by the hinge-area of the Stublick Fault System.

Between the Northumberland Trough and the Main Basin there was an upland massif corresponding to the Askrigg and Alston Blocks and consisting of highly folded and faulted Lower Palaeozoic and probably also pre-Cambrian rocks, which had suffered deformation during the Caledonian Orogeny. This area of considerable relief was therefore surrounded, at least on its northern, western and southern flanks, by subsiding regions where deposition was already taking place. Little is known of the situation to the east but the Cleveland Hills Boring (Fowler 1944) suggested that deposition of the type found in the Main Basin occurred there, implying a north-easterly trend of the northern shoreline of the basin. Further north however, the upland area is known to have extended at least as far to the east as the Roddymoor Boring, near Crook, Co. Durham (Woolacott 1924).

These conditions were maintained until after the Michelinia grandis (C_2) zone had been deposited in the troughs. Finally, during S times, the then extensively-peneplaned massif was flooded. The surface was nevertheless still quite irregular and monadnocks for a time stood out as islands, the most important of which was probably Cross-Fell. The Basement Series, consisting of conglomerates, sandstones and shales, thus at first filled the hollows and gradually obscured the surface relief and as a result varies greatly in thickness.

It was therefore during S zone times that the sea covered the whole area from the Main Basin to the Scottish Border, for the first time, and it was under the epi-continental conditions of the blocks that the accumulation of dominantly limestone commenced. Meanwhile rhythmic sediments were already being deposited in the Northumberland Trough. For much of D_1 zone times these conditions prevailed, with rhythmic sediments in the north and massive limestone on the blocks. On the Askrigg Block the Great Scar Limestone represents practically the whole of D_1 zone times but rhythmic sediments spread on to the Alston Block from the Northumberland Trough before the end of D_1 zone times. The result is that on the Alston Block, the Melmerby Scar Limestone plus the Robinson and Peghorn Cyclothems are equivalent to the Great Scar Limestone of the south.

(b) Evidence of Shallow-Water Deposition of the Yoredale Series

As will be seen, the environments represented within a single cyclothem are varied, but all the rock-types were deposited in shallow-water or under terrestrial conditions. This is still true of the Northumberland Trough, where there is a great thickness of rhythmic deposits. The evidence of shallow-water is of two types, organic and inorganic.

The inorganic evidence consists of rock-types such as calcite mudstone, pseudobreccia, conglomerate, oolite (reported by Tiddeman from Wharfedale), coal, fire-clay and ganister. Other features indicative of either shallow-water or terrestrial conditions include potholing of limestone surfaces, current-bedding, ripple-marks, sun-cracks, etc. Also many of the sandstones have erosional bases.

The organic evidence includes Algae such as Girvanella and Brachiopods and Corals which are often found overturned and eroded, sometimes being scattered into bands or winnowed into lenticular masses. Annelid and mollusc tracks are common, as are roots in situ. Broken fossils are numerous.

(c) Major Features of the Palaeogeography of Yoredale Times

The palaeontologic sequence in each cyclothem indicates a division into a lower marine unit and an upper deltaic and terrestrial unit. The cyclothems must therefore represent conditions of alternating marine, deltaic and terrestrial environments.

Most authors are agreed upon the conditions represented by the marine environment of the limestones but although most British authors classify the upper part of the sequence of a cyclothem as deltaic, few have made a detailed comparison with a modern delta. This was, however, made possible after the detailed work of Fisk et al (1954) who studied the Mississippi Delta and were able to divide its active part into several deposition facies. Moore (1958) compared these modern facies with the sediment types displayed in the Yoredale Series and he found that a direct comparison could be made.

He compared the pro-delta facies with the richly fossiliferous shales of the Yoredale Series and considered the upward reduction in fauna to correspond closely to the lateral diminution of the modern fauna towards the delta. The delta-front facies he compared with the unfossiliferous shales and siltstones overlying the fossiliferous shales. Every rock type of the Yoredale Series occurring between the top of the lowest siltstone and the base of the succeeding cyclothem Moore considered to be equivalent to the interdistributary trough facies. This involves a wide variety of lithologies in the Yoredale Series from limestones to seat-earths and coals but except for the limestones each may be found on the modern delta. The degree of comparison may be summarised as follows:-

Modern Facies	Lithology in Yoredale Series
Pro-Delta	Fossiliferous shales
Delta Front	Barren siltstones and thin sandstones
Interdistributary Trough	Some silts, all thinly-bedded sandstones, fine to very fine massive and false-bedded sandstones, minor limestones.
Marsh	Ganister and Fireclays, Coals
Bar (and Channell Fill)	Coarse False-bedded sandstones with linear outcrop patterns.

There therefore seems to be little doubt that the environment of the Yoredale Series, except for the major marine horizons, was a deltaic environment in many ways similar to that found on the Mississippi Delta. The most likely source of the clastic sediments was the old Caledonian Mountains of Scotland and Scandinavia.

The Middle Limestone Group palaeogeography therefore consisted of a Caledonian landmass to the north which was being eroded by a large river-system flowing to the south and carrying with it large quantities of sediment. The latter was deposited on a large delta system which extended southwards over northern England into the open water marine conditions. Occasionally this delta was overwhelmed by the sea, during which limestone was deposited on top of the clastic sediments. There was therefore a gradual change in environment from the south to the north of the area from a limestone environment, through the Yoredale Series environment to the truly deltaic or shore-line conditions in the north. At this time conditions were continuous from the blocks into the Northumberland Trough, though the latter was subsiding at a relatively faster rate.

These variations in environment during the formation of a single cyclothem were not repeated in successive cyclothems in exactly the same geographic position. The shore-line and northern margin of the Yoredale cyclothems had moved steadily northwards during Lower Limestone Group times. Similarly the boundary of the massive limestones moved southwards during Lower and Middle Limestone Group times. It is significant that after the shoreline had moved to the north and marine conditions to the south the major cyclothems, which were continuous over the whole area, were deposited. Optimum conditions for the formation of a cyclothem therefore appear to have been when the distance between the shore-line and the open ocean, and therefore the extent of the delta, were greatest. During this time the whole area must have been extremely flat and near sea-level since slight changes in sea-level exposed or overwhelmed great areas.

These conditions continued into Upper Limestone Group times but the deltaic environment gradually pushed out the marine conditions and evidence of terrestrial conditions became abundant.

The Mirk Fell Beds were considered by Hudson (1941) to have been deposited in a very shallow sea or on a shoal. Most authors suggest that the deposition of the phosphatic material of the nodules was facilitated by the presence of decaying organic matter whose ammoniacal decomposition results in the abnormally high alkaline environment necessary. The circulation of the water must therefore have been restricted since the alkalinity was not dispersed. Hudson considered that these beds must have been deposited in a body of water which was virtually isolated from the open ocean.

(d) Mechanism of Formation of Cyclothemic Deposits

Most authors agree that the complete Yoredale cyclothem represents marine conditions followed by deltaic and finally terrestrial conditions. The problem is to find a mechanism which would facilitate the repeated establishment of a large delta after each marine transgression had overwhelmed the previous one. The quiescent, clear, marine conditions represented by the limestone must have remained for a relatively long period of time. This was followed by a short period during which terrigenous sediments were laid down and finally by a long quiescant period of terrestrial conditions.

Cyclothemic deposits bearing a close similarity to those of the Yoredale Series were being formed in many parts of the world from Mississippian (U.S.A.) or Viséan times until Permian times. There are, as a result, large numbers of theories explaining the mechanism of their formation and these may be grouped into two major categories dependant upon the major control they postulate. It must be remembered however, that though similar to the Yoredale Series cyclothem, that of for instance, the Chester Series of the Mississippi of the U.S.A, differs in one important respect. In the latter cyclothem the non-sequence occurs beneath the main sandstone unit whereas in the Yoredale Series, although sandstones are occasionally transgressive, there is normally a complete gradation from shale through silt to sandstone and the non-sequence occurs above the limestone, which may bear an eroded upper surface. This factor has not generally been taken into account by authors but it is considered that a fundamental difference of this type would have resulted from differing mechanisms of formation.

Two of the early theories are completely inadequate since they were based upon the assumption either that the whole sequence, including the coal, was marine (Simeons, 1918, Differential Settling Theory) or that all except the coal was marine (Stout, 1931, Intermittent Subsidence Theory).

(i) "Tectonic Control Theories"

A number of theories, including those by Hudson (1924, 1933), Dunham (1950) and R. C. Moore (1936, 1950) were based upon a simple cyclical uplift followed by erosion to base-level. Here the influx of the sea at the end of deltaic sedimentation was attributed to normal subsidence of the area of deposition. R. C. Moore, however, made the qualification that the controlling factor in his theory was a change in sea-level rather than movements of the continental masses. The Diastrophic Control Theory of Weller (1930, 1931, 1956) was also similar but differed in that the sea transgressed on to an actively downwarping area rather than a simply subsiding area.

(ii) "Climatic Control Theories"

The Precipitation Control Theory (Brough 1929) was based upon alternately rapid and slow deposition in a uniformly subsiding basin corresponding with climatic fluctuations in the source area. Wanless and Shepard (1936) believed that the period of time recorded by the cyclic sediments was probably contemporaneous with epochs of widespread glaciation, particularly in the southern hemisphere. Glaciation lowered the sea-level and caused a temporary withdrawal of waters from large portions of shallow seas. They believed the Glacial Control Theory to be satisfactory in view of the widespread nature of these sediments and the great extent which is possible for individual strata. Robertson (1948, 1952) believed that uniform subsidence and supply of sediment took place but that variations in the amount of deposition were cased by plant growth inhibiting the release of sediment from time to time.

Most of the theories outlined above contain points which fit the character of cyclothemic deposits but none, however, are perfect.

The theory of D. Moore (1958) is described in greater detail since it is the result of recent work, carried out specifically upon the Yoredale Series in their type-area, in a comparison with a modern delta. Moore's theory is based upon the two-fold division of a cyclothem into marine and deltaic units. The rate of deposition of the limestone and marine shale he considered to be less than the rate of subsidence, which in turn was exceeded by the rate for formation of the delta. A cyclothem must therefore have been achieved by some catastrophe overtaking the river which was depositing the delta thus forcing it to abandon its task. The whole sequence of events is summarised as follows:-

(1) Diversion of the river and resulting abandonment of the delta.

(2) The delta subsides and is colonised by sessile organisms. A small amount of erosion may take place. Calcareous sandstones give way to limestones.

(3) Limestone formation ceases & mud represents the first-stage of the re-establishment of the delta. These conditions persist, resulting in the formation of fossiliferous calcareous shales, until the delta is near.

(4) As the delta-front approaches the fauna disappears, the shale becomes micaceous and develops into a siltstone. As the delta-front crosses the area the silt is superceded by sandstone.

(5) The delta is thus established, soils and vegetation develop on its surface where it has emerged. In a single cyclothem only one land surface is found but in a complex cyclothem three or four successive land surfaces may occur.

(6) Diversion of the river and resulting abandonment of the delta.

(e) Conclusions

The palaeogeography of Yoredale times is therefore fairly well known. Although the Northumberland Trough is a distinct tectonic unit at the present-day, conditions were continuous from the trough to the rigid blocks in Yoredale times, the only difference resulting from the tectonic nature of the trough being that it attracted more clastic sediment than the blocks as a result of its faster rate of subsidence. Apart from this the two regions must have been indistinguishable at that time since the marine transgressions and regressions affected both areas as a single unit even though the actual changes in sea-level must have been slight. The Yoredale deltas never extended south beyond the Craven area.

There is far less agreement concerning the actual mechanism of cyclothem formation.

Most of the tectonic control theories envisage unexplained, regular, methodical movements of the continental mass, either in one direction or upwards and downwards. R. C. Moore prefers change in sea-level rather than these movements, but in view of the number of cyclothems involved particularly in the U.S.A., the total changes in sea-level must have been very great. Brough's Precipitation Control Theory implied that abundant precipitation resulted in large-scale erosion and therefore deposition of terrigenous sediments and the formation of coal. Unfortunately the formation of coal requires a humid atmosphere combined with a lack of deposition. Wanless and Shepard considered the Glacial Control Theory to be convenient but when it is remembered that in Virginia there are 100 cycles in the Pennsylvanian alone, this theory appears less attractive. These cyclothems may differ in some respects from those of the Yoredale Series but Wanless and Shepard considered one of the advantages of this theory to be its world-wide application since changes in sea-level due to glacial epochs would themselves be world-wide. Robertson's Plant Control Theory was considered by Weller not to possess the ability to affect the large areas over which cyclothems are found. Also Weller pointed out that according to this theory the underclay to the coal must have been formed below water and yet underclays are found displaying "fossilised soil profiles". Finally, although D. Moore's theory was described in greater detail, it too is not without its problems. For instance, in his succession of events describing the formation of a single cyclothem, the ferruginous shale, which is almost always present, is omitted. Also he describes the abandonment of the delta as being the result of a "catastrophe"which overtook the river, a catastrophe which must have occurred regularly for at least a dozen times on the Alston Block. Finally the non-sequence which is commonly present above the limestone is not taken into account in his succession of events.

It is therefore obvious that there are numerous trains of thought involved in this problem and as yet no single theory has been completely acceptable, at least for the Yoredale Series. The present work has served to emphasise the extremely long period of time relative to the formation of the other lithologies, represented by the limestones, since the conodont faunas have indicated that in the Middle Limestone for instance 4ft. of limestone plus 1ft. of shale represent the whole succession between the Single Post and Cockle-Shell Limestones of the Alston Block.

5. CONCLUSIONS TO THE STRATIGRAPHY AND APPLICATIONS OF THE PRESENT WORK

It is apparent from the foregoing sections that much has been written about the Yoredale Series, largely because it is in many ways unique in the British Stratigraphic sequence. The exact conditions under which the series was formed is not known with certainty, though the environments involved have been described. Cyclothemic development of the type seen in the Yoredale Series has also attracted the attention of authors in other parts of the world, particularly the U.S.A.

The difficulties concerning the Yoredale Series which have become apparent as a result of the intensive investigation they have received, may be summarised as consisting of their extremely variable character combined with a lack of reliable and abundant zonal fossils. In spite of this variability, both vertically and laterally, the series is in certain respects extremely regular and problems also arise as a result of this factor. The best example of regularity in the Yoredale Series is the regular appearance through the succession of prominent, laterally extensive limestones, which may only be attributed to regular marine transgressions, the mechanism of which is a matter for some debate.

In such a succession where lithologies are repeated many times and where "marker horizons" are relatively few, recognition of individual beds has been difficult, particularly in tectonically disturbed areas. Subdivision of the strata and the majority of correlations with other regions have therefore been mainly tentative. Lithologies and thicknesses of limestones are not sufficiently reliable features for correlation except on a purely local scale and the intervening sediments show even great variability.

In her review of the Lower Carboniferous Rocks in the North of England, Rayner (1953) stated, "What is particularly wanted is a method of correlating the Yoredale Facies with that of the Bowland Shales or Millstone Grit". At that time the goniatites provided the only method possible and consequently all the records of goniatites from the Yoredale series were listed in the review. This list consisted of only 13 records, of which Rayner concluded that only two were beyond question. The situation has improved somewhat since then, particularly as a result of the work of Johnson, Hodge and Fairbairn (1962) but the total number of records still remains low. The latter authors subdivided the succession from the Scar Limestone upwards by means of goniatites but the rarity of these fossils renders such a scheme of little practical application, no matter how accurate.

Conodonts possess a number of characteristics which are invaluable in stratigraphic work and most of which are essential to zonal fossils. They range from the Upper Cambrian to the Triassic or possibly Cretaceous Periods and during this time exhibit a constantly changing and wide variation in form. These changes are particularly rapid during Devonian and Carboniferous times. The conodont animal was also nektonic or planktonic and consequently conodonts are of world-wide distribution, with species appearing simultaneously throughout the world. One advantage they have over goniatites is that they are found in a much wider lithological range of strata. They are also essentially free from facies control on all scales, whether it be from lithology to lithology or from basic facies to shelf facies. Conodonts have therefore a great potentiality in stratigraphy and they are being increasingly used throughout the world.

Fortunately, in view of these potentialities, conodonts have been found in abundance in the Yoredale Series. Only one limestone, the Crow, has not yielded any of these fossils and this was because the samples were too siliceous to be digested by means which are harmless to conodonts. They were, however, particularly abundant in the Three Yard Limestone, where one sample contained over 500 specimens per Kgm. of rock. Conodonts were also fairly abundant in the Underset and Main Limestones, which according to the evidence provided by the goniatites occur respectively in the Lower and Upper Carboniferous. Another very interesting feature of the Yoredale conodonts is their distribution through individual limestones. This distribution shows a fairly constant pattern thus making it possible to forecast the horizons containing the most abundant conodonts. The implications of this fact in sampling are obvious.

In the following sections of this report the palaeontology of these fossils is described, as they occur in the Yoredale Series and a resultant zonal scheme compiled. The implications of such a scheme are considered in detail and follow two main trends. Primarily, in a study of this sort there are the stratigraphic implications, of recognition of beds, subdivision of strata and the correlation of beds on a local scale plus correlation of the succession with other areas on a wider scale. Secondly there are the ecologic and palaeontologic implications. These involve a study of the conodont environment and the other faunas found in association with the conodonts, as well as the purely palaeontologic considerations of taxonomy.

C H A P T E R T W O

TECHNIQUES OF STUDY

CHAPTER II

1. SAMPLING TECHNIQUES

The object of the original sampling of the Yoredale Series was to ascertain which lithologies contained conodonts and whether or not their presence or absence in particular lithologies was a constant feature. As a result many different rock-types were sampled, including all types of limestone, calcareous shale, ferruginous shale, nodules from ferruginous shale, siltstone, sandy siltstone and a marine sandstone, the Faraday House Marine Band. Arbitrary sample intervals of 5 ft. for the limestones and 3ft. for the shales and siltstones were chosen but this system was disregarded when there were rapid changes in lithology. This was particularly so for the "grey-beds" or minor cyclothems, where successive beds of different lithologies were often less than 1ft. in thickness.

Representative samples from all these lithologies were broken down and the conodonts, if present, extracted. Of all these early samples, only the limestones yielded conodonts and all the other samples were barren, in spite of the fact that these included definite marine shales lying immediately upon limestone which contained conodonts. Eventually conodonts had been obtained from the Hawes, Gayle and Hardraw Scar Limestones, plus the lower half of the Simonstone Limestone.
In view of this apparent restriction of the conodonts to the limestones and their interesting distribution through these beds it was decided to concentrate upon the limestones of the series and to take only occasional samples from other marine horizons.

Although the digested portions of the limestone samples had not been weighed, each had been treated with the same equipment and by the same techniques and was therefore assumed to approximate the weight of the others. It was thus interesting that in the Gayle and Hardraw Scar Limestones the sample 5ft. below the top-bedding plane in each case yielded the largest number of conodonts and that there was a fairly regular decrease in numbers below this horizon. The Hawes Limestone had this same pattern even though the upper half only (above the *Girvanella* Band) was studied and the evidence from the lower half of the Simonstone Limestone also indicated a similar pattern.

In order to enable a quantitative study of this distribution pattern the Gayle Limestone was re-sampled at 1ft. intervals and the portions for digestion in acid from each sample weighed. The distribution pattern was shown to be even more regular than had been previously foretold and showed a definite abundance of conodonts in the upper third of the bed.

Using the Gayle Limestone as a standard the remaining limestones were sampled at closer intervals in the upper third of each bed. The Hawes and Simonstone Limestones were also re-sampled and treated in the same manner but the Hardraw Scar Limestone was not re-sampled in view of its relatively large thickness, scarce conodonts and less pronounced maximum in its upper part. In no case did the sample interval exceed 5ft. and the positions of all the limestone samples are shown on text fig. (8).

In view of the large amount of phosphatic material in the Mirk Fell Beds, they were sampled in detail, in spite of the fact that they consist of a shale sequence with ironstones.

At a later stage, when many samples had been studied, the distribution pattern shown by the Middle Limestone was somewhat irregular. The close interval samples in its upper part showed a distribution of conodonts typical of the other limestones, but a sample 8ft. above its base (37ft. thick) contained an unexpected abundance of conodonts. The Middle Limestone was thus also re-sampled at 1ft. intervals. The significance of this irregularity in distribution is described in a later section.

Early samples weighed 1½–2Kgms but later samples collected weighed about 3Kgms. Of this 3Kgms., 1¾Kgms. was digested as a standard sized sample to conform with the earlier work and to continue the quantitative study of the conodont distribution but at horizons which were for various reasons particularly interesting a further amount of the same sample was digested to increase the number of conodonts available.

The localities from which samples were taken were chosen mainly for their continuous exposure. The Hawes Limestone, Gayle Shale, Gayle Limestone, and the shale above the Gayle Limestone were sampled from the excellent section which is their type area. Here there is complete exposure in the bed of Duerly Beck between Hawes and Gayle, a distance of about ½ mile, in Wensleydale. In order to achieve an intentional degree of overlap of samples from one locality to another, the shale above the Gayle Limestone was partly re-sampled in Whitfield Gill, Askrigg, 3 miles east of Hawes, on the north side of the valley. Here exposure was not absolutely complete but the major components of the cyclothems plus their boundaries, are exposed. The sampled succession above the shale consisted of siltstone, Hardraw Scar Limestone, shale and then a complicated sequence, parts of which were sampled in detail, making up the 3 minor cyclothems of the Hardraw Scar cyclothem. Above this sequence the Simonstone Limestone was sampled, together with the shales and silts above it, followed by the Middle Limestone.

The Scar Limestone, the equivalent on the Alston Block of the upper leaf of the Middle Limestone, was sampled from Middlehope Burn, Westgate, in Weardale. Here once again exposure is practically continuous. The other horizons sampled above the Scar Limestone were shales, siltstone, shale, 5 Yard Limestone, shale and 3 Yard Limestone.

Most of the 3 Yard Limestone was re-sampled in Gunnerside Gill, a tributary of the River Swale, in order to connect the thick Underset and Main Limestones with those already sampled below. Their equivalents on the southern end of the Alston Block were sampled from the Borrowdale Beck section, Stainmore, where they were much thinner. The horizons sampled here included the Four Fathom Limestone, the Iron Post Limestone, the Great Limestone, the Little Limestone, shales, the Faraday House Marine Band, shales, Crow Limestone and the shales above the Crow Limestone. The Mirk Fell Beds were sampled from their type area of Mirk Fell Gill, Tan Hill, north of Swaledale.

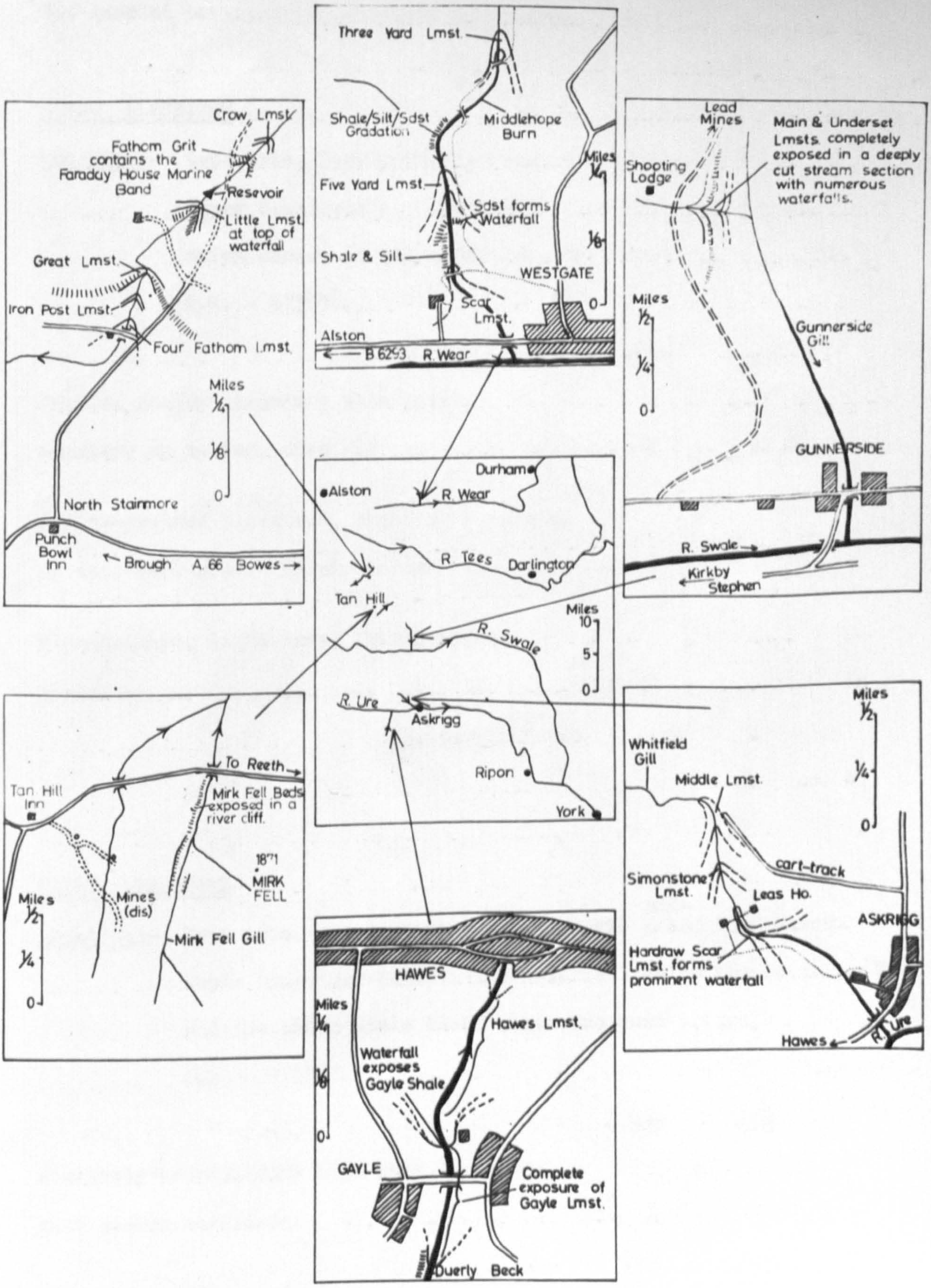


Fig. 7. LOCATION OF SAMPLED HORIZONS WITH SKETCH MAPS OF INDIVIDUAL LOCALITIES

Comparative sections of the limestones sampled in their entirity are shown in text fig (8) and brief descriptions follow. The sampled horizons of the Mirk Fell Beds are indicated in text fig (9).

HAWES LIMESTONE

Locality:- type area, Duerly Beck section between Hawes and Gayle, Upper Wensleydale. Section starts at the Girvanella Band which occurs at the middle of the limestone.
G.R. - 873896.

	Ft.	Ins.	
Impure, shaley limestone with pyrite clusters up to 1cm. diameter	2	0	
Medium-grained Limestone, light grey passing up into dark-grey. Thinly bedded	18	0	
Fine-grained, light grey, thinly-bedded limestone	5	0	D_2
Girvanella Band			
			D_1

GAYLE LIMESTONE

Locality:- Type area, Duerly Beck section, Gayle ½ mile south of Hawes. Gayle Limestone between the Waterfall below the roadbridge and the thick shale bluff above the road bridge.
G.R. - 872893.

	Ft.	Ins.
Massively-bedded, dark blue-grey limestone with sparse macrofauna	8	5
Calcareous Shale band		7
Massively-bedded, light-grey, coarsely crinoidal limestone. Numerous Giganto-productus giganteus up to 25cms. in width and corals in situ. Thinly bedded at base	16	0
Total Thickness	25	0

HARDRAW SCAR LIMESTONE

Locality:- Whitfield Gill, ½ mile W.N.W. of Askrigg, Wensleydale.
This limestone forms a very prominent waterfall about 80ft. in height.
G.R. - 939915.

	Ft.	Ins.
Dark-grey calcite mudstone	2	0
Light-grey, medium-grained crinoidal limestone	23	0
Blue-grey, crinoidal, massively bedded, fine-grained, limestone	25	0
Base grades into sandstone beneath		
Total Thickness	50	0

SIMONSTONE LIMESTONE

Locality:- Whitfield Gill, 1¼ miles W.N.W. of Askrigg, Wonsleydale.
G.R. - 935920.

	Ft.	Ins.
Massively-bedded, light-grey crinoidal limestone. Several colonies of *Lithostrotion junceum*	13	6
Friable shale		9
Pseudobreccia, nodular weathering	1	0
Silty shale, irregular thickness		3
Massively bedded, fine-grained, blue-grey limestone with few crinoids	7	0
Total Thickness	22	6

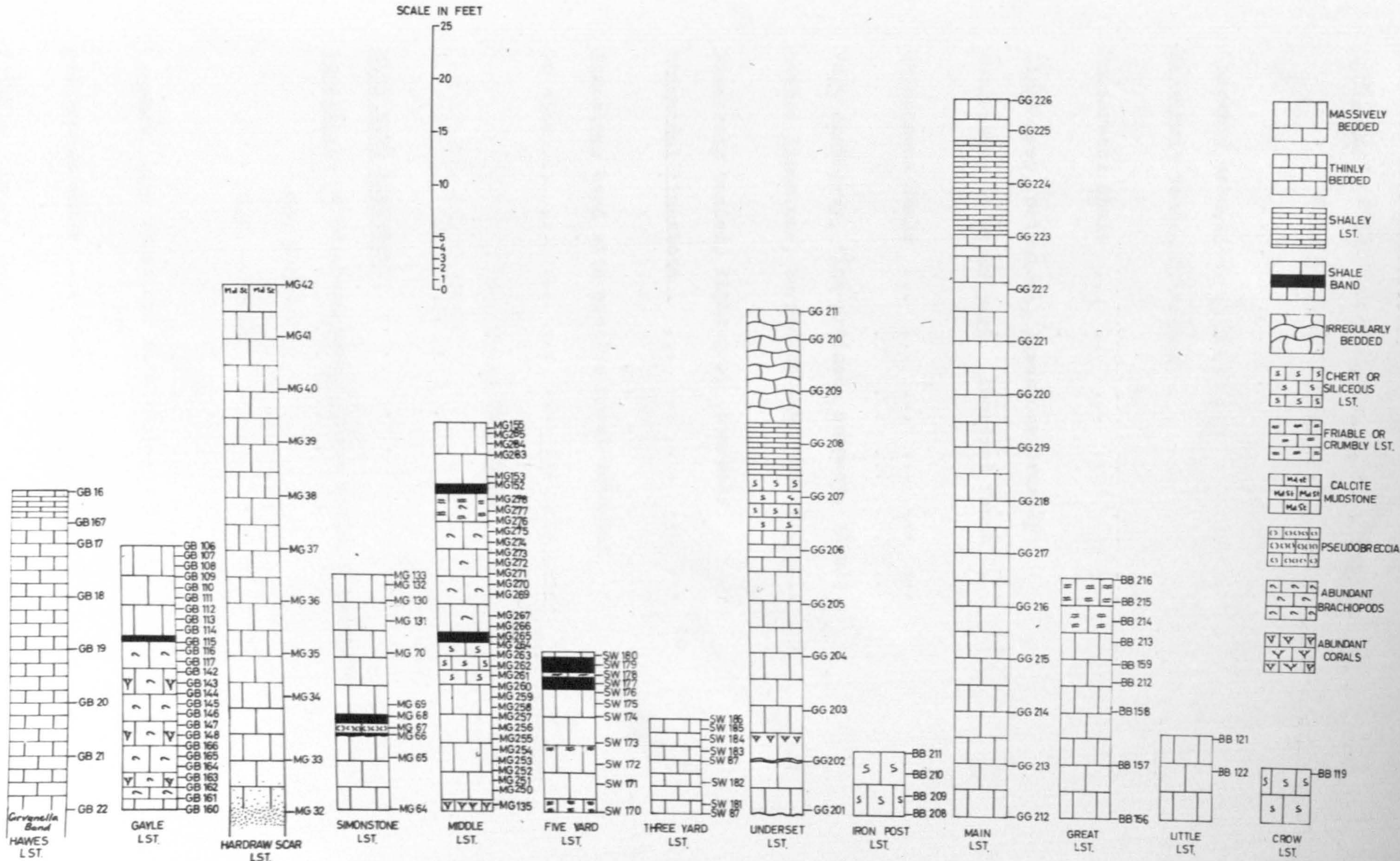


Fig. 8. COMPARATIVE SECTIONS OF THE YOREDALE LIMESTONES SAMPLED IN THEIR ENTIRETY, PLUS THE UPPER HALF OF THE HAWES LIMESTONE ILLUSTRATING THE VARIATIONS IN LITHOLOGY AND THE HORIZONS AND NUMBERS OF THE SAMPLES

MIDDLE LIMESTONE

Locality:- Whitfield Gill, 2 miles N.W. of Askrigg, Wensleydale.

G.R. - 930923.

	Ft.	Ins.
Coarsely crinoidal, light grey, massively bedded limestone	6	0
Calcareous Shale	1	0
Light-grey, crinoidal, limestone crumbly weathering in upper part. Abundant fauna ...	13	0
Calcareous Shale	1	0
Very dark-grey, fine-grained, compact, thinly bedded limestone, barren of any fauna	5	0
Massively bedded, light-grey, coarsely crinoidal limestone	10	0
Limestone band with massive coral colonies in situ	1	0
Total Thickness	37	0

FIVE YARD LIMESTONE

Locality:- Middlehope Burn, ½ mile north of Westgate, Weardale, Co. Durham.

G.R. - 906385

	Ft.	Ins.
Compact, dark limestone with abundant pyrite		6
Calcareous shale	1	6
Friable, impure, Limestone		6
Calcareous, shelly, shale	1	0

Massive, blue-grey, limestone, soft and impure at its base but otherwise compact and pure ...	11	9
Total Thickness	15	3

THREE YARD LIMESTONE

Locality:- Middlehope Burn, 1 mile north of Westgate, Weardale, Co. Durham

G.R. - 906387

	Ft.	Ins.	
Uniformly crinoidal, crumbly, ironstained limestone which varies from dark-grey at base to purple 7ft. above base	9	0	Total Thickness

UNDERSET LIMESTONE

Locality:- Gunnerside Gill, small tributary on west side of valley, 2 miles north of Gunnerside, Swaledale.

G.R. - 938006.

	Ft.	Ins.
Hard, light-blue, thinly & irregularly bedded limestone, honeycomb weathered in places	11	0
Friable shaley limestone	5	0
Hard thinly-bedded siliceous limestone	5	0
Thinly-bedded shaley limestone	4	0
Massive, light-grey crinoidal limestone band of rolled dissiophyllid corals between 7 and 9ft. above its base	23	0
Total Thickness	48	0

IRON POST LIMESTONE

Locality:- Borrowdale Beck, Stainmore, 1 mile north of Punch Bowl Inn on A.66. Thin limestone below the prominent waterfall of the Great Limestone.

G.R. - 834159

	Ft.	Ins.	
Massive, dark, hard, siliceous limestone ...	6	0	Total Thickness

GREAT LIMESTONE

Locality:- Borrowdale Beck, Stainmore, 1 mile north of Punch Bowl Inn on A.66. Forms prominent waterfall and well marked feature.

G.R. - 835160

	Ft.	Ins.	
Massive, uniform, pure, light-coloured limestone, crumbly on upper surface	23	0	Total Thickness

MAIN LIMESTONE

Locality:- Gunnerside Gill, small tributary on west side of valley below "shooting box", 2 miles north of Gunnerside, Swaledale.

G.R. - 935006.

	Ft.	Ins.
Massive, grey limestone with irregular weathering due to distribution of iron	4	0
Impure, friable, shaley limestone	9	0
Impure, thinly-bedded limestone	2	0
Very massive, very pure, coarsely crinoidal limestone	53	0
Total Thickness	68	0

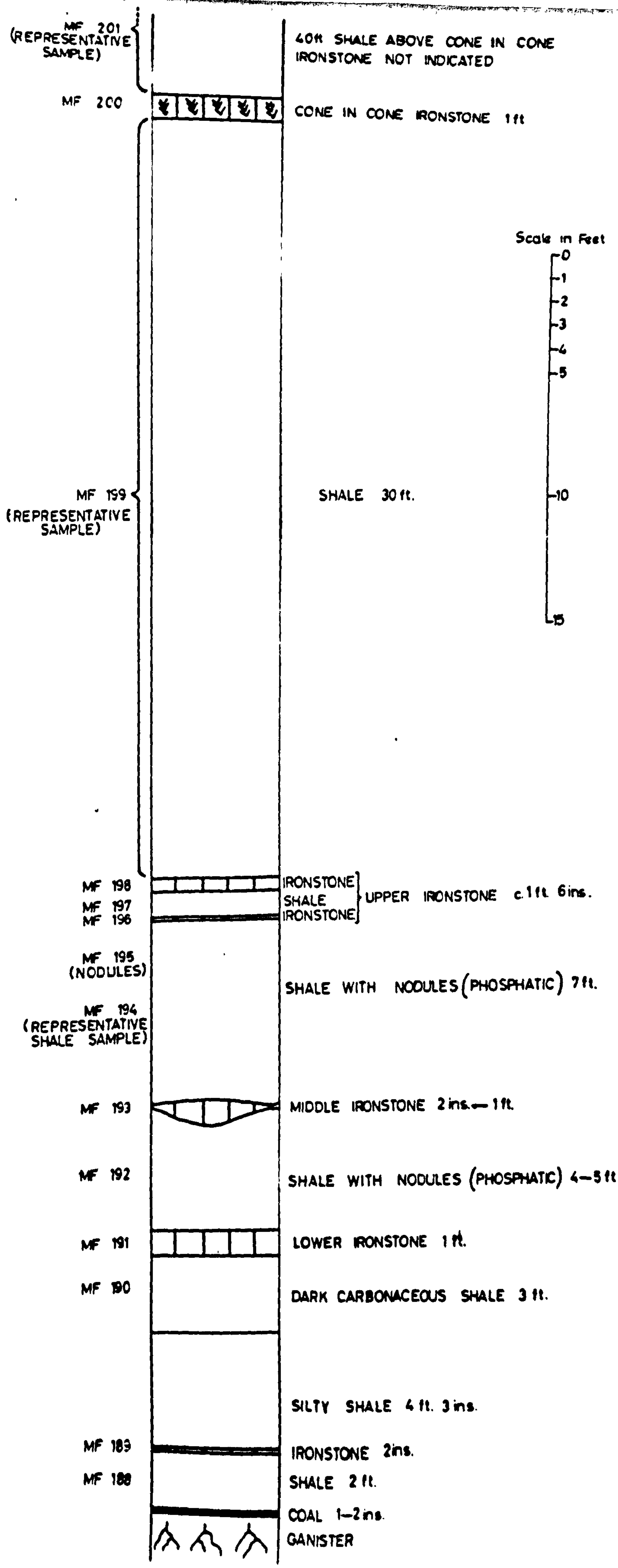


Fig. 9 THE MIRK FELL BEDS OF MIRK FELL GILL INDICATING THE POSITION OF THE IRONSTONES & SAMPLED HORIZONS

LITTLE LIMESTONE

Locality:- Borrowdale Beck, Stainmore, 1½ miles north of Punch Bowl Inn on A.66. Caps prominent waterfall above the Great Limestone waterfall.

G.R. - 838165

	Ft.	Ins.	
Uniform light-grey, crinoidal limestone	8	0	Total Thickness.

CROW LIMESTONE

Locality:- Borrowdale Beck, Stainmore, 2 miles north of Punch Bowl Inn on A.66. Occurs just above the 10 Fathom Grit and above small reservoir.

G.R. - 840167

	Ft.	Ins.	
Dark blue-grey, unfossiliferous, highly siliceous limestone	6	0	Total Thickness

2. SAMPLE BREAKDOWN TECHNIQUES

(a) Breakdown of Limestone Samples

1¾ Kgms. of 1 inch cubes of limestone were digested in 10-15% Acetic Acid. When the sample was placed in the base of the container the reaction only continued for one or two days, due to the lack of circulation of the acid and the formation of insoluble salts. The undigested sample plus the residue had therefore to be frequently washed, sieved and placed in clean acid, until only residue remained. By suspending the sample upon a stainless steel mesh tray in a large tank of acid, which need be no more concentrated than 5%, the reaction normally remained active a sufficient length of time for the whole of the sample to be digested in one process. Such a reaction, though gradually diminishing, might remain active for up to 3 weeks.

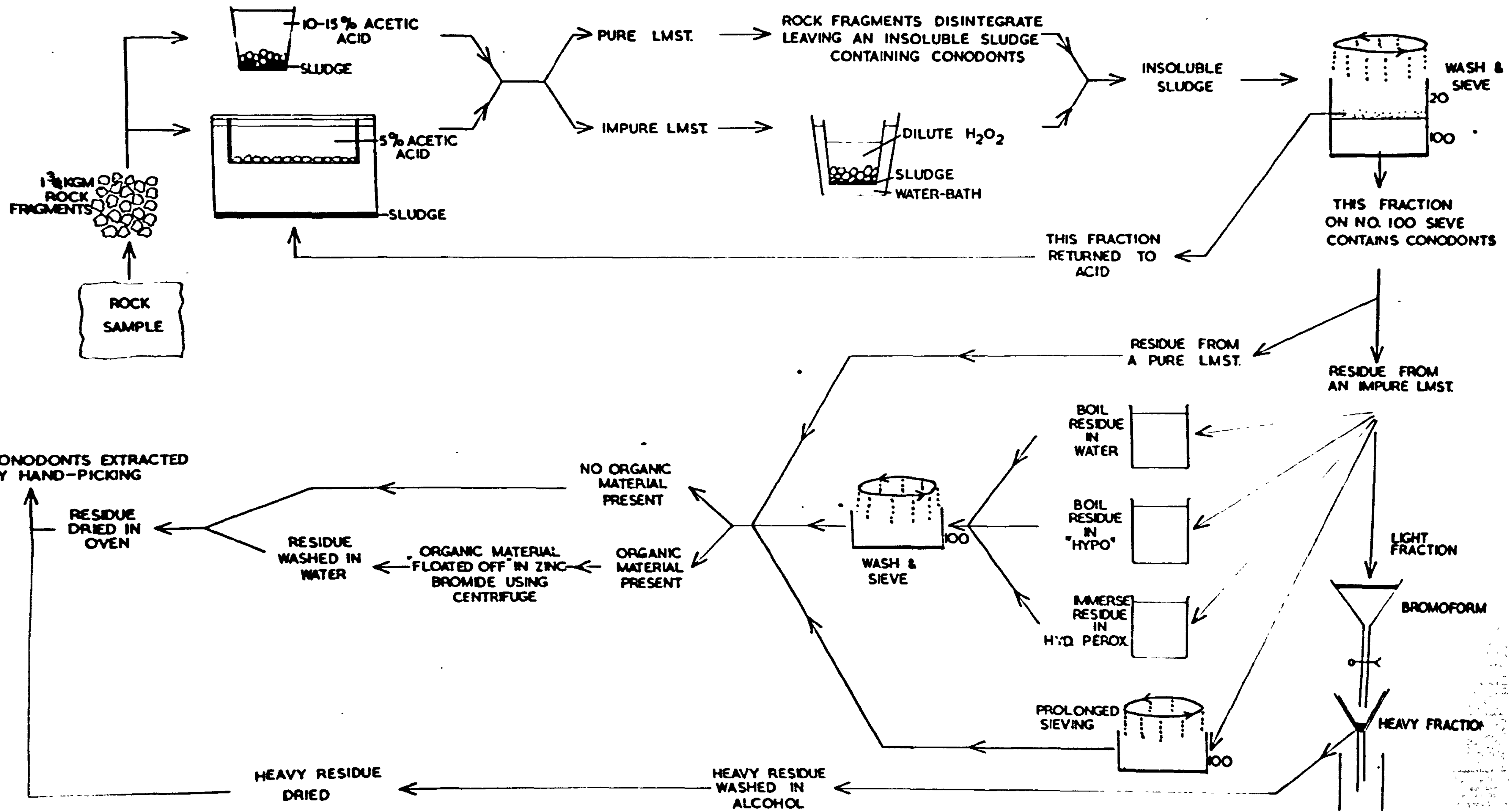


Fig. 10 PROCESSES INVOLVED IN RETRIEVING CONODONTS FROM A LIMESTONE SAMPLE

The Yoredale limestones were in general very pure and therefore the amount of residue was small. Also much of the residue was so fine grained that it was lost during the sieving operation.

Occasionally, however, a limestone was so impure that the carbonate was dissolved but the fragments did not disintegrate. These fragments of porous material, which had diminished little in size from the original fragments and which contained the conodonts, could often be disintegrated by the action of dilute Hydrogen peroxide, a reaction which occasionally became violent. If this was unsuccessful the fragments were gently kneaded between the fingers under water.

(b) Breakdown of Shale Samples

The techniques employed for the breakdown of shale were varied and depended largely upon the characteristics of the sample.

Some shale samples, for example certain horizons in the shale above the Gayle Limestone, disintegrated by continuous flushing with water. Others were sufficiently calcareous to be treated as for limestones.

An extensively used technique was to immerse the shale in Sodium hypochlorite for 1-2 weeks after which it was thoroughly washed and sieved. The action of the "hypo" was to soften the shale by forcing the minute partings open.

Dilute Hydrogen peroxide was occasionally used in a similar manner but this reaction was unpredictable, sometimes being unsuccessful and on other occasions violent.

An extremely efficient and rapid method which was sometimes successful where others had failed was to soak the thoroughly dry shale sample in White Spirit so that the latter completely penetrated the rock. For a soft fissile shale 2 hours were sufficient and for a hard, compact shale no more than 12 hours were necessary. The spirit was then decanted and replaced by water. The immediate effect of this was to reduce the sample to a sludge by the penetrating action of the water replacing the spirit.

The few siltstones which were broken down were considered as shales.

(c) Breakdown of Ironstone Samples

The ironstones were the most difficult lithology to break down and it was therefore necessary to break the sample into smaller fragments (1 cm.). Occasionally ironstones were sufficiently calcareous to react as impure limestones. Most, however, would only respond very slowly to alternations of the Acetic Acid, Hydrogen Peroxide and Sodium Hypochlorite reactions.

(d) Breakdown of Sandstone

The only sandstone attempted was the Faraday House Marine Band, which was only slightly calcareous and therefore reacted very slowly with Acetic Acid.

3. RECOVERY OF CONODONTS

The affect of all these techniques upon the varied lithologies was to reduce the solid rock to a sludge which contained the conodonts. This sludge was washed and sieved, the size fraction containing the conodonts passing a No.20 sieve and being retained by a No.100 sieve.

(a) Methods of concentrating the conodonts by reducing the amount of residue.

Continual washing often reduced the conodont fraction residue to workably small amounts. This was particularly the case for limestones. Other lithologies, plus the impure limestones, gave rise to greater quantities of residue. This could be reduced by boiling the residue in water or Sodium Hypochlorite followed by a second washing and sieving. The same result was also achieved by prolonged gentle washing of the residue using a mechanical sieving apparatus consisting of a rotating sprinkler connected to the water supply and fitting into the top of the No.100 sieve. Hydrogen Peroxide would also occasionally reduce the amount of residue if the latter had been obtained by other methods.

(b) Methods of concentrating conodonts by heavy liquid separations

An alternative method was to concentrate the conodonts in a heavy liquid fraction by using bromoform. The clay minerals and quartz, which make up the bulk of the unwanted residue, were easily floated off leaving a heavy residue consisting of conodonts, iron pyrites, and other heavy minerals.

When the amount of residue was small but contained unnecessary organic material, the latter was floated off in Zinc Bromide. In this method the viscosity of the heavy liquid necessitated the use of the centrifuge though the r.p.m. required were low (10 minutes at 750-1000 r.p.m.). The advantage of using Zinc Bromide is that it is water soluble and thus eases the washing of the residue.

(c) Extraction of Conodonts

The resultant small amount of residue was dried and the conodonts extracted by hand-picking. A perforated picking-tray was used, the conodonts being placed through any perforation in the field of view of the microscope and collected into a slide-well centred beneath.

4. TECHNIQUE FOR CLEANING CONODONTS

The conodonts obtained from the Yoredale Series were generally well-preserved and it has not been necessary to clean the specimens for normal use. In photography, however, they should be free from adhering material, since it is necessary to coat the specimens with white powder. Conodonts can be efficiently cleaned by their being immersed, in water, into the oilbath of the ultrasonic for 10 secs. It is important not to exceed this time-limit as this would result in breakage of the specimens and for this reason fractured or poorly preserved specimens were not subjected to this treatment.

5. PHOTOGRAPHY OF CONODONTS

The techniques employed in the photography of conodonts are not universally standard and only the methods used in the present study are described below.

Two main methods were employed, though all the conodont plates in this report are the result of the second or later method which is considered to be superior to the first.

(a) Method One

The processes involved by the first method in the photography of a single specimen are as follows.

A clean specimen was coated with a thin layer of white Magnesium Oxide "dust" by suspending the glass slide bearing the conodont in the vapour ofburning Magnesium Ribbon. This is a rapid process, the actual coating taking only a fraction of a second and great care is necessary to avoid depositing too great a thickness of powder and thus obscuring the surface detail of the specimen. The coated specimen was then transferred on to a dull, black background and placed upon the microscope stage. This transferring operation was very delicate and was carried out by using a very fine, sharply pointed artist's brush (number 00) in such a manner that the coating of the specimen remained undisturbed. The microscope was fitted with a Zeiss Ikon camera and the specimen illuminated by 3 high intensity lights. Kodak Plus X film was used and exposed for 1 sec. at F.4.

The prints resulting from this method had too great a contrast and lacked clear definition. Hard paper was used in order to obtain a uniform background which was sufficiently black to "drown" the interference from dust, etc. Unfortunately this also increased the contrast on the specimen to such an extent that if a print was slightly overdeveloped, the outline of the specimen could be lost into the background in shadowed parts. Another objection to this method was that the clarity of definition was largely dependent upon the microscope used.

(b) Method Two

In this method the specimen was coated with Ammonium Chloride sublimate. The process was less rapid than in Method One and was therefore more easy to control. This method also had the added advantages that the actual coating of powder was less readily disturbed during the transferring operation and also, if this was disturbed, its removal was easily affected with a wet brush. The technique involved the heating of a small quantity of Ammonium Chloride crystals in the nozzle of a glass tube and directing the resulting sublimate on to the conodont specimen. Although this method was successful, there were a number of adverse factors to be considered. For instance if the quantity of Ammonium Chloride heated was too great, the Ammonium Chloride present was not allowed to completely disappear, or the humidity of the atmosphere was too high, re-crystallisation was liable to take place on the specimen, thus obscuring all detail.

The actual method of photography was developed by Dr. A. C. Higgins in the present department. This method dispensed with the use of a microscope and consisted of a Zeiss Ikon camera as used in Method One, mounted vertically on a long bellows which was fitted with a Zeiss 63 mm. iris diaphragm objective. The coated specimen was transferred to a red perspex plate which absorbed much of the background interference of the photographs. This plate was mounted on the top of an old microscope barrel, beneath the objective and the specimen could therefore be focused by racking the barrel up or down.

The focal length of the apparatus, from film to specimen, was about 50 cms. Two high intensity lights were used, in fixed positions at right angles and slightly above the plane of the specimen, thus giving a standard illumination for all exposures. The light was evenly distributed over the specimen by placing on the latter a ground glass or perspex cylinder, 1·2 cms. in diameter and 1·6 cms. in length, on to which the light beams were focused.

Kodak Plus X film was again used, being exposed for 1 sec. at F.8 and developed in D.76 developer. Normal Bromesko paper was used for the majority of prints and their magnification was in most cases X 40. The exposure and development times and even the type of paper used for the prints were sometimes varied in individual cases but the majority were exposed for 10 secs. with the diaphragm stopped down to No.16 and developed for 2 minutes in D.163 developer.

The results from this method were superior to those employing Method One in their much greater definition, which was mainly due to the Zeiss lens, and their lack of brilliance as well as very dark shadows, which were the result of the uniform and standard illumination.

CHAPTER THREE

PALAEONTOLOGY OF YOREDALE CONODONTS

CHAPTER III

1. INTRODUCTION

(a) A Brief Summary of the History of Research on Conodonts of Viséan/Namurian Age.

A summary of the history of Viséan/Namurian conodont studies involves the problem of intercontinental correlation since a large amount of work has been done both in Europe and America, particularly on the Viséan or its American equivalents. For many years work was concentrated in America, but studies of this age now involve much of Europe and part of North Africa. Unfortunately the exact American equivalents of the Viséan and Namurian are a matter for some debate. The Mississippian and Pennsylvanian correlations committee (Weller et al. 1948, Moore et al. 1944) considered the Namurian to be in part equivalent to the Chester Series (Mississippian) and the Lower Pennsylvanian. The lower part of the Chester Series, plus the whole of the Valmeyeran Series below it, are taken as equivalent to the Viséan (Collinson, Scott and Rexroad 1962, p.13).

(i) 'Major Works' of General Interest which affected Conodont Research on Specific Horizons:-

The course taken by conodont research on specific horizons was to a large extent governed by a small number of 'major-works' which concerned wider aspects of conodont research.

The first of these was in fact the first major work on conodonts, by Pander (1856), who described and illustrated 56 species of conodonts from Ordovician, Silurian and Carboniferous beds of Estonia, Russia. Pander also illustrated the internal structure of conodonts and concluded that they were parts of fish.

Following Pander, Ulrich and Bassler (1926) produced a large and important publication entitled "A classification of the tooth-like fossils, conodonts, with descriptions of American Devonian and Mississippian species". This work included descriptions of 129 species, only 3 of which had previously been described, and the erection of 15 new genera. It is thus not surprising that Ulrich and Bassler should also have compiled the first real classification of conodonts, based mainly upon the major features of conodont morphology, which became the basic classification for many years to follow and has only during the last 15 years or so been challenged by new ideas.

The next major advance following Ulrich and Bassler (1926) concerned the Morphology of Conodonts (Hass 1941). Hass investigated the internal structure of conodonts petrographically and was able to show that the conodont unit was built up, or grew, by the accretion of lamellae over the whole surface except the aboral cavity. Such a study of a single conodont was therefore a record of the growth stages through which the unit had passed and had important repercussions on thought concerning the zoological position of conodonts.

Finally there has more recently been the controversy of classification of conodonts, largely the result of the extreme utilitarian views expressed by Lindström (1954,1959) and the description of highly complicated natural conodont assemblages from the Upper Carboniferous (Rhodes 1952, 1953, 1954). (Both these subjects are considered in the section of the report dealing with conodont classification and need be described no further at this point). As a result two major schools of thought developed concerning the classification of conodonts, with numerous compromises between.

(ii) Conodont Works Specifically Concerning Viséan/ Namurian Horizons:-

The only accounts published before Ulrich and Bassler (1926) were Notes and descriptions of Scotch Carboniferous conodonts (Hinde 1900) and The microfauna in Mississippian Formations of San Saba County, Texas (Roundy 1926), both of which have since been revised, the former by Clarke (1960) and the latter by Hass (1953).

Between 1926 and 1941 a large amount of research was carried out, mainly descriptive works based upon the classification of Ulrich and Bassler. These included conodonts from the John's Valley and

Wapanucka Formations of Oklahoma (Harlton 1933, Harris and Hollingsworth 1933), Late Mississippian and Lower Pennsylvanian Conodonts (Branson and Mehl 1939), the Keokuk Formation (Branson and Mehl 1941), New and Little Known Carboniferous Conodont Genera (Branson and Mehl 1941) and Conodonts from the Caney Shale of Oklahoma (Branson and Mehl 1941). Branson and Mehl's 1939 paper is the only work to have dealt with the relationship of Mississippian and Pennsylvanian Faunas.

By this time work had also begun in Europe and in 1933 Schmidt published his work on Namurian conodonts from Germany, which he treated as genetic assemblages. Schmidt was followed in 1939 and 1941 by Demanet in Belgium, who studied conodonts of a similar age and also treated them as genetic assemblages.

Only three relevant papers appeared between Hass (1941) and Lindström (1954), all from America and each following the pattern of earlier works in consisting of descriptions of faunas with comparisons and correlations with faunas from other areas. They included the first description of Chester Series conodonts from the type-area (Upper Kinkaid microfauna from Johnson County, Illinois, Cooper 1947) and conodonts from the Pella Beds of South Central Iowa (Youngquist and Miller 1949) and the Barnett Formation (Hass 1953), the latter being an extensions and revision of the work of Roundy (1926).

Since 1954 research on Viséan/Namurian conodonts has greatly increased, not only in America but also in Europe, particularly Germany, where apart from Schmidt (1933) very little work had been done up to this time.

Recent work in Germany has primarily concerned the production of Conodont Zones as an aid to stratigraphy. This trend was started by Bischoff (1957), who described conodonts from beds ranging in age from Upper Devonian to the top of the _Goniatites_-Stufe and included an extensive range chart of species. Two years later the upper part of Bischoff's sequence i.e. the _Gattendorfia_-Stufe and the _Pericyclus_-Stufe was greatly elaborated by Voges (1959), who described the first conodont zones, five in number, based upon species of _Siphonodella_, Scaliognathus and Gnathodus. In 1960 the same author recognised 7 conodont zones from the same horizons, each of which was tied to other fossil zonations. These zones have been applied by later workers such as Böger (1962) and Meischner (1962) both of which included a section on conodonts in their largely stratigraphic work.

This recent period (post 1954) has seen an even greater number of publications from America, many of which were in the same pattern of the earlier works and were descriptions of faunas from individual formations, with suggested correlations. These include the Caney Shale (Elias 1956), the Glen Dean Formation (Rexroad 1958), the High Resistivity Black Shale (Stanley 1958), the Golconda Group (Chesterian)(Rexroad and Jarrell 1961), the Kinkaid Formation (Rexroad and Burton 1961), the Paoli Formation (Rexroad and Liebe 1962), the St. Louis Formation (Valmeyeran Series)(Rexroad and Collinson 1963) and the Pella Formation (Rexroad and Furnish 1964).

In addition a number of further lines of research were being carried out. As a preliminary to his work, Rexroad (1957) studied the whole of the Chester Series from the type-area of S.W.Illinois in an attempt to ascertain the amount of lateral and vertical variation in the faunas. This work was carried a stage further by Rexroad and Clarke (1960), who carried out a distributional survey within the single horizon of the Glen Dean Formation, comparing faunas from a shelf and geosynclinal environment. In 1961, Rexroad and Collinson produced, with the help of the previous information from individual formations, a preliminary range-chart of conodont species from the Chester Series of the Illinois Basin. This was followed up by the Six Charts Showing Biostratigraphic Zones and Correlations based on Conodonts from the Devonian and Mississippian rocks of the Upper Mississippi Valley (Collinson, Scott and Rexroad 1962). Chart No. 6 of this latter work indicated the conodont assemblage zones from the Upper Mississippi Valley, ranging from the base of the Upper Devonian to the top of the Mississippian.

The remaining conodont works of Viséan/Namurian age were widely scattered throughout Europe and North Africa. They began with

Flugel and Ziegler (1957) who described large faunas from the Pericyclus-Stufe and Goniatites-Stufe of Austria and established the Devonian/Carboniferous boundary with their aid. Ziegler (1959) also studied conodont faunas of Devonian and Mississippian age from the Montagne Noire in Southern France and various localities in the Spanish Pyrenees. Serre and Lys (1960) worked primarily on Upper Devonian conodonts from Northern France and Belgium but also included some Viséan and Tournaisian faunas. Lys, Mauvier and Serre (1962) described a Namurian microfauna containing conodonts, from Northern France. Study of Namurian conodonts indicated the absence of beds of E_1 age from the Belgian succession (Bouckaert and Higgins 1963). Higgins (1962) also described a fauna from the "Griotte" Limestone, which forms a marker horizon at the base of the Carboniferous in Northern Spain and contains the Viséan/Namurian boundary. Clarke (1960) published the first British work of conodonts of Viséan-Namurian age since Hinde (1900). Clarke's paper, on the Lower and Upper Limestone Groups and Millstone Grit of Scotland, was a revision and extension of Hinde's work. The first English work on Namurian conodonts was that of Higgins (1961), who described a fauna from the Eumorphoceras aff. pseudobilingue zone of North Staffordshire. Finally, Remack-Petitot (1960) covered a very wide range of rocks from Silurian to Pennsylvanian, from three localities in the Sahara, with comparisons from the Montagne Noire and the Pyrenees.

The history of Viséan/Namurian conodont research has thus been long and although many authors have been involved, the path taken has largely been guided by a small number of authors who studied the wider aspects of conodont research. Between such times when these works were published, a large number of detailed works appeared which substantiated, enlarged and applied the earlier ideas. This pattern was however complicated fairly recently by the controversy involving classification, the large number of papers produced in any particular year, and the much extended areas of research.

(b) Classification of Conodonts

A study of conodont faunas involves problems which are seldom encountered in most other groups of fossils. The reasons for this are varied and include the lack of knowledge of their origin, the fact that they usually appear as single disjunct parts rather than whole animals or known parts of animals, the lack of knowledge of their function and the lack of knowledge of the very rare natural conodont assemblages. Thus a fundamental question such as orientation is often conjectural and designed to "fit the pattern" of earlier work.

For many years conodonts were treated as single individuals and the amount of variation allowed within a species was small. The modern trend, however, has been to consider whole faunas rather than individuals and the amount of variation now recognised as possible within a species is much greater, particularly since the work on variation studies (Hass 1941, Müller 1956, Tatge 1956, Scott and Collinson 1959). This variation is the result not only of morphological variation of mature individuals, but also the result of ontogenetic changes which are now recognised as having taken place in conodonts and which are considered in the erection of new categories. The synonomies listed in the systematic palaeontology section are therefore evidence of the fact that the modern conception of a conodont species is radically different from the conception of earlier conodont workers.

The classification of conodonts is a matter of considerable interest and controversy and a question about which numerous authors have expressed their opinions. The controversy is the result of the discovery of the natural conodont assemblage and the realisation that a single natural assemblage contained several "form genera" and that a single "form genus" could occur in several "natural genera".

The issue is therefore whether to classify conodonts according to their relationships or whether the classification should be purely utilitarian. Unfortunately a strictly phylogenetic classification is difficult to apply since natural assemblages are very rare and difficult to interpret.

However it seems more than coincidence that the highly complicated assemblages have only been found from the Upper Carboniferous and it is likely that many assemblages particularly from the Devonian were much more simple. Müller (1956) for instance described Middle Devonian faunas consisting only of several species of Icriodus. It is therefore possible that a phylogenetic classification will be compiled on the basis of evolutionary trends. For instance, there were probably at least two parallel lines of conodont evolution producing the same forms but at different times. In this way the simple cone gave rise to the Bryantodus-type, which in turn produced the Spathognathodids and from these developed the Gnathodids. However this line occurred more than once since there are forms in the Lower part of the Tournaisian which are almost identical to forms in the Upper Viséan (e.g. the Gnathodus commutatus type) with no apparent connection between them. The question is therefore whether these two forms should be classified into the same group on the grounds of their morphological similarity or into different groups on the grounds of their contrasting evolution. In the latter case a group would contain morphologically variable forms which were genetically related, as in a natural assemblage and when more is known of the evolution of conodonts such a classification could be extremely useful.

The utilitarian view is feasible at the present time but even this scheme must be based upon morphology and is therefore open to personal opinion in the selection of characters. Probably the greatest exponent of the utilitarian scheme is Lindström, who considers that a classification should be constructed in such a way that there should be no hesitation into which 'form-genus' a given 'form-species' should be placed. Such a classification he considered readily applicable providing a rigid scheme was adhered to. Lindström's classification used absolute characters, which for compound conodonts would be the number, denticulation and relative position of processes. As far as the denticulation is concerned, the only criterion he used was its presence or absence. He thus ignored characters such as the relative width and height of bars or their curvature. In this way he considered the thickened ridge of Bryantodus to be the only distinction of the genus from Ozarkodina, since the aboral cavity is not an absolute character and varies in size from species to species in both genera.

The disadvantage of this system is that it is the complete reverse of the genetic system and types which are brought together because of a superficial resemblance they bear to each other in a few characters, may be otherwise completely unrelated.

A utilitarian classification of a different sort but with just as drastic results, is that of Hass (1959). This was based upon the fact than an individual conodont is built up by the accretion of lamellae, each of which is open towards the aboral surface, with the result that in all views except aboral, only the most recent lamella is visible. Hass therefore used the aboral cavity as a basis of reference for all other parts of the conodont structure. He believed that the many different forms now recognised, developed because the lamellae in any conodont were separated from each other along growth axes and in one or more directions. Hass therefore separated into different families the closely related genera Lonchodina and Metalonchodina and also Subbryantodus and Ozarkodina and yet grouped together Metalonchodina and Subbryantodus on the basis of the "pulp cavity beneath main cusp at or near the posterior end of a denticulated blade-like unit".

Ellison (1946) and Beckmann (1953) noted that generally the platform conodonts are good index fossils. Müller (1956) however considered that this particular time sensitivity of platform types seemed to be in relation to their systematic significance, since even if the entire animal was known, the systematics would still rely upon those parts which show the most significant evolutionary changes. He therefore believed that a modified classification of isolated platform types would not differ much from a system based upon the entire assemblage containing these and other forms.

It is therefore considered necessary to compromise between the phylogenetic system of classification and the extreme utilitarian scheme. As Müller (1956) pointed out a system of stratigraphic palaeontology, particularly of such isolated types as conodonts, should be an aid to determination and therefore for the bar and blade types of conodonts it is necessary to compromise between the two systems.

Such a compromise is used in the present study, where supra-generic categories are only used for the Hibbardellidae (Müller 1956) and the Polygnathaceae (Müller and Müller 1957) in which the relationships are known. All the other genera are described in alphabetical order.

(c) Conodont Terminology

For many years conodonts were considered to be the mouth parts of an extinct group of vertibrates and their descriptive terminology was based upon this belief. These fossils are however no longer considered to be mouth parts, and as a result many of the standard terms are obsolete and are only retained because they are so deeply entrenched in the literature.

The terminology used in the present study is as follows:-

Aboral	lower surface, surface of attachment.
Aboral Groove	groove or furrow along lower surface of unit.
Adapical	opposite to apical, away from the apex of the unit.
Anterior	in bars, the end bearing the main cusp or away from which the denticles are inclined; in blades the end away from which the denticles are inclined; in platforms the end with the blade; in Spathognathodus the high end; in symmetric forms the end bearing the main cusp.
Anterior Arch	the arch of the lateral limbs in symmetric types.
Anticusp	the downward projection of the main cusp in simple bar types.
Apex	the point where the limbs join.
Apical	towards the apex
Apical lamella	in Apatognathus the slight projection connecting the two limbs.

Arched	curvature in the vertical plane.
Axis of Unit	the long axis.
Bar	any conodont with a main cusp which is much larger than the majority of the remaining denticles. Also the posterior and anterior extensions of the unit.
Bar Cusp	in <u>Apatognathus</u> a cusp on one or both bars in addition to the apical cusp.
Blade	the anterior extension in platform types or those conodonts which are relatively thin compared with height and bear a main cusp in their middle third.
Carina	central nodose or denticulated ridge of platforms.
Compressed	flattened laterally
Cup	Lateral thickenings of the blade on which the platform is built.
Denticles	small teeth borne on a bar, blade or carina.
Germ Denticles	minute, undeveloped denticles
Inner Side	concave lateral side
Height	oral/aboral distance
Keel	Median ridge on aboral side of platforms
Lateral Flange	in <u>Apatognathus</u>, the sharp unthickened margin of the cusp.
Lateral Process	denticulate bar or blade arising on the side of the unit usually at the base or slightly anterior to the main cusp.
Main or Apical Cusp	usually the largest denticle of the unit, situated above the basal pit.
Nodes	tubercles or bumps on a platform or carina.
Oral	oral surface on which denticles are borne, upper surface, surface without basal pit.
Oral Trough	in <u>Mestognathus</u> it is the trough between the parapets; in <u>Streptognathodus</u> and <u>Cavusgnathus</u> it is the longitudinal groove extending along the oral survace of the platform.
Outer side	the convex lateral side.

Parapets	the sides of the platform in Cavusgnathus, anterior extensions of the margins of the platform in Mestognathus.
Platform	Laterally thickened area of the cup on both sides of the carina.
Posterior	Opposite to anterior.
Transverse Ridges	ridges running at right angles to the axis of the unit.
Unit	the complete conodont.

2. SYSTEMATIC PALAEONTOLOGY

(a) Method of Presentation

There has been so much variation in style of systematic descriptions that it is necessary to outline the plan used in this report. This plan is maintained where possible, throughout the description of the new forms in order to attain some measure of uniformity. The latter is naturally desirable as an aid to comparison. The plan is as follows:-

(i) Diagnosis

(ii) Description

- (a) Oral View - where necessary
- (b) Lateral View - usually the inner lateral view but the outer view is described where desirable.
- (c) Aboral View.

(iii) Comparisons

(iv) Discussion

(v) Remarks - where necessary

(vi) Known Range and Distribution

(vii) Occurrence - this refers to the Yoredale Series only and includes a list of horizons and sample numbers.

(viii) Type Specimen - its number and figure

(ix) Number of Specimens

(x) Type Locality

The full list of species found in the Yoredale Series are described in the following three sections:-

(i) New species, named and unnamed, in alphabetical order of genera, plus revised descriptions of previously described species.

(ii) Previously described species, other than those belonging to the Family Hibbardellidae (Müller 1956) or Super Family Polygnathaceae (Müller and Müller 1957), in alphabetical order of genera.

(iii) Previously described species belonging to the Family Hibbardellidae and the Super Family Polygnathaceae in alphabetical order of genera.

The synonomies listed in sections (ii) and (iii) include only those references which give plates or text-figures of the species in question.

(b) Systematic Descriptions

(i) Species described for the first time in the present report plus species with revised descriptions.

GENUS APATOGNATHUS Branson and Mehl 1934

Type Species:- Apatognathus varians Branson and Mehl 1934.

The generic description of Branson and Mehl (1934 p.201) is as follows:-

"Units consisting of a sharply-arched base, the limbs of which are denticulate, bar-like and parallel or slightly divergent. The limbs are joined at the apex on one side of the arch by a thin lamella of variable length. An apical denticle of large size is curved toward one limb of the arch and toward the face of the arch opposite the apical lamella. The limb-teeth are small, discrete and directed toward the face of the arch toward which the apical denticle bends. The symmetry of the arch is broken by the trend of the apical denticle and in some forms by the asymmetrical development of limb denticles".

Known Range and Distribution

North America: Upper Devonian, Lower Mississippian, Middle Mississippian, Permian.

Germany: Upper Devonian, Upper Viséan, Middle Triassic.

Great Britain: Lower (P_2) and Upper (E_2) Limestone Groups of Scotland.

P and E zones of the Northern Pennines.

Belgium: Middle Tournaisian.

Portugal: Upper Devonian.

Africa: Upper Devonian (Sahara).

Cretaceous (Cameroons).

Orientation of Units

The very variable and yet basically simple form of the genus Apatognathus has resulted in much confusion concerning its orientation. Difficulties have arisen over the following factors. 1. The highly arched character of the unit 2. The extreme asymmetry in some forms of the genus and the virtual symmetry of others 3. The variable amount of thickening and twisting which may affect one or both bars 4. The bars are invariably in different planes 5. The very variable denticulation 6. The unequal length of limbs - this applies particularly to the post-Carboniferous forms.

The result is that no two authors have adopted the same method of orientation in their descriptions. The original description and orientation by Branson and Mehl was based upon the assumption that the unit functioned as a sheath about the anterior end of the mandible of the conodontifer, with the limbs or bars roughly horizontal. They therefore suggested the following descriptive terms:- the face of the arch without the connecting lamella was designated upper or oral, the side with the lamella aboral and the limb towards which the apical denticle bends the outer limb or oral bar. As already stated, however, the conodont is no longer considered to be a jaw-supporting mechanism and in addition the orientation suggested by Branson and Mehl causes confusion since it does not follow the accepted pattern for the orientation of conodonts in general.

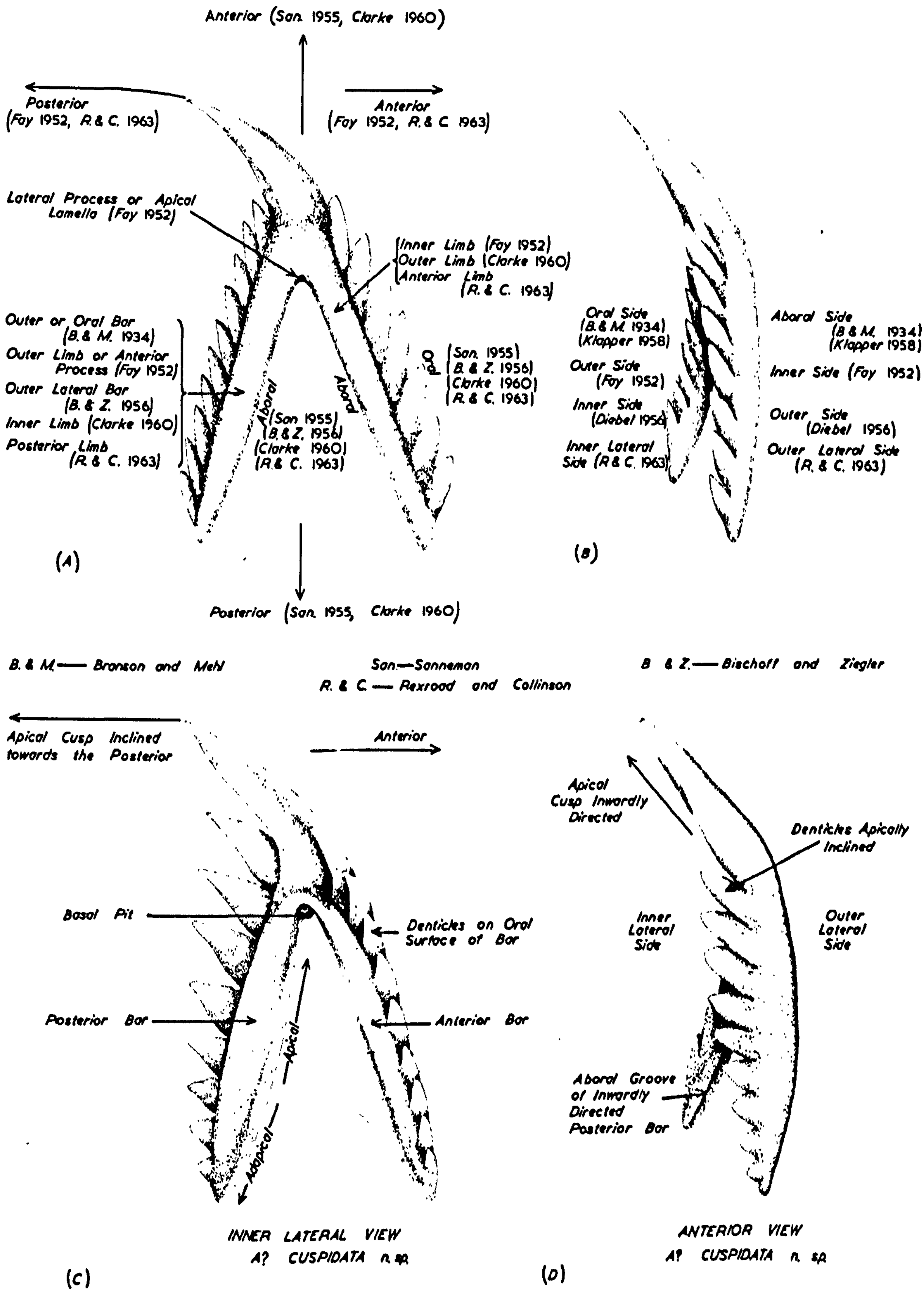


FIG. 11. ORIENTATION AND NOMENCLATURE OF THE GENUS APATOGNATHUS?

(A) and (B) PREVIOUS AUTHORS (C) and (D) PRESENT WORK

The orientations used by all the authors who have previously described this genus are indicated on the hypothetical specimen of Apatognathus in text figs.(11a + b). The orientation and nomenclature used in the present report are indicated in text-figs (11c + d), are outlined below and can be seen to follow the conventional pattern for the majority of conodonts.

The convex side of the unit is the outer lateral side, and the concave side the inner lateral side. The denticles are borne on the oral surfaces of the bars irrespective of the inclination or twisting of the bars. The aboral surface is that which bears the aboral groove and basal pit, the latter being situated at the apex of the unit beneath the base of the apical cusp. The apical cusp always curves away from the anterior bar and towards the posterior bar, whether it be in a sinistral or dextral form.

The posterior bar may be recognised by the use of several factors, including 1. the apical cusp curves towards the posterior bar in asymmetric forms 2. if the bars are unequally thickened the posterior bar always has the greatest amount of thickening 3. the posterior bar is always inwardly directed, in varying degrees, relative to the anterior bar.

In the present report, the genus is referred to as Apatognathus? since it is possible that only the type species is properly classified and all others should be placed in a different genus. The whole question of the various anomolies surrounding this genus are discussed in a later section (page 173).

Apatognathus? chaulioda sp.nov.

Plate 1. Figs. 1-6.

Diagnosis: An Apatognathus? on each bar of which is a bar cusp approximately the size of the apical cusp and separated from the latter by a few small, compressed denticles.

Description: An asymmetric unit with two bars diverging at 26-35°.

Inner Lateral View:-

Two bars of equal dimensions, with inner lateral sides inclined to each other, particularly at the apex. Each bar is divided into an apical and a longer adapical part by a prominent bar cusp. Thickening in mature specimens is concentrated at the apex of the unit and extends equally along each bar as a smooth, wide and sometimes diminishing ridge.

The usually strong apical cusp is of variable length, as wide and thick as a bar at its base, sharply-pointed, posterially curved and inclined and may be laterally flanged. The bar cusps are similar in size and shape, may be even wider at their bases than the apical cusp and are apically inclined.

The denticles between the apical and bar cusps are shorter than the height of the bar and though fused, they may be discrete in juvenile forms. There is a maximum of about 5 denticles in this position on each bar but never more on the posterior bar than on the anterior bar. The remining denticles are discrete, usually longer than the height of the bar and similar in shape to the apical set.

Outer Lateral View:-

A prominent wide ridge curves round the apex of the unit and is gradually reduced along the bars. The aboral margin of the bars is sharp and the apical lamella variable in size.

Anterior View:-

The base of the bar is straight but the height of the bar increases apically and culminates in the inwardly directed apical cusp. Inward inclination of the denticles is slight.

Aboral View:-

The aboral groove is prominent, deep and wide and the basal pit is deep and circular.

Comparisons: This species is distinctive in its possession of a large bar cusp on each bar. A? scalena sp.nov. has a bar cusp on the posterior bar only.

Discussion: The major variations in this species concern the number of denticles between the apical and bar cusps and also the extent of the thickening of the bars. If thickening extends from the apex beyond the base of the bar cusps, the whole length of the bar is usually thickened.

Known Range and Distribution:

The Yoredale Series of the North of England (Upper Viséan) (Present Study).

Occurrence: Hawes Limestone (Samples GB17, GB19, GB18).

Gayle Limestone (Samples GB107, GB109-111, GB113, GB114, GB116, GB142, GB143, GB145, GB166, GB163).

Middle Limestone (Samples MG272, MG278, MG283, MG284, MG285, MG155).

Scar Limestone (Samples SW104, SW105).

Five Yard Limestone (Sample SW73).

Three Yard Limestone (Samples SW86, SW183, SW184, SW186).

Underset Limestone (Samples GG201, GG202, GG203, GG204, GG205).

Four Fatham Limestone (Sample BB206).

Type Specimen: 26(5)GG202. Plate 1. Figs. 1,4.

Number of Specimens: 68

Type Locality: Underset Limestone of Gunnerside Gill, Swaledale G.R. 938006.

Apatognathus? cuspidata sp.nov.

Plate 1. Figs. 7 - 13.

Diagnosis: An Apatognathus? with small subequal denticles on the anterior bar, larger denticles increasing in size apically on the posterior bar and an apical cusp which is more than half the bar length.

Description: An asymmetric species with bars diverging at about 25°.

Inner Lateral View:-

The anterior bar is straight and high with a prominent narrow ridge, which in mature specimens extends the whole length of the bar on the inner side of the denticles. The inner lateral surface is steeply and uniformly inclined inwards. The denticles are triangular, sharply pointed, apically inclined, strongly inclined inwards, with a small decrease in size adapically and number from 8 to 10, but always one in excess of the posterior bar.

The apical cusp is at least half as long as the bars, sharply pointed, as stout as a bar at its base where it is laterally flanged, and inwardly and posteriorly directed.

The posterior bar is straight and highest ⅔rds the distance from the apex. A prominent ridge extends along the bar on the inner side of the denticles. The inclination of the inner lateral side is less than that of the anterior bar and also decreases adapically. Apical and inward inclination of the denticles is also less than on the anterior bar, though they may be larger and more discrete.

Outer Lateral View:-

The base of the apical cusp is smooth, convex and continuous with a strong ridge which extends along each bar. That of the anterior bar curves upwards to the oral margin and accentuates the steep inclination of the outer lateral side. That of the posterior bar is straight. The aboral margins of the bars are sharp. Apical lamella small.

Anterior View:-

The prominent ridge on the outer lateral side forms the base of the bar in this view. Base slightly convex and the height of the bar decreases adapically. The denticles are fused for ⅓rd their length.

Aboral View:-

The aboral groove is narrow, deep and bounded by two prominent ridges. The basal pit is circular.

<u>Comparisons</u>: This species differs from the other species of the genus in its combination of a very large apical cusp, strong regular denticulation and the difference in inclination of the anterior and posterior bars. It does however bear some similarities to the juvenile forms of the species figured by Rexroad and Collinson (1963) as <u>A? porcata</u> (Hinde).

<u>Known Range and Distribution</u>:

Upper Viséan to Lowermost Namurian (E_1)(Present Study)

<u>Occurrence</u>: Simonstone Limestone (Samples MG130, MG131)

Middle Limestone (Samples MG253 to MG257, MG259, MG266, MG285, MG155)

Five Yard Limestone (Sample SW175)

Three Yard Limestone (Samples GG217, SW182, SW86, SW183, SW184)

Underset Limestone (Samples GG201, GG202, GG205, GG211)

Four Fathom Limestone (Samples BB204, BB205, BB207)

Main Limestone (Samples GG214, GG215)

Great Limestone (Samples BB157, BB158, BB159, BB213 to BB216)

Type Specimen: 28(6)BB205 Plate 1 Fig. 10

No. of Specimens: 85

Type Locality: Great Limestone, Borrowdale Beck, Stainmore, Westmorland. G.R. 834160

Apatognathus? gemina (Hinde)

Plate 2. Figs. 1-3.

Prioniodus geminus Hinde 1900, p.344, pl.10, fig.25.

Prioniodina? gemina (Hinde) Holmes, 1928, p.19, pl.5, fig.10.

List after Clarke 1960.

Apatognathus geminus (Hinde) Clarke 1960, p.4, pl.1, figs.1,2.

Description: An asymmetric unit with bars diverging at about 20°.

Inner Lateral View:-

The unit is strong, highly thickened and twisted at its apex. The bars are straight, with the thickening evident as a prominent ridge extending along each bar. The ridge of the posterior bar, where the thickening is most strongly developed, is higher and sharper than that of the anterior bar. The posterior bar is strongly inclined inwards adapically. The apical twisting of the unit results in the bars being in different planes and the aboral side of the anterior bar may be visible in this view. The apically inclined denticles of the anterior bar are irregular but at least equal in length to the height of the bar and with little inward inclination. Inward inclination of the cusp is strong. The latter is inclined slightly posteriorly and is often flanged asymmetrically with the posterior flange being the larger. The cusp is as broad and thick as a bar at its base. The posterior bar denticles are smaller and more numerous than those of the anterior bar, apically and inwardly inclined, roughly triangular in outline and may be fused at their bases.

Outer Lateral View:-

The outer lateral side of the anterior bar is continuous with the base of the denticles and has a low ridge running near the base of the bar. The cusp is smooth, broad, flat and continuous with the bars. The posterior bar has an exaggerated, sharp, narrow ridge extending its whole length. The apical lamella is very small and may not be visible.

Posterior View;

Lateral Thickening of the posterior bar is very strong with the result that its oral surface is wider than the height of the bar, convex and with slightly irregular lateral margins. The apical cusp is thick at its base and curves strongly inwards in a smooth curve.

Aboral View:-

The aboral groove is wide, deep and bounded by two prominent lips. The basal pit is deep and circular.

Comparisons: This species differs from all others of the genus in the exaggerated thickening of the posterior bar.

Discussion: The denticulation of this species is variable but the number of denticles on the posterior bar exceeds those of the anterior bar. Those adjacent to the apical cusp may be somewhat larger than the remaining denticles.

Known Range and Distribution:

Lower (P_2) and Upper (E_2) Limestone Groups of Scotland (Hinde 1900, Clarke 1960).

Upper Viséan (P_2) of the Northern Pennines (Present Study).

Occurrence: Hawes Limestone (Samples GB167, GB17, GB18).

Gayle Limestone (Samples GB107, GB109 to GB114, GB116, GB142 to GB144, GB147, GB163, GB161).

Hardraw Scar Limestone (Sample MG41).

Simonstone Limestone (Samples MG67, MG70, MG131).

Middle Limestone(Samples MG259, MG271, MG273-275, MG279, MG283, MG285, MG155).

Scar Limestone (Sample SW105).

Type Locality: Upper Limestone, Glencart, Dalry.

Apatognathus? librata sp.nov.

Plate 2. Figs. 4-11.

Diagnosis: A robust, wide angled, almost symmetric Apatognathus? with large subequal denticles on both limbs.

Description: Mature specimens are large, strong, approximately symmetric in lateral view and with bars diverging at 45-50°.

Inner Lateral View:-

Both bars are thick, strong, high at the apex, gradually decreasing in height adapically and with flat oral surfaces on which are borne strongly inwardly inclined denticles. The inner lateral surfaces of the bars are steeply inclined towards each other, particularly at the apex, and are almost flat.

Denticles of each bar are subequal, longer than the height of the bar, sharply pointed, in contact for over half their length and with a slight regular decrease in size adapically. In mature specimens a large denticle may be developed on one or both bars and separated from the apical cusp by a denticle of normal size.

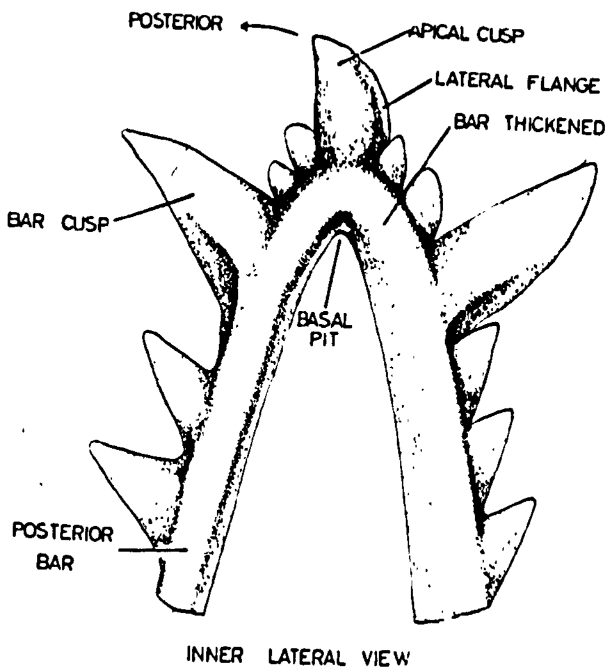
The apical cusp is central, little larger than the denticles and of similar shape, strongly inclined inwards and with no posterior inclination.

Outer Lateral View:-

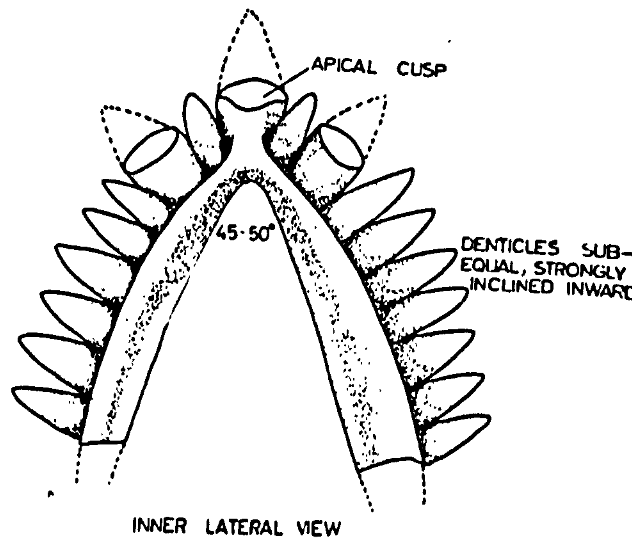
The outer lateral surface in convex and continuous with the outer surfaces of the denticles, the growth lamellae of which are seen to extend into the bars. The small apical lamella is continuous with a prominent ridge which passes down the outer side of each bar becoming more orally placed adapically.

Anterior View:-

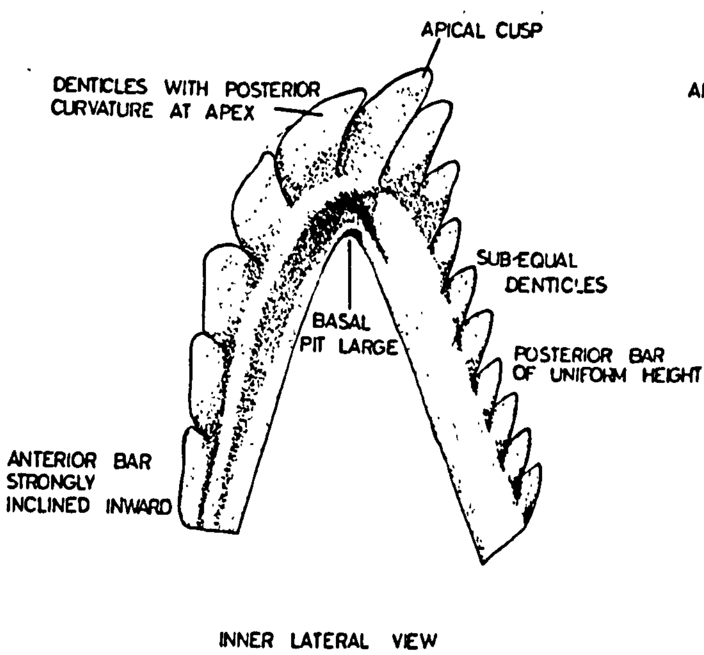
The aboral margin of the bar is slightly convex. The denticles are inclined very strongly inwards and decrease in length adapically. The apical cusp is inwardly inclined at 45-50° and leaves the apex of the unit at an abrupt angle.



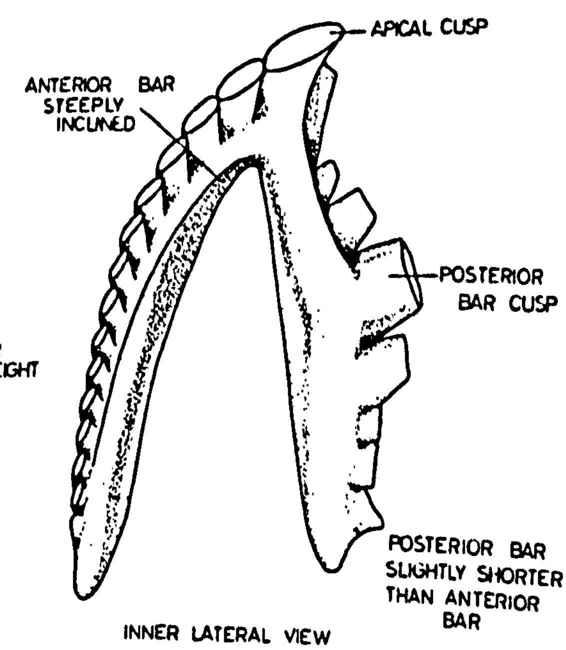
A. Apatognathus? chaulioda



B Apatognathus? librata



C. Apatognathus? petila



D. Apatognathus? scalena

Fig. 12. Morphology of New Species

Aboral View:-

The aboral groove is narrow, shallow and borne on the sharp aboral margin. In mature specimens the basal pit is small and circular.

Discussion: This species is probably the most distinctive of the six species described in this report since no other has such uniform denticulation combined with so high a degree of symmetry. In young specimens the bars are delicate, blade-like and equal in thickness to the denticles, whilst the basal pit is spindle-shaped and relatively larger. The onset of maturity is marked by an extensive thickening of the inner lateral sides of the bars, particularly at the apex. Thus the oral surfaces of the bars become flattened, the inner lateral sides steepened and the basal pit constricted. Thickening also affects the apical cusp and denticles.

Known Range and Distribution:

Upper Viséan to Lower Namurian (E_1) (Present Study).

Occurrence: Gayle Limestone (Samples GB113, GB143, GB144).

Hardraw Scar Limestone (Sample MG32).

Simonstone Limestone (Samples MG64, MG69, MG130-133).

Middle Limestone (Samples MG251-259, MG155).

Five Yard Limestone (Samples SW174, SW175, SW176).

Three Yard Limestone (Samples GG217, SW182, SW86, SW185, SW186).

Underset Limestone (Samples GG201, GG203-205).

Four Fathom Limestone (Samples BB204-207).

Main Limestone (Samples GG213, GG214, GG217-219).

Great Limestone (Samples BB158, BB212, BB159, BB213-216).

Little Limestone (Sample BB123).

Type Specimen: 18(2)MG132. Plate 2 Fig. 9

Number of Specimens: 157

Type Locality: Simonstone Limestone, Whitfield Gill, Askrigg, Wensleydale, G.R.935918.

Apatognathus?petila sp.nov.

Plate 2. Figs. 12-14.
Plate 3. Figs. 1 & 2.

Diagnosis: An Apatognathus? with a small apical cusp, a strongly inwardly inclined anterior bar on which the denticles increase in size apically and a posterior bar with uniform denticulation and no inward inclination.

<u>Description</u>: An asymmetric unit with limbs diverging at 38-43°.

Inner Lateral View:-

The anterior bar is blade-like and curved mainly at the adapical end. The inner lateral side is steeply inclined inwards particularly at the apex. Thickening varies but is often slight. The denticles near the apex of the unit are large, sharply-pointed, sharp edged, apically directed, fused for $\frac{2}{3}$rds their length and highly inclined inwards. In addition those denticles adjacent to the cusp may be posteriorly curved and inclined. Adapically the denticles are shorter and develop an adapical inclination, with the last denticle terminating the bar.

The apical cusp in only slightly larger than the adjacent denticles of the anterior bar, is of similar shape, highly inclined inwards and posteriorly inclined and curved.

The posterior bar is of uniform height, slightly thickened, and is in a plane almost at right angles to that of the anterior bar. It has no inward inclination on its inner lateral side or denticles. The latter are of uniform length, shorter than the height of the bar, fused for $\frac{2}{3}$rds their length, apically directed and narrower and more sharply pointed than those of the anterior bar.

Outer Lateral View:-

The outer lateral surface of the unit is smooth, convex and continuous with the base of the denticles. A low ridge extends down the anterior bar a uniform short distance above the aboral margin and disappears at $\frac{2}{3}$rds the length of the bar. On the posterior bar, however, the ridge crosses the outer lateral surface from an aboral to an oral position and then runs along the base of the denticles. The denticles of both bars may be irregular in shape or contorted in the region of the apical cusp.

Anterior View:-

The aboral margin of the bar is convex. The adapical decrease in height of the bar and length of the denticles is pronounced. The apical cusp and adjacent denticles are directed very strongly inwards.

Aboral View:-

The aboral groove is wide and deep and bounded by two sharp ridges. The basal pit is large and spindle-shaped.

Comparisons: This species differs from others of the genus in its combined lack of a distinct apical cusp and the contrast in inclination of the bars. The latter feature, which is more marked than in A? scalena sp.nov. increases towards the apex, where the denticles and anterior bar may be directed inwards at 90°. The contortion of the denticles in the region of the apical cusp has not been seen in other species.

Discussion: Only a small amount of thickening takes place but denticles may become fused. Posterior bar denticles appear to be most prone to fusion, occasionally becoming completely fused in groups of three. This species bears some similarities with some of the specimens figured by Rexroad and Collinson (1963) as A? porcata (Hinde), particularly the large mature forms but the ontogeny of A?petila sp.nov. shows less variation in form as well as other differences and in view of the fact that the type-specimen of A? porcata (Hinde) is a broken specimen consisting of a single bar, the Yoredale specimens are described as a new species.

Known Range and Distribution:

Upper Viséan to Lower Namurian (E_1) (Present Study).

Occurrence: Gayle Limestone (Samples GB110, GB114, GB115, GB144).

Hardraw Scar Limestone (Samples MG32, MG39, MG41).

Simonstone Limestone (Samples MG130-133).

Middle Limestone (Samples MG252, MG253, MG255-259, MG266, MG155).

Five Yard Limestone (Samples SW174, SW175).

Three Yard Limestone (Samples GG217, SW182, SW183, SW185, SW186).

Underset Limestone (Samples GG201-205).

Four Fathom Limestone (Sample BB206).

Main Limestone (Samples GG212, GG214, GG217, GG218, GG220).

Great Limestone (Samples BB157, BB158, BB212, BB159, BB213-216).

<u>Type Specimen</u>: 16(6)MG39. Plate 3 Fig. 1.

<u>Number of Specimens</u>: 130

<u>Type Locality</u>: Hardraw Scar Limestone, Whitfield Gill, Askrigg, Wensleydale. G.R.939915.

<u>Apatognathus? scalena</u> sp.nov.

Plate 3. Figs. 3-8.

<u>Apatognathus? gemina</u> (Hinde) Rexroad and Collinson 1963 p.7, pl.1, figs. 12-17.

<u>Diagnosis</u>: An <u>Apatognathus?</u> with subequal denticles on the anterior bar and a large, single bar-cusp on the posterior bar.

<u>Description</u>: A highly asymmetric species with bars diverging at about 20°.

Inner Lateral View:-

The anterior bar is straight, twisted on its own axis, its inner lateral side steeply inclined at the apex and less steeply adapically. The apical part of the bar is thickened with its flat oral surface slightly wider than the denticles it bears. Adapically the bar is blade-like and of equal thickness to the denticles. The latter decrease in size adapically and are of uniform shape. The inward inclination of the denticles increases apically and the denticles adjacent to the apical cusp are, in addition, posteriorly inclined.

In young forms the apical cusp appears as a posteriorly directed extension of the anterior bar but in mature forms it is similar in shape and only slightly larger than the adjacent denticles of the anterior bar.

The posterior bar is slightly shorter than the anterior bar and straight, with its inner lateral surface uniformly and less steeply inclined. Occurring at its mid-length is a large, compressed bar cusp, which is wider than the height of the bar. Between the apical and bar cusps are a few denticles which in mature forms are small and regular.

Also in mature forms the denticle on each side of the bar cusp is commonly larger than the others and may rival the bar cusp in size. Adapically from the latter the denticles decrease in size.

Outer Lateral View:-

A prominent sharp ridge extends along each bar from the apex. That of the anterior bar maintains a uniform distance from the aboral margin, but that of the posterior bar curves up to the base of the bar cusp. The anterior bar is of uniform height whereas the posterior bar increases in height from the apex to the bar cusp and then decreases adapically. Apical lamella small.

Anterior View:-

The aboral margin of the bar is sharp and strongly convex. The anterior bar denticles, up to 16 in number, are of uniform width and shape and in contact for most of their length. The bar curves into the inwardly inclined apical cusp in a single smooth curve.

Aboral View:-

The aboral groove is wide, deep and bounded by strong ridges. Basal pit deep and spindle-shaped.

Comparisons: This species differs from other species of Apatognathus? in its large posterior bar cusp which is similar to that found on both bars of A? chauliodа sp.nov. The anterior bar however bears more resemblance to that of A? petila sp.nov. in its uniform denticulation, twisting and high angle of inclination.

Discussion: The bar cusp in young forms is relatively larger than in mature forms.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (E_1) (Present Study).

North America: St. Louis Formation (Meramec). (Rexroad and Collinson 1963).

Occurrence: Simonstone Limestone (Samples MG130-133).

Middle Limestone (Samples MG258, MG259, MG271, MG279, MG285, MG155).

Five Yard Limestone (Samples SW72, SW175).

Three Yard Limestone (Samples GG217, SW182, SW183, SW185, SW.186)

Underset Limestone (Samples GG201, GG202, GG204, GG205)

Four Fathom Limestone (Sample BB205)

Main Limestone (Sample GG217)

Great Limestone (Samples BB212, BB159, BB213, BB214)

Type Specimen: 32(4) BB213. Plate. 3. Figs. 3, 4.

Number of Specimens: 51

Type Locality: Great Limestone, Borrowdale Beck, Stainmore, Westmorland. G.R.834160.

GENUS CAVUSGNATHUS Harris and Hollingsworth 1933.
(for the description and classification of this genus see page 159).

Cavusgnathus middlehopensis sp.nov.
Plate 10. Figs. 10-12.

Diagnosis: A Cavusgnathus with a long, straight blade with a horizontal oral margin and a straight platform with a wide oral trough and finely ornamented parapets.

Description: Oral View:-

The unit is long and straight, with its inner and outer margins parallel, except at the posterior end where the unit is sharply pointed. The inner parapet is narrow, sharp and finely nodose opposite the blade, but posteriorly it may be wider. The fine nodose ornamentation may continue to the posterior end of the inner parapet if this is narrow, but if it widens posteriorly to the blade the ornament changes to that found on the outer parapet and consists of fine, closely spaced, parallel transverse ridges, which disappear into the oral trough. The outer parapet shows less variation in width and usually equals the width of the straight oral trough, which is shallow posteriorly and deepens anteriorly. The blade is denticulate, upright and the same width as the outer parapet. A U-shaped cleft occurs between the blade and the inner parapet at the anterior end of the unit. The cup, which is expanded on the inner side to almost the width of the platform is at least half the length of the unit.

Inner Lateral View:-

The oral margin of the blade is irregularly denticulate, bearing 5 to 8 small fused denticles, of regular size except for the posterior-most denticle, which may be larger though not extending above the horizontal outline. The anterior margin of the blade is convex, the posterior low and vertical. The oral margin of the platform is convex, the outer parapet higher than the inner. The anterior margin of the inner parapet slopes aborally and posteriorly, is sharp and does not extend to the aboral margin of the unit. The latter is concave in outline, although interrupted by the cup. The blade is half the length of the unit.

Aboral View:-

The basal pit is long, shallow and asymmetric and contains a central groove which extends along the sharp aboral margin of the blade.

Comparisons: C.middlehopensis differs from the following species in that C. characta has a shorter blade and possesses a notch between blade and parapet, C.convexa has a shorter blade with a convex oral outline, C. unicornis has a distinct large and long posterior denticle, C.regularis has less fused denticles on the blade, a shorter cup and a convex anterior margin to the inner parapet, and C.cristata is larger, has a narrower oral trough and much coarser ornamentation.

Discussion: Although the number of specimens of this new species is small, they were fairly well preserved, and all occurred in the same sample. These specimens could not be put into any existing species.

Remarks: C. middlehopensis appears to be most closely related to C. convexa and C. regularis.

Known Range and Distribution:

Great Britain: Upper Viséan (Present Study).

Occurrence: Three Yard Limestone (Sample SW181).

Type Specimen: 67/3/SW181 Plate 10 Figs. 10-12.

Number of Specimens: 8

Type Locality: Three Yard Limestone, Middlehope Burn, Westgate, Weardale. G.R.906387.

GENUS GNATHODUS Pander 1856

(For the description and classification of this genus see page 161).

Gnathodus confixus sp.nov.

Plate 12. Figs. 13 - 15.
Plate 13. Figs. 1 - 3.

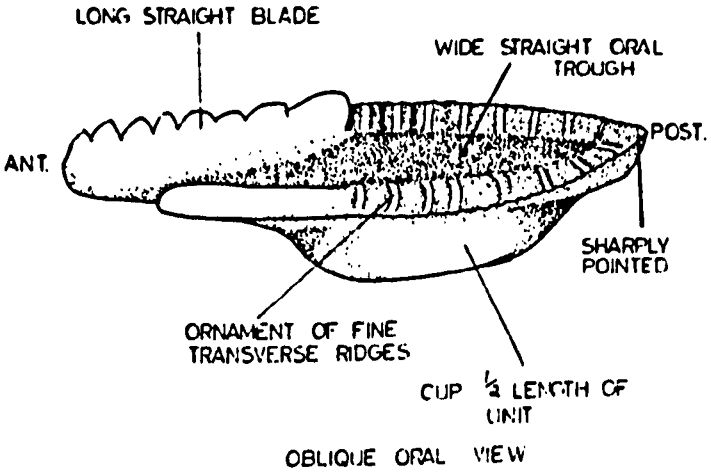
Diagnosis: A species of Gnathodus closely related to G. girtyi, in which the posterior nodes of the inner or inner and outer sides of the platform have become fused with the carina.

Description: Oral View:-

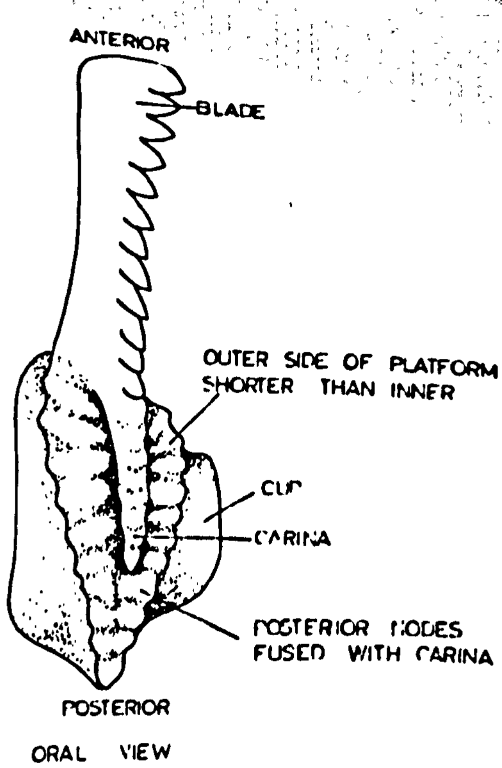
The unit is straight or slightly bowed. The blade is as long as the platform, thin and denticulated. The platform is asymmetric, the inner side longer than the outer, with both sides extending to the posterior margin of the unit. The sides of the platform are of equal width in the posterior part but anteriorly the inner side increases in width and becomes wider than the outer side. The ornamentation of the anterior part of the platform consists of ridges and or nodes as in G. girtyi girtyi but posteriorly fusion takes place between the nodes of the platform and the carina. A single, central node is usually situated at the posterior limit of the platform. Anterior to this the first 1 or 2 nodes of both sides of the platform or 1, 2 or 3 nodes of the inner side are fused to the carina. In the first case ridges are produced which traverse the platform and in the second they extend to the carina, the outer side being noded in the normal manner. A combination of these two patterns produces some forms with 1½ or 2½ ridges traversing the posterior end of the platform.

Lateral and Aboral Views as in G. girtyi girtyi.

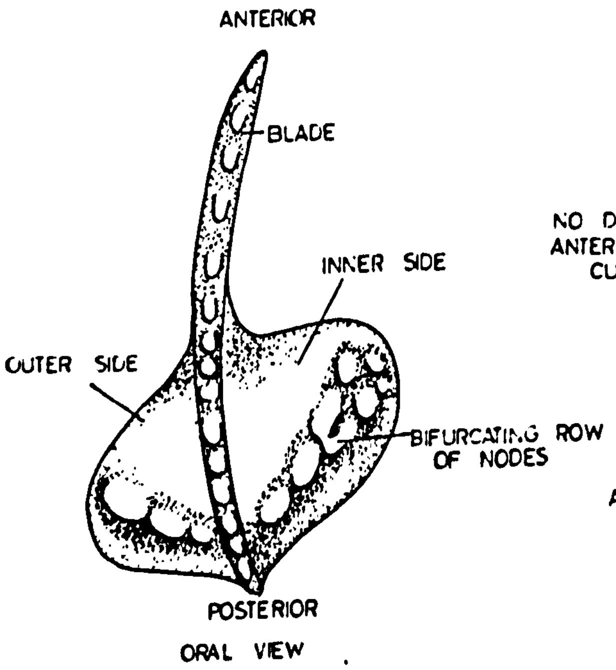
Comparisons: G. confixus differs from G. girtyi girtyi in possessing posterior nodes which have become fused to the carina producing strong



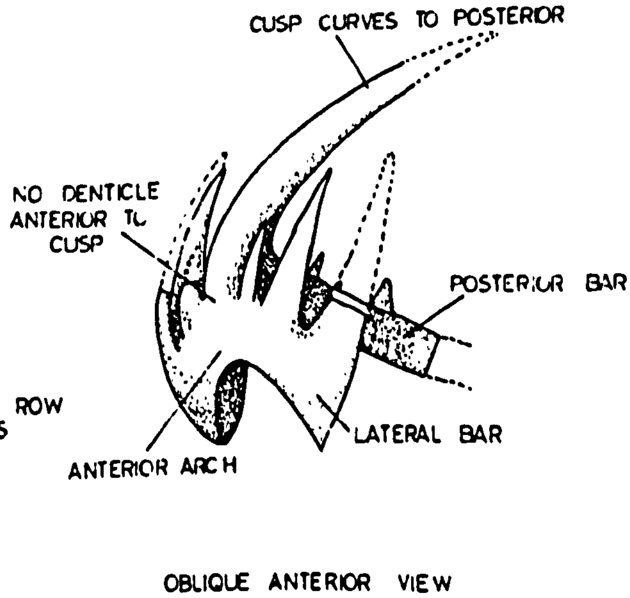
A **Cavusgnathus middlehopensis**



B **Gnathodus confixus**



C **Gnathodus nodosus radiolus**



D **Hibbardella apsida**

Fig. 13 Morphology of New Species and Variety transverse ridges crossing the whole or half the width of the platform. It differs from G. girtyi sulcatus in possessing a strong carina, much stronger posterior ornamentation and a pointed posterior extremity to the unit.

Discussion: G. confixus was confined to the Mirk Fell Beds, the highest of the succession. Although closely related to G. girtyi it has been described as a separate species because of the fusion which takes place between the nodes of the carina and platform. To include such transitional forms into G. girtyi would necessitate even wider limits for that species. This fusion is regarded as a late development from G. girtyi resulting in G. confixus being transitional between that species and other genera which originated in the Namurian. Those forms of G. confixus in which fusion involved both sides of the platform with the production of complete transverse ridges could have given rise to Idiognathodus, whilst those in which the outer side remained unaffected could have produced Idiognathoides by the obliteration of the inner side of the platform.

Known Range and Distribution:

Great Britain: Lower Namurian (E_2) (Present Study).

Occurrence: Mirk Fell Beds (Samples MF191, MF192, MF194, MF196, MF197, MF198).

Type Specimen: 78/2/MF191 Plate 12 Fig. 14.

Number of Specimens: 243

Type Locality: Mirk Fell Beds, Tan Hill, Swaledale. G.R.912072.

Gnathodus girtyi Hass 1953

Gnathodus girtyi	Hass 1953, p.80, pl.14, figs. 22-24.
Gnathodus girtyi	Hass, Elias 1956, p.118, plIII, figs 30,31.
Gnathodus girtyi	Hass, Bischoff 1957, p.24, pl4, figs. 16-23.
Gnathodus girtyi	Hass, Flugel and Ziegler 1957, p.40, pl3, figs.6,9-13,20.
Gnathodus clavatus	Clarke 1960, p.25, pl.IV, figs. 4-9.
Gnathodus girtyi	Hass, Higgins 1961, pl.1, fig.4.
Gnathodus girtyi	Hass, Meischner 1962, p.31, fig.10.
Gnathodus girtyi	Hass, Higgins 1962, pl.3, fig.31.

In his description of the species Hass (1953, p.80) remarked that "G. girtyi resembles G. texanus but the two species can be identified by the ornamentation of the cup." It therefore appears that Hass encountered less variation in form than has been encountered in the present study since the variation also affects the shape of the platform and most specimens differ in this respect from G. texanus as well as in ornamentation. In addition the exact form described by Hass has not been encountered in Great Britain and it is possible that it is fairly atypical of the species.

Gnathodus girtyi var sulcatus Higgins 1961, in manuscript, is also described and includes several distinctive specimens which show much less variation than G. girtyi girtyi.

Gnathodus girtyi Hass var girtyi

Plate 14. Figs. 1-15.

Description: Oral View:-

The unit consists of an anterior blade and a posterior platform, usually of about equal length, bowed or straight, The blade is thin and sharp anteriorly but thickens posteriorly, sometimes strongly, and in some cases may be as thick as the width of the platform at its junction with the latter. The sharply-pointed denticles of the blade are upright and merge posteriorly into the nodes of the carina. The latter may vary in width, may be fused into a longitudinal ridge or bear discrete nodes and extends to or beyond the pointed posterior margin of the platform. The platform is usually asymmetric, with its lateral margins crenulate or smooth, convex or with its outer side parrellel to the carina, or its inner side sigmoidal and widest anteriorly. The inner and outer sides of the platform may be equal or unequal in width. The anterior and posterior margins of the two sides of the platform may originate from the same positions on the carina, but usually the inner side is more anteriorly set.

The ornamentation consists of strong transverse ridges and large or small, discrete or fused nodes. The inner side of the platform is usually ridged and the outer side noded but this is not always the case.

Both sides may have similar ornamentation or the ornament may change along the platform, often from ridges anteriorly to nodes posteriorly. When the carina extends beyond the platform it may or may not bear large bulbous nodes. If the inner side of the platform is unusually short, the posterior part of the inner side of the unit may be decorated with one or several nodes parallel to the carina and not situated on the platform. Occasionally the nodes of the carina and platform may become much enlarged at the posterior end of the unit.

The cup is smooth, wide on the outer side and long on the inner side.

Lateral view:-

The aboral margin of the unit is straight or concave and the posterior end may be aborally projecting. The summit line of the blade is strongly denticulate, highest at about 3 denticles from the anterior end, from which it decreases in height in both directions. The summit line of the carina is nodose or fused, usually convex, usually considerably higher than the outer side of the platform, and occasionally lower than the inner side. The anterior margin of the unit is straight upright or convex. The posterior margin is upright or posteriorly sloping.

Aboral View:-

The base of the blade is thin and grooved. The groove passes posteriorly into the large basal pit, which is deepest at the centre or anterior to this point. The outer side of the basal pit may be deeper than the inner.

Discussion: G. girtyi is the most dominant single species of the Yoredale conodont faunas, and has been found throughout the succession except the Little and Crow Limestones. The variation witnessed is wide and a later section of this report (page 178) is devoted to a consideration of the variation and distribution of the various forms of this species through the Yoredale succession.

Known Range and Distribution:

Belgium: Upper Viséan to Lower Namurian (Serre and Lys 1960, Bouckaert and Higgins 1963).

France: Viséan (Remack-Petitot 1960, Lys, Mauvier and Serre 1962).

Germany: Viséan (Bischoff 1957, Flugel and Ziegler 1957, Meischner 1962).

Great Britain: Upper Viséan to Lower Namurian (Clarke 1960, Higgins 1961, Present Study).

North Africa: Viséan to Lower Namurian (Remack-Petitot 1960).

North America: Meramec to Chester (Hass 1953, Elias 1956, Rexroad and Jarrell 1961, Collinson Scott and Rexroad 1962).

Spain: Upper Tournaisian to Upper Viséan (Higgins 1962, Higgins, Wagner-Gentis and Wagner 1964).

Occurrence: Hawes Limestone (Samples GB17, GB19, GB167).

Gayle Limestone (Samples GB107-114, GB116, GB117, GB142-146, GB148, MG160, MG165, MG166).

Hardraw Scar Limestone (Sample MG40).

Simonstone Limestone (Samples MG69, MG70, MG130-133).

Middle Limestone (Samples MG135, MG250-259, MG272, MG274, MG276, MG278, MG283-285, MG155).

Scar Limestone (Samples SW104, SW105).

Five Yard Limestone (Samples SW172, SW174, SW73, SW175).

Three Yard Limestone (Samples GG217, SW182, SW86, SW183-186).

Underset Limestone (Samples GG202-205, GG211).

Four Fathom Limestone (Samples BB202-204, BB206).

Main Limestone (Samples GG212-214, GG216, GG219-222, GG226).

Great Limestone (Samples BB157, BB158, BB212, BB159, BB213-216).

Mirk Fell Beds (Samples MF191, MF192, MF194, MF196, MF197).

Gnathodus girtyi Hass, var. *sulcatus* Higgins 1961 in manuscript.

Plate 13. Figs. 11, 12, 14, 15.

Description: Oral View:-

The axis of the unit is slightly bowed. The blade is strong and thick, $\frac{1}{3}$ of the width of the anterior part of the platform. The platform is long, heavy, posteriorly rounded and widest anteriorly. The inner and outer sides of the platform are of equal height and the same height as the carina in the posterior part but slightly lower anteriorly. The outer side is of uniform width, ornamented with short nodose ridges anteriorly and nodes posteriorly with a smooth area free from ornament adjacent to the carina. The nodes encircle the posterior margin of the unit and gradually change once more on the inner side to anterior transverse ridges, on the laterally expanded part of the platform. The carina is thick and fused or nodose anteriorly but degenerates posteriorly into a row of discrete central nodes.

Lateral View:-

The base of the unit is almost straight. The denticulate blade merges posteriorly into the strongly fused carina. The posterior margin of the unit is high and vertical and the ornament of the platform low and regular.

Aboral View:- As for G. girtyi girtyi.

Comparisons: This variety differs from G. girtyi girtyi in having a rounded posterior margin, a platform which equals the carina in height and a carina which degenerates into a row of discrete nodes.

Discussion: G. girtyi sulcatus is a relatively uncommon form of this species and is actually found in its typical development in the Hawes Limestone, at the base of the succession and in the Mirk Fell Beds at the top of the succession. However there are very closely related forms which have been included under this heading and which fit the diagnosis given by Higgins (1961), in the Three Yard, Underset (=Four Fathom) and Main (=Great) Limestones. In the latter forms the carina is nodose along its whole length, but the nodes are not as discrete as those described.

Remarks: The gradual degeneration of the carina is a line of development which could have given rise to Streptognathodus in the Namurian.

Known Range and Occurrence:

Great Britain: Upper Viséan to Middle Namurian.

(Higgins 1961, in manuscript; Present Study).

Occurrence: Hawes Limestone (Sample GB18).

Three Yard Limestone (Samples GG217, SW186).

Underset Limestone (Samples GG204, GG205).

Four Fathom Limestone (Sample BB204).

Main Limestone (Sample GG218).

Great Limestone (Samples BB159, BB213-215).

Mirk Fell Beds (Sample MF191).

Gnathodus nodosus Bischoff 1957

(For synonomy see page 170).

Gnathodus nodosus Bischoff var. radiolus nov

Plate 12. Figs. 8-12.

Diagnosis: A variety of G. nodosus the platform of which bears a bifurcating, double or clustered row of nodes on the inner or inner and outer sides.

Description: Oral View:-

The unit is bowed and consists of an anterior blade and a posterior platform of about equal length. The blade is thin, denticulate and thickens posteriorly where it merges into the broad, nodose carina of the platform. The latter is very roughly circular in outline but rarely symmetric, usually being wider than its length and having a more pronounced development posteriorly on the outer side and anteriorly on the inner side. The surface of the platform is smooth except for the rows of nodes on the inner or inner and outer sides. The nodes may be arranged in a bifurcating row, a double row, or clustered, though in the latter case still maintaining the anteriorly radiating orientation which is common to all these forms. The inner and outer rows of nodes usually originate from the same point on the carina but when this is not the case, the inner is anterior to the outer. The outer rows of nodes are never longer than those on the inner side, though they may be shorter. The nodes do not normally extend to the margin of the platform but occasionally they do this and may project beyond the margin.

Lateral View:-

The oral margin of the unit is straight or slightly convex, denticulate anteriorly becoming nodose posteriorly. The anterior margin of the unit is sharp and vertical and the posterior margin sloping and indented at half its height. The aboral margin of the unit is slightly concave in broad outline but is complicated by the outline of the cup, which may be straight, concave or convex. The platform is hemispherical with the rows of nodes at or near the summit, usually not projecting above the oral margin of the carina but occasionally doing so.

Aboral View:-

The basal pit is found beneath the whole extent of the platform, deepest at its centre and contains a central groove which extends anteriorly as the gradually diminishing aboral groove on the very sharp aboral margin of the blade.

Comparisons: G. nodosus radiolus differs from G. commutatus in having platform ornamentation, from G. homopunctatus in having a more circular cup with nodes arranged radially, from G. multinodosus in having nodes arranged in radial rows which may extend to the margin of the cup, and from G. nodosus in having nodes orientated in bifurcating, double or clustered rows.

Discussion: G. nodosus radiolus develops from G. nodosus in the upper part of the Yoredale sequence and is found in association with the latter in the Main (=Great) Limestone. The emended diagnosis of Gnathodus commutatus nodosus (Higgins 1961, p.213), which is here raised to specific level, (see page 167), states that the latter bears a node or nodes on the inner or inner and outer sides of the cup. G. nodosus radiolus forms a transitional series with G. nodosus in that the single row of nodes of the latter bifurcates or is replaced by a double row of nodes or an orientated cluster of nodes. The relationship of this new variety is thus much closer to G. nodosus than to G. multinodosus in which the nodes lack orientation and are found irregularly over the upper surface of the unit.

Known Range and Distribution:

Great Britain: Lower Namurian (E_1) (Present Study).

Occurrence: Main Limestone (Samples GG213-215, GG217, GG219-222, GG226).

Great Limestone (Samples BB159, BB213, BB215).

Type Specimen: 69/2/BB159 Plate 12. Fig. 11.

Number of Specimens: 39

Type Locality: Great Limestone, Borrowdale Beck, Stainmore, Westmorland. G.R. 834160.

GENUS HIBBARDELLA Bassler 1925

(For description and classification of genus see page 152).

Hibbardella apsida sp. nov.

Plate 9. Figs. 7, 8, 10, 11.

Hibbardella milleri Rexroad, Clarke 1960, p.6, pl.1, fig.6.

Hibbardella milleri Rexroad, Higgins 1961, pl.XII, fig.7.

Diagnosis: A species of Hibbardella with short, steeply inclined lateral bars, which are in the same plane and at 45° to each other and bear denticles which increase in size away from the strongly recurved cusp.

Description: Oral View:-

The anterior margin of the unit is straight or slightly convex with the lateral bars in more or less the same plane and forming a T-shape with the posterior bar. The lateral bars and posterior bar are of equal thickness to each other and to the posteriorly curving and oval-sectioned cusp which they support at their junction. The denticles of the lateral bars are long, slender and posteriorly curving.

Lateral View:-

The strongly convex anterior margin consists of the recurved cusp and the aborally and posteriorly curving lateral bar(s). The thickness of the cusp diminishes only gradually upwards. The posterior bar is slightly arched and bears discrete denticles of two sizes on its convex upper surface. The denticles of the lateral bars are sharply pointed, slender, anteriorly inclined at their bases but posteriorly curving upwards.

Anterior View:-

The anterior arch is acute, with the angle between the lateral bars being about 45°. The latter are short, increase in height distally and bear 3 discrete denticles which increase in length away from the upright cusp. Base of lateral bars sharp.

Aboral View:-

The basal pit is small, circular and situated beneath the cusp from where prominent aboral grooves pass along the narrow aboral surfaces of the three bars.

Comparisons: This species differs from H. milleri in having a more acute angle between the lateral bars and lacking a denticle anterior to the cusp. It differs from H. ortha in having a more acute angle between the lateral bars and a large strongly recurved cusp.

Discussion: The number of specimens available was small but the species is distinct from H. Milleri and the amount of variation is slight. In his description of H. milleri Rexroad (1958, p.18) stated that his species was "characteristically with a small central denticle immediately anterior to the main cusp". This denticle has not been seen in any of the Yoredale specimens and Clarke (1960) also remarked on its absence from his specimens from the Lower Limestone Group of Scotland. The specimens figured by Higgins (1961) have also been examined and these too lack the anterior denticle, and in common with those specimens from Scotland and the present study have a more acute angle between the anterior arch. The records of Clarke (1960) and Higgins (1961) are therefore placed in synonomy with this new species which appears to be fairly restricted stratigraphically.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian
(Clarke 1960, Higgins 1961, Present Study).

Occurrence: Main Limestone (Sample GG226).
Great Limestone (Samples BB159, BB213, BB214, BB215).

Type Specimen: 50/6/BB213 Plate 9. Figs. 7, 8, 10, 11.

Number of specimens: (in the Present Study) 6.

Type Locality: Great Limestone, Borrowdale Beck, Stainmore, Westmorland. G.R. 834160.

GENUS HINDEODELLA Bassler 1925

(For generic description see page 110).

Hindeodella hamatilis sp.nov.

Plate 4. Figs. 4, 6-9.

Diagnosis: A Hindeodella with a small apical cusp and inward curvature of the extremity of the anterior bar, the denticles of which are inwardly, outwardly and upwardly directed in successive part of the bar.

Description: Oral View:-

The posterior bar is thick and straight or slightly bowed. The unit thins at the cusp and the anterior bar is only half as thick as the posterior bar and inwardly curving at its extremity. The posterior bar denticles are inwardly curved and inclined. The cusp is strongly curved and inclined inwards, the anterior bar denticle adjacent to the cusp has little or no inward inclination, the next three denticles are outwardly inclined, sometimes strongly and the remaining 2 or 3 denticles at the anterior extremity are upright.

Inner Lateral View:-

The posterior bar is straight or slightly arched and the anterior bar may have a slight downward curvature. The anterior bar is slightly higher than the posterior bar. The denticles of the posterior bar are in two sets, the larger up to twice as long as the height of the bar and separated by two or three short denticles. All are sharply pointed and needle-like. The cusp is small, circular in section, diminishing rapidly in thickness upwards and posteriorly inclined. The denticles of the anterior bar, five to eight in number, may be more uniform in size than those of the posterior bar. Those anterior bar denticles adjacent to the cusp are posteriorly inclined, but anteriorly they become upright and may have a slight anterior inclination. The anterior margin of the unit is upright or aborally posteriorly inclined.

Aboral View:-

Groove wide, straight and shallow on the posterior bar. That of the anterior bar is correspondingly narrow. Basal pit small or indistinguishable.

Comparisons: This species appears to be most closely related to H. germana. However, it is distinct in having a circular cusp, little larger than the larger denticles and more strongly inwardly and posteriorly inclined than the large cusp of H. germana. Also the anterior bar denticles differ in attitude, for although the anterior denticles of H. germana may have a slight outward and anterior inclination this is greatly exaggerated in H. hamatilis sp.nov., an exaggeration which is increased by the strong inward inclination of the cusp.

Discussion: The main variation in this species concerns the relative length of the anterior bar denticles. Some specimens have almost uniform denticles whilst in others the denticles are separated by germ denticles. The amount of inward curvature of the anterior bar is also variable.

Known Range and Distribution:

Upper Viséan to Lower Namurian (E_1) (Present Study).

Occurrence: Gayle Limestone (Samples GB106, GB111, GB145).
Simonstone Limestone (Samples MG70, MG131-133).
Middle Limestone (Samples MG252, MG259).
Four Fathom Limestone (Sample BB206).
Great Limestone (Samples BB158, BB159).

Type Specimen: 51/5/MG132 Plate 4. Figs. 4, 7.

Number of specimens: 11

Type Locality: Simonstone Limestone, Whitfield Gill, Askrigg, Wensleydale. G.R.935918.

GENUS HINDEODUS Rexroad and Furnish 1964

Type Species:- Trichonodella imperfecta Rexroad 1957.

The generic description given by Rexroad and Furnish (1964, p.671) is as follows:-

"Because this genus includes homeomorphs of an established genus and is based upon phylogeny rather than morphology, diagnosis and description must include evolutionary relationships. Hindeodus is derived from Hindeodella. Hindeodus includes specimens that evolved directly from Hindeodella and are morphologically like the Devonian genus Falcodus Huddle. Further development of Hindeodus results in a symmetrically arched form that has a small pit below the main fang and lacks a posterior bar. Only these two forms of Hindeodus, together with transitional specimens, have been recognised with certainty as belonging within the one lineage."

They further remarked, "One form of Hindeodella found in the Pella Formation has a shortened posterior bar bearing denticles of nearly equal size rather than alternate ones as is typical. The trend of shortening of the posterior limb and equalization of denticles combined with the development of the anterior process, leads from this Hindeodella to the species formally referred to as Falcodus? alatoides. Continuation of the equalization of the limbs results in the species formerly referred to as Trichonodella imperfecta and Synprioniodina? compressa."

Known Range and Distribution:

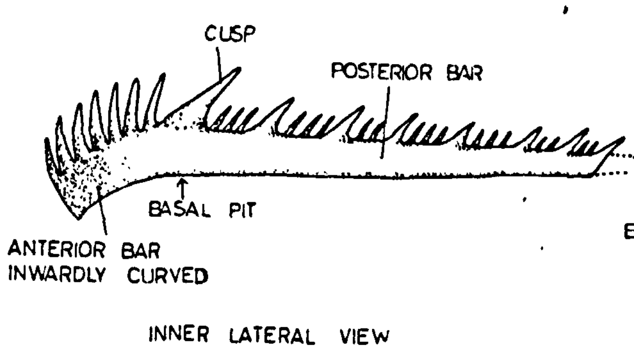
North America: Upper Mississippian and Lower Pennsylvanian (Ellison and Graves 1941, Rexroad 1957, Rexroad and Burton 1961, Rexroad and Furnish 1964).

Great Britain: Upper Viséan and Lower Namurian (Present Study).

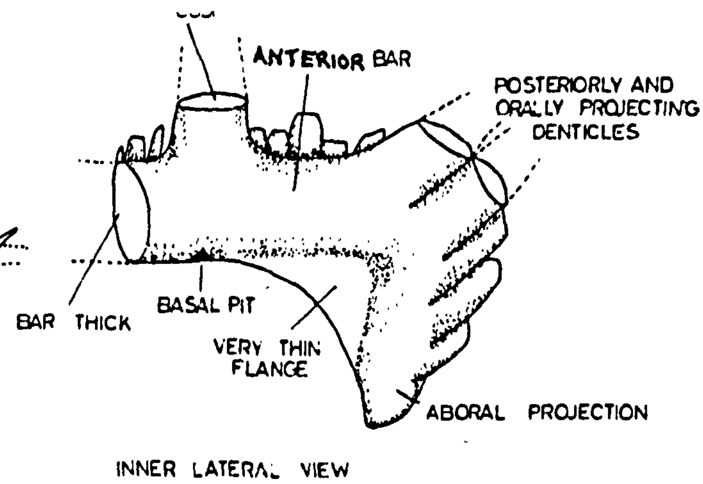
Hindeodus sp. A.

Plate 4 Fig . 16

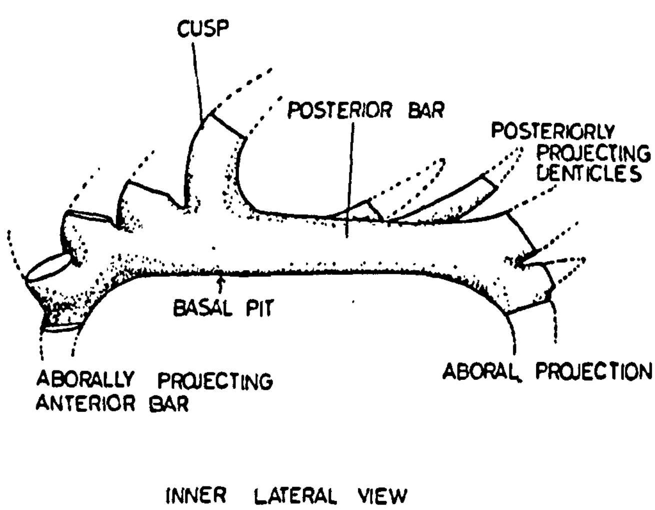
Discussion: Only eight incomplete specimens referrable to the genus Hindeodus have been obtained from the Yoredale Series. Five of these are grouped together as Hindeodus sp. A., for although they quite



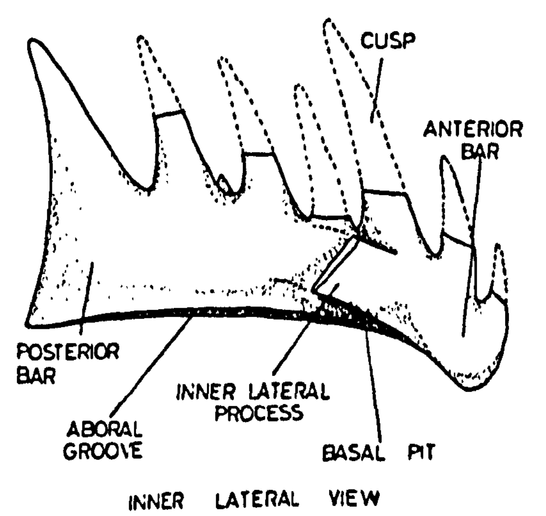
A **Hindeodella hamatilis**



B **Hindeodus sp. A.**



C **Hindeodus sp. B.**



D **Lambdagnathus n. sp. A.**

Fig. 14. Morphology of New Species

obviously vary widely, they appear to be related to each other, particularly in the nature of their Hindeodella-like denticulation. One specimen (Sample MG259, Plate 4 Fig. 16) is closely similar to Hindeodus alatoides (Rexroad and Burton 1961) but differs in that the aboral projection of the anterior bar is more strongly developed and bears three upwardly and anteriorly inclined denticles as well as two large anteriorly inclined denticles at the junction of the bar and projection. The latter denticles, though broken, must have rivalled the cusp in size. A further contrast is that the anterior downward projection of the Yoredale specimens is at 90° to the anterior bar. The cusp is upright and bears beneath it in the slight angle of the two bars, a small basal pit.

One other badly broken specimen is closely similar to the above (Sample MG257).

The three remaining specimens (Samples BB156-two, and GG211) show a close relationship to each other and differ from the specimen outlined above in the much greater length of the anterior bar. They also illustrate the close relationship with Hindeodella although each bears the large anteriorly directed denticle characteristic of the genus Hindeodus.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (E_1)
(Present Study).

Occurrence: Middle Limestone (Samples MG257, MG259).
Underset Limestone (Sample GG211).
Great Limestone (Sample BB156).

Hindeodus sp. B.

Plate 4. Fig. 15.

The three specimens in Hindeodus sp.B., are certainly of one species and most closely resemble the specimen figured by Rexroad and Furnish (1964) as Hindeodus sp. (plate III, Fig.II).

Description: The unit is thick and consists of a downwardly and inwardly curving anterior bar bearing at least three fairly large discrete denticles which are circular in cross-section. From the two other fragments, however, it is possible that this bar had at least 6 denticles and curved downwards and inwards until it was at 90° to the posterior bar in the horizontal as well as the vertical plane.

The cusp is as thick as the bars, large, circular in cross-section and posteriorly curving.

The posterior bar is larger than the anterior bar, straight and with a few large denticles, terminating in a larger posteriorly directed denticle which rivals the cusp in size and continues aborally as a denticulated downward projection.

Discussion: Hindeodus sp. B. shows less variation than Hindeodus sp. A. and also bears much less similarity to the Hindeodellids since the bars are as thick as high and the denticles much fewer in number, larger and circular in cross-section.

Known Range and Distribution:

Great Britain: Lower Namurian (E_2) (Present Study).

Occurrence: Mirk Fell Beds (Sample MF190).

GENUS LAMBDAGNATHUS Rexroad 1958

(For the generic description turn to page 116).

Lambdagnathus n.sp.A.

Plate 5. Fig. 3.

Description: Unit short and arched.

Oral View:-

The anterior and posterior bars are continuous and outwardly curving posteriorly. The inner lateral process, of equal thickness to the bars at its point of emergance, curves sharply posteriorly until it becomes almost parallel with the posterior bar. The triangular cusp is situated at the junction of the three processes and curves posteriorly and inwardly in line with the inner lateral process. The posteriorly directed denticles curve inwards only slightly.

Inner Lateral View:-

The aboral margin of the unit is arched. The short anterior bar is $\frac{1}{4}$ to $\frac{1}{3}$ the length of the posterior bar, thin and bearing one or two highly compressed, sharp-edged denticles. The posterior bar is thicker than the anterior bar, increases in height posteriorly and bears about four large, wide, sharp-edged, compressed denticles which increase in size posteriorly. Occasional minor denticles may occur. The cusp is similar to the denticles, being triangular in section only at its base. The inner lateral process is not as high as the bar at its point of emergance and is directed inwards and slightly orally relative to the posterior bar. The aboral groove may be visible in this view.

Aboral View:-

The base of the unit is wide, widest at the midlength of the posterior bar. The aboral groove is wide and deep and bounded by two pronounced lips, the outer being the more prominent. The deep, triangular basal pit is at the junction of the three processes.

Comparisons: L. n.sp.A. differs from L. fragilidens Rexroad, in having a very short anterior bar and fairly short posterior bar. The inner lateral process was in all cases incomplete. It also differs from L. macrodentata Higgins in having a short posterior bar which increases in height posteriorly, an inner lateral process which is posteriorly and orally projecting and in lacking regular minor denticles separating the smaller number of major denticles.

Discussion: The small number of specimens available (4), none of which are complete, does not warrant a complete description and name, even though the specimens are considered to belong to a new and separate species.

Known Range and Distribution:

Great Britain: Upper Viséan (Present Study).

Occurrence: Gayle Limestone (Sample GB112).

Simonstone Limestone (Samples MG131, MG132).

Middle Limestone (Samples MG259, MG272).

Lambdagnathus sp.B.

Plate 5. Figs. 4, 5.

Discussion: Two small fragile specimens were found which do not fit into either L. fragilidens or L. macrodentata and similarly do not belong to L. n.sp.A., described in the present report. These two specimens both from the Middle Limestone, had the following distinguishing features:- a straight, thin, blade-like posterior bar of uniform height, bearing uniformly short, triangular, widely spaced denticles, a very short non-denticulate anterior bar in line with the posterior bar, and a thin posteriorly curving inner lateral process. In each case the latter was broken, non-denticulate and in the same horizontal plane as the bars. The cusp was indistinguishable from the denticles.

Known Range and Distribution: Very rare, found only in one locality from the Upper Viséan (Present Study).

Occurrence: Middle limestone (Samples MG272, MG283).

GENUS LIGONODINA Bassler 1925

(For the generic description turn to page 117).

Ligonodina n. sp.A.

Plate 5 Figs. 15, 16.

Description: Unit small and fragile.

Oral View:-

The posterior bar is thin, twisted and outwardly curving posteriorly. The inward curvature of the denticles increases distally. The inner lateral process is posteriorly directed, the same thickness as the posterior bar and bears three posteriorly and inwardly curving denticles.

Inner Lateral View:-

The posterior bar is long, arched, delicate, with a convex oral surface and truncated base and bears posteriorly directed denticles in two sets. The larger are about as wide at their bases as the height of the bar and are separated by 2 or 3 much smaller denticles. The cusp is twice the thickness of the larger denticles, posteriorly curving and of unknown length. The aborally directed inner lateral process originates at the anterior margin of the cusp as in L. tenuis with its first denticle anterior to the cusp, although not in line with the latter and the two remaining denticles each larger than the one preceding it. The process ends in a thin rounded termination.

Aboral View:-

The base of the unit is truncated and very narrow, its whole width being occupied by a strong aboral groove, which expands into a small basal pit beneath the cusp.

Comparisons: Ligonodina n.sp.A. resembles L. tenuis in the attitude of its inner lateral process but it differs in that it has a long, thin, posterior bar which is well denticulated and an inner lateral process which is thinner and bearing posteriorly curving delicate denticles. L. n.sp.A also closely resembles L. fragilis Hass 1953, but differs in that the posterior bar of the latter is straight and untwisted with denticles alternating singly in size, its inner lateral process bears 4 or 5 denticles and finally in the presence, in the latter, of a strong ridge along the aboral margin of the unit.

Discussion: Although this species is considered to be quite distinct, relatively few specimens have been obtained, all of which were incomplete. The species therefore remains unnamed.

Remarks: Ligonodina n.sp.A appears to be most closely related to L. fragilis Hass.

Occurrence: Gayle Limestone (Samples GB117, GB144).
Simonstone Limestone (Sample MG133).
Great Limestone (Samples BB159, BB215, BB216).

GENUS LONCHODINA Ulrich and Bassler 1926

(For generic description turn to page 124).

Lonchodina n.sp.A.

Plate 6. Figs. 6,7.

Description: This is only a single specimen but it is well preserved and has an unusual arrangement of its denticles.

Oral View:-

The anterior bar is straight and increases in width towards the cusp. The inward curvature of the denticles also increases in this direction, being very slight distally. The cusp is strongly inclined inwards and is biconvex in section, with sharp anterior and posterior margins. The posterior bar is strongly directed outwards at about 60° to the plane of the anterior bar, is slightly sinuous and only half the thickness of the anterior bar.

Lateral View:-

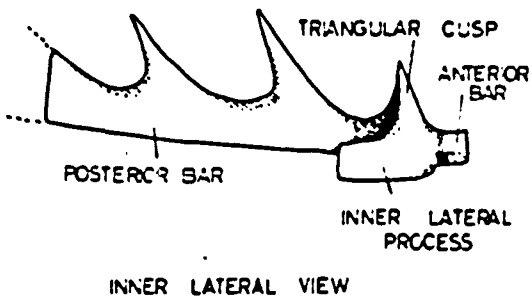
The unit is large and strongly arched, with a high, downwardly projecting, strongly thickened anterior bar bearing eight denticles. The latter vary considerably in size and shape. The three proximal denticles are sharply pointed, the third twice the length of the first two, the fourth denticle is wide and broken, the fifth small and blunt, the sixth wide and thick, the seventh like the first two and the eighth very small and blunt. All are fused quite strongly at their bases, particularly at the midlength of the bar, rendering to the bar an impression of increased height.

The cusp is inwardly curved, stout at its base and equal in thickness to the two adjacent denticles of the anterior bar. The unit swells out at the base of the cusp into the prominent flare of the basal pit.

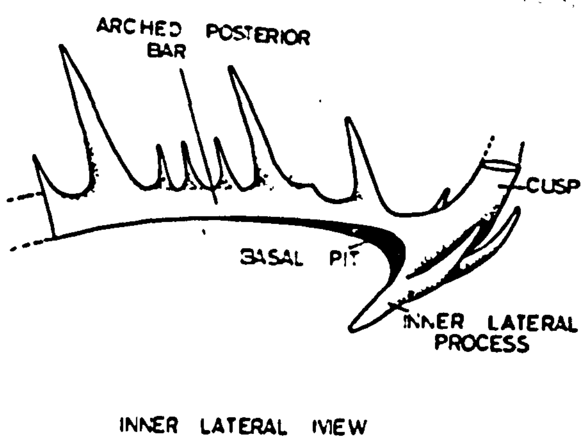
The posterior bar is downwardly and outwardly projecting, straight, $\frac{2}{3}$rds the length of the anterior bar and only $\frac{1}{2}$ its height, slightly thickened, the latter being greatest at the base of the denticles, and bearing five discrete, sharply pointed denticles.

Aboral View:-

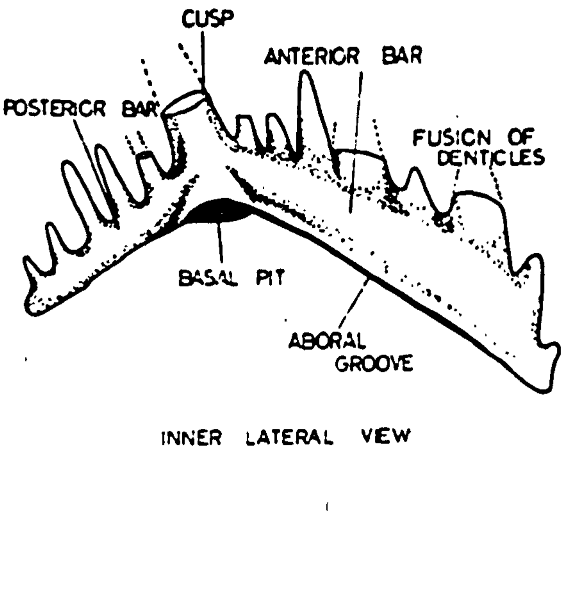
The aboral groove is deep and extends into a deep asymmetric basal pit, the inner flare of which is larger than the outer. The base of the anterior bar is only slightly wider than that of the posterior bar.



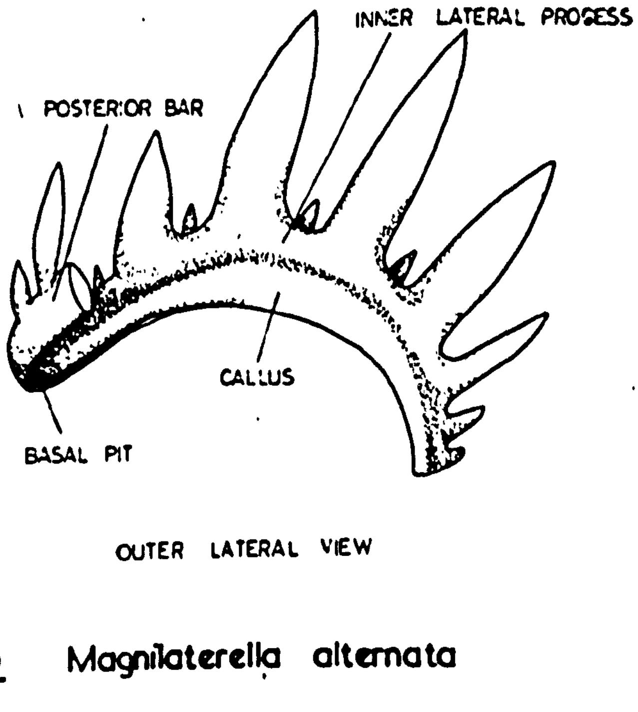
A Lambdagnathus sp. B.



B Ligonodina n. sp. A.



C Lonchodina n. sp. A.



D Magnilaterella alternata

Fig. 15. Morphology of New Species

Discussion: The relationships of L. n.sp.A are a problem since its most distinctive features, which are here listed, readily distinguish it from the other species of this genus. 1. Highly arched, 2. Posterior bar strongly projecting outwards, 3. Anterior bar much thicker than posterior bar, 4. Denticles of anterior bar strongly fused, those of posterior bar discrete, 5. Denticles very variable in size and shape.

Occurrence: Gayle Limestone (Sample GB117).

Lonchodina sp.B.

Description: Two broken specimens.

Oral View:-

The anterior bar straight, diminishing in thickness distally and sharply pointed. The cup posteriorly projecting on inner side, poorly developed on the outer side. Cusp inwardly curving, denticles upright.

Lateral View:

The anterior bar is straight, thickened proximally, of uniform height, truncated at its base and bearing nine laterally compressed, sharp-edged denticles which are in contact at their bases. Cusp less than twice the size of the adjacent denticles, strongly ridged on the inner side.

Aboral View:-

The base of the bar is truncated and slender, with the groove prominent, straight and continuing the whole length of the bar. The pit is large, deep, asymmetric and thick-lipped.

Discussion: Lonchodina sp.B consists of only two specimens which are both incomplete and the posterior bar is unknown. However the small part of the posterior bar which is present is projecting strongly outwards. This species may therefore be most closely related to L. n.sp.A.

Known Range and Distribution:

Hawes Limestone to Simonstone Limestone - Upper Viséan (Present Study).

Occurrence: Hawes Limestone (Sample GB17).

Simonstone Limestone (Sample MG133).

GENUS MAGNILATERELLA Rexroad and Collinson 1963

(For the generic description turn to page 128).

Magnilaterella alternata sp.nov.

Plate 7. Figs. 4, 5.

Diagnosis: A Magnilaterella with a thin, low posterior bar bearing needle-shaped denticles and a long, high, strongly arched and thickened inner lateral process bearing regularly alternating denticles.

Description:

Oral View:-

Posterior bar thin, straight and of uniform length. The inner lateral process is straight or slightly outwardly curving distally, thick and of uniform thickness except at the anterior end where it is of equal thickness to the bar, which it joins in a smooth round curve at an angle of 45-50°.

Lateral View:-

Posterior bar thin, low and bearing at least two slender denticles, the distal of which is the longest and is twice as long as the height of the bar. The lateral process is strongly arched, downwardly projecting, highest at its midlength, strongly thickened and with the distinctive callus almost parallel to its aboral margin. The denticles are upright on the process or slightly posteriorly inclined and in two sets. The larger denticles, up to six in number, are largest at the midlength of the process, uniform in shape, sharply-pointed, strongly compressed, sharp-edged and diminishing in width over their whole length. In the smooth, rounded depression between the base of the large denticles is a single, small sharply pointed denticle, as long as half the height of the bar.

Aboral View:-

The posterior bar is unthickened and is of uniform width to its base. The base of the inner lateral process is much narrower than the thickness of the process itself and bears a prominent groove which is bounded by blunt, rounded lips. The basal pit is situated at the junction of the bar and process and is only a distended portion of the aboral groove.

Comparisons: Magnilateralla alternata differs from M. robusta in having a larger number of denticles, of two sizes, the larger of which are broader, more compressed and more sharp edged than those of the latter; from M. recurvata in the highly thickened character of its process, and from M. complectens in its larger number of denticles.

Discussion: This species was most common in the Middle Limestone. The delicate unthickened nature of the posterior bar results in the latter being incomplete in the majority of specimens.

Remarks: M. alternata appears to be most closely related to M. robusta in its strongly arched, thickened process and in the angle between bar and process.

Known Range and Distribution:

Gayle Limestone to the Underset Limestone, Viséan (Present Study).

Occurrence: Gayle Limestone (Sample GB112).

Middle Limestone (Samples MG253, MG254, MG272, MG278, MG284, MG155).

Underset Limestone (Sample GG205).

Type Specimen: 54/1/MG155 Plate 7. Figs. 4, 5.

Number of Specimens: 12

Type Locality: Middle Limestone, Whitfield Gill, Askrigg, Wensleydale, G.R. 930923.

Magnilaterella sp.A.

Plate 6. Fig. 14.

Description: Oral View:-

The posterior bar is thin, straight and joins the inner lateral process in a smooth rounded angle. The inner lateral process is strongly bowed, convex side towards the bar. Proximal part of process and bar parallel. The process is thicker than the bar and its denticles, circular in cross-section, are strongly curved towards the bar.

Lateral View:-

The posterior bar is thin, with a sharp oral edge and a truncated base. The inner lateral process is only slightly arched, of fairly uniform height and only slightly thickened. The process bears three large denticles, each longer than that proximal to it, slender and posteriorly curving. Between each large denticle is a very small sharply pointed denticle. A single, large, posteriorly curving denticle is situated at the junction of bar and process.

Aboral View:-

The base of the bar is narrow, with a central aboral groove. The base of the process is broad, convex and smooth, with a central groove which, like that of the bar, runs into a shallow basal pit at the anterior extremity of the unit.

Comparisons: This species differs from the other species described in having a short, only slightly arched process of fairly uniform height and with strongly curving, long, slender denticles. Also it differs in that the bar and process are parallel for a short distance from their junction.

Discussion: This is a distinct species but the small number of specimens renders it impossible to give an accurate diagnosis and description and name.

Known Range and Distribution:

Upper Viséan to Lower Namurian (E_1) (Present Study).

Occurrence: Middle Limestone (Samples MG254, MG270).

Three Yard Limestone (Sample GG217).

Great Limestone (Sample BB159).

Magnilateralla spp.

Three apparently unrelated fragments of *Magnilateralla* which do not easily fit into any of the five species described.

One specimen, from the Gayle Limestone has an unthickened low, arched, bowed inner lateral process bearing four slender asymmetric, strongly posteriorly curving denticles and a large basal pit beneath the rounded junction of bar and process. The posterior bar is broken.

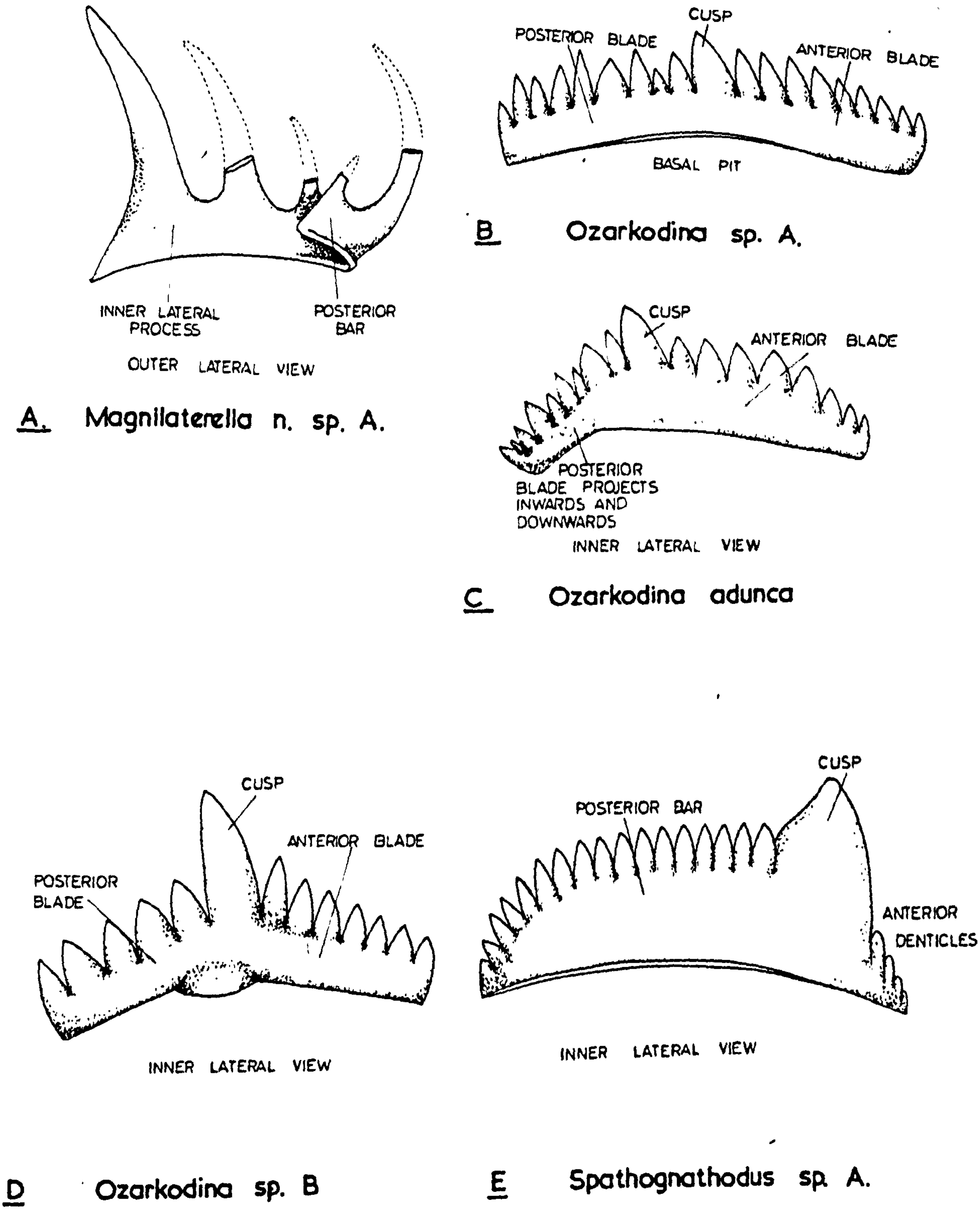


Fig. 16. Morphology of New Species

The second specimen, from the Three Yard Limestone, is similar to M. sp.A but differs in that the process increases in height distally to its broken extremity and the large denticles (2 preserved) are relatively shorter and wider and are interspaced by 2 small denticles.

The third specimen, from the Great Limestone, is a broken fragment of a lateral process and is identified as this genus on the basis of its arched form and thickened callus.

GENUS OZARKODINA Branson and Mehl 1933

(For generic description turn to page 141).

Ozarkodina adunca sp.nov.

Plate 8. Figs. 8, 9.

Diagnosis: A species of Ozarkodina with a straight or slightly arched anterior bar bearing 7 or 8 regular denticles and a low, strongly arched, strongly bowed posterior bar with 9 or 10 varied denticles.

Description: Oral View:-

Unit bowed, particularly in the posterior half where the blade curves strongly inwards, narrow, the same width as the cusp and denticles and diminishing in width anteriorly and posteriorly to sharply-pointed extremities. The denticles are upright on the anterior blade but they may develop a slight outward inclination posteriorly as a result of the inward twist of the blade.

Inner Lateral View:-

Unit arched, particularly in the posterior blade, highest beneath the cusp and diminishing in height only slightly in the anterior blade but strongly in the posterior blade resulting in the latter being $\frac{3}{4}$ to $\frac{1}{2}$ the height of the former. The anterior blade bears 7 or 8 sharply pointed, sharp-edged denticles, which may be in contact at their bases or discrete. They are posteriorly inclined, of uniform size, and as long as the height of the bar, except for the 3 most distal denticles which are smaller.

The cusp is twice as wide and long as the adjacent anterior blade denticles, asymmetric in shape due to its strong posterior inclination, compressed, sharply-pointed and sharp edged.

The posterior blade is low, curving aborally and inwards and bears 9 or 10 denticles which are less regular in size and shape and are smaller than those of the anterior blade.

Aboral View:-

The anterior blade is wider than the posterior blade and bears a distinct aboral groove along its whole length. The posterior blade groove is narrow and indistinct. The basal pit is deep and spindle-shaped and equally flaring on the outer and inner sides.

Comparisons: O. adunca differs from O. cf. curvata, O. laevipostica and O. cf. laevipostica in having a longer, less strongly arched form, more numerous denticles and a strongly bowed posterior blade which is lower and less regularly denticulated than the anterior blade. O. adunca differs from O. cf. hindei in being much smaller, less thickened, with lower anterior and posterior blades and a much smaller cusp, from O. sp.A in having fewer denticles and being strongly bowed and from O. sp.B in having fewer denticles, a smaller cusp and being less thickened.

Discussion: O. adunca was one of the more common species of this genus in the Yoredale Series. It was found from the base of the succession to the Great Limestone but was particularly common in the middle part of the succession, i.e. the Middle and the Three Yard Limestones.

Remarks: This species appears to be most closely related to O. sp.A, but its relationship to previously described species of this genus is uncertain.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (E_1) (Present Study).

Occurrence: Hawes Limestone (Samples GB17, GB18).

Gayle Limestone (Samples GB107, GB111, GB117, GB142).

Simonstone Limestone (Samples MG70, MG131).

Middle Limestone (Samples MG257, MG259, MG285, MG155).

Three Yard Limestone (Samples GG217, SW182-186).

Four Fathom Limestone (Sample BB206).

Main Limestone (Samples GG213, GG215, GG218).

Great Limestone (Sample BB215).

Type Specimen: 55/6/GB111 Plate 8. Fig. 8.

Number of Specimens: 45

Type Locality: Gayle Limestone, Gayle, nr. Hawes, Wensleydale.
G.R. 872893.

Ozarkodina sp.A

Plate 8. Fig. 13.

Description: Oral View:-

The unit is straight or slightly bowed, slightly twisted at its midlength and narrow except beneath the cusp.

Inner Lateral View:-

The unit is slightly arched, the main arching being at its midlength, of fairly uniform height along its whole length and with the aboral margins of the anterior and posterior blades straight or nearly-so. The anterior blade denticles are 9 or 10 in number, uniform in size and shape, as long as the height of the bar, sharply pointed, posteriorly inclined and fused for up to half of their length.

The cusp is only slightly larger than the anterior blade denticles and is of similar shape.

The posterior blade denticles are 11 to 13 in number, more variable in size than those of the anterior blade but rarely longer than the height of the bar.

Aboral View:-

The anterior and posterior blades are of equal width and bear an aboral groove which extends the whole of the length of the unit and swells into a symmetric, spindle-shaped basal pit beneath the cusp.

Discussion: O. sp.A was an uncommon species in the Yoredale Series and a large proportion of the specimens were broken. The form was therefore considered unworthy of the erection of a formal specific category but was also considered to be distinct from the other species and appeared to be most closely related to O. adunca sp.nov.

Known Range and Distribution:

Great Britain: Upper Viséan (Present Study).

Occurrence: Gayle Limestone (Samples GB109, GB111, GB113, GB117 GB143, GB147).

Three Yard Limestone (Sample GG217).

Ozarkodina sp. B.

Plate 8. Fig. 17.

Description: Oral View:-

Unit thickened, straight or slightly bowed, denticles upright, half the thickness of the blade.

Inner Lateral View:-

Unit slightly arched, may be high particularly in the anterior blade, diminishing in height posteriorly. The anterior blade denticles are as long as the height of the bar, of uniform shape, sharply pointed, fused for up to ⅔rds their length and posteriorly inclined. The length of the anterior blade and the number of denticles it bears are unknown.

The cusp is large, at least twice the length and width of the adjacent denticles and posteriorly inclined.

The posterior blade is aborally projecting, diminishes in height and thickness posteriorly and bears at least 13 uniform, partly fused, posteriorly inclined denticles.

Aboral View:-

The base of the unit is relatively narrow, the basal pit is small and spindle shaped and the aboral grooves distinct.

Discussion: O. sp.B was a rare Yoredale species and is unknown in its entirity. However the posterior bar and cusp are known and these are sufficient to distinguish this form from the previously described species. The large cusp of O. sp.B bears some resemblance to that of O. cf. hindei but the denticles of the former are more numerous.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (Present Study).

Occurrence: Middle Limestone (Sample MG283).

Three Yard Limestone (Sample GG217).

Great Limestone (Sample BB159).

GENUS SPATHOGNATHODUS Branson and Mehl 1941

(For generic description see page 145).

Spathognathodus sp.A.

Plate 9. Fig. 5.

Description: Inner Lateral View:-

Strongly arched unit, at the anterior end of which is a broken cusp which is wide at its base and bears a sharp anterior margin. The latter extends into a sharply pointed, non-denticulate aboral projection. The posterior bar bears 14 or more denticles which are of uniform shape and width although gradually decreasing in length posteriorly The denticle adjacent to the cusp is somewhat smaller than those posterior to it. The posterior inclination of the denticles is slight anteriorly but increases to the posterior.

Aboral View:-

The unit is only slightly bowed. The aboral surface of the anterior bar is narrower than that of the posterior bar but the aboral grooves are of equal dimensions. These grooves pass into a central basal pit, which is deep and probably symmetric (broken).

Discussion: Only two broken specimens of *S.* sp.A have been obtained but are described because they are distinct from the other species of *Spathognathodus* which have been described in this report. Their most distinctive features are their large size, the large number of denticles, the strong aboral projection of the cusp, the strong arching and the virtual absence of bowing.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (E_1)

(Present Study).

Occurrence: Simonstone Limestone (Sample MG132).
Great Limestone (Sample BB215).

(ii) Previously Described Species other than those belonging to the Family Hibbardellidae (Müller 1956) and the Super Family Polygnathaceae (Müller and Müller 1957).

GENUS ANGULODUS Huddle 1934.

Type Species: Angulodus demissus Huddle 1934

Huddle's generic description (1934, p.76) is as follows:-

"Bar heavy, rounded, with both the anterior and posterior ends deflected downward; anterior end curved laterally. Cusp subcentral, rounded and straight or slightly curved; denticles at the posterior end of the bar point straight backward; denticles usually increase in size from the cusp to the posterior end of the bar.

The genus differs from Metaprioniodus in the apparent insertion and close appression of the denticles and in the subcentral position of the cusp; from Bryantodus in the lack of lateral ridges and possession of posterior downward projection".

Known Range and Distribution:

Germany: Middle Devonian to Upper Viséan.

Great Britain: Upper Viséan to Lower Namurian.

North Africa: Middle Devonian to Namurian.

North America: Middle? Devonian to Lower Mississippian.

Angulodus walrathi (Hibbard 1927)

Plate 3. Figs. 11, 12.

Hindeodella walrathi Hibbard 1927, p.205, figs. 4a-b.

Angulodus walrathi (Hibbard), Huddle 1934, p.77, pl.4, fig.15, pl.10, fig.5.

Hindeodella catacta Huddle 1934, p.40, pl.4, fig.18.

Angulodus elongatus Stauffer 1940, p.419-420, pl.58, figs.1,8,21,22.

Hindeodella ampla Cooper and Sloss 1943, p.173, pl.28, fig.30.

Angulodus walrathi (Hibbard), Bischoff 1957, p.17, pl.5, figs.44,45.

Angulodus walrathi (Hibbard), Flugel and Ziegler 1957, p.36, pl.5, fig.19.

Angulodus walrathi (Hibbard), Higgins 1961, pl.X, fig.16.

Angulodus walrathi (Hibbard), Higgins 1962, pl.1, fig.10.

Known Range and Distribution:

Germany: Middle Devonian to Upper Viséan (Bischoff and Ziegler 1956, Bischoff 1957, Flugel and Ziegler 1957, Dvořák and Freyer 1961).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, and Present Study).

North America: Middle Devonian to Lower Mississippian (Hibbard 1927, Stauffer 1940, Cooper and Sloss 1943).

North Africa: Middle Devonian to Namurian (Remack-Petitot 1960).

Portugal: Upper Devonian to Lower Carboniferous (Van Den Boogaard 1963).

Spain: Lower Viséan to Lower Namurian (Higgins 1962, Higgins, Wagner-Gentis and Wagner 1964).

Occurrence: Gayle Limestone (Samples GB144, GB142, GB117, GB116 GB111, GB109.

Simonstone Limestone (Samples MG130, MG132, MG133).

Middle Limestone (Samples MG258, MG259, MG155).

GENUS GENICULATUS Hass 1953

Type Species:- Polygnathus claviger Roundy 1926

Hass generic description (1953, p.77) is as follows:-

"A geniculate, asymmetric, massive, barlike unit which tapers from the vertex toward the anterior and posterior extremities. Unit slightly arched, denticulated. Main cusp at vertex. Aboral side grooved along midline; pulp-cavity located beneath main cusp. An immature specimen consists of a distinct posterior bar, a main cusp, and a distinct anterior bar which is joined to the inner side of the main cusp. A large geniculate unit was built about this framework through the accretion of numerous lamellae."

Known Range and Distribution:

Germany: Viséan.

Great Britain: Lower Namurian.

North America: Upper Mississippian.

Geniculatus claviger (Roundy 1926)

Plate 3. Figs. 9, 10.

Polygnathus? claviger Roundy 1926, p.14, pl.4, figs.1a-c; 2a,b.

Prioniodus healdi Roundy 1926, p.10, pl.4, figs. 5a,b.

Prioniodus sp.D. Roundy 1926 (part), p.11, pl.4, figs.13a,b.

Euprioniodina? sp. Branson and Mehl 1941, p.171, pl.5, figs. 17,18.

Metalonchodina? sp.Branson and Mehl 1941, p.172, pl.5, fig.15.

Bactrognathus inornata Branson and Mehl 1941, p.100, pl.19, figs.14,15.

List after Hass 1953(p.77).

Geniculatus claviger (Roundy) Hass 1953, p.77, pl.15, figs.10-19.

Geniculatus claviger (Roundy) Elias 1956, p.121, pl.4, figs. 8-21.

Geniculatus claviger (Roundy) Bischoff 1957, p.21, pl.1, figs.1-6.

Geniculatus claviger (Roundy) Higgins 1961, plXI, fig.11.

Geniculatus claviger (Roundy) Higgins 1962, p.13, pl.1, fig.6.

Discussion: These specimens were found only in the Mirk Fell Beds in the present study and were unfortunately fragmentary. Nevertheless several specimens were obtained consisting of the cusp and parts of both bars. The amount of variation within these specimens consisted chiefly in the extent to which the accretion of lamellae had taken place and was well within the range of variation of *Geniculatus claviger*. A number of bar fragments were extremely broad, at least five times broader than the height of the bar.

Known Range and Distribution:

North America: Meramec? and Chester Series (Hass 1953, Branson and Mehl 1941, Elias 1956).

Germany: Viséan (Bischoff 1957, Voges 1959, 1960).

Great Britain: Lower Namurian (Higgins 1961, Present Study).

Spain: Viséan (Higgins 1962, Higgins, Wagner-Gentis and Wagner 1964).

Occurrence: Mirk Fell Beds (E_2)(Samples MF191, MF192, MF196).

GENUS HINDEODELLA Bassler 1925

Type Species:- Hindeodella subtilis Bassler 1925

Bassler's original description is as follows:-

"Bar long and straight, bearing 6-8 small denticles in front of the strong, long, main denticle and a long series of small denticles, often alternating behind it".

In 1933 Branson and Mehl (p.194) further added:-

"At this time we may add to the generic description by Ulrich and Bassler as follows: long bar- or somewhat blade-like piece - straight or slightly curved laterally, or arched, or both. Some species with the upper edge laterally sinuous. Anterior end broadly flexed or sharply curved inward in the horizontal plane or slightly bent downward. Posterior end tapered, spatulate, slightly down-curved or recurved beneath the bar. Denticulation consisting of a fang of large size at or somewhat behind the anterior curvature and closely spaced to articulating, more or less sheathed denticles of appreciably smaller size in front and back of the fang. The smaller denticles usually alternate in size regularly or irregularly with one to several minute denticles between the larger. The aboral side of the bar is sharp, usually without evidence of longitudinal groove except near a small pit, which marks the position of the sub-terminal fang. Orientation: for convenience of description all units are orientated as though edging the lower jaw with the anterior curvature directed toward the median line. In species where the anterior end is not curved inward, there is more or less lateral flexure of the unit as a whole and the concave side is designated the inner side.

The genus is closely related to *Ligonodina*, differing chiefly in that the anterior end of *Ligonodina* is much more conspicuously downturned and the smaller denticles suggest an arrangement of alternating sizes and are not sheathed".

Discussion: This genus, absent from a number of horizons in the upper part of the Yoredale sequence, was a major constituent of the faunas in the lower and middle part of the sequence. Unfortunately the proportion of specifically identifiable specimens was low and as a result the chart indicating the occurrences of all the Yoredale conodont species misrepresents the abundance of this genus.

Known Range and Distribution:

Belgium: Upper Viséan to Lower Namurian.

France: Upper Devonian to Upper Namurian.

Germany: Upper Ordovician to Namurian.

Great Britain: Upper Ordovician to Namurian.

North Africa: Middle Devonian to Lower Namurian.

North America: Upper Ordovician to Triassic.

Portugal: Upper Devonian to Lower Viséan.

Spain: Tournaisian to Lower Namurian.

Hindeodella brevis Branson and Mehl 1934.

Plate 4. Figs. 1, 2.

Hindeodella brevis Branson and Mehl 1934, p.195, pl.14, figs. 6-7.

Hindeodella brevis Branson and Mehl, Bischoff and Ziegler 1956, p.147, pl.14, figs.10,11.

Hindeodella brevis Branson and Mehl, Bischoff 1957, p.26, pl.6, fig.24.

Hindeodina uncata Hass 1959, p.383, pl.47, fig.6.

Hindeodella brevis Branson and Mehl, Higgins 1961, pl.X, fig.14.

Hindeodella brevis Branson and Mehl, Higgins 1962, pl.1, fig.12.

Discussion: Specimens which are here referred to as *H. brevis* were found in only five samples and in each case were incomplete. However each consisted of a laterally bowed and twisted posterior bar of uniform height bearing denticles of two sizes, 3 to 6 smaller denticles separating the larger. The cusp was small and the anterior bar, though incomplete, was directed inwards at 90° to the plane of the posterior bar. The amount of variation within this species is quite wide. These Yoredale specimens were closely similar to those figured by Bischoff and Ziegler (1956), Bischoff (1957), and Higgins (1961) and also to Hindeodina uncata Hass 1959, which is here included in synonomy. In each case the bar is more delicate and the cusp less distinct than in the holotype figured by Branson and Mehl (1934)

Known Range and Distribution:

Belgium: Namurian (Bouckaert and Higgins 1963).

Germany: Upper Devonian to Viséan (Bischoff and Ziegler 1956, Bischoff 1957).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, Present Study).

North America: Upper Devonian to Mississippian (Branson and Mehl 1934, Hass 1959).

Portugal: Upper Devonian (Van Den Boogaard 1963).

Occurrence: Hawes Limestone (Sample GB19).

Gayle Limestone (Sample GB144).

Middle Limestone (Samples MG256, MG283).

Three Yard Limestone (Sample GG217).

Hindeodella germana Holmes 1928

Plate 4 Figs. 3, 5.

Hindeodella germana Holmes 1928, p.25, pl.9, fig.9.

Hindeodella aculeata Huddle 1934, p.40, pl.4, figs 19-21.

Hindeodella grandis Huddle 1934, p.41, pl.4, fig.22.

Hindeodella gracilis Huddle 1934, p.43, pl.5, fig.11.

Hindeodella germana Holmes, Bischoff 1957, p.27, pl.6, figs. 32,34.

Hindeodella germana Holmes, Flugel and Ziegler 1957, p.41, pl.5, fig.16.

Hindeodella germana Holmes, Higgins 1961, pl.X, figs. 12,13.

Hindeodella germana Holmes, Dvořák and Freyer 1961, pl.1, fig.1.

Discussion: The main variation in this species involves the length and denticulation of the anterior bar. The anterior bar of the Yoredale specimens is short, slightly inwardly curved and with about 6 denticles of variable length in close contact with each other. Those adjacent to the cusp are posteriorly inclined but those at the anterior extremity of the bar may be slightly anteriorly and outwardly inclined.

Known Range and Distribution:

Belguim; Lower Namurian (Bouckaert and Higgins 1963).

France: Upper Devonian to Lower Viséan (Remack-Petitot 1960, Serre and Lys 1960).

Germany: Upper Devonian to Viséan (Bischoff and Ziegler 1956, Bischoff 1957, Flugel and Ziegler 1957).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, Present Study).

North Africa: Middle Devonian to Lower Namurian (Remack-Petitot 1960).

North America: Upper Devonian to Lower Mississippian (Holmes 1928, Huddle 1934).

Portugal: Upper Devonian to Lower Viséan (Van Den Boogaard 1963).

Spain: Upper Viséan to Middle Namurian (Higgins 1962).

Occurrence: Gayle Limestone (Samples GB106, GB111).

Simonstone Limestone (Samples MG130-133).

Middle Limestone (Samples MG257, MG259, MG155).

Three Yard Limestone (Samples GG217, SW182, SW183, SW186)

Main Limestone (Sample GG215).

Great Limestone (Samples BB158, BB159).

Hindeodella ibergensis Bischoff 1957

Plate 4. Fig. 10, 11.

Hindeodella spp Ellison 1941, p.118, pl.20, fig.18.

Hindeodella spp Ellison and Graves 1941, pl.1, fig.6.

Hindeodella component (part) Rhodes 1952, pl.126, fig.7.

Hindeodella ibergensis Bischoff 1957, p.28, pl.6, figs. 33,37, 39.

Hindeodella ibergensis Bischoff, Flugel and Ziegler 1957, p.42, pl.5 figs. 14, 21.

Hindeodella sp. Rexroad 1957, p.32, pl.3, fig.2.

Hindeodella redunca Stanley 1958, p.466, pl.63, figs. 1-4.

Hindeodella fragilis Hass 1959, p.383, pl.48, figs. 18,21,26.

Hindeodella ibergensis Bischoff Higgins 1961, pl.X, fig.15.

Hindeodella ibergensis Bischoff, Higgins 1962, pl.1, fig.11.

Discussion: The main source of variation in this species is the length and denticulation of the anterior bar, plus the degree to which it projects downwards and inwards. The Yoredale specimens in general bear a fairly short anterior bar but this is often projecting so strongly downwards that its sharply-pointed extremity is posteriorly directed. Inward inclination is only slight. As a result of the posterior curvature of the anterior bar, the three or four denticles at its anterior extremity are anteriorly inclined although posteriorly curving.

Known Range and Distribution:

Belgium: Lower Namurian (Bouckaert and Higgins 1963).

Germany: Lower Carboniferous (Bischoff 1957, Flugel and Ziegler 1957, Ziegler 1959, Dvořák and Freyer 1961).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, Present Study).

North Africa: Upper Devonian to Westphalian (Remack-Petitot 1960).

North America: Lower Mississippian to Lower Permian (Ellison 1941, Ellison and Graves 1941, Rhodes 1952, Rexroad 1957, Stanley 1958 Hass 1959).

Spain: Lower Viséan to Lower Namurian (Higgins 1962, Higgins Wagner-Gentis and Wagner 1964).

Occurrence: Hawes Limestone (Sample GB17).

Gayle Limestone (Samples GB107, GB111-113, GB117, GB143).

Simonstone Limestone (Sample MG133).

Middle Limestone (Sample MG155).

Underset Limestone (Sample GG202).

Four Fathom Limestone (Sample BB206).

Great Limestone (Sample BB156).

Hindeodella undata Branson and Mehl 1941

Plate 4. Figs. 12 - 14.

Hindeodella undata Branson and Mehl 1941, p.169, pl.5, fig.3.

Hindeodella sp. Branson and Mehl 1941, p.170, pl.5, fig.9.

Hindeodella undata Branson and Mehl, Hass 1953, p.82, pl.16, figs.5-7.

Hindeodella undata Branson and Mehl, Elias 1956, p.108, pl.1, figs.2,10.

Hamulosodina hassi Elias 1956, p.108, pl.1, figs.11,12.

Hindeodella undata Branson and Mehl, Bischoff 1957, p.29, pl.6, figs.21-23.

Hindeodella undata Branson and Mehl, Flugel and Ziegler 1957, p.43, pl.6, figs., 21-23.

Discussion: No complete specimen of H. undata was found in the Yoredale Series but unlike most species of this genus, identification of bar fragments is possible. This is the result of the distinct morphology of the species, with denticles in 2 sizes, of which the inclination of the two sets differs from each other and the sinuosity of the bar is accentuated by the placing of the major denticles. The Yoredale specimens were all posterior bar fragments, as figured by Bischoff 1957 (Pl.6, figs.21-23)

Known Range and Distribution:

France: Lower Viséan (Remack-Petitot 1960).

Germany: Viséan (Bischoff 1957, Flugel and Ziegler 1957).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961 Present Study).

North America: Meramec and Chester Series (Branson and Mehl 1941, Hass 1953, Elias 1956, Rexroad and Clarke 1960).

Occurrence: Hawes Limestone (Samples GB19, GB167).

Gayle Limestone (Samples GB111, GB112, GB146).

Simonstone Limestone (Samples MG69, MG70, MG130, MG132, MG133).

Middle Limestone (Samples MG252, MG253, MG257, MG259, MG283).

GENUS <u>LAMBDAGNATHUS</u> Rexroad 1958

Type Species:- <u>Lambdagnathus fragilidens</u> Rexroad 1958

The generic description by Rexroad (p.19) is as follows:-

"Complex unit consisting of a posterior denticulate process and blade-like anterior and inner lateral denticulate processes with an apical denticle, usually triagular in shape, at the juncture of the three, and, aborally, a triangular shaped pit at their juncture. The posterior bar is usually the shortest of the three branches, is thin, and aborally bears a median groove as do the other processes. The anterior process may continue nearly in line with the posterior bar or may incline somewhat outward and down, and it may be slightly sinuous. The denticles of the posterior bar and the anterior process are subequal in size and approximately equal to the apical denticle at the juncture of the three limbs.

Typically the inner lateral process is the longest and deepest of the three processes. It commonly branches from the posterior bar nearly at right angles but may be inclined posteriorly or slightly anteriorly and also is inclined sharply downward. Typically, it is arched, slightly bowed convexly anteriorly, is deepest near its midlength and has denticles largest near its mid-section and decreasing in size in each direction, the larger denticles being considerably larger than the apical denticles. Attachment scars may be prominent on the faces of the inner lateral process, less so on the posterior bar and anterior process. Chief variations in the genus are expected to be in the proportions of the lengths of the three processes, and their angular relationships to each other, plus variations in the denticulation and depths of the processes, particularly the inner lateral one.

Relationships of this genus to other genera are problematical. The general form is most similar to that of <u>Centrognathodus</u> Branson and Mehl, but it differs particularly in the angular relations of the three processes, in the presence of a pronounced triangular subapical pit in <u>Lambdagnathus</u> and its triangular apical denticle".

<u>Known Range and Distribution</u>:

Belgium: Lower Namurian.

Great Britain: Upper Viséan to Lower Namurian.

North America: Chester Series (Mississippian).

Lambdagnathus macrodentata Higgins 1961

Plate 5. Figs. 1, 2.

Lambdagnathus macrodentata Higgins 1961, p.214, pl.12, figs.1-3.

Discussion: L. macrodentata Higgins is a rare species in the Yoredale Series and only 5 specimens have been found, from three limestones. The amount of variation was very small.

Known Range and Distribution:

Belgium: Lower Namurian (E_2) (Bouckaert and Higgins 1963).

Great Britain: Upper Viséan and Lower Namurian (Higgins 1961, Present Study).

Occurrence: Simonstone Limestone (Sample MG132).

Middle Limestone (Sample MG155).

Three Yard Limestone (Samples SW184, SW186).

GENUS LIGONODINA Bassler 1925

Type Species:- Ligonodina pectinata Ulrich and Bassler 1926

The generic description given by Ulrich and Bassler (1926) is as follows:-

"General form of tooth as in Prioniodina but distinguished by the development of sucker-like impressions on one side of the downward extension of the main cusp".

Branson and Mehl further described the genus in 1933. Their description is as follows:-

"Complex dental units consisting of a moderately long, straight to down-curved basal bar with aboral side more or less excavated lengthwise, oral surface set with discrete denticles of nearly circular cross-section; bar terminated anteriorly with an erect or recurved long, stout denticle, typically with a circular cross-section and with base (aboral surface) more or less excavated; inner side produced strongly downward, in some cases extended to a conspicuous point. Lower inner side bearing a few stout discrete denticles which project inward and downward".

Known Range and Distribution:

Belgium: Lower Namurian.

France: Upper Devonian to Lower Viséan.

Germany: Silurian to Upper Viséan.

Great Britain: Middle Ordovician to Lower Namurian.

North Africa: Upper Devonian to Lower Namurian.

Portugal: Upper Devonian to Lower Viséan.

Spain: Viséan to Lower Namurian.

Ligonodina levis Branson and Mehl 1941

Plate 5. Figs. 7, 8.

Ligonodina levis Branson and Mehl 1941, p.185, pl.6, fig.10.

Ligonodina sp. Youngquist and Miller 1949, p.620, pl.101, figs,12,13.

Ligonodina levis Branson and Mehl, Bischoff 1957, p.30, pl.5, figs.8,9; pl.6, fig.25.

Ligonodina obunca Rexroad 1957, p.32, pl.1, figs, 22,23.

Ligonodina obunca Rexroad, Rexroad 1958, pp.10,11,21, pl.3, figs.7,8.

Ligonodina levis Branson and Mehl, Rexroad and Burton 1961, pp.1147, 1149, 1154, pl.141, figs.7 8.

Ligonodina obunca Rexroad, Rexroad and Collinson 1961, pl.1.

Ligonodina levis Branson and Mehl, Rexroad and Collinson 1963, p.11, pl.2, figs. 24,25.

Ligonodina levis Branson and Mehl, Rexroad and Furnish 1964, p.672, pl.111, fig.38.

Discussion: Although not one of the common species as far as absolute numbers are concerned, L. levis was more abundant than L. tenuis and had a similar range through the Yoredale Series. The main variation in L. levis was in the length and denticulation of the inner lateral process, ranging from forms with a fairly long slender process with three slender denticles, to forms with a shorter, thick, process with two thick denticles. In all cases, however, the proximal denticle was adjacent to, and similarly orientated to the cusp, as opposed to L. tenuis where it was anterior to the cusp.

Known Range and Distribution:

Germany: Viséan (Bischoff 1957).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, Present Study).

North Africa: Lower Namurian (Remack-Petitot 1960).

North America: Middle and Upper Mississippian (Branson and Mehl 1941, Youngquist and Miller 1949, Rexroad 1957, 1958, Rexroad and Clarke 1960, Rexroad and Collinson 1961, Rexroad and Jarrell 1961, Rexroad and Liebe 1962, Rexroad and Collinson 1963, Rexroad and Furnish 1964).

Spain: Viséan to Lower Namurian (Higgins 1962, Higgins, Wagner-Gentis and Wagner 1964).

Occurrence: Gayle Limestone (Samples GB116, GB117).

Simonstone Limestone (Sample MG131).

Middle Limestone (Samples MG253, MG255, MG257, MG275, MG283, MG284, MG155).

Scar Limestone (Sample SW104).

Five Yard Limestone (Samples SW174, SW175).

Three Yard Limestone (Samples SW183-186).

Underset Limestone (Samples GG202, GG204, GG211).

Four Fathom Limestone (Samples BB204, BB207).

Great Limestone (Samples BB156, BB159, BB216).

Mirk Fell Beds (Samples MF191, MF192, MF194).

Ligonodina tenuis Branson and Mehl 1941

Plate 5. Figs. 6, 9.

Prioniodus tulensis Pander 1856, p.30, tab.2a, fig.19.

Prioniodus tulensis Pander, Hinde 1900, p.343, pl.9, fig.15.

Prioniodus tulensis Pander, Holmes 1928, p.22, pl.3, fig.22.

List after Clarke 1960

Ligonodina tenuis Branson and Mehl 1941, p.170, pl.5, figs.13,14.

Ligonodina sp. Youngquist and Miller (part) 1949, pl.101, fig.11.

Ligonodina tenuis Branson and Mehl, Elias 1956, p.126, pl.5, figs.4,5.

<u>Ligodina hamata</u> Rexroad 1957, p.32, pl.1, figs. 24,25.

<u>Ligonodina</u> sp. Rexroad 1957, p.33, pl.1, figs. 20,21.

<u>Ligonodina hamata</u> Rexroad, Rexroad 1958, p.21, pl.3, figs. 9-14.

<u>Ligonodina tulensis</u> (Pander) Clarke 1960, p.11, pl.II, fig.14.

<u>Ligonodina obunca</u> Rexroad, Higgins 1961, pl.XI, fig.9.

<u>Ligonodina hamata</u> Rexroad, Rexroad and Burton 1961, pp.1147-1149, pl.141, figs. 5,6.

<u>Ligonodina hamata</u> Rexroad, Rexroad and Collinson 1961, p.8, pl.1.

<u>Ligonodina tenuis</u> Branson and Mehl, Rexroad and Furnish 1964, p.672, pl.111, fig.40.

<u>Discussion</u>: <u>L. tenuis</u> was found through most of the Yoredale Series, though never actually being common. This species is closely related to <u>L.levis</u> with which it forms a transitional series by the progressive forward movement of the lateral process. <u>L. tenuis</u> may be distinguished from <u>L. levis</u> in that the former has the first denticle of the process anterior to and in line with the cusp.

<u>Known Range and Distribution</u>:

Great Britain: Upper Viséan to Lower Namurian (Hinde 1900, Holmes 1928, Clarke 1960, Higgins 1961, Present Study).

North America: Mississippian (Youngquist and Miller 1949, Rexroad 1957,1958, Rexroad and Burton 1961, Rexroad and Collinson 1961, Rexroad and Jarrell 1961, Rexroad and Liebe 1962).

U.S.S.R.: Çarboniferous Limestone (Pander 1856).

<u>Occurrence</u>: Gayle Limestone (Sample GB117).

Simonstone Limestone (Sample MG132).

Middle Limestone (Samples MG253, MG283).

Five Yard Limestone (Sample SW174).

Three Yard Limestone (Samples SW184-186).

Underset Limestone (Samples GG203, GG204, GG211).

Four Fathom Limestone (Sample BB203).

Great Limestone (Samples BB212, BB213, BB215).

Mirk Fell Beds (Sample MF191).

Ligonodina typa (Gunnell 1933)

Plate 5. Figs. 10-12.

Prioniodus sp.A. Roundy 1926, p.11, pl.4, fig.9.

Prioniodus sp.C. Roundy 1926, p.11, pl.4, fig.11.

Idioprioniodus typus Gunnell 1933, p.265, pl.31, fig.47.

Prioniodus? galesburgensis Gunnell 1933, p.267, pl.31, fig.12.

Ligonodina typa (Gunnell), Ellison 1941, p.114, pl.20, figs. 8-11.

Ligonodina roundyi Hass 1953, p.82, pl.15, figs. 5-9.

Ligonodina typa (Gunnell), Bischoff and Ziegler 1956, p.149, pl.13, fig.25.

Ligonodina roundyi Hass, Elias 1956, p.126, pl.V, figs. 10-14.

Ligonodina typa (Gunnell), Bischoff 1957, p.31, pl.5, figs. 3-5, 12.

Ligonodina roundyi Hass, Stanley 1958, p.468, pl.68, figs. 3-4.

Ligonodina roundyi Hass, Rexroad 1958, p.21, pl.3, figs. 1-4.

Ligonodina typa (Gunnell), Higgins 1961, pl.XI, fig.6.

Ligonodina roundyi Hass, Rexroad and Collinson 1961, pl.1.

Ligonodina typa (Gunnell), Higgins 1962, p.13, pl.1, fig.7.

Discussion: In his remarks on his new species L. roundyi, Hass (1953) indicated that it closely resembled L. typa (Gunnell) but differed in that it had a larger main cusp and discrete denticles on the anticusp instead of partly fused ones. Reference to the descriptions and figures listed in the synonomy however shows that the two species are indistinguishable. It would therefore appear that size of cusp and fusion of denticles are insufficient grounds to separate these two species. A comparison of L.typa (Gunnell) in Bischoff 1957, pl.5, figs. 3,4,5,12 and L. roundyi Hass in Rexroad 1958 pl.3, figs. 1-4 illustrates the point. In addition Gunnell made no reference either to the size of the cusp or the fusion of the anticusp denticles in his original description (1933), p.265).

Known Range and Distribution:

Belgium: Lower Namurian (Bouckaert and Higgins 1963).

France: Lower Viséan (Remack-Petitot 1960).

Germany: Viséan (Bischoff and Ziegler 1956, Bischoff 1957, Flugel and Ziegler 1957).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, Present Study).

North Africa: Viséan to Lower Namurian (Remack-Petitot 1960).

North America: Merameo? to Lower Permian (Roundy 1926, Gunnell, 1933, Ellison 1941, Ellison and Graves 1941, Hass 1953, Stanley 1958, Rexroad 1958, Rexroad and Clarke 1960, Rexroad and Collinson 1961, Rexroad and Jarrell 1961).

Portugal: Upper Tournaisian to Lower Viséan (Van Den Boogaard 1963).

Spain: Middle Viséan to Lower Namurian (Higgins 1962, Higgins, Wagner-Gentis and Wagner 1964).

Occurrence: Gayle Limestone (Samples GB107, GB111, GB117).

Simonstone Limestone (Sample MG133).

Middle Limestone (Samples MG259, MG271, MG284).

Three Yard Limestone (Samples GG217, SW183, SW186).

Underset Limestone (Samples GG202, GG203).

Four Fathom Limestone (Sample BB204).

Main Limestone (Samples GG213, GG215).

Great Limestone (Samples BB215, BB216).

Mirk Fell Beds (Samples MF191, MF192).

Ligonodina ultima Clarke 1960

Plate 5, Figs. 13, 14, 17.

Ligonodina ultima Clarke 1960, p.12, pl.II, figs. 9,11.

Discussion: *L. ultima* Clarke is one of the more common Ligonodinids in the Yoredale Series, thirty-six specimens having been found in twenty-six samples, from six limestones. It is distinguished from *L. tenuis* and *L. levis* by its large, stout, strongly recurved cusp, the anterior margin of which is smooth and convex in lateral view and continues aborally into the lateral process, which arises from about the midlength of the cusp. *L. ultima* therefore possibly represents the initial stage from which *L. levis* and *L. tenuis* were produced by the progressive anterior movement of the lateral process. No transitional stages were found, however to substantiate this.

Known Range and Distribution:

Great Britain: Lower Limestone Group of Scotland (P_2) (Clarke 1960).

Upper Viséan to Lower Namurian (E_1) (Present Study).

Occurrence: Gayle Limestone (Samples GB111, GB164, GB163).

Simonstone Limestone (Samples MG64, MG69, MG130).

Middle Limestone (Samples MG251, MG253, MG255, MG259, MG271, MG279, MG284, MG155).

Five Yard Limestone (Samples SW172, SW72, SW73, SW176).

Three Yard Limestone (Samples SW86, SW186).

Main Limestone (Sample GG212).

Great Limestone (Samples BB215, BB212, BB216, BB159, BB157).

Ligonodina cf ultima Clarke 1960

Plate 6. Figs. 1, 2.

Discussion: Two broken specimens, which may or may not be comparable to each other, are grouped together under this heading because of their similarity to L. ultima.

One specimen (Sample BB123, from the Little Limestone) consists of an extremely long, complete, strongly recurved, sharply pointed cusp, a short, broken posterior bar and a broken lateral process. It bears a strong resemblance to L. ultima but differs in the extreme length of its cusp and the fact that the lateral process emerges at the posterior margin of the cusp rather than at the midlength.

The other specimen (Sample BB202, from the Four Fathom Limestone) agrees in all respects with L. ultima except that the inner lateral process is larger than has been otherwise found, bears three denticles instead of two and is aborally curving. The anterior margin of the unit therefore presents a sigmoidal curve in lateral view.

Occurrence: Four Fathom Limestone (Sample BB202).

Little Limestone (Sample BB123).

Ligonodina sp.

Discussion: This is a single broken specimen which consists of a thick, arched, aborally ridged posterior bar bearing at least two very large, posteriorly curving denticles. The cusp is broken. The aborally and posteriorly projecting inner lateral process originates anteriorly to the cusp and bears a single, large, anteriorly inclined and posteriorly curving denticle anterior to the cusp. The remainder of the process is non-denticulate.

This specimen differs from L. tenuis in that the bar is too long and arched, and the denticles are grossly oversize. Also the denticle anterior to the cusp is too large. It also differs from L. fragilis and L. n.sp.A. in that the bar is too thick, the denticulation too strong, the process is non-denticulate except for the single large denticle anterior to the cusp, and the process is much higher than the bar and thin, with sharp oral and aboral margins.

Occurrence: Five Yard Limestone (Sample SW73).

GENUS LONCHODINA Bassler 1925

Type Species:- Lonchodina typicalis Ulrich and Bassler 1926

The generic description given by Ulrich and Bassler (1926, p.15) is as follows:-

"Like Euprioniodina (like Prioniodina, but main cusp much more produced and anterior part of bar smaller, shorter, more sharply deflected and carrying on its upper edge a series of closely arranged denticles) but ends of bar more equal in length and the entire bar strongly bowed, bent in two directions, one with the usual upward curvature at the middle and the other outwardly as seen in a view of the underside of the base; denticles more irregular and further separated. Main cusp sometimes not readily distinguished from the denticles.

The main characteristics of the genus are its outwardly bowed form, the greater length and separation of the rounded, needle-shaped denticles, and their usually unsymmetrical arrangement. The bowing of the tooth is especially characteristic, this occurring in two directions, upward and outward."

Known Range and Distribution:

Belgium: Lower Namurian.

France: Middle Devonian to Lower Viséan.

Germany: Silurian to Upper Triassic.

Great Britain: Devonian to Lower Namurian.

North Africa: Middle Devonian to Lower Namurian.

North America: Silurian to Lower Triassic.

Portugal: Upper Devonian to Lower Viséan.

Spain: Middle and Upper Viséan.

Lonchodina furnishi Rexroad 1958

Plate 6. figs. 4, 5.

Lonchodina furnishi Rexroad 1958, p.22, pl.4, figs. 11-13.

Lonchodina furnishi Rexroad, Higgins 1961, pl.XI, fig.8.

Lonchodina furnishi Rexroad, Rexroad and Collinson 1961, pl.1.

Lonchodina furnishi? Rexroad, Higgins 1962, p.13, pl.1, fig.4.

Lonchodina furnishi Rexroad, Collinson, Scott and Rexroad 1962, pp.11,12

Discussion: *L. furnishi* was an uncommon species in the Yoredale Series and was mainly concentrated in the Gayle Limestone.

Known Range and Distribution:

Belgium: Lower Namurian (Bouckaert and Higgins 1963).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, and Present Study).

North America: Golconda Group to Glen Dean Formation:- Chester Series (Rexroad 1958, Rexroad and Clarke 1960, Rexroad and Jarrell 1961, Rexroad and Collinson 1961, Collinson, Scott and Rexroad 1962).

Spain?: Middle and Upper Viséan (Higgins 1962).

Occurrence: Gayle Limestone (Samples GB109, GB111, GB148, GB163).

Middle Limestone (Sample MG284).

Great Limestone (Sample BB215).

Lonchodina paraclarki Hass 1953

Plate 6. Figs. 8, 11.

Lonchodina paraclarki Hass 1953, p.83, pl.16, figs.15,16.

Lonchodina paraclarki Hass, Elias 1956, p.122, pl.V, figs. 6 7.

Lonchodina paraclarki Hass, Stanley 1958, p.468, pl.67, fig.1.

Lonchodina cf. paraclarki Hass, Rexroad 1958, p.22, pl.4, figs. 4,5.

Lonchodina cf. paraclarki Hass, Rexroad and Collinson 1961, pl.1.

Lonchodina paraclarki Hass, Collinson, Scott and Rexroad 1962, pp.11,25, 26.

Discussion: This was a very rare species in the Yoredale Series and only two specimens were obtained in the whole study.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (E_2) (Present Study).

North America: Upper Mississippian (Hass 1953, Elias 1956, Rexroad 1958, Stanley 1958, Collinson and Rexroad 1961, Rexroad and Jarrell 1961, Collinson, Scott and Rexroad 1962).

Occurrence: Three Yard Limestone (Sample GG217).
Mirk Fell Beds (Sample MF192).

Lonchodina paraclaviger Rexroad 1958

Plate 6. fig . 3.

Lonchodina paraclaviger Rexroad 1958, p.22, pl.4, figs.7-10.

Lonchodina paraclaviger Rexroad, Rexroad and Collinson 1961, pl.1.

Lonchodina paraclaviger Rexroad, Collinson, Scott and Rexroad 1962, pp.11,26.

Discussion: This species, like L. paraclarki Hass, was very rare in the Yoredale Series and in addition was usually badly broken. The species was recognised on the basis of a number of distinctive features, including the straightness of the bars, the upright nature of the denticles which are similar in shape and sometimes in size to the cusp and the extreme thickening of the bars, forming a very heavy unit approaching the genus Geniculatus.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (E_1) (Present Study).

North America: Glen Dean Formation, Chester Series.

Occurrence: Gayle Limestone (Sample GB117).

Middle Limestone (Samples MG253, MG257).

Three Yard Limestone (Sample GG217.

Main Limestone (Samples GG217, GG218).

Lonchodina cf. projecta Ulrich and Bassler 1926

Plate 6. Fig. 10.

Lonchodina cf projecta Ulrich and Bassler, Bischoff 1957, p.34, pl.1 fig.20.

Lonchodina cf projecta Ulrich and Bassler, Higgins 1961, pl.XI, fig.10.

Lonchodina cf projecta Ulrich and Bassler, Higgins 1962, p.13, pl.1, fig.5.

Discussion: The few specimens of L. cf. projecta recovered from the Yoredale Series tended to be more juvenile forms than that illustrated by Bischoff (1957). They nevertheless had the distinctive curvature at the base of the large cusp, the outline of which was followed by the series of long, discrete, uniform denticles of the anterior bar.

Known Range and Distribution:

Belgium: Lower Namurian (Bouckaert and Higgins 1963).

Germany: Goniatites crenistria zone (Bischoff 1957).

Great Britain: Upper Viséan to Lower Namurian (E_1), (Higgins 1961, Present Study).

Spain: Middle-Upper Viséan (Higgins 1962).

Occurrence: Three Yard Limestone (Samples SW185, SW186).

Great Limestone (Samples BB156, BB212, BB159).

GENUS MAGNILATERELLA Rexroad and Collinson 1963

Type Species:- Magnilaterella robusta Rexroad and Collinson 1963.

Rexroad and Collinson's description (p.12) is as follows:-

"Representatives of this genus consist of a small denticulate posterior bar and a large denticulate inner lateral limb. The lateral limb arises from the anterior end of the posterior bar and generally is directed obliquely downward and rearward. The largest denticles are found on the lateral bar, but the anteriormost denticle is not the largest. A basal pit is generally present at the anterior of the posterior bar or its juncture with the lateral bar and grooves may extend from it along the lower edge of either bar."

Rexroad and Collinson further remarked, "For many years conodont-workers have had difficulty in assigning to an extant genus the Ligonodina-like forms we are referring to Magnilaterella .... As Magnilaterella is here drawn, three species are assigned to it. The most common is the type, M. robusta, which is widespread and common in the Upper Mississippian formations throughout midcontinent United States .... More like M. robusta than any other species is M. recurvata (Bischoff) from the cuIIIα - III/β Zones of the Harz Mountains in Germany .... M. complectens (Clarke) from the Carboniferous Lower Limestone at Law, Dalry, the Upper Limestone at Glencart, Dalry and a shale bed above the Skateraw Middle Limestone at Catcraig, Dunbar, all in Scotland, has a robust lateral bar like M. robusta, but is much shorter and has only a single major denticle on the lateral bar along with two small denticles".

Known Range and Distribution:

Germany: cuIIIα-III/β zones - Goniatites-Stufe (Bischoff 1957).

Great Britain: Upper Viséan to Lower Namurian (Clarke 1960, Present Study).

North America: Upper Mississippian (Branson and Mehl 1940, Youngquist and Miller 1949, Elias 1956, Rexroad 1957, 1958, Rexroad and Jarrell 1961, Rexroad and Furnish 1964).

Magnilaterella complectens (Clarke) 1960

Plate 6. Figs. 12, 13.

Prioniodus tulensis Pander, Hinde 1900 (part), p.343, pl.9, fig.16.

Prioniodus tulensis Pander, Holmes 1928 (part), p.22, pl.3, fig.20.

List after Clarke 1960

Ligonodina complectens Clarke 1960, p.9, pl.1, figs.14,15.

Magnilaterella complectens (Clarke), Rexroad and Collinson 1963, pp.12, 13,14,15,17.

Discussion: M. complectens is found throughout the Yoredale Series and is the most common species of this genus. The amount of variation witnessed, both within the Yoredale Series and between the Yoredale and Scottish occurrences is very small. However the placing of Ligonodina complectens Clarke 1960 into Magnilaterella has rendered Clarke's orientation erroneous. The posterior bar of Magnilaterella is that which Clarke described as the "anterior process", and is horizontal. The inner lateral limb is Clarke's "posterior bar", and is aborally projecting (see Rexroad and Collinson, p.12, text-fig.2).

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (Hinde 1900, Holmes 1928, Clarke 1960, Present Study).

Occurrence: Gayle Limestone (Sample GB166).

Middle Limestone (Samples MG252, MG258, MG285).

Five Yard Limestone (Sample SW174).

Three Yard Limestone (Samples SW182, SW86, SW184, SW185).

Four Fathom Limestone (Samples BB206, BB204).

Main Limestone (Sample GG216).

Great Limestone (Samples BB212, BB159, BB213, BB216).

Mirk Fell Beds (Samples MF192, MF194).

Magnilaterella recurvata (Bischoff 1957)

Plate 6. Fig. 9.

Lonchodina? recurvata Bischoff 1957, p.34, pl.5, figs.17,18.

Magnilaterella recurvata (Bischoff) Rexroad and Collinson 1963, pp.11 12,14,15,17.

Discussion: Only a single specimen of M. recurvata was recovered from the Yoredale Series. This specimen was obviously closely related to M. robusta Rexroad and Collinson, but as in Bischoff's figs., the bar is much thinner and more delicate, relatively longer and with slender upright denticles. It is possible that this specimen is merely a juvenile specimen of M. robusta but it does correspond closely with Bischoff's species.

Known Range and Distribution:

Germany: cu IIIα - IIIβ (Goniatites-Stufe) (Bischoff 1957).

Great Britain: Upper Viséan (Present Study).

Occurrence: Middle Limestone (Sample MG259).

Magnilaterella robusta Rexroad and Collinson 1963

Plate 7. Figs. 1-3.

Lonchodina sp. Branson and Mehl (part) 1940, p.171, pl.5, fig.10.

Metalonchodina? sp. Elias 1956, p.124, pl.4, fig.3.

Genus indeterminate Rexroad (part) 1957, p.42, pl.4, figs. 19-21 only.

Genus indeterminate Rexroad 1958, p.26, pl.5, figs. 1,2.

Genus novum? Clarke (part) 1960, p.15, pl.II, figs. 10, 13 only.

Magnilaterella robusta Rexroad and Collinson 1963, pp.13-16, pl.1, Figs. 4,5,9; text figs. 3A-C, 4A-F.

Magnilaterella robusta Rexroad and Collinson, Rexroad and Furnish 1964 p.673, pl.111, figs. 27-29, 31.

Discussion: The Yoredale specimens of M. robusta were few in number and closely resembled the holotype in the length and thickness of the bar and in the number and thickness of the denticles. All had the thickened lower lateral surface on the inner lateral process, described by Rexroad and Collinson (1963) as a callus. Two specimens (from samples BB159, GG217) closely resembled the specimen in text-fig. 4E/1963, having only two large denticles on the inner lateral process.

Known Range and Distribution:

Great Britain: Upper Viséan and Lower Namurian (Clarke 1960 and Present Study).

North America: Chester Series and upper part of the Valmeyeran Series (Mississippian). (Branson and

Mehl 1940, Elias 1956, Rexroad 1957, 1958, Rexroad and Collinson 1963, Rexroad and Furnish 1964).

Occurrence: Middle Limestone (Samples MG259, MG272).

Three Yard Limestone (Samples SW186, GG217).

Great Limestone (Sample BB159).

GENUS METALONCHODINA Branson and Mehl 1941

Type Species: Metalonchodina bidentata (Gunnell 1931)

The generic description of Branson and Mehl (1941, pp.105, 106) is as follows:-

"Base of teeth bar-like, with one long and one short limb; strongly arched in a laterally warped plane; with straight or recurved, sharply-pointed, discrete, widely spaced or closely adjacent denticles. A denticle at the summit of the arch called the apical is distinguishable by basal pit of small size. The short limb commonly supports only one denticle, longer and of greater width than those of the long limb, but it may have three or more denticles.

Remarks. Pennsylvanian representatives of this genus have commonly been referred to Prioniodus, but the base of the terminal denticle in that genus contains the pit and none of the other denticles is excavated. Metalonchodina seems to have originated from Lonchodina through the abortion of the anterior limb. Some of the Mississippian species of Metalonchodina retain as many as three denticles on the short limb. The lateral swing or offset of the arch at the union of the short limb and the long limb is not evident in all species".

Known Range and Distribution:

Belgium: Lower Namurian.

Germany: Viséan.

Great Britain: Upper Viséan - Lower Namurian.

North Africa: Viséan - Lower Namurian.

North America: Meramec? to Lower Permian.

Spain: Viséan - Lower Namurian.

Metalonchodina bidentata (Gunnell 1931)

Plate 7, Figs. 8, 9.

Prioniodus bidentata Gunnell 1931, p.247, pl.29, fig.6.

Prioniodus dactylodus Gunnell 1933, p.265, pl.31, fig.1.

Metalonchodina bidentata (Gunnell) Branson and Mehl 1941, p.106, pl.19, fig.34.

Metalonchodina bidentata (Gunnell) Ellison 1941, p.116, pl.20, figs.35,36.

Metalonchodina sp.A Hass 1953, p.85, pl.16, figs. 17,18.

Metalonchodina bidentata (Gunnell), Bischoff 1957, p.37, pl.5, figs.13,14,46.

Metalonchodina cf. bidentata (Gunnell), Bischoff 1957, p.38, pl.5, fig.16.

Metalonchodina bidentata (Gunnell), Higgins 1961, pl.XII, fig.9.

Metalonchodina bidentata (Gunnell), Higgins 1962, pl.1, fig.3.

Discussion: M. bidentata was restricted to the Mirk Fell Beds, from which five specimens were obtained, none of which was complete. Four of these specimens without doubt belonged to this species. The fifth, although having a thicker posterior bar and a sharper-edged anterior denticle, was included since it was in other respects similar to the other specimens and the amount of variation in this species is wide.

Known Range and Distribution:

Belgium: Lower Namurian (Bouckaert and Higgins 1963).

Germany: Pericyclus and Goniatites-Stufe (Bischoff 1957 Dvořák and Freyer 1961).

Great Britain: Lower Namurian (Higgins 1961, Present Study).

North Africa: Viséan? and Lower Namurian (Remack-Petitot 1960).

North America: Middle Pennsylvanian (Gunnell 1931, 1933, Branson and Mehl 1941, Ellison 1941).

Spain: Viséan and Lower Namurian (Higgins 1962, Higgins, Wagner-Gentis and Wagner 1964).

Occurrence: Mirk Fell Beds (E_2)(Samples MF191, MF192).

GENUS NEOPRIONIODUS Rhodes and Müller 1956

Type Species:- Prioniodus conjunctus Gunnell 1931

The description of Rhodes and Müller (1956, p.698) is as follows:-

"Diagnosis. Compound conodonts consisting of a denticulated posterior bar, at the anterior end of which a large fang (main cusp) is developed. The base of the fang may or may not extend downward below the level of the bar to form an "anticusp", the anterior edge of which may or may not be denticulated. There is usually a basal cavity below the fang, which may be extended as a shallow groove on the aboral surface of the posterior bar".

Known Range and Distribution:

Belgium: Lower Namurian.

France: Upper Tournaisian to Lower Viséan.

Great Britain: Devonian to Lower Namurian.

Germany: Viséan.

North Africa: Upper Viséan to Lower Namurian.

North America: Devonian to Triassic.

Spain: Middle Viséan to Middle Namurian.

Neoprioniodus camurus Rexroad 1957

Plate 7. Fig. 6.

Neoprioniodus camurus Rexroad 1957, p.33pl.2, figs. 18-20.

Neoprioniodus camurus Rexroad, Rexroad 1958, p.23, pl.5, figs. 5,6.

Neoprioniodus camurus Rexroad, Rexroad and Collinson 1961, pl.1.

Neoprioniodus camurus Rexroad, Rexroad and Burton 1961, p.1155, pl.140, fig.11.

Neoprioniodus camurus Rexroad, Rexroad and Furnish 1964, p.674, pl.111, fig.33 (not 32, as in paper).

Discussion: Only a single specimen of N. camurus was found in the Yoredale Series. This specimen was typical of those described by Rexroad (1957) in having an upright, straight, compressed cusp with a strong anticusp, and a long posterior bar which was straight in lateral view, strongly aborally projecting and bearing 13 compressed denticles.

Known Range and Distribution:

Great Britain: Upper Viséan (Present Study).

North America: Upper Valmeyeran Series to top of Chester Series (Mississippian), (Rexroad 1957, 1958, Rexroad and Collinson 1961, Rexroad and Jarrell 1961, Rexroad and Burton 1961, Rexroad and Liebe 1962, Rexroad and Furnish 1964).

Occurrence: Middle Limestone (Sample MG270).

Neoprioniodus conjunctus (Gunnell 1931).

Plate 7. Figs. 11, 12.

Prioniodus sp. D. Roundy (part) 1926, p.11, pl.4, fig.12.

Prioniodus conjunctus Gunnell 1931, p.247, pl.29, fig.7.

Prioniodus cacti Gunnell 1933, p.267, pl.31, figs. 4,5.

Prioniodus sp. Gunnell 1933, p.267, pl.32, fig.32.

Prioniodus conjunctus Gunnell, Ellison 1941, p.113, pl.20, figs. 1-3,16.

Prioniodus bulbosus Ellison 1941, p.114, pl.20, figs.4-7.

Prioniodus inclinatus Hass 1953, p.87, pl.16, figs. 10-14.

Prioniodus? inclinatus Hass, Elias 1956, p.112, pl.IV, fig.1.

Prioniodus bulbosa (Ellison), Bischoff 1957, p.46, pl.5, fig.37.

Neoprioniodus inclinatus (Hass), Higgins 1961, pl.XI, fig.3.

Neoprioniodus conjunctus (Gunnell), Higgins 1962, p.10-11, pl.1, fig.2

List after Higgins 1962.

Discussion: As Higgins (1962,p.11) has pointed out, the amount of variation in this species is sufficient to include the several species listed in synonomy. The majority of the Yoredale specimens had discrete denticles on the posterior bar and closely resembled the form illustrated by Hass (1953, pl.16, fig.11). Others, however, had a greater amount of thickening and fusion of the denticles.

Known Range and Distribution:

Germany: Viséan (Bischoff and Ziegler 1956, Bischoff 1957).

Great Britain: Upper Viséan and Lower Namurian (Higgins 1961 and Present Study).

North America: Meramec? to Upper Pennsylvanian (Hass 1953, Roundy 1926, Gunnell 1931, 1933, Ellison 1941).

Spain: Upper Viséan or Lower Namurian (Higgins 1962).

Occurrence: Simonstone Limestone (Sample MG132, MG130).

Four Fathom Limestone (Sample BB203).

Mirk Fell Beds (Samples MF191, MF192, MF194, MF196).

Neoprioniodus peracutus (Hinde 1900)

Plate 8. Figs. 3,4.

Prioniodus peracutus Hinde 1900, p.343, pl.10, fig.22.

Prioniodus peracutus Hinde, Roundy 1926, p.10, pl.4, figs. 6-8.

Prioniodus peracutus Hinde, Holmes 1928, p.21, pl.3, fig.38.

Prioniodus ligo Hass 1953, p.87, pl.16, figs. 1-3.

Neoprioniodus erectus Rexroad 1957, p.34, pl.2, figs. 23,25.

Neoprioniodus peracutus (Hinde), Clarke 1960, p.14, pl.II, fig.6.

Neoprioniodus peracutus (Hinde), Rexroad and Collinson 1961, pl.1.

Neoprioniodus peracutus (Hinde), Rexroad and Furnish 1964, p.674, pl.111, fig.25.

Discussion: This common species, which was found practically throughout the Yoredale Series exhibits a wide degree of variation. The latter consists mainly in variations in the thickness and length of the anticusp. Thickened forms may resemble N. scitulus whilst unthickened forms N. spathatus, though in the latter case the anticusp of N. peracutus tends to be larger and not so 'spatulate' in shape.

Known Range and Distribution:

Great Britain: Lower Limestone Group of Scotland (Viséan) (Hinde 1900, Holmes 1928, Clarke 1960).
Upper Viséan to Lower Namurian of N. of England (Present Study).

North America: Upper Meramec to Middle Chesterian. (Roundy 1926, Hass 1953, Rexroad 1957, Rexroad and Collinson 1961, Rexroad and Jarrell 1961, Rexroad and Liebe 1962, Rexroad and Furnish 1964).

Occurrence: Gayle Limestone (Samples GB107, GB109, GB111, GB112, GB114, GB116, GB142, GB143, GB147).

Simonstone Limestone (Samples MG70, MG130-133).

Middle Limestone (Samples MG251, MG254-249, MG278, MG283, MG284, MG272, MG285, MG155).

Scar Limestone (Sample SW104).

Five Yard Limestone (Sample SW73).

Three Yard Limestone (Samples GG217, SW181, SW182-186).

Underset Limestone (Samples GG211, GG204, GG203, GG202).

Four Fathom Limestone (Samples BB203-205, BB207).

Main Limestone (Samples GG212, GG215, GG222, GG226).

Great Limestone (Samples BB158, BB159, BB213, BB216, BB215).

Little Limestone (Sample BB123).

Mirk Fell Beds (Samples MF191, MF198).

Neoprioniodus scitulus (Branson and Mehl 1941)

Plate 7. Figs. 14, 15.

Prioniodus scitulus Branson and Mehl 1941, p.173, pl.5, figs. 5,6.

Prioniodus scitulus Branson and Mehl, Cooper 1947, p.92, pl.20, figs.1-3.

Neoprioniodus scitulus (Branson and Mehl), Rexroad 1957, p.35, pl.2, figs.22,26.

Neoprioniodus striatus Rexroad 1957, p.35, pl.2, figs. 11,12.

Neoprioniodus scitulus (Branson and Mehl), Rexroad 1958, p.23, pl.5, Figs 10-14.

Neoprioniodus scitulus (Branson and Mehl), Higgins 1961, pl.XI, fig.1

Neoprioniodus scitulus (Branson and Mehl), Rexroad and Burton 1961, p.1155 pl.140, figs. 15-17.

Neoprioniodus scitulus (Branson and Mehl), Rexroad and Collinson 1961, pl.1.

Neoprioniodus scitulus (Branson and Mehl), Rexroad and Furnish 1964, p.674, pl.111, figs.36,37.

Known Range and Distribution:

Belgium: Lower Namurian (Bouckaert and Higgins 1963).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, Present Study).

North America: Meramec to Chester Series (Branson and Mehl 1941, Cooper 1947, Rexroad 1957, 1958, Rexroad and Burton 1961, Rexroad and Jarrell 1961, Rexroad and Collinson 1961, Rexroad and Liebe 1962, Rexroad and Furnish 1964).

Occurrence: Gayle Limestone (Samples GB107, GB113).

Simonstone Limestone (Samples MG67, MG70, MG130, MG131).

Middle Limestone (Samples MG252, MG259, MG272, MG278, MG283-285).

Five Yard Limestone (Samples SW172, SW173, SW72, SW174).

Three Yard Limestone (Samples SW86, SW185, SW186).

Underset Limestone (Sample GG211).

Four Fathom Limestone (Sample BB207).

Neoprioniodus singularis (Hass 1953)

Plate 8. Figs. 1,2.

Prioniodus barbatus Branson and Mehl, Ellison and Graves (part) 1941, pl.1, fig.25 only.

Prioniodus singularis Hass 1953, p.88, pl.16, fig.4.

Prioniodus singularis Hass, Elias 1956, pl.II, fig.15.

Prioniodus roundyi var dividen Elias 1956, p.110, pl.II, figs. 39-41.

Prioniodus roundyi var parviden Elias 1956, p.112, pl.II, figs. 42,43.

Prioniodus cf singularis Hass, Elias 1956, p.112, pl.II, fig.45.

Prioniodina alatoidea (Cooper), Bischoff 1957, p.45, pl.5, figs. 33,34,36.

Neoprioniodus singularis (Hass), Stanley 1958, p.471, pl.66, figs.2,3.

Neoprioniodus singularis (Hass), Rexroad and Burton 1961, p.1155, pl.140, figs. 13,14,18.

Neoprioniodus singularis (Hass), Higgins 1961, pl.XI, fig.6.

Neoprioniodus singularis (Hass), Rexroad and Collinson 1961, pl.1.

Neoprioniodus singularis (Hass), Higgins 1962, pl.1, fig.8.

Neoprioniodus singularis (Hass), Rexroad and Furnish 1964, p.674, pl.111, fig.32, (not 33 as in paper).

Discussion: This species represents one of the major elements of Yoredale Series conodont faunas. In general these specimens are less massive than the holotype, often with a slightly twisted and sharp-edged cusp but this variation is considered to fall within the range of N. singularis.

Known Range and Distribution:

Belgium: Lower Namurian (Higgins 1962).

France: Upper Tournaisian to Lower Viséan (Remack-Petitot 1960).

Germany: Viséan (Bischoff 1957, Flugel and Ziegler 1957).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, Present Study).

North Africa: Upper Viséan to Lower Namurian (Remack-Petitot 1960).

North America: Meramec to Lower Pennsylvanian (Ellison and Graves 1941, Hass 1953, Elias 1956, Stanley 1958, Rexroad and Clarke 1960, Rexroad and Burton 1961, Rexroad and Collinson 1961, Rexroad and Jarrell 1961, Rexroad and Liebe 1962, Rexroad and Furnish 1964).

Spain: Middle Viséan to Middle Namurian (Higgins 1962, Higgins, Wagner-Gentis and Wagner 1964).

Occurrence: Hawes Limestone (Samples GB17, GB167).

Gayle Limestone Samples GB107-109, GB111-114, GB116, GB117, GB142, GB144).

Hardraw Scar Limestone (Sample MG41).

Simonstone Limestone (Samples MG70, MG130-133).

Middle Limestone (Samples MG251-259, MG278, MG283-285, MG155).

Three Yard Limestone (Samples GG217, SW182, SW86, SW183, SW184, SW186).

Underset Limestone (Samples GG202, GG205, GG211).

Four Fathom Limestone (Samples BB203, BB205).

Iron Post Limestone (Sample BB211).

Main Limestone (Samples GG213-215, GG217, GG219, GG220, GG226).

Great Limestone (Samples BB156, BB158, BB159, BB213- 216).

Mirk Fell Beds (Sample MF197).

Neoprioniodus spathatus Higgins 1961

Plate 7. Figs. 13, 16.

Neoprioniodus spathatus, Higgins 1961, p.217, pl.XI, figs. 2,4, Text fig.5.

Discussion: N. spathatus was uncommon in the Yoredale Series. The majority of the specimens closely resembled that figured by Higgins (1961) as pl.XI, fig.4, and did not bear a denticulated anticusp, though the latter was spatulate in shape. One specimen, from the Gayle Limestone, did bear a single denticle on the anticusp. It therefore appears that the presence of a denticulated anticusp bearing up to 5 denticles as described by Higgins from the Namurian, was a development which was just in its earliest stages in the Yoredale Series.

Known Range and Distribution:

Belgium: Lower Namurian (Bouckaert and Higgins 1963).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961 and Present Study).

Occurrence: Gayle Limestone (Sample GB108).

Simonstone Limestone (Samples MG130, MG132, MG133).

Neoprioniodus varians (Branson and Mehl 1941)

Plate 7, figs. 7, 10.

Prioniodus varians Branson and Mehl 1941, p. 174, pl. V, figs. 7,8.

Prioniodus varians Branson and Mehl, Elias 1956, pl. II, figs. 7,8.

Prioniodina varians (Branson and Mehl), Bischoff 1957, p.49, pl.5, fig.35.

Neoprioniodus varians (Branson and Mehl), Rexroad 1957, p. 35, pl.2, fig.10.

Neoprioniodus varians (Branson and Mehl), Rexroad 1958, p.24, pl.5, figs.3,4.

Neoprioniodus varians (Branson and Mehl), Higgins 1961, pl.XI, fig.7.

Neoprioniodus varians (Branson and Mehl), Rexroad and Burton 1961, p.1155, pl.140, figs. 9,10.

Neoprioniodus varians (Branson and Mehl), Rexroad and Collinson 1961, pl.1.

Known Range and Distribution:

Germany: Goniatites-Stufe, Viséan (Bischoff 1957, Flugel and Ziegler 1957).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, Present Study).

North Africa: Lower Namurian (Remack-Petitot 1960).

North America: Meramec to Chester (Branson and Mehl 1941, Elias 1956, Rexroad 1957,58, Rexroad and Clarke 1960. Rexroad and Burton 1961, Rexroad and Collinson 1961, Rexroad and Collinson 1963).

Occurrence: Gayle Limestone (Sample GB116).

Middle Limestone (Samples MG251, MG259, MG274).

Underset Limestone (Sample GG211).

Four Fathom Limestone (Sample BB207).

NEW GENUS Rexroad and Collinson 1963

Rexroad and Collinson's diagnosis (1963, p.21) of this as yet unnamed genus is as follows:-

"Diagnosis- A denticulate posterior bar that is large, long and straight or nearly-so is attached to a relatively small denticulate lateral bar at the latter's anterior end and extends inward and rearward. There are generally three major denticles on the main bar and they curve posteriorly in the plane of the bar. Both bars are truncated along the lower edge and bear narrow median grooves. The lateral bar bears small denticles along with one or two larger denticles, none of which is as large as those on the posterior bar".

Rexroad and Collinson further commented (p.26) -

"We have only a single relatively complete representative of this form along with a dozen incomplete specimens, which we feel does not represent sufficient materal for erection of a formal generic category .... This form appears to be confined to the St. Louis and Ste. Genevieve Formations, although at least two similar specimens from the lower part of the Chesterian Series have been seen".

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (E_1)(Present Study)

North America: Upper Meramec to Lower Chesterian (Mississippian)

New Genus and New Species. Rexroad and Collinson 1963

Plate 8. Figs. 5-7, 10.

New Genus and New Species, Rexroad and Collinson 1963, p.21, pl.2, figs. 2,7,8: text figs. 5A,B.

Discussion: Rexroad and Collinson (1963, pp.21,26) fully described their only relatively complete specimen of this new genus and included a number of other broken specimens under this heading. The Yoredale specimens are confidently compared with that figured by Rexroad and Collinson (Text figs. 5A and B). Their main features would appear to be a slightly arched bar which may be ridged along its base (see R.& C. pl.2, fig.2) and bearing strongly posteriorly curving denticles. Unlike the specimens of Rexroad and Collinson, however, the denticles of several of the Yoredale specimens were outwardly as well as posteriorly curving.

The lateral bar is as broad as the posterior bar, at first curving strongly posteriorly and slightly aborally but at about its midlength it curves away from the posterior bar and may be at 90° to the bar in its distal part.

Unlike the majority of the Yoredale specimens, the bar of one (pl. 8 fig. 7) was straight in lateral view, had a strong process bearing four denticles, and in similarity with those of Rexroad and Collinson, curved aborally rather than laterally. The amount of variation in this group is therefore considered to be wider than was expected by Rexroad and Collinson, although the similarities between the St. Louis and Yoredale specimens are strong. The lack of sufficient material however, still deters from the erection of a formal generic category.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (E_1) (Present Study).

North America: Upper Meramec to Lower Chesterian (Rexroad and Collinson 1963).

Occurrence: Gayle Limestone: (Sample GB146).

Hardraw Scar Limestone (Samples MG34, MG39, MG41).

Simonstone Limestone (Sample MG132).

Middle Limestone (Samples MG253, MG272, MG276, MG284, MG155).

Scar Limestone (Sample SW104).

Three Yard Limestone (Samples SW184, SW185, SW186).

Great Limestone (Sample BB159).

GENUS OZARKODINA Branson and Mehl 1933

Type species:- Ozarkodina typica Branson and Mehl 1933

The original generic description of Branson and Mehl (1933, p.51) is as follows:-

"Compound dental units consisting of a thin, blade-like, denticulated arched bar, with a denticle of superior size near midlength and approximately an equal number of subequal smaller denticles on either side of it. Denticles laterally compressed, sharp-edged, more or less confluent or actually sheathed. Base excavated beneath large denticle."

Known Range and Distribution:

Belgium: Upper Devonian to Lower Namurian.

France: Lower Devonian to Namurian.

Germany: Silurian to Triassic.

Great Britain: Ordovician to Namurian.

North Africa: Ordovician to Pennsylvanian.

North America: Ordovician to Permian.

Portugal: Upper Devonian to Lower Carboniferous.

Spain: Lower Carboniferous.

Ozarkodina cf. curvata Rexroad 1958

Ozarkodina curvata Rexroad 1958, p.24, pl.4, figs.1-3.

Ozarkodina curvata Rexroad, Rexroad and Burton 1961, p.1156, pl.141, figs. 13,14.

Ozarkodina curvata Rexroad, Rexroad and Collinson 1961, pl.1.

Ozarkodina curvata Rexroad, Rexroad and Collinson 1963, p.19, pl.2, fig.11.

Ozarkodina curvata Rexroad, Rexroad and Furnish 1964, p.674, pl.111, figs. 10, 11.

Discussion: Although the 2 Yoredale specimens possibly belong to a new species, they are closely related to O. curvata, with which they are compared. The main difference between the Yoredale and Chester forms is that the basal pit of the former is large and has an extension passing down the posterior bar. The basal pit as described by Rexroad was small but deep.

Known Range and Distribution:

Great Britain: Upper Viséan (Present Study).

Occurrence: Four Fathom Limestone (Samples BB204, BB206).

Ozarkodina cf. hindei Clarke 1960

Plate 8. Fig. 15.

Polygnathus dubius Hinde 1897, p.363, pl.16, fig.8.

Polygnathus dubius Hinde 1900, p.341, pl.IX, fig.1.

Prioniodina (Polygnathus) dubius Holmes 1928, p.19, pl.8, fig.1.

Ozarkodina hindei Clarke 1960, p.18, pl.III, figs. 1,6.

Discussion: The single Yoredale specimen which is compared with O. hindei Clarke, is similar to the latter in its unusually high anterior and posterior bars and its very wide, sharply-pointed, sharp-edged cusp, which is strongly directed posteriorly and is 3 times the width and twice the height of the adjacent posterior bar denticles. It is also similar in its sharp base which bears a relatively small, elongate, basal pit. The Yoredale specimen differs from O. hindei in that the denticles of its anterior bar are relatively smaller and more numerous (four are present but bar is incomplete) and the unit appears to be somewhat thicker.

It is therefore possible that the comparison made is not a valid one but until such a time when more material is available, the present method is preferred.

Known Range and Distribution:

Great Britain: Upper Viséan (Present Study).

Occurrence: Simonstone Limestone (Sample MG69).

Ozarkodina laevipostica Rexroad and Collinson 1963

Plate 8. Figs. 11, 12.

Ozarkodina laevipostica Rexroad and Collinson 1963, p.19, pl.1, figs.1-6.

Discussion: O. laevipostica was found in the lower part of the Yoredale succession and appeared to be succeeded in the upper part by the form described as O. cf. laevipostica. The chief variation within the species was in the extent of the denticulation of the posterior bar. No specimens were found in which the posterior bar was devoid of denticles but in all of the specimens referred to this species, the denticles were poorly developed and usually widely spaced. There appears to be a transition from this form to O. cf. laevipostica by the acquisition of a stronger denticulation.

Known Range and Distribution:

Great Britain: Upper Viséan (Present Study).

North America: St. Louis Formation (Meramec) (Rexroad and Collinson 1963).

Occurrence: Gayle Limestone (Samples GB111, GB112, GB117, GB148).

Middle Limestone (Sample MG285).

Ozarkodina cf. laevipostica Rexroad and Collinson 1963

Plate 8. Figs. 14, 16.

Description: Oral View:-

Unit strongly bowed, short, thick at its midlength but diminishing rapidly in thickness in the anterior and posterior directions.

Lateral View:-

Unit small, strongly arched and bearing a cusp at its midlength. The anterior bar is strongly aborally projecting, straight, short and bearing 1 to 5 sharply-pointed, sharp-edged denticles, which are strongly inclined posteriorly and also increase in size in that direction. The cusp is large, at least twice the size of the adjacent anterior bar denticle although of similar shape and strongly directed posteriorly. The posterior bar is strongly projecting aborally, of the same length or slightly longer than the anterior bar and bearing about 4 or 5 well-developed close-set denticles of the same shape, although slightly smaller than those of the anterior bar.

Aboral View:-

The basal pit is large and deep and extends posteriorly along the posterior bar.

Discussion: This form is fairly common in the Yoredale Series and although fairly distinct from O. laevipostica, transitional forms do occur, where the denticles are too strongly developed for the latter but are relatively weak for the former. The anterior limb of all the specimens of O. cf. laevipostica except one had 3 to 5 denticles and so compared closely with the St. Louis form. In all respects the two forms are extremely similar and it is therefore considered unnecessary to erect a new specific category for O. cf. laevipostica. The latter also appears to be fairly close related to O. cf. curvata, especially in its highly arched, short form and the size, shape and attitude of its cusp.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (Present Study).

Occurrence: Gayle Limestone (Sample GB112).

Middle Limestone (Samples MG254-257, MG259, MG155).

Five Yard Limestone (Samples SW72, SW73).

Three Yard Limestone (Samples GG217, SW181, SW182, SW86 SW183, SW185).

Underset Limestone (Samples GG201, GG205, GG211).

Four Fathom Limestone (Samples BB206, BB204).

Main Limestone (Sample GG219).

Great Limestone (Sample BB157, BB158, BB159, BB213, BB215, BB216).

GENUS SPATHOGNATHODUS Branson and Mehl 1941.

(Spathodus Branson and Mehl 1933)

Type-Species:- Spathodus primus Branson and Mehl 1933

The generic description of Branson and Mehl (1933, p.46) is as follows:-

"Compound, straight, blade-like dental units with a nearly straight aboral margin, and, oral margin curved or straight but highest at or near anterior end. A short lateral expansion near midlength produces on the otherwise comparatively sharp aboral edge a cup-like excavation or navel, which ranges in shape from slightly elongate antero-posteriorly, through circular, to laterally elongate; either bilaterally symmetrical or asymmetrical in relation to the blade. Oral edge or crest consisting of a single row of "germ denticles", evident in transmitted light, completely sheathed to form a continuous crenulate oral edge. Oral surface of midlength basal expansion or navel typically smooth but in some species bearing one or a few denticles.

Species of this genus with accessory denticles on the oral side of the navel expansion constitute connecting links between typical Spathodus and another development in which more or less fused navel denticles produce a denticulated platform on either side, comparable in appearance to Polygnathus".

Known Range and Distribution:

France: Upper Devonian to Upper Viséan.

Germany: Devonian to Viséan.

Great Britain: Silurian to Lower Namurian.

North Africa: Ordovician to Pennsylvanian.

North America: Silurian to Permian.

Portugal: Upper Devonian to Lower Viséan.

Spain: Upper Devonian to Upper Viséan.

Spathognathodus cristula Youngquist and Miller 1949.

Plate 8. Figs. 18, 20.

Spathognathodus cristula Youngquist and Miller 1949, p.621, pl.101, figs.1-3.

Spathognathodus cristula Youngquist and Miller, Rexroad 1957, p.38, pl.3, figs. 16, 17.

Spathognathodus cristula Youngquist and Miller, Rexroad 1958, p.25, pl.6, figs. 3,4.

Spathognathodus cristula Youngquist and Miller, Rexroad and Burton 1961, p.1156, pl.141, fig.9.

Spathognathodus cristula Youngquist and Miller, Rexroad and Collinson 1961, pl.1.

Spathognathodus cristula Youngquist and Miller, Rexroad and Furnish 1964, p.674, pl.111, fig.15.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (E_2)(Present Study).

North Africa: Namurian (Remack-Petitot 1960).

North America: Upper Meramec to Upper Chester Series (Mississippian)(Youngquist and Miller 1949, Rexroad 1957,1958, Rexroad and Jarrell, 1961, Rexroad and Burton 1961, Rexroad and Collinson 1961, Rexroad and Liebe 1962, Rexroad and Furnish 1964).

Occurrence: Hardraw Scar Limestone (Samples MG41, MG42).

Middle Limestone (Samples MG258, MG270, MG271).

Four Fathom Limestone (Sample BB204).

Underset Limestone (Sample GG211).

Main Limestone (Samples GG217, GG226).

Great Limestone (Sample BB157).

Mirk Fell Beds (Sample MF191).

Spathognathodus minutus (Ellison 1941)

Plate 9. Figs. 2,3.

Spathodus minutus Ellison 1941, p.120, pl.20, figs. 50-52.

Spathognathodus minutus (Ellison), Youngquist and Downs 1944, p.169, pl.30, fig.4.

Spathognathodus minutus (Ellison), Sturgeon and Youngquist 1949, p.385, pl.74, figs. 9-11, pl.75, fig.19.

Spathognathodus minutus (Ellison), Rexroad and Burton 1961, p.1156, pl.141, figs. 10,11.

Spathognathodus minutus (Ellison), Rexroad and Collinson 1961, pl.1.

Discussion: S. minutus, which was found in association with S. cristula and was more common than the latter, is regarded by Rexroad and Burton (1961, p.1156) as being one of an evolutionary series of spathognathodids which includes an unnamed species from the Valmeyer Series, S. cristula from the Chester Series and S. minutus from the Pennsylvanian. The main distinction between the two forms found in the Yoredale Series is the presence in the latter of a series of secondary denticles along the anterior margin of the cusp.

The Yoredale occurrence of S. minutus, which first appears in the middle unit of the Middle Limestone, is the lowest recorded occurrence (Upper Viséan - P_2). One further interesting fact is that S. cristula, which according to Rexroad and Burton precedes S. minutus in the evolutionary scale, and does in fact appear before the latter in the Yoredale Series, extends higher in the succession and is the only species of the genus to be found in the Mirk Fell Beds with S. scitulus.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (E_1) (Present Study).

North Africa: Namurian to Pennsylvanian (Remack-Petitot 1960).

North America: Kinkaid (topmost Chester Series) to Pennsylvanian (Ellison 1941, Youngquist and Downs 1949, Sturgeon and Youngquist 1949, Rexroad and Burton 1961, Rexroad and Collinson 1961).

Occurrence: Middle Limestone (Samples MG270, MG273-275, MG278, MG283, MG285, MG155).

Five Yard Limestone (Sample SW73).

Three Yard Limestone (Samples GG217, SW181, SW182, SW86, SW186).

Underset Limestone (Samples GG201, GG204, GG205, GG211).

Four Fathom Limestone (Samples BB202-206).

Main Limestone (Samples GG220).

Spathognathodus cf. minutus

Plate 8. Fig. 19.
Plate 9. Fig. 1.

Description: Unit small, with an arched aboral margin. The cusp is situated ¼ to ⅓ the distance from the anterior, is wide, compressed, sharp-edged and sharply-pointed, narrower at its base than at half its height and asymmetric in lateral view with its anterior margin longer than its posterior margin. Anterior to the cusp are 3 well-developed, fused denticles equal in size to those in the posterior part of the posterior bar. Posterior to the cusp are 9 denticles as found in S. minutus.

Discussion: This form is very closely related to S. minutus and is considered to be a development of the latter in which the germ denticles anterior to the cusp have developed into strong denticles. This process has necessitated a slight modification of outline in lateral view since the anterior aboral projection is longer in this form than in S. minutus proper.

Known Range and Distribution:

Great Britain: Upper Viséan (Present Study).

Occurrence: Underset Limestone (Samples GG204, GG211).

Four Fathom Limestone (Sample BB204).

Spathognathodus scitulus (Hinde 1900)

Plate 9. Figs. 4,6.

Polygnathus scitulus Hinde 1900(part), p.343, pl.9, figs. 9,11.

Panderodella scitula (Hinde), Holmes 1928 (part), p.16, pl.6, figs.26,28.

Spathognathodus scitulus (Hinde), Youngquist and Miller 1949, p.622, pl.101, fig.4.

Spathognathodus scitulus (Hinde), Clarke 1960, p.21, pl.III, figs.12,13.

Spathognathodus scitulus (Hinde), Rexroad and Collinson 1963, p.20, pl.2, figs.14,19,29-31.

Discussion: S. scitulus was the most common species of this genus to be found in the Yoredale Series and exhibited extremely little variation in form.

Known Range and Distribution:

Great Britain: Lower (P_2) and Upper(E_2) Limestone Groups of Scotland (Hinde 1900, Holmes 1928, Clarke 1960): Upper Viséan to Lower Namurian of the North of England (Present Study).

North America: Meramec and Chester Series (Youngquist and Miller 1949, Rexroad and Collinson 1963).

Occurrence: Hawes Limestone (Samples GB18, GB21).
Gayle Limestone (Samples GB107, GB108, GB110).
Hardraw Scar Limestone (Sample MG42).
Simonstone Limestone (Samples MG69, MG131-133).
Middle Limestone (Samples MG252, MG253, MG255-260, MG271, MG278, MG155).
Scar Limestone (Sample SW105).
Five Yard Limestone (Sample SW173).
Three Yard Limestone (Samples GG219, SW182, SW86, SW183, SW184, SW186).
Underset Limestone (Samples GG201-205, GG211).
Four Fathom Limestone (Sammpes BB205, BB206).
Iron Post Limestone (Sample BB211).
Main Limestone (Samples GG214, GG216, GG218, GG219, GG221).
Great Limestone (Samples BB159, BB213-216).
Mirk Fell Beds (Sample MF191).

GENUS SUBBRYANTODUS Branson and Mehl 1934

Type Species:- Subbryantodus arcuatus Branson and Mehl 1934. The generic description of Branson and Mehl (1934, p.285) is as follows:-

"Conspicuously arched denticulate bars with the anterior limb commonly the longer, and one or both limbs laterally flexed so as to produce a fairly regular concave inward curve of the unit as a whole;

denticles confined to a single row on the oral edge, all somewhat laterally compressed and closely crowded or in contact, all inclined somewhat backward, one denticle of exceptional size, the apical denticle at the apex of the arch; germ denticles not conspicuously developed but when present corresponding to oral terminations; the aboral edge of the bar excavated beneath the arch apex by a long pit that tends to extend as a distinct groove along the edge of each limb.

Orientation. The denticles are inclined posteriorly and the laterally concave side of the arch is the inner side. In most specimens the posterior limb is the shorter.

This genus is probably most closely related to Bryantodus Ulrich and Bassler. It differs most in that ordinarily there is no tendancy toward lateral thickening of the oral edge of the bar and no development of apical lip on the aboral edge as in Bryantodus, and its trend is toward a split or grooved aboral edge through the development of the elongate pit rather than the sharp edge and limited pit of Bryantodus. Subbryantodus approaches some forms of Ozarkodina Branson and Mehl, in the curvature of the bar and its blade-like proportions but lacks the germ denticle development and the suppression of germ denticles which is characteristic of Ozarkodina. Furthermore, all the ozarkodinids have thin sharp aboral edges. The closely crowded to fused, laterally compressed denticles and tendancy toward split aboral edge serve to distinguish Subbryantodus from Prioniodina Ulrich and Bassler, in which the denticles are discrete and nearly circular in cross-section".

Known Range and Distribution:

Belgium: Lower Namurian.

Great Britain: Upper Viséan to Lower Namurian.

North America: Middle Devonian to Chester Series.

Spain: Middle Viséan to Lower Namurian.

Subbryantodus subaequalis Higgins 1961

Plate 9. Fig. 13.

Subbryantodus subaequalis Higgins 1961, p.218, plXII, fig.15, Text-fig.6.

Discussion: The amount of variation exhibited by the Yoredale specimens of this genus was quite wide and it is probable that several species were represented. However the number of specimens was small and their preservation was, on the whole poor thus rendering positive identification difficult. Two specimens of S. subaequalis were definitely recognised.

Known Range and Distribution:

Belgium: Lower Namurian (Bouckaert and Higgins 1963).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, Present Study).

Occurrence: Gayle Limestone (Sample GB109).

Simonstone Limestone (Sample MG133).

Middle Limestone (Samples MG254, MG257, MG259).

GENUS SYNPRIONIODINA Bassler 1925

Type Species:- Synprioniodina alternata Ulrich and Bassler 1926.

Bassler's original description (1925, p.219) is as follows:-

"Like Palmatodella, except that the down-turned front is much smaller, bar thick, denticles not turning forward so sharply, and the main cusp proportionally very large".

The following was further added by Huddle (1934, p.53-54):-

"Tooth consisting of cusp denticulated bar and anticusp. The denticles on the anticusps are in the vertical plane of the bar and cusp. Synprioniodina differs from Euprioniodina in having the denticles closely appressed and joined by bar material; and the cusp is inclined upward rather than forward as in Palmatodella. The anticusp in Palmatodella is longer than the anticusp in Synprioniodina.

Known Range and Distribution:

Great Britain: Devonian to Namurian.

North America: Ordovician to Permian.

Spain: Middle and Upper Viséan.

Synprioniodina forsenta Stauffer 1940

Plate 9. Figs. 9, 12.

Synprioniodina forsenta Stauffer 1940, p.432, pl.59, figs. 31-33, 38-41.

Synprioniodina forsenta Stauffer, Higgins 1961, pl.XII, fig.8.

Discussion: S. forsenta was an uncommon species in the Yoredale Series and as such exhibited only a small amount of variation. The genus as a whole however has been split into numerous species which are separated by minor differences and requires a considerable amount of re-organisation.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, Present Study).

North America: Ordovician to Middle Devonian (Stauffer 1940).

Spain: Middle and Upper Viséan (Higgins 1962.).

Occurrence: Gayle Limestone (Samples GB111, GB144).

Simonstone Limestone (Samples MG131, MG132).

Middle Limestone (Sample MG283).

Three Yard Limestone (Sample GG217).

(iii) Previously Described Species belonging to the Family Hibbardellidae and the Super Family Polygnathaceae:-

FAMILY HIBBARDELLIDAE Müller 1956

Müller's diagnosis for this family is as follows (1956, p.824)

"Bilaterally symmetric, not paired, compound conodonts with a large main denticle. These units have apparently been arranged in the median line of the animal. A median branch may or may not be present".

GENUS HIBBARDELLA Bassler 1925

Type Species:- Prioniodus angulatus Hinde 1897.

The original description (1925, p.219) is as follows:-

"Anterior and posterior ends equally developed, the tooth being bilaterally symmetrical and the main cusp erect and enormously developed."

In 1941, Branson and Mehl issued the following revised description (1941, p.176).

"Highly-arched, bar-like teeth, bilaterally symmetrical with limbs of equal length that bear discrete, erect or recurved denticles, an erect or recurved denticle of large size at the apex of the arch; a bar bearing discrete denticles extending back from the base of the apical denticle normal to the plane of the arch; without conspicuous excavation beneath the apex of the arch at the union of the arch limbs and the posterior bar.

Remarks. This genus resembles closely Trichognathus, differing chiefly in that the latter is deeply excavated beneath the apex of the arch at the union of the arch limbs and posterior bar. In its later development Hibbardella may have the posterior bar very much shortened and in some species there is only a vestage of the arch-limbs".

Known Range and Distribution:

Belgium: Lower Namurian.

Great Britain: Devonian to Lower Namurian.

North America: Devonian to Triassic.

Spain: Upper Viséan.

Hibbardella abnormis Branson and Mehl 1940

Plate 9. Figs. 14, 15.

Hibbardella abnormis Branson and Mehl 1940, p.184, pl.6, fig.14.

Hibbardella abnormis Branson and Mehl, Rexroad and Collinson 1963, p.10, pl.2, figs. 15,18,20,21.

Discussion: Branson and Mehl figured only an aboral view of the broken holotype but it does illustrate the expanded nature of the base of the posterior bar, which appears to be typical of the species. Rexroad and Collinson (1963) figured better preserved material, to which the Yoredale specimens bear a close resemblance. The main differences are that the Yoredale specimens have a smoother anterior margin, rather than having the sharp angle at the junction of the base of the cusp and lateral processes (Rexroad and Collinson 1963, pl.2, fig.18) and the lateral processes tend to curve slightly aborally, as opposed to being straight in lateral view. The amount of variation within the Yoredale Series is small. All the variations described here are considered to be intraspecific.

Known Range and Distribution:

Great Britain: Upper Viséan (Present Study).

North America: Valmeyeran Series (Mississippian). (Branson and Mehl 1940, Rexroad and Collinson 1963).

Occurrence: Gayle Limestone (Sample GB117).

Simonstone Limestone (Sample MG67).

Middle Limestone (Samples MG135, MG250, MG251, MG253, MG259, MG278, MG283, MG155).

Four Fathom Limestone (Samples BB203, BB204).

Hibbardella fragilis Higgins 1961

Plate 10, Fig. 1.

Hibbardella fragilis Higgins 1961, p.213, pl.XII, fig.4, Text-fig.2.

Discussion: Only 3 specimens of this species were found none of which were complete. These specimens differed from the type-specimen in having a more strongly arched posterior bar but this variation was considered to fall within the range of H. fragilis.

Known Range and Distribution:

Belgium: Lower Namurian (Bouckaert and Higgins 1963).

Great Britain: Upper Viséan and Lower Namurian (Higgins 1961, Present Study).

Spain: Upper Viséan (Higgins 1962).

Occurrence: Gayle Limestone (Sample GB111).

Three Yard Limestone (Sample SW184).

Great Limestone (Sample BB159).

GENUS ROUNDYA Hass 1953

Type Species:- Roundya barnettana Hass 1953

The generic description given by Hass (1953, p.88) is as follows:-

"A bilaterally symmetrical unit consisting of adenticulate anterior arch which is surmounted by a large main cusp and a denticulated posterior bar which is joined to the basal posterior side of the main cusp. Denticles of posterior bar and anterior arch discrete. Main cusp erect or curved posteriorly. Pulp cavity large, located beneath main cusp".

Known Range and Distribution:

Belgium: Lower Namurian.

France: Upper Devonian.

Germany: Upper Devonian to Viséan.

Great Britain: Upper Devonian to Lower Namurian.

North Africa: Middle Devonian to Lower Namurian.

North America: Upper Devonian to Upper Pennsylvanian.

Portugal: Upper Devonian to Lower Carboniferous.

Spain: Upper Devonian to Middle Namurian.

Roundya subacoda (Gunnell 1931)

Plate 10. Figs. 2, 3.

Prioniodus subacodus Gunnell 1931, p.246, pl.29, fig.5.

Prioniodus missouriensis Gunnell 1931, p.247, pl.29, fig.9.

Idioprioniodus striatus Gunnell 1933, p.265, pl.32, figs. 36,37.

Hibbardella subacoda (Gunnell), Ellison 1941, p.118, pl.20, figs. 22,26.

Hibbardella subacoda (Gunnell), Youngquist and Heezon 1948, p.768, pl.118, fig.13.

Roundya barnettana Hass 1953, p.89, pl.16, figs. 8,9.

Roundya barnettana Hass, Elias 1956, p.121, pl.IV, figs. 22,23.

Roundya barnettana Hass, Bischoff 1957, p.52, pl.5, figs. 19,20.

Roundya costata Rexroad 1958, p.26, pl.2, figs. 5,8.

Roundya subacoda (Gunnell), Higgins 1961, pl.XI, fig.13.

Roundya costata Rexroad, Rexroad and Collinson 1961.

Roundya barnettana Hass, Collinson, Scott and Rexroad 1962, p.11.

Roundya subacoda (Gunnell), Higgins 1962, p.13, pl.1, fig.1.

Discussion: The variation in this species, as witnessed in the Yoredale Series consists of variation in the amount of thickening and the size of the unit, both of which are considered to be intraspecific characters. Rexroad and Clarke (1960, p.1205) placed R. costata in synonomy with R. Barnettana when it was realised that these species were completely intergrading and dependant upon the amount of thickening which had taken place. Hass, however, distinguished his species (R. barnettana) from R. subacoda in that the latter was less massive. R. barnettana and R. costata are thus placed in synonomy with R. subacoda (Gunnell)

Known Range and Distribution:

Belgium: Lower Namurian (Bouckaert and Higgins 1963).

Germany: Viséan (Bischoff 1957, Flugel and Ziegler 1957).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, Present Study).

North Africa: Lower Namurian (Remack-Petitot 1960).

North America: Meramec to Upper Pennsylvanian (Gunnell 1931, Stauffer and Plummer 1932, Ellison 1941, Youngquist and Heezen 1948, Hass 1953, Elias 1956, Rexroad 1958, Rexroad and Clarke 1960, Rexroad and Jarrell 1961, Rexroad and Collinson 1961, Collinson, Scott and Rexroad, 1962).

Spain: Upper Viséan to Middle Namurian (Higgins 1962).

Occurrence: Simonstone Limestone (Sample MG70).

Middle Limestone (Samples MG259, MG278).

Three Yard Limestone (Sample SW184).

Main Limestone (Sample GG221).

Great Limestone (Samples BB212, BB213).

Mirk Fell Beds (Samples MG191, MF192).

SUPER FAMILY POLYGNATHACEAE Müller and Müller 1957

The description given by Müller and Müller (1957, p.1083) is as follows:-

"Under this name are united those form types which have been evolved from Ctenognathus by development of a plate. The more or less pronounced blade and carina are adorned with a row of ± approximated nodes. Included are the Polygnathidae Ulrich and Bassler 1926, Gnathodontidae Branson and Mehl 1944, and Icriodidae, n. fam."

FAMILY POLYGNATHIDAE Ulrich and Bassler 1926

The original family diagnosis as given by Ulrich and Bassler (1926, p.43) is as follows:-

"Plates with a high denticulated median or lateral crest which is often extended stalklike from one end".

Branson and Mehl's revised description (1944, p.244) is as follows:-

"Dental units leaflike plates, fundamentally bilaterally symmetrical; a median blade extends forward from one plate; aboral surface with small attachment scar in middle of plate".

In 1957, Müller and Müller (p.1083) redefined the family:-

"Paired, platformlike conodonts with a well-developed blade, part of which is free. Lower side has a crimp and only a small escutcheon which is homologous to the basal cavity in other families. In some groups the escutcheon is reduced to a node. Carina is present, one or more secondary carinae may be developed.

Remarks. To the diagnosis of Branson and Mehl the following change is proposed: fundamentally bilaterally symmetrical has to be omitted, for partial genera like Palmatolepis and Ancyroides demonstrate asymmetry."

GENUS MESTOGNATHUS Bischoff 1957

Type Species:- Mestognathus beckmanni Bischoff 1957

The generic diagnosis given by Bischoff (1957, p.36) is as follows:-

"Ornamentierte, trogförmige Plattform mit einem kurzen, vorn nicht oder nur wenig über die Plattform hervorragenden, nach hinten ansteigenden und abrupt endenden Blatt auf der vorderen Aussenkante, einer ± brustungsähnlichen vorderen Innenkante und einer im Querschnitt konvexen Aboralfläche mit kleiner Basalgrube im mittleren Teil."

Known Range and Distribution:

Germany: Viséan.

Great Britain: Upper Viséan to Lower Namurian.

Mestognathus bipluti Higgins 1961

Plate 10. Figs. 4 - 7.

Mestognathus bipluti Higgins 1961, p.216, pl.X, figs. 1,2, Text fig.4.

Discussion: Only five specimens of M. bipluti were obtained from the Yoredale Series, each from the Simonstone Limestone and exhibiting a marked degree of variation. These specimens nevertheless fitted the diagnosis of the species in having two denticulate parapets instead of the one which characterises M. beckmanni. The variation consisted mainly of differences in shape of the platform in oral view. One specimen was slender, smoothly convex in outline and sharply posteriorly pointed, another was broad, spatulate-shaped and posteriorly rounded and the remaining three specimens had parallel inner and outer margins in the anterior half of the unit whilst the posterior half was angular and sharply pointed. On all except the spatulate-shaped unit the inner parapet was more pronounced than that found on the holotype. These variations are considered to be intra-specific.

Known Range and Distribution:

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, Present Study).

Occurrence: Simonstone Limestone (Samples MG69, MG70, MG130).

FAMILY GNATHODONTIDAE Branson and Mehl 1944

Branson and Mehl's description (1944, p.245) is as follows:-

"Elongate, platform or trough-like dental units with an anterior blade; broadly excavated aborally".

GENUS <u>CAVUSGNATHUS</u> Harris and Hollingsworth 1933

Type Species:- <u>Cavusgnathus alta</u> Harris and Hollingsworth 1933

The generic description given by Harris and Hollingsworth (1933, pp.200-201) is as follows:-

"This genus is erected to include those lanceolote-plated conodonts with no semblance of a median crest in the median oral channel . Outline of plate lanceolate to claviform; oral face of plate with complete, deep, median longitudinal channel without crest and bordered by marginal rims ornamented with denticles, nodes, corrugations or combinations of the same; posterior bar denticulate".

In 1941 Ellison produced the following revised description (1941, pp.125-126).

"Elongate platform-like teeth with high sides extending parapet-like above a median longitudinal trench; one parapet continued into a free longitudinal blade and connected at the posterior end to opposite parapet whose length is limited by the length of the platform; aboral surface of platform smooth, deeply excavated as a longitudinally elongate, laterally asymmetrical, spathodid-like cup, pointed at each end, traversed by a median longitudinal groove which extends to the ends of the platform and along the aboral edge of the blade; sides of platform somewhat constricted laterally above the aboral margin to produce a lip-like lateral margin of variable width; oral surface of platform more or less grooved transversely; oral edge of blade denticulate and crenulate.

For purposes of description the blade is directed anteriorly. It is continued posteriorly as the outer edge of the platform, the blade parapet. The elevated inner edge of the platform is the inner parapet".

<u>Known Range and Distribution</u>:

Belgium: Lower Namurian.

France: Namurian.

Germany: Viséan - cu II γ to cu III γ.

Great Britain: Upper Viséan to Lower Namurian.

North Africa: Lower Namurian.

North America: Middle Mississippian to Middle Permian.

Spain: Middle Namurian.

Cavusgnathus convexa Rexroad 1957

Plate 10. Figs. 8, 9.

Cavusgnathus convexa Rexroad 1957, p.17, pl.1, figs. 3-6.

Cavusgnathus convexa Rexroad, Rexroad 1958, p.16, pl.1, figs. 12-14.

Cavusgnathus convexa Rexroad, Rexroad and Burton, 1961, p.1151, pl.138, fig.14

Cavusgnathus convexa Rexroad, Rexroad and Collinson 1961, pl.1.

Cavusgnathus convexa Rexroad, Rexroad and Furnish 1964, p.670, pl.111, fig.1.

Discussion: This record of C. convexa in the Yoredale Series is the first outside of the United States and consists of only a single specimen. The specimen is nevertheless fairly-well preserved and fits the diagnosis and description given by Rexroad (1957, p.17).

Known Range and Distribution:

Great Britain: Upper Viséan (Present Study).

North America: Upper Mississippian (Rexroad 1957, 1958, Rexroad and Collinson 1961, Rexroad and Burton 1961, Rexroad and Jarrell 1961, Collinson, Scott and Rexroad 1962, Rexroad and Furnish 1964).

Occurrence: Underset Limestone (Sample GG201).

Cavusgnathus navicula (Hinde 1900)

Plate 11. Figs. 1-3.

Polygnathus navicula Hinde 1900, p.342, pl.IX, fig.5.

Polygnathus navicula Hinde, Holmes 1928, p.18, pl.7, fig.14.

Cavusgnathus cristata Branson and Mehl, Cooper 1947, p.91, pl.20, figs.4-10.

Cavusgnathus cristata Branson and Mehl, Bischoff 1957, p.19, pl.2, figs.7a,b.

Cavusgnathus navicula (Hinde), Clarke 1960, p.23, pl.IV, figs. 1-3.

Cavusgnathus inflexa Clarke 1960, p.23, pl.III, figs. 17,19.

Cavusgnathus navicula (Hinde), Rexroad and Burton 1961, p.1151, pl.139, figs. 4-13.

Cavusgnathus unicornis Youngquist and Miller, Higgins 1961, pl.X, fig.3.

Discussion: This distinctive species of Cavusgnathus, which is characteristic of the upper part of the succession and is not found below the Main Limestone, is one in which substantial changes of the unit occur during ontogenetic development. These changes, which take the form of the gradual obliteration or filling-in of the oral trough, have caused considerable confusion in the past in the recognition of the species. Thus C. inflexa (Clarke) represents an earlier stage of development than the C. navicula figured by Clarke. In forms in which these changes are advanced the oral trough may be completely obliterated except at the extreme anterior end of the unit and the platform may then in some respects resemble that of Mestognathus in oral view.

Rexroad and Burton (1961) considered C. navicula to have developed from C. unicornis and this is in agreement with the stratigraphic relations of the two species as seen in the Yoredale Series. Also in support of this, the juvenile forms of C. navicula have much in common with C. unicornis.

Known Range and Distribution:

Great Britain: Lower Limestone Group (P_2) of Scotland (Hinde 1900, Holmes 1928, Clarke 1960).

Lower Namurian of the Midlands and North of England (Higgins 1961, Present Study).

Germany: cu III γ (topmost Viséan)(Bischoff 1957).

North America: Kinkaid Formation - topmost Mississippian (Cooper 1947, Rexroad and Burton 1961).

Occurrence: Great Limestone (Samples BB213-216).

Little Limestone (Sample BB123).

Mirk Fell Beds (Samples MF191, MF196, MF197).

Cavusgnathus unicornis Youngquist and Miller 1949

Plate 11. Figs. 5-7.

Cavusgnathus unicornis Youngquist and Miller 1949, p.619, pl.101, figs.18-23.

Cavusgnathus unicornis Youngquist and Miller, Rexroad 1957, p.17, pl.1, fig.7.

Cavusgnathus unicornis Youngquist and Miller, Rexroad 1958, p.17, pl.1, figs.6-11.

Cavusgnathus unicornis Youngquist and Miller, Rexroad and Burton 1961, p.1152, pl.138, figs.13,15.

Cavusgnathus unicornis Youngquist and Miller, Rexroad and Collinson 1963, p.9, pl.1, figs.26,27.

Cavusgnathus unicornis Youngquist and Miller, Rexroad and Furnish 1964, p.670, pl.111, fig.6.

Discussion: This is the most common of the various species of *Cavusgnathus* recorded in this report.

Known Range and Distribution:

Belgium: Lower Namurian (Bouckaert and Higgins 1963).

Great Britain: Upper Viséan to Lower Namurian (E_2)(Present Study)

North America: Meramec and Chester Series (Youngquist and Miller 1949, Rexroad 1957, 1958, Rexroad and Clarke 1960, Rexroad and Jarrell 1961, Rexroad and Collinson 1961, Collinson, Scott and Rexroad 1962, Rexroad and Burton 1961, Rexroad and Liebe 1962, Rexroad and Collinson 1963, Rexroad and Furnish 1964).

Occurrence: Gayle Limestone (Samples GB148, GB163).

Simonstone Limestone (Sample MG133).

Middle Limestone (Samples MG253, MG272, MG283).

Three Yard Limestone (Sample SW185).

Underset Limestone (Samples GG201, GG211).

Four Fathom Limestone (Samples BB202, BB203).

Main Limestone (Sample GG213).

Great Limestone (Samples BB156, BB157).

Mirk Fell Beds (Samples MF190, MF191).

GENUS *GNATHODUS* Pander 1856. Emend.

Gnathodus Pander 1856, pp.33,34.

Gnathodus Pander, Bryant 1921, p.22.

Gnathodus Pander, Ulrich and Bassler 1926, p.54.

Gnathodus Pander, Roundy 1926, p.12.

Gnathodus Pander, Branson and Mehl 1938, pp.134, 144.

Dryphenotus Cooper 1939, p.386.

Gnathodus Pander, Branson and Mehl, in Shimer and Shrock 1944, p.245.

(List after Hass 1953, p.78)

Type Species by monotypy:- Gnathodus mosquensis Pander 1856.
Pander's original description (1856, pp.33-34) is as follows:-

"In den Mergeln, der untersten Schichten des Bergkalks im Tulaschen und der höheren des Moskauschen Gouvernements kommon wohlerhaltene kieferartige Ueberreste vor, die sich durch ihre Gestalt und die Beschaffenheit ihrer Basis von den bis jetzt beschriebenen unterscheiden, durch die mikroscopische Structur aber sich eng an sie anschliessen. Auf einer hohen, aus doppelten Wänden bestehenden, schmalen Platte, erheben sich, in einer Reihe, kleine Zähnchen und geben dieser das Ansehen, als wenn sie von einem gezähnten Rande begrenzt werde. Nach unten gehen diese Platten auf der einen Seite stark auseinander und bilden eine Höhle, während sie auf der entgegengesetzen noch aneinander bleiden. Diese Höhle welche die Pulphöle darstellt, verlängert sich seitwärts hinein und giebt, wie zu vermuthen ist, für jedes Zähnchen einen hinaufsteingenden Fortsatz ab."

The revised description issued by Branson and Mehl (1938, p.144) is as follows:-

"Jaw pieces consisting of a thin straight or slightly curved, Spathodus-like blade which at the posterior end is expanded into a more or less, hemispherical, thin-walled cup, opening aborally; the blade extending across the oral surface of the cup as a low, nodose or denticulate carina that terminates on the cup or a short distance behind it; oral edge blade sharply crenulate through the growth of laterally compressed, partly fused denticles; oral surface of cup ornamented by nodes that tend to align themselves into ridges which typically radiate from the centre of the cup.

Orientation. For purposes of description the cup is called posterior. In forms with curved axes the concavity is towards the inner side. This seems to correspond to a less expanded cup on the inner side in markedly asymmetric forms. The greater lateral extension of the cup marks the outer side and should take precedence over curved axes orientations that do not agree with the above."

Since Branson and Mehl revised this description a number of species have been added to the genus Gnathodus which differ from the more typical species, such as G. bilineatus (Roundy 1926) in that they have a small sub-circular or ovate cup which may be free from ornamentation or decorated with nodes in various numbers and orientations. The generic description is therefore amended to include these forms, which include Gnathodus commutatus (Branson and Mehl 1941) and Gnathodus kockeli Bischoff 1957. The varieties of Gnathodus commutatus are raised to specific level in this report. There is thus a growing amount of evidence in favour of splitting these sub-circular or ovate cupped forms from Gnathodus and forming a new genus and it seems likely that this will be accomplished in the near future, when their ranges and stratigraphic relationships are more fully known.

Known Range and Distribution:

Belgium: Upper Viséan to Lower Namurian.

France: Upper Tournaisian to Upper Viséan.

Germany: Basal Tournaisian to Viséan.

Great Britain: Devonian to Lower Namurian.

North Africa: Mississippian to Middle Triassic.

North America: Upper Devonian to Triassic.

Portugal: Upper Tournaisian to Lower Viséan.

Spain: Tournaisian to Middle Namurian.

Gnathodus bilineatus (Roundy 1926)

Plate 13. Figs. 4-10, 13.

Polygnathus bilineata Roundy 1926, p.13, pl.3, figs. 10a-c.

Polygnathus texana Roundy 1926, p.14, pl.3, figs. 13a-b.

Gnathodus pustulosus Branson and Mehl 1941, p.172, pl.5, figs. 32-39.

Gnathodus texana Roundy, Ellison and Graves 1941, p. 2, pl.2, figs. 8-10,12.

Gnathodus bilineatus (Roundy), Hass 1953, p.78, pl.14, figs. 25-29.

Gnathodus pustulosus Branson and Mehl, Elias 1956, p.115, pl.3, figs.1-8.

Gnathodus bilineatus (Roundy), Elias 1956, p.118, pl.3, figs. 23-29.

Gnathodus modocensis Rexroad 1957, p.30, pl.1, figs. 15-17.

Gnathodus bilineatus (Roundy) bilineatus Bischoff 1957, p.21, pl.3, figs. 11,15-20; pl.4, fig.1.

Gnathodus bilineatus (Roundy) bilineatus Flugel and Ziegler 1957, p.38, pl.3, figs. 1,2.

Gnathodus modocensis Rexroad, Rexroad 1958, p.17, pl.1, figs. 1,2.

Gnathodus bilineatus (Roundy), Stanley 1958, p.464, pl.68, fig.7.

Gnathodus bilineatus (Roundy), Voges 1959, p.282, pl.33, figs. 28-30.

Gnathodus smithi Clarke 1960, p.26, pl.IV, figs. 13,14; pl.V, figs. 9,10.

Gnathodus bilineatus (Roundy), Higgins 1961, pl.X, fig.5.

Gnathodus bilineatus (Roundy), Higgins 1962, pl.3, fig.32.

Gnathodus bilineatus (Roundy) modocensis Rexroad and Furnish 1964, p.670, pl.111, figs. 4,5.

Discussion: G. bilineatus is not an abundant species in the Yoredale Series but it is found practically throughout the succession of limestones and a fairly large number of specimens have been studied. This material shows a wide degree of variation with complete intergradation between the variants. Rexroad's species G. modosensis (1957) is included in synonomy with G. bilineatus since this was done by Collinson, Scott and Rexroad in 1962 (Chart 4, p.11). This form was, however, later described as a sub-species of G. bilineatus by Rexroad and Furnish (1964). The latter believed G. bilineatus modocensis to differ from G. bilineatus only because of its geographic isolation and although it is considered that there is value in describing the form in this way, the Yoredale specimens have shown so much variation, even within a single sample, that this form has once again been included in synonomy.

The variation exhibited by the Yoredale specimens is briefly outlined below:-

1. Ornamentation. The inner platform is normally transversely ridged but may become noded posteriorly and the ridges may be regular and parallel, irregular, coarse or fine. The platform is noded in all cases but there is great variation in the concentration and altitude of the nodes. In extreme cases the whole of the platform is covered with coarse, closely-packed nodes which extend posteriorly and obliterate

the carina in the rounded posterior extremity of the unit. The other extreme is a form approaching G. semiglaber Bischoff 1957, in which the nodes are confined to the more or less flat upper surface of the outer platform and are poorly developed with large smooth areas in between. There appears to be a complete gradation between these two extremes.

The nodes are usually arranged in concentric rows but when the concentration of nodes becomes greater, they may lose all sense of arrangement, or become fused into irregular concentric ridges. The width of the smooth margin around the outer platform is usually directly related to the concentration of nodes on the platform, being wide in those with poorly developed nodes and absent in the strongly noded types.

2, Shape of Platforms:- In the larger, more heavily noded specimens the outer platform is usually rectangular, with parallel anterior and posterior margins and an outer margin which is roughly parallel with the carina. Some forms may develop a very large platform in which the outer margin is of greater length than that part of the platform which is in contact with the carina. The opposite extreme is a form in which the platform is small and triangular and may completely lack the outer margin parallel to the carina.

The inner platform is usually of uniform width along its length but occasionally increases in width anteriorly or posteriorly. This platform is also separated from the carina by a groove of variable depth but deepening anteriorly.

3. Width of Posterior Extremity of Unit:- The posterior of the unit is normally sharply pointed with the carina extending to the extremity but in the heavily noded types this part may become rounded and the carina obliterated.

4. The Relative Width of the Platforms varies

5. Height of the Inner Platform:- The inner platform is normally low posteriorly and gradually increases to the same height as the carina anteriorly. In some forms however, the inner platform may be appreciably higher than the carina.

Known Range and Distribution:

Belgium: Upper Viséan to Lower Namurian (Serre et Lys 1960, Bouckaert and Higgins 1963).

France: Tournaisian to Upper Viséan (Remack-Petitot 1960, Serre et Lys 1960).

Germany: Viséan (Bischoff 1957, Flugel and Ziegler 1957, Voges 1959, 1960, Meischner 1962, Böger 1962).

Great Britain: Upper Viséan to Lower Namurian (Clarke 1960, Higgins 1961, Present Study).

North Africa: Viséan (cuIII/β) to Lower Namurian (Remack-Petitot 1960).

North America: Meramec to Lower Pennsylvanian (Roundy 1926, Branson and Mehl 1941, Ellison and Graves 1941, Hass 1953, Elias 1956, Rexroad 1957, 1958, Rexroad and Clarke 1960, Rexroad and Jarrell 1961, Rexroad and Collinson 1961, Collinson, Scott and Rexroad 1962, Rexroad and Liebe 1962, Rexroad and Furnish 1964).

Spain: Middle Viséan to Middle Namurian (Higgins 1962).

Occurrence: Hawes Limestone (Sample GB17).
Gayle Limestone (Samples GB109, GB111, GB112, GB117).
Middle Limestone (Samples MG251, MG257, MG259, MG285).
Five Yard Limestone (Samples SW172, SW73).
Three Yard Limestone (Samples GG217, SW182-186).
Underset Limestone (Samples GG202, GG204, GG205).
Four Fathom Limestone (Samples BB202-207).
Main Limestone (Samples GG212, GG214, GG215, GG218, GG220-222).
Great Limestone (Samples BB158, BB212, BB159, BB213, BB215).

Gnathodus commutatus (Branson and Mehl 1941)

Discussion: Gnathodus commutatus was a distinctive but extremely variable species with a wide occurrence and a long stratigraphic range. When Bischoff described the species (1957, pp.22-24), the full stratigraphic value of the various forms was unknown and this is probably the reason for their being described as the following subspecies of the already existant species G. commutatus - Gnathodus commutatus commutatus, G. commutatus nodosus and G. commutatus punctatus (homopunctatus Ziegler 1962). Since then two further subspecies or varieties have been added, G. commutatus multinodosus (Higgins 1962, p.8), and G. commutatus pellaensis (Rexroad and Furnish 1964, p.671). In the present report these five subspecies are raised to the specific level, since they are now known to have different, if overlapping, stratigraphic ranges, each is of value in its own right and each is readily distinguished from the others. This also dispenses with the large and cumbersome species as it stood, which was of little stratigraphic value as a single taxonomic unit.

The following three forms (species) were found in the Yoredale Series, Gnathodus commutatus, G. homopunctatus and G. nodosus of which a new variety has already been described of the latter (see page 85).

Gnathodus commutatus (Branson and Mehl 1941)
Plate 11. Figs. 13-15.

Spathognathodus commutatus Branson and Mehl 1941, p.98, pl.19, figs.1-4.

Spathognathodus commutatus Branson and Mehl, Branson and Mehl 1941, p.172, pl.V, figs.19-22.

Spathognathodus commutatus Branson and Mehl, Ellison and Graves 1941, pl.2, figs. 4,6.

Gnathodus inornatus Hass 1953, p.80, pl.14, figs.9-11.

Spathognathodus commutatus Branson and Mehl, Elias 1956, p.119, pl.III, figs.19-22.

Spathognathodus inornatus (Hass), Elias 1956, p.119, pl.III, figs.37-39.

Spathognathodus cf. inornatus (Hass), Elias 1956, p.119, pl.III, figs. 41,42,62,63.

Spathognathodus cf. commutatus Branson and Mehl, Rexroad 1957, p.38, pl.3, figs. 23,24.

Gnathodus commutatus (Branson and Mehl), sub.sp.commutatus Flugel and Ziegler 1957, p.39, pl.III, fig.21.

Gnathodus commutatus (Branson and Mehl), sub.sp.commutatus Bischoff 1957, p.22, pl.IV, figs.2-15.

Spathognathodus cf. commutatus Branson and Mehl, Rexroad 1958, p.26, pl.6, fig.8.

Gnathodus inornatus Hass, Stanley 1958, p.465, pl.68, figs. 5,6.

Gnathodus commutatus (Branson and Mehl) sub.sp.commutatus Lys and Serre 1958, p.891, pl.IX, figs.2a,b.

Spathognathodus commutatus Branson and Mehl, Clarke 1960, p.19, pl.III, figs. 4,5.

Gnathodus commutatus (Branson and Mehl) var. commutatus Higgins 1961, p.212, pl.X, fig.6; Text fig.1a.

Gnathodus commutatus (Branson and Mehl), Rexroad and Burton 1961, p.1153, pl.139, figs. 1-3.

Gnathodus commutatus (Branson and Mehl) var. commutatus Higgins 1962, p.13, pl.2, fig.22.

Discussion: The emended G. commutatus is a compact species with little variation and in all cases completely devoid of surface ornament on the platform. The Yoredale specimens vary only in thickness and in the amount of bowing, which may be quite strong and range from the base of the succession to the Main (=Great) Limestone. This species is a common feature of the faunas within this range.

Known Range and Distribution:

Belgium: Lower Namurian (Bouckaert and Higgins 1963).

Germany: Viséan (Bischoff 1957, Flugel and Ziegler 1957, Voges 1959, Böger 1962, Meischner 1962).

Great Britain: Upper Viséan to Lower Namurian (Clarke 1960, Higgins 1961, Present Study).

North Africa: Upper Viséan to Lower Namurian (Remack-Petitot 1960).

North America: Meramec to Lower Pennsylvanian (Branson and Mehl 1941, Ellison and Graves 1941, Hass 1953, Elias 1956, Rexroad 1957, 1958, Stanley 1958, Rexroad and Clarke 1960, Rexroad and Burton 1961, Rexroad and Collinson 1961, Rexroad and Jarrell 1961, Rexroad and Liebe 1962).

Spain: Upper Viséan to Middle Namurian (Lys and Serre 1958 Higgins 1962).

Occurrence: Hawes Limestone (Samples GB17-19, GB21, GB167).

Gayle Limestone (Samples GB106-108, GB111-114, GB116, GB117, GB142-144, GB147-148.).

Hardraw Scar Limestone (Sample MG40).

Simonstone Limestone (Samples MG70, MG130, MG132, MG133).

Middle Limestone (Samples MG250-259, MG272, MG276, MG278, MG283, MG285, MG155).

Scar Limestone (Sample SW105).

Three Yard Limestone (Samples GG217, SW181-186, SW86).

Underset Limestone (Samples GG203-205).

Four Fathom Limestone (Samples BB202, BB203, BB207).

Main Limestone (Samples GG213-220, GG226).

Great Limestone (Samples BB156, BB157, BB212, BB159, BB213-216).

<u>Gnathodus homopunctatus</u> Ziegler 1962.

Plate 12. Figs. 1 - 4.

<u>Gnathodus commutatus</u> (Branson and Mehl) sub.sp. <u>punctatus</u> Bischoff 1957, p.24, pl.4, figs. 7-11, 14.

<u>Gnathodus commutatus</u> (Branson and Mehl) sub.sp. <u>homopunctatus</u> n.nom. Ziegler, 1962, p.395, pl.4, fig.3.

<u>Gnathodus commutatus</u> (Branson and Mehl) var. <u>homopunctatus</u> Ziegler, Higgins 1961, pl.X, fig.9.

<u>Gnathodus commutatus</u> (Branson and Mehl) sub.sp. <u>homopunctatus</u> Ziegler, Meischner 1962, p.31, fig.10.

<u>Gnathodus commutatus</u> (Branson and Mehl) var. <u>homopunctatus</u> Ziegler, Higgins 1962, pl.2, fig.21.

<u>Discussion</u>: This species is found only in the lower part of the Yoredale Succession. The amount of variation is slight and consists mainly of the development in the upper part of its range, of forms with double rows of nodes on each side of the platform instead of the usual single row.

<u>Known Range and Distribution</u>:

France: Upper Viséan (Remack-Petitot 1960, Serre and Lys 1960).

Germany: Viséan (Bischoff 1957, Voges 1959, Meischner 1962).

Great Britain: Upper Viséan to Lower Namurian (Higgins 1961, Present Study).

Spain: Middle Viséan to Middle Namurian (Higgins 1962).

Occurrence: Hawes Limestone (Samples GB167, GB18, GB19).

Gayle Limestone (Samples GB108, GB110-114, GB116, GB117, GB142-145, GB147, GB148, GB166).

Middle Limestone (Samples MG257-259, MG283, MG285).

Gnathodus nodosus Bischoff 1957 nodosus.

Plate 12. Figs. 5-7.

Gnathodus commutatus (Branson and Mehl) sub.sp. nodosus Bischoff 1957, p.23, pl.4, figs. 12,13.

Gnathodus commutatus (Branson and Mehl), sub.sp. nodosus Bischoff, Flugel and Ziegler 1957, p.40, pl.3, fig.4.

Gnathodus cruciformis Clarke 1960, p.25, pl.IV, figs. 10-12.

Gnathodus commutatus (Branson and Mehl), var nodosus Bischoff, Higgins 1961, p.213, pl.X, figs.7,8; Text fig. 1 b.

Gnathodus commutatus (Branson and Mehl), sub.sp. nodosus Bischoff, Meischner 1962, p.31, fig.10.

Gnathodus commutatus (Branson and Mehl), var nodosus Bischoff, Higgins 1962, pl.2, fig.19.

Discussion: The diagnosis given by Bischoff (1957) was emended by Higgins (1961, p.213), to include those forms with more than one node on the inner or inner and outer sides of the cup. The Yoredale specimens exhibit a gradual increase in the number of nodes as they are traced up the succession. In the lower part of the succession only those forms with a single node on the inner side are found. The first specimen with a single node on both sides of the cup appears at the top of the Simonstone Limestone. Above this horizon forms appear with a radiating row of nodes on the inner or inner and outer sides and finally in the Main Limestone G. nodosus radiolus var. nov. (see p.85) appears in which the rows of nodes are bifurcating, double or clustered. The simpler forms remain throughout the range of the species and are combined with rather than replaced by the more complex forms in the upper part of the succession.

Known Range and Distribution:

Belgium: Upper Viséan to Lower Namurian (Serre and Lys 1960, Bouckaert and Higgins 1963).

Germany: cuIIIβ to cuIII γ (Goniatites-Stufe)(Bischoff 1957, Flugel and Ziegler 1957, Meischner 1962).

Great Britain: Upper Viséan to Lower Namurian (Clarke 1960, Higgins 1961, Present Study).

North Africa: Lower Namurian (Remack-Petitot 1960).

Spain: Upper Viséan to Middle Namurian (Higgins 1962).

Occurrence: Gayle Limestone (Samples GB107, GB108, GB110).

Simonstone Limestone (Samples MG132, MG133).

Middle Limestone (Samples MG254, MG256-259, MG283, MG285, MG155).

Scar Limestone (Sample SW105).

Five Yard Limestone (Sample SW174).

Three Yard Limestone (Samples GG217, SW182-186, SW86).

Underset Limestone (Samples GG202, GG204, GG205).

Four Fathom Limestone (Samples BB203, BB204, BB206).

Main Limestone (Samples GG213-222, GG226).

Great Limestone (Samples BB157, BB158, BB212, BB159, BB213-216).

GENUS STREPTOGNATHODUS Stauffer and Plummer 1932

Type Species: Streptognathodus excelsus Stauffer and Plummer 1932.

The generic description given by Stauffer and Plummer (1932, p.47) is as follows:-

"Plate somewhat lanceolate, subsymmetrical, with a deep axial furrow, toward which the 8 to a dozen or more lateral ridges marking the upper surface extend from each side and in which they disappear. Usually shelf-like processes extend out from each side at the base of the plate and may bear nodes.

A long and usually tapering bar extends from the basal end of the plate, and the denticles of its upper edge are fused throughout the greater part of their length, anteriorly decreasing in prominence and finally becoming a nearly smooth-edged ridge or carina, which extends into the furrow and usually ends at some point between the base and middle of the plate. The axis of the tooth is usually curved or bent laterally at or near the base of the plate.

Under surface is marked by a longitudenal groove bounded by ridges that flare out suddenly beneath the plate expanding the groove into a wide cavity, which tapers to the pointed end of the plate."

In 1941 Ellison issued a revised description (p.127), which is as follows:-

"The blade is the anterior denticulate process. This attaches in a median position to the platform. The platform may bear laterally directed nodose processes called accessory lobes. The large excavated aboral surface of the platform is the attachment scar. For purposes of description the blade directed anteriorly. The side of the aboral attachment scar having the greatest lateral extension near the anterior portion of the platform is designated the inner side. If the axis of the tooth is curved laterally, the concave side is inward.

Remarks. Because Streptognathodus and Idiognathodus are supposed to be derivatives of the genus Spathodus, the anterior and posterior ends are placed opposite to the orientation given by Stauffer and Plummer."

Known Range and Distribution:

France: H_2 and R_1 zones (Namurian).

Great Britain: Namurian.

North Africa: Westphalian.

North America: Uppermost Mississippian to Permian.

Streptognathodus unicornis Rexroad and Burton 1961

Plate 11. Figs. 11, 12.

Taphrognathus varians Branson and Mehl, Cooper 1947, p.92, pl.20, figs.14-16.

Streptognathodus unicornis Rexroad and Burton 1961, p.1157, pl.138, figs.1-9.

Discussion: Streptognathodus unicornis was found only in the highest beds of the succession, i.e. the Mirk Fell Beds and exhibited an interesting transitional series from Cavusgnathus unicornis to an atypical form of Streptognathodus unicornis. The Cavusgnathus end of the series is fairly typical of that species but the specimens referred to Streptognathodus are not typical of the forms illustrated and described by Rexroad and Burton (1961). The transitional series of the Mirk Fell Beds must parallel that described by the latter authors (1961, p.1156). The derivation of Streptognathodus from Cavusgnathus is demonstrated by the migration of the blade from alignment with the outer parapet to a central position. The prominent posterior blade denticle of C. unicornis is retained by S. unicornis but the Yoredale forms of the latter species differ in that the blade represents only ¼ the length of the unit as opposed to ½ the length of the unit in the Kinkaid forms. The nodose ornamentation of the platform is closely similar in the 2 areas and is also identical to that of some specimens of Cavusgnathus lower in the Yoredale Succession.

Known Range and Distribution:

Great Britain: Lower Namurian (E_2)(Present Study).

North America: Kinkaid Formation - topmost Mississippian (Rexroad and Burton 1961)

Occurrence: Mirk Fell Beds (Samples MF190, MF191).

3. SOME CONSIDERATIONS OF THE GENUS APATOGNATHUS? IN THE LIGHT OF INFORMATION RESULTING FROM THE STUDY OF THE CONODONTS OF THE YOREDALE SERIES.

The presence of the genus Apatognathus? in abundance in the Yoredale Series represents a fairly unique situation in Carboniferous conodont faunas and renders it possible to study a number of interesting features concerning this genus. Apatognathus? comprises over 10% of the whole fauna in many of the samples studied and is found throughout the succession of limestones up to and including the Little Limestone. Elsewhere in the world the genus is relatively uncommon but has a wide geographic distribution and is found sporadically through the stratigraphic column from Upper Devonian to Triassic or possibly Cretaceous times. The sporadic stratigraphic occurrences are as yet unexplained but the geographic distribution is considered in the light of information resulting from the Yoredale occurrences.

(a) Previously Recorded Occurrences of the Genus Apatognathus:-

For many years this genus was considered to be an index fossil of the Upper Devonian (Branson and Mehl 1934; Ellison 1946; Weller et al. 1948, Mehl 1960). Specimens referred to this genus have however been found at higher horizons during recent years and the genus is now known to occur in Upper Devonian, Middle Tournaisian, Upper Viséan and Lower Namurian or Middle Mississippian, Permian, Middle Triassic and possibly Cretaceous strata. Both the stratigraphic and geographic distribution of these occurrences are important in this section of the report and a summary of these is outlined below.

Three species of Apatognathus have been recorded from the Upper Devonian of Europe, the U.S.A. and Africa. The most restricted in range is the type species, A. varians Branson and Mehl 1934, recorded from the Grassy Creek Formation of America and also from similar horizons by Klapper (1958) and Klapper and Furnish (1962). In Europe the species is recorded from zone to V of Germany by Bischoff and Ziegler (1956) and Freyer (1961).

A. inversus (Sannemann 1955) ranges from zone to I (Frasnian) to zone to V (Fammenian) in Germany (Bischoff and Ziegler 1956, Flugel and Ziegler 1957) and has also been recorded from the Louisiana Limestone and Saverton Shale (Scott and Collinson 1961) of America, equivalent in part to the Upper Fammenian.

The third species, A. lipperti Bischoff 1956, was recorded from Germany (Bischoff and Ziegler 1956), Portugal (Van Den Boogaard 1963), the Sahara (Remack-Petitot 1960) and America (Scott and Collinson 1961) with ages ranging from Upper Frasnian to Upper Fammenian.

The first record of the genus in the Caboniferous System was that of Bischoff (1957), when he recorded A. varians in the Goniatites striatus zone (cuIIIβ) of Germany. In view of the restricted range of this species in the Upper Devonian and the fact that this record was of a single unfigured specimen, little emphasis could be placed upon this Carboniferous occurrence. However Conil (1959) has since recorded this species and a form which he compared with this species, both undescribed and unfigured, from the Tn_2 zone of Belgium (equivalent to Z_2 zone of England).

Hinde (1900) first described specimens of this genus from a fauna from the Scottish Carboniferous Limestone Series. Several new species of conodonts, including Prioniodus geminus and Prioniodus porcatus were described and these two species have since been re-described by Clarke (1960) and transferred to the genus Apatognathus. This genus has also appeared in large numbers in the St. Louis Formation (Valmeyeran Series) of America (Rexroad and Collinson 1963), which was equated with the Goniatites crenistria zone (cu IIIα) of Europe (Collinson, Scott and Rexroad 1962).

Three species of the genus have been found in post-Carboniferous strata. Diebel (1956) described a conodont fauna, which included A. ziegleri n. sp., from the Upper Chalk, Cretaceous, of the Cameroons but since there have been no reports of any conodonts from the whole of the Jurassic period, a certain amount of uncertainly is cast upon this Cretaceous fauna. In 1956 Tatge described A. longidentatus n. sp. from the upper part of the Lower Muschelkalk to the top of the Upper Muschelkalk and finally in 1962 Clark and Ethington found 20 specimens which they named A. tribulosus from two localities in the Permian of the U.S.A.

There have therefore been eight species of Apatognathus previously described and in addition two unnamed species; one by Scott and Collinson (1961) and the other by Tatge (1956). The post-Carboniferous forms bear a striking resemblance to each other and A. longidentatus Tatge was equated with A. ziegleri Diebel by Clark and Ethington (1962), with which they also favourably compared their own species, A. tribulosus.

(b) A Consideration of possible Homeomorphy within the Genus *Apatognathus*:-

An examination of the distribution of this genus illustrates the apparently disconnected nature of its various appearances through time and throughout the world. Several workers have therefore considered most of the forms of *Apatognathus* to be homeomorphic. Scott and Collinson (1961) remarked that in spite of the occurrence of the genus in the St. Louis Formation, equivalent to the base of the *Goniatites* stage of Germany, they have not found it in the Hannibal, Chouteau or any of the other Lower Mississippian Formations of Western Illinois and therefore concluded that this Middle Mississippian occurrence might represent a case of homeomorphy similar to that discussed by Rexroad (1958) for the conodont genera *Taphrognathus* and *Streptognathodus*. Clark and Ethington (1962) considered that "of the various species which are referred to *Apatognathus* only the type seems to be properly classified. All the others probably should be placed in a different genus."

If this is the case and the gap in occurrence is the criterion for concluding that a form might be homeomorphic then it follows that homeomorphy possibly occurred a second time to give rise to the post-Carboniferous forms, which appear to have a definite relationship to each other. However, the sporadic occurrence of the genus *Apatognathus* also results in the ancestry not being known for any of these forms. It is therefore, strictly speaking, impossible to refer to homeomorphy, since this term implies a knowledge of different ancestry for similar forms. A more desirable term in this case, which has no implications of ancestry and refers only to the appearance of the specimens is "morphic equivalents". Collinson, Scott and Rexroad (1962) expressed this doubt of the origin of the various species of *Apatognathus* by referring to them as *Apatognathus? ______* and the practice is continued in the present report. It is inevitable that this group will need a considerable amount of reorganisation in the future when the gaps in the record have been filled but until that date the amount of confusion is restricted to a minimum by including all the species, with reservation in this genus and by not complicating the issue with homeomorphy when this cannot be substantiated.

(c) Facies Control of the Viséan/Middle Mississippian Representatives of the Genus *Apatognathus?*:-

During Viséan or Middle Mississippian times *Apatognathus?* appeared to have favoured certain conditions to the exclusion of others. After a long period of absence the genus suddenly appeared in relative abundance in three separate regions and at approximately similar horizons. These three regions, the Illinois Basin of the U.S.A., the Midland Valley of Scotland and the Askrigg and Alston Blocks of the North of England, although not identical lithologically are each represented by shallow-water cyclic sediments in which goniatites are rare and the fauna is mainly benthonic. The contrast is therefore between a coral/brachiopod facies where *Apatognathus?* is present and a cephalopod facies where the genus is absent. This is particularly well-shown in Britain, where *Apatognathus?* is absent from the P and E_1 zones in the Midlands and Lancashire (Dr. A. C. Higgins - personal communication) but is present at equivalent horizons in the coral/brachiopod facies of the Askrigg and Alston Blocks. The facies control of the genus is further illustrated by the fact that even within the Yoredale Series there are no representatives of *Apatognathus?* in the Mirk Fell Beds, which consist of a shale and ironstone sequence containing goniatites of E_2 age but they do occur at this horizon in the Upper Limestone Group of the Midland Valley of Scotland (Clarke 1960).

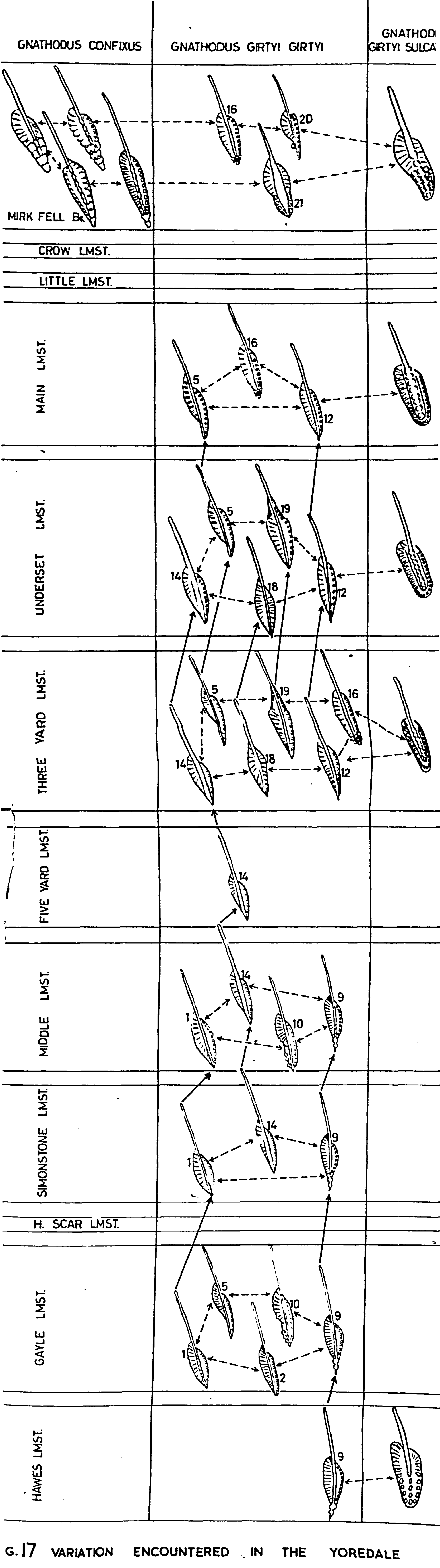
It is therefore considered that unlike most conodont genera the Carboniferous representatives at least of the genus *Apatognathus?* were facies controlled. The conodont animal bearing this form genus must have favoured shelf and shore line conditions, where the water was shallow and where terrigenous material was periodically deposited in the form of a delta. Evidence available from the Yoredale Series suggests that the conodonts in general preferred the very shallow, clear-water conditions which prevailed after the submergance of the land surface and before the formation of the delta but that Apatognathus? was the only genus tobe confined to these conditions.

It is therefore probable that if the gaps in the record of the genus are to be filled and the question of homeomorphy clarified, the answer must lie in sediments which were deposited under similar conditions to those described for the Yoredale Series.

4. A CONSIDERATION OF THE EVOLUTION OF GNATHODUS GIRTYI GIRTYI HASS THROUGH THE YOREDALE SUCCESSION

Gnathodus girtyi Hass 1953 is known to range from Upper Tournaisian to Lower Namurian strata. The Yoredale Succession, which ranges from the Upper Viséan to Lower Namurian therefore provides a record of the upper part of this range. The large number of specimens and the large amount of variation witnessed in the Yoredale Series are probably indicative of the species having reached its acme of development at about this time, thus giving rise to new genera and species in the Namurian. Clarke (1960) recorded G. clavatus (in synonomy with G. girtyi) as being very frequent in the Lower Limestone Group (P_2) and frequent in the Upper Limestone Group (E_2) of the Midland Valley of Scotland, with specimens occurring in almost every productive sample. The latter is also true in the Yoredale Series and well over 1500 specimens of G. girtyi have been examined.

G. girtyi exhibits variation both within single horizons and from one horizon to another, the variants being completely gradational. Nevertheless many of the forms do appear at more than one horizon and are considered to range through the strata whilst at the same time taking part in the variation at any particular horizon. Text-fig.(17) is an attempt to illustrate both the amount of variation exhibited by the 2 varieties of G. girtyi plus the new species G. confixus in each limestone and to indicate the range of those forms which appear in more than one limestone. The faunas of the Hardraw Scar Limestone were small and are



G. 17 VARIATION ENCOUNTERED IN THE YOREDALE
TUDY IN THE CONODONT SPECIES GNATHODUS
GIRTYI AND GNATHODUS CONFIXUS

not therefore included in this study. The Little and Crow Limestones are also excluded because of the lack of specimens. Since the forms are gradational, those indicated in the figure tend to be the extreme forms.

The following remarks refer only to G. girtyi girtyi and the features described are the most distinctive features of the forms in question.

Only Form 9 (see text-fig.17) was found in the Hawes Limestone. It bears a prominent posterior extension to the carina, on which are situated two large bulbous nodes, one behind the other. The posterior margin of both sides of the platform is formed by the anterior margin of the anterior-most of the two nodes.

In the Gayle Limestone Form 9 was joined by the following 4 types:- (a) Form 5, which bears a strongly bowed carina, an outer side to the platform which extends to the sharply pointed posterior margin of the unit and is of fairly uniform width along its length and an inner side which is more anteriorly set than the outer since it does not extend to the posterior margin of the unit. The ornamentation of the two sides differs and consists of small discrete nodes on the outer margin of the outer side and transverse ridges on the inner side.

(b) Form 2, which is closely related to Form 5 but differs from the latter in that the inner and outer sides of the platform both extend to the posterior margin of the unit.

(c) Form 1, which has a posteriorly pointed platform to which both sides plus the carina extend. The inner side is longer than the outer side and is ornamented with transverse ridges which diminish into nodes posteriorly. The outer side bears a row of discrete nodes along its outer margin.

(d) Form 10, which bears a nodose carina, a nodose outer side which extends to the posterior extremity and a very short, convex, transversely ridged inner side which has a noded extension to the posterior margin of the unit.

The Simonstone Limestone contains Forms 4 and 9 and these are joined by Form 14. The latter has a sharply-pointed posterior consisting of the noded outer side of the platform plus the carina. Its inner side extends to $\frac{1}{4}$ to $\frac{1}{3}$ the length of the platform from the posterior end and terminates anteriorly in the same position as the outer side. The inner margin of the unit is straight and lacks the indentation caused by the offset inner side of the platform in Form 5.

The Middle Limestone contains Forms 1,9,10 and 14, all of which have been described from lower horizons, whilst Form 14 is the only one present in the Five Yard Limestone.

The Three Yard Limestone contains 6 types, of which Forms 5 and 14 have already been described. The remaining 4 are as follows:-

(a) Form 12, which is similar to Form 9 but has a posterior extension to the carina which is unmodified by nodes.

(b) Form 16, which bears 7 pronounced nodes at the posterior end of the unit. These are arranged in two rows of 3, one behind the other, representing the inner side, carina and outerside, with a single central node terminating the unit.

(c) Form 18, which is the only form in which both sides of the platform are transversely ridged and of equal size.

(d) Form 19, in which the posterior part of the blade is greatly thickened to equal the width of the platform into which it merges.

The Underset Limestone contains Forms 5,12,14,18 and 19 and the Main Limestone Forms 5,12, and 16, all of which have been described from lower horizons.

The only remaining new forms are those of the Mirk Fell Beds, where the Gnathodus fauna was very distinctive since this is the only horizon to contain both varieties of G. girtyi and the new species G. confixus. G. girtyi girtyi consists of 3 main types, one of which, Form 16, has already been described. The 2 remaining forms are as follows:-

(a) Form 20, in which the inner side of the platform is very short and has retreated even further from the posterior margin of the unit than the outer side, its place being taken by a single large node adjacent to the carina.

(b) Form 21, in which the platform is indented at both its margins at half its length, the carina is broad and extends to the posterior margin of the unit and the ornamentation of both sides of the platform consists of ridges anteriorly and nodes posteriorly.

Gnathodus girtyi thus exhibits the greatest amount of variation of any single species in this report. G. girtyi sulcatus is a distinctive variety which could have given rise to Streptognathodus in the Namurian by the continued degeneration of the carina. The closely related new species G. confixus is confined to the Mirk Fell Beds and could be the ancestor of Idiognathodus or Idiognathoides, by the continued fusion of the nodes. The single variety G. girtyi girtyi is extremely variable but little value can be seen in further splitting since the various forms are completely gradational and it would no doubt cause great confusion to erect further artificial boundaries.

5. A CONSIDERATION OF THE NATURAL CONODONT ASSEMBLAGES WHICH COULD HAVE GIVEN RISE TO THE FORM GENERA AND SPECIES OF THE YOREDALE SERIES

A consideration of the natural conodont assemblages which have been described (Schmidt 1934, 1939; Jones 1938; DuBois 1943; Scott 1934, 1942; Cooper 1945; Rhodes 1952) indicates that two natural assemblage genera i.e. Westfalicus (Schmidt 1934) and Lewistownella Scott 1942, could have given rise to a part of the faunas of form genera and species found in the Yoredale Series.

Schmidt (1934) described a natural assemblage containing the form genera Gnathodus, Bryantodus and Lonchodus (Hindeodella) which he named Gnathodus integer. In view of the difficulties involved in nomenclature it was suggested by Rhodes (1962) that the only solution would be to give new names to natural conodont assemblages and to retain the existing system of nomenclature for isolated conodonts. Thus Schmidt's assemblage appears as Westfalicus in the Treatise on Invertebrate

Palaeontology. Rhodes (1962) expressed the opinion that although it is difficult to check Schmidt's determinations from his figures, the Bryantodus seems to be Ozarkodina and the Lonchodus blades include Hindeodella and Synprioniodina. If this is so, Westfalicus could well have given rise to a small part of the Yoredale conodont faunas.

Lewistownella Scott 1942, comprises the following form genera:- Cavusgnathus, Subbryantodus, Neoprioniodus and Hindeodella, each of which have been found in the present study. Unfortunately Subbryantodus is very uncommon and Cavusgnathus is also uncommon in the lower half of the succession. It therefore seems likely that although Lewistownella could have contributed to the Yoredale conodont faunas its importance must not be overestimated.

Illinella typica Rhodes 1952, could not have been present since each assemblage contains one pair of Gondolella, which is completely absent in the Yoredale Series, plus a predominance of Lonchodus, of which only occasional fragments have been recognised. Scottognathus typica (Rhodes 1952) contains Idiognathodus, which is also absent, plus a predominance of Streptognathodus, which has only been found, atypically developed, in the Mirk Fell Beds. The latter form genus was also an important constituent of the Pennsylvanian natural assemblage described by DuBois (1943). Duboisella typica Rhodes 1952, could possibly have been present in the Yoredale Series but only in its upper part because it includes Metalonchodina, which is restricted to the Mirk Fell Beds. Lochriea Scott 1942, contains the form genera Spathognathodus, Neoprioniodus and Hindeodella each of which are present in the Yordale Series but also contains Prioniodella, which is completely absent.

The only known natural conodont assemblages which could have contributed to the Yoredale conodont faunas are therefore Westfalicus (Schmidt 1943) and Lewistownella Scott 1942. Their exact importance, if present, is unknown since they were by no means the only contributors and may only have been of minor importance. The majority of the form genera and species of conodonts present in the Yoredale Series therefore probably originated from an as yet unknown natural assemblage.

6. CONCLUSIONS TO THE PALAEONTOLOGY OF YOREDALE CONODONTS

The conodont faunas of the Yoredale Series have been of great interest both because of the large number of species present, many of which are new, and the large number of specimens available. About 9,000 specimens have been obtained from 11 limestones and their lateral equivalents, plus the Mirk Fell Beds and about 65-70% of this number of individuals were preserved sufficiently completely for an accurate identification to be made. A total of 76 species and 4 varieties have been described from 22 genera. 23 of the forms were described for the first time in the present report and are listed below:-

Apatognathus? chaulioda

Apatognathus? cuspidata

Apatognathus? librata

Apatognathus? petila

Apatognathus? scalena

Cavusgnathus middlehopensis

Gnathodus confixus

Gnathodus nodosus radiolus

Hibbardella apsida

Hindeodella hamatilis

Hindeodus sp. A.

Hindeodus sp. B.

Lambdagnathus n.sp. A.

Lambdagnathus sp. B.

Ligonodina n.sp.A.

Lonchodina n.sp.A.
Lonchodina sp.B.
Magnilaterella alternata

Magnilaterella sp.A.
Ozarkodina adunca
Ozarkodina sp. A.

Ozarkodina sp. B.

Spathognathodus sp. A.

In addition 3 existing varieties have been raised to specific level.

The majority of the Yoredale conodont faunas have been dominated by the genus Gnathodus, which in individual samples may comprise over 60% of the whole fauna and in individual limestones may be 50%. G. girtyi seemed to bear a sympathetic relationship to the Gnathodus commutatus/nodosus/homopunctatus series of forms, for whilst the former was the most common species, its occasional presence in much smaller numbers was compensated by an increase in numbers in the latter species. G.bilineatus was rarely a common form although it was often present in small numbers.

The Yoredale conodont faunas were unique in the combined abundance of Gnathodus and Apatognathus?. Six species of the latter genus have been described, 5 of which were new, representing 10-15% of the individual faunas, although occasional small faunas contained a much greater proportion.

Other important genera, as far as numbers of individuals and species are concerned, were Neoprioniodus, Ligonodina, Spathognathodus and Hindeodella. The latter genus is undoubtedly underestimated in a study of this sort since its remains are so often fragmentary that most are probably lost in the preparation procedures and the majority of those specimens which are retained are beyond specific identification. This is substantiated to some extent by the fact that Hindeodella was 4 times as abundant as each of the other components in a number of the natural assemblages discussed earlier, including Westfalicus.

Another very interesting feature of Yoredale conodont faunas has been the presence of Magnilaterella. This genus has for many years appeared in small numbers in America and in Europe and has been variously referred to Lonchodina, Ligonodina or simply New Genus. It was only in 1963 that Rexroad and Collinson were able to describe sufficient material to erect a new genus, with Magnilaterella robusta as the type species. This species, plus M. complectens (Clarke), M. recurvata (Bischoff) and several new forms have been found in the Yoredale Series, where the combination of Magnilaterella with Apatognathus? bears a striking resemblance to the faunas of the St. Louis Formation, described by Rexroad and Collinson (1963).

The presence of Streptognathodus in the Mirk Fell Beds has had a number of important repercussions, most of which will be discussed later. One, however, is that it appears that this genus could have arisen from two sources. In the Yoredale Series a definite transition is visible from Cavusgnathus unicornis to an admittedly atypical Streptognathodus unicornis. The latter is atypical in the short length of its blade but this structure is definitely centrally placed, as opposed to the lateral position in Cavusgnathus. It is therefore considered that all the Yoredale representatives of Streptognathodus originated from Cavusgnathus. It is also possible, however, that later forms originated from Gnathodus girtyi sulcatus. The latter appears sporadically and in small numbers from the Hawes Limestone to the Mirk Fell Beds and differs from Gnathodus girtyi girtyi mainly in the partial or complete degeneration of the carina into discrete nodes. A continued degeneration of the central structure in this way would result in a platformed conodont, with a central sulcus, lateral ornamentation and a central blade i.e. Streptognathodus.

A consideration of the known natural conodont assemblages has shown that the natural assemblage genera Westfalicus (Schmidt 1934) and Lewistownella Scott 1942, could have contributed to the Yoredale conodont faunas of the form genera and species. These could not, however, have been the only natural assemblages involved for several reasons. Firstly, the genus Gnathodus is much more common than its nearest rival and yet the only natural assemblage containing this form genus did so in equal proportions to Ozarkodina and Synprioniodina. The latter have only been obtained in very small numbers compared with Gnathodus, as is illustrated by the following ratios.

	Gnathodus	:	Ozarkodina	:	Synprioniodina
Westfalicus	1	:	1	:	1
Yoredale Series	194	:	9	:	1

Other form genera present in both natural assemblages and the Yoredale Series may be very rare in the latter e.g. the form genus Subbryantodus of Lewistownella.

In addition 9 of the 22 genera present in the Yoredale Series have never been described from a natural assemblage. Included in this category is Apatognathus?, the second most common genus of the study.

It is therefore considered that at least one, probably several, unknown natural assemblage genera have contributed to the Yoredale conodont faunas and that their most important constituents must have been the form genera Gnathodus, Apatognathus?, Neoprioniodus and Ligonodina.

C H A P T E R   F O U R

STRATIGRAPHY OF YOREDALE CONODONTS

CHAPTER IV

1. INTRODUCTION

It has already been pointed out (Chapter One) that the Yoredale Series does not lend itself to subdivision by any of the accepted zonal schemes. The Coral/Brachiopod zonal scheme has been relatively unsuccessful because of the insensitivity of the latter over such a relatively short period of time and although the base of the succession in the present report has been taken at the D_1/D_2 junction, it was the Girvanella Band, which coincides with this junction, which was the important marker horizon. The Goniatite zonal scheme, of prime importance in other regions, is of little "working value" in the Yoredale Series because of the extreme rarity of these fossils and the poor state of preservation of those which are found.

The importance of conodonts in the Yoredale Series may therefore be judged in the light of the absence of an accurate or readily applicable zonal scheme and also in the light of the present chapter. It has already been seen (Chapter Three) that conodonts are abundant in these beds and exhibit a wide degree of variation, both within specific horizons and from one horizon to another. In a series of variable strata such as those of the Yoredale Series, where many different environments from fully marine to terrestrial are represented, it is inevitable that any zonal scheme would have to concentrate on certain specific horizons from each cyclothem and would not be based upon the findings from the whole of the succession of strata. The conodont animal is considered to have been virtually, if not completely restricted to a marine environment, with the result that conodonts may only be found in the marine horizons of each cyclothem. These horizons are represented by limestone, which is often the dominent lithology of each cyclothem and calcareous shale, which is in almost all cases present. The present report however has concerned only the thick limestone at the base of each cyclothem plus the shales and ironstones of the Mirk Fell

Beds. The reason for this was the failure to obtain any conodonts from the marine shales in the preliminary sampling and the finding of abundant specimens in the limestones. Since that time only the limestones have been studied, with the exception of the Mirk Fell Beds but it is possible that conodonts are nevertheless present in some of the marine shales at restricted horizons. The following remarks therefore refer only to the limestone of each cyclothem unless otherwise stated.

Providing fossils are present in a series of beds, it is their distribution through those beds which is most important to stratigraphy. The present chapter discusses the various aspects of conodont distribution within the Yoredale Series and summarises the major factors influencing this distribution. Also included is a short summary of the associated microfaunas encountered in this study.

2. DISTRIBUTION OF CONODONTS THROUGH INDIVIDUAL YOREDALE LIMESTONES

Throughout this study the samples of limestone have been weighed and a standard size of 1750 gms. has in all cases been digested in acid. At certain horizons a further amount of sample may have been digested separately, but all the following remarks refer to the number of conodonts obtained from the standard-sized sample.

A record of the number of conodonts obtained from each limestone sample has illustrated a remarkable constancy in pattern of distribution of these fossils through the individual limestones. Reference to text fig.(23) however indicates that this pattern may be complicated by several factors. A description of the distribution of conodonts through each of the individual limestones follows.

(a) Hawes Limestone:-

Only the upper 30ft. of the Hawes Limestone has been sampled in the present study. This limestone contained only small faunas of conodonts, the three lowest samples yielding only 7 specimens, but the number of conodonts per sample increased upwards and reached a maximum of 42 in the sample from 5ft. below the top bedding-plane.

From this position there was a decrease to the top of the limestone, which was barren.

(b) Hardraw Scar Limestone:-

The pattern of distribution in the Hardraw Scar Limestone (50ft. thick) was very similar to that of the Hawes Limestone with small faunas containing a maximum of 6 specimens, in the lower 35ft. of the limestone, a maximum abundance (22 specimens) at 10ft. below the top bedding plane and a decrease to the top of the bed, which contained 12 specimens.

(c) Scar Limestone:-

Only the upper 10ft of the Scar Limestone was sampled but the 3 samples available indicated that the conodont distribution in this bed was almost identical to that of the Hawes Limestone, with a maximum concentration of conodonts at a position 5ft. below the barren top of the bed.

(d) Great Limestone:-

The Great Limestone (23ft. thick) of Borrowdale Beck contained much larger faunas than those so far described but their distribution was fairly typical. The basal sample contained 12 conodonts, the next samples (18, 13 and 10ft. below the top) varied between 25 and 30 specimens, the maximum concentration at 8ft. contained a sudden increase to 350 specimens and from this point the decline in numbers to the top bedding plane was interrupted only by the sample from 4ft. below the top, which contained rather fewer conodonts than might have been expected. (46 specimens as opposed to 69 in the top bedding plane).

(e) Four Fathom Limestone:-

Only the upper 7ft. of the Four Fathom Limestone was sampled from Borrowdale Beck but the 6 samples collected from this thickness indicated a comparable distribution pattern with those limestones already described. One difference however was that in this limestone the horizon of maximum concentration of conodonts (108 specimens) occurred at only 1ft. below the top of the bed but there was nevertheless an appreciable decline in numbers to the top, which contained only 23 specimens.

(f) Five Yard Limestone:-

The Five Yard Limestone, collected from Middlehope Burn, Weardale, was complicated lithologically by a shale/limestone/shale/limestone sequence making up its top $3\frac{1}{2}$ft. Samples were taken from each of these bands but all proved to be barren. The remaining 12ft. of massive limestone however conformed closely to the pattern already described and the maximum concentration of conodonts (34 specimens) occurred at 3ft. below the top of this massive unit, with a decrease upwards and downwards.

(g) Gayle Limestone:-

The Gayle Limestone was especially interesting for three reasons. Firstly it contains a thin calcareous shale band between 8 and 9ft. below the top, secondly the conodont distribution pattern was very pronounced and thirdly, the limestone was sampled at 1ft. intervals throughout its thickness so that the distribution of conodonts could be accurately studied. The close sampling has resulted in slight irregularities in the concentration of conodonts being apparent but the general pattern conforms with that already described. The only irregularity is an interruption in the distribution at the horizon of the shale band. From the base the faunas become gradually larger up through the bed, but 1ft. below the shale band there was a sudden reduction in numbers of conodonts, and the sample immediately underlying the shale was, like the shale itself, barren. Above the shale there was a rapid increase in numbers and the pattern continued in its original form.

The general form of the conodont distribution through all the limestones so far described has therefore been a gradual increase in concentration upwards from the base to a point within the upper $\frac{1}{3}$rd of the bed, from where there was a decrease to the top bedding plane, which may or may not be barren. Interruptions in the lithology gave rise to interruptions in the distribution of conodonts, but did not substantially change the pattern of distribution.

(h) Three Yard Limestone:-

A second pattern of distribution, amply illustrated by the Three Yard Limestone from both its sampled localities, appeared as an extension of the trend already described in the Four Fathom Limestone, where the maximum concentration of conodonts was only 1ft. below the top of the bed. In the Three Yard Limestone from Weardale, the maximum concentration of conodonts (478 specimens) was actually at the top of the bed with a decrease downwards to the barren base. In the Swaledale locality this trend was even more exaggerated. The sample from 6ft. below the top of the bed was barren, those from 4ft. and 2ft. below the top each contained 4 conodonts and that from the top bedding plane contained 950 specimens, the highest concentration of the whole study.

(i) Simonstone Limestone:-

The only other limestone which possibly showed this trend was the Simonstone Limestone. This limestone contains two thin shale bands but they occur in its lower half where the concentration of conodonts was low and their effect was neglible. The upper part of the limestone contained moderately large faunas with a maximum concentration of 111 specimens at 1ft. below the top bedding plane. In contrast to the Four Fathom Limestone, however, the Simonstone Limestone exhibits no rapid decrease to the top of the bed, from which 107 specimens were obtained.

(j) Middle Limestone:-

The Middle Limestone contained in its 37ft. the most complicated conodont distribution of any limestone studied. The limestone itself is divided into 3 units by two thin calcareous shale bands each 1ft. thick and occurring at 7 and 21ft. below the top of the limestone. Practically the whole of the limestone has been sampled at 1ft. intervals so the pattern of distribution described is the actual distribution and has not been deduced from wider interval sampling.

The basal 10ft. of limestone exhibited a strong increase in numbers from 6 at the base to 212 in the sample 27ft. below the top or 5ft. below the lower shale band. Above this horizon there was a very abrupt reduction in numbers, the sample 4ft. below the shale containing only 2 specimens and the remaining samples up to and including the shale were barren. The middle unit of limestone has a less regular distribution of conodonts but the maximum concentration of 91 specimens occurred at the top of the unit, immediately below the upper shale band. The upper unit of limestone was barren at its base and strongly increased to a maximum concentration of 196 specimens at the top bedding plane.

The distribution of the conodonts through this limestone was therefore strongly influenced by the division into 3 limestone units, each of which had its own separate conodont distribution pattern.

The remaining limestones are not important in the present discussion and include the Underset Limestone of Swaledale, in which 5 samples from its upper part could not be digested, the Main Limestone of Swaledale, in which the same problem was encountered in 3 samples and the digestion of a number of others was only partly successful, the Iron Post Limestone, which was highly siliceous and yielded a total of only 10 specimens, the Little Limestone, from which only one sample was taken and the Crow Limestone, which was again too siliceous to be digested. The sampled horizons from the Mirk Fell Beds are included in text fig. (9) but these samples, of shales and ironstones were not of standard size since a comparison of conodont concentrations could hardly be made between different lithologies.

(k) Conclusions:-

A number of interesting facts have thus emerged from the foregoing discussion.

(i) All the limestones from which samples have been digested contained conodonts.

(ii) These conodonts are not randomly distributed through each limestone but occur in a distribution pattern which is repeated, with certain modifications, in all the limestones described above.

(iii) With the exception of the Middle Limestone, the lower $\frac{1}{3}$ of each limestone contains the lowest concentration of conodonts, the upper $\frac{1}{3}$ the greatest concentration and the concentration in the middle $\frac{1}{3}$ is governed by the detailed distribution, the actual abundance of conodonts and the thickness of the limestone.

(iv) The thin limestones tend to have greater concentrations of conodonts than the thick limestones. Not only does the Three Yard Limestone (9ft. thick) contain the largest faunas of the whole study but also the Great Limestone contains very large faunas in Borrowdale Beck, where at 23ft. thick this limestone is at about its minimum known thickness. Unfortunately a direct comparison cannot be made with the Main Limestone of Swaledale (68ft. thick) but there are indications that the faunas from the latter locality are at least smaller than those of Borrowdale Beck.

(v) The increase in numbers of conodonts through a limestone is an actual increase and is not due to the incoming of new forms absent below. Large faunas are almost bound to contain a larger number of species than small faunas but any species present at the horizon of maximum abundance is liable to be present at any other horizon in that limestone.

(vi) A comparison of the distribution patterns exhibited by these limestones may give some indications of the palaeogeography of the Yoredale Limestones. This is especially the case when comparing the Gayle and Middle Limestones. The former is divided into 2 units by a calcareous shale band and the latter into 3 units by 2 shale bands. The contrast is in the conodont distribution. In the Gayle Limestone the shale band interrupts the pattern of conodont distribution but does not greatly affect its form. In the Middle Limestone, however, the threefold division of the lithology is reflected in the distribution of the conodonts, since each limestone unit possesses its own distribution pattern with its own horizon of maximum abundance and in effect behaves as a single separate limestone. This contrast is important when it is remembered that the Gayle (=Smiddy) Limestone remains as a single limestone over the whole of its outcrop area but the Middle Limestone splits northward into the Single Post, Cockle Shell and Scar Limestones, in ascending order, each of which has its associated cyclothem of clastic sediments. It is therefore suggested that the barren limestone below the lower shale of the Middle Limestone, plus the shale, must represent the whole of the cyclothem on the Alston Block which occurs between the Single Post and Cockle Shell Limestones. Similarly, the Upper Shale Band of the Middle Limestone, plus possibly the lower 2ft. of the upper limestone unit, must represent the sequence which occurs between the Cockle Shell and Scar Limestones on the Alston Block. The horizon of maximum concentration in this way acts as a "time-plane" thus making a direct correlation possible between complete and split limestones merely by recording the abundance of conodonts. This is substantiated by the lack of a double peak in the Gayle Limestone, which closely resembles the Middle Limestone in Wensleydale, but does not split northwards.

(1) Possible Causes of the Distribution Pattern:-

It was probably the interaction of several different factors which produced the distribution patterns of conodonts described above. One important factor was probably the rate of deposition and this could possibly have been the only cause in simple cases such as the Hawes or Hardraw Scar Limestones. Small faunas would therefore represent periods of relatively rapid deposition and large faunas periods of slow deposition. The difference between large faunas of some limestones and the small faunas of others, however, must reflect fluctuations in absolute conodont abundance from one time to another. There must also have been other influences. For instance, the barren limestone beneath the lower shale band of the Middle Limestone must represent a much thicker sequence of beds on the Alston Block and was therefore probably deposited slowly. This limestone contrasts with the more characteristic lithology of the remainder of the Middle Limestone in being very fine grained, dark coloured, compact and lacks even the abundant crinoid remains which characterise most of the Yoredale Limestones. This lithology must therefore represent a change in conditions of deposition and this change probably resulted in the lack of conodonts as well as the macrofossils. The presence of terrigenous material in the limestones is often associated with small faunas in the Yoredale Series but this is not invariably the case. The thin calcareous shales in the various limestones have in all cases been barren, in spite of the fact that the limestone above and below may contain conodonts. This appears to be a peculiarity of the Yoredale Series, however, since calcareous shales have often produced rich faunas in other regions and shales were for many years considered to produce more prolific faunas than the limestones. One possible cause is that the barren limestone within the Middle Limestone plus the shale bands, were perhaps deposited under a non-marine environment, since a large proportion of the strata to which they are considered to be equivalent is known to be of non-marine origin.

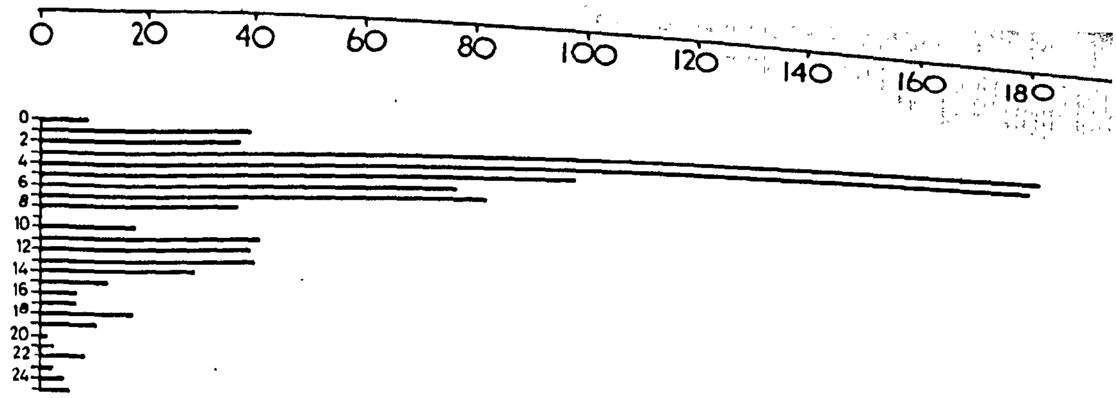
3. THE ASSOCIATED MICROFAUNAS AND COMPOSITION OF RESIDUES OF THE YOREDALE LIMESTONES

The following discussion refers to that microfauna which has been recorded from the conodont fraction of the samples of Yoredale Limestone and as such probably only represents a small part of the complete microfauna. The reasons for this are that the techniques employed for extracting conodonts destroy the calcareous organisms and part of the microfauna is bound to be lost on the 20 mesh sieve or by passing through the 100 mesh sieve. The only fossils to be unaffected by the action of the acid were fish remains, scolecodonts, sponge spicules, conodonts and any others which had been replaced by iron pyrites. Fortunately however, the calcareous fossils were often the last of the calcareous part of the sample to be destroyed and their partly digested remains are common in the conodont residue.

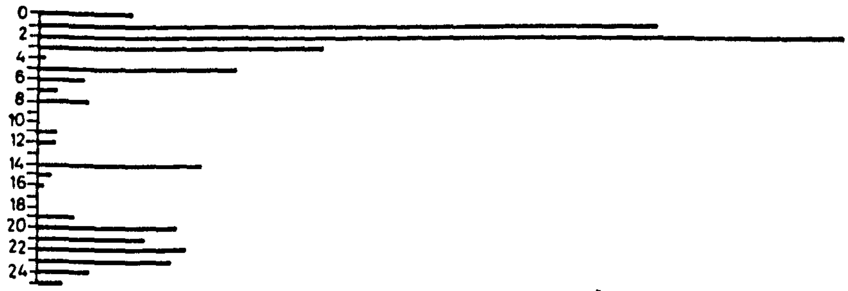
The microfauna found in association with the conodonts in the Yoredale Series was very varied, both in the variety of forms present and also in actual abundance. A record of the whole microfauna was not made for every sample studied but a sufficient number of samples were recorded to enable a broad outline of the variety and distribution to be made. This study also includes a fairly detailed record from the 1ft. interval samples of the Gayle Limestone. No attempt has been made to make generic or specific identifications of the various fossils concerned. A brief summary of the various elements of the microfauna is as follows.

(a) Fish Remains

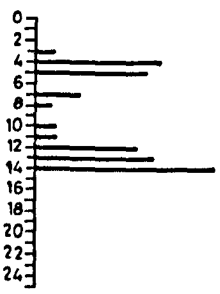
Fish remains were very abundant at certain horizons and were sometimes the dominant element of the associated microfauna. The most distinctive fossils under this heading and usually also the most



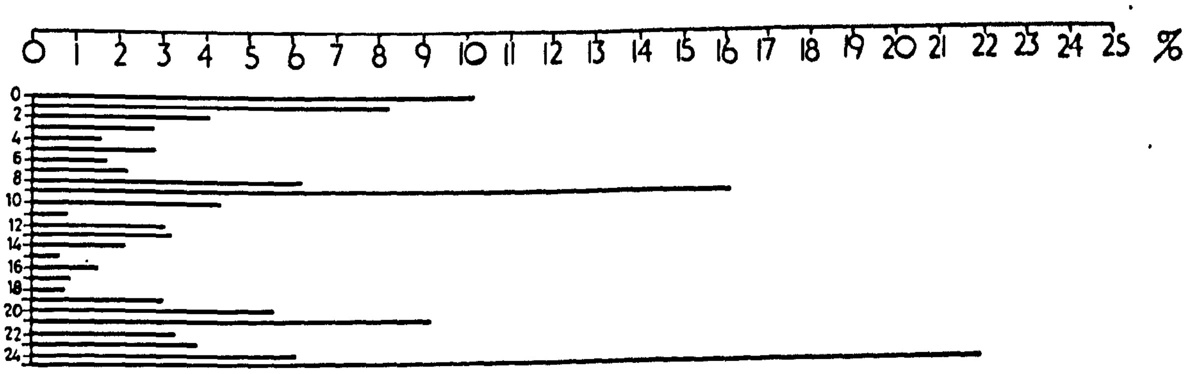
A. DISTRIBUTION OF CONODONTS IN THE GAYLE LIMESTONE



B. DISTRIBUTION OF '*ICTHYODUS*-TYPE' FISH TEETH IN THE GAYLE LIMESTONE



C. DISTRIBUTION OF SCOLECODONTS IN THE GAYLE LIMESTONE



D. PERCENTAGE INSOLUBLES (IN HCl) IN THE GAYLE LIMESTONE SAMPLES

Fig. 18 illustrating the Distribution of Conodonts, Fish-Teeth and Scolecodonts through the Gayle Limestone compared with the Relative "Purity" of the Limestone at each Horizon. A uniform vertical scale is used in each case and the figures represent the depth of samples below the top bedding plane. The horizontal scale of A, B & C is uniform and scaled in number of specimens.

common were fish teeth of the "Icthyodus-type". These simple, conical, sharply-pointed teeth, with a curved axis, circular section and a translucent tip, were present in all except 5 of the Gayle Limestone samples with numbers ranging up to 146 per sample. They were also present at many other horizons, particularly in the Middle and Five Yard Limestones and showed extremely little variation except for the ratio of length to basal diameter. There seemed to be little association between these fossils and the conodonts for although they were both found in many samples, each could be abundant without the presence of the other. The distribution of the fish teeth also tended to be more erratic than that of the conodonts and they could suddenly appear in abundance at a particular horizon. Reference to text-fig. (18) indicates that in the Gayle Limestone, the fish-teeth were, like the conodonts, most common in the upper part of the limestone but rather than indicating an association between the two it probably indicates the influence of the same conditions on two different organisms.

Other fish remains consisted of scales or plates, such as the thick, rhombic-shaped "Holmesella-type" or the thin, diamond shaped scales, single vertebrae or various irregular plates, often with a "honey-comb" structure, which were identified as fish remains because of their association and appearance. These remains were naturally found in association with the fish-teeth but the absolute abundance of the various elements concerned varied greatly. The greatest variety of fish remains was found in the middle unit of the Middle Limestone, where at least four kinds of scales were present along with numerous other unidentified remains assumed to be those of fish. Finally there were at several horizons, extremely erratically distributed, small, black, smooth, ovoid coprolites of unknown origin but included with the fish remains as being their most likely source.

(b) Scolecodonts

Worm jaws, or scolecodonts, are known from most geological systems and show a relatively small amount of variation from Cambrian to Recent Times. The specimens found in the Yoredale Series were mainly confined to the Gayle Limestone, from which 135 specimens were recorded and were closely similar to the forms illustrated by Moore, Lalicker and Fischer as Devonian forms. Other specimens were found in the Five Yard (21 specimens), Great (6 specimens) and Middle (one specimen) Limestones. All were black, shiny and horny and showed variations in denticulation. In view of the fragile nature of these fossils, it is probable that a large proportion of them were lost through breakage in the sieving and washing of the residue.

(c) Foraminifera

Foraminifera were present at numerous horizons in the Yoredale Limestones and their distribution was interesting for two reasons. Firstly they were occasionally present in an otherwise barren sample (e.g. S.W.85 from the base of the Three Yard Limestone) and secondly they were occasionally present in great abundance. Four main forms were recognised and these did not appear to be regularly distributed since certain horizons seemed to be characterised by certain forms. The Gayle Shale (6ft of calcareous shale between the Gayle and Hawes Limestones) for instance, contained numerous coiled foraminifera of the "*Endothyra*-type" and this same form was also found at certain horizons in the Five Yard Limestone. The most abundant form however, which was found throughout the succession of limestones up to and including the Great Limestone, was an irregular, tubular form, of the "*Tolypammina*-type". This form was very abundant at certain horizons in the Gayle and Middle Limestones. The third form, which was often found in association with the second, although usually in smaller numbers, was a spherical form, with a varying number of tubular spines, of the "*Astrorhiza*-type". This latter form was found throughout most of the succession but appeared to be most abundant in the Gayle Limestone. Finally, a less-common form, which appeared sporadically in small numbers, was a uniserial form with a curved axis and almost spherical chambers increasing regularly in size, of the "*Nodosinella*-type".

(d) Bryozoa

Bryozoa were found throughout the succession studied, not only in the limestone residues but also in hand specimen from many of the calcareous shales overlying the limestones and also from the Mirk Fell Shales. Those specimens found in the limestone residues were invariably replaced by iron pyrites and often exhibited what must have been almost complete detail of structure. The distribution of these fossils tended to be extremely erratic, samples in which they were abundant often being preceded and followed by samples in which they were absent. The most abundant specimens obtained were calcareous and were extracted without the use of acid from the top of the Gayle Shale. All were cylindrical of varying diameter and bearing closely or widely spaced autopores of various shapes and sizes, arranged in diagonal rows.

(c) Sponge Spicules

Sponge spicules were among the less-common microfossils of the Yoredale Series but in view of their small size it is probable that many specimens were lost through the 100 mesh sieve. Spicules were only found in the Gayle Limestone (at two horizons) and Middle Limestone. In the latter several horizons contained large numbers of spicules, primarily triaxons of various sorts but tetraxons were also present. Since these fossils have been found in two of the limestones which were closely sampled, it appears that they are present at restricted horizons and may well be present in some of the other limestones which were sampled at wider intervals.

(f) Ostracods

Of the remaining microfossils encountered in this study the most important were the Ostracods. These fossils, although often present, were usually represented by small numbers of specimens and it is probable that most of their remains were lost in the digestion of the sample. In general their preservation was poor and the only well-preserved specimens were iron pyrites replacements. The highest concentration of Ostracods was 50 specimens from Sample S.W.73 of the Five Yard Limestone of Weardale.

The only other microfossils present in the conodont residues were the spat of Gastropods and Lamellibranchs.

Replacement by iron pyrites has been an important process in the preservation of the calcareous microfauna of the Yoredale Series and the foregoing paragraphs are evidence that a large amount of this replacement has taken place. Pyritised fossils are common in many systems and the pyrite is thought to have been produced by the interaction of iron present in the sediment and sulphur formed from decaying organic matter and from sea-water. In the Yoredale Series the replacement has, in the majority of cases, preserved the detailed structure of the unit, but occasionally, fossils may be replaced by clusters of pyrite spheres or cubes. Sometimes the spheres themselves are made up of clusters of even smaller spheres.

In view of the different techniques employed for the extraction of the various microfossils in a sample, it is not surprising that the conodont distribution shows much more regularity than any of the other forms described. The extent to which this contrast is merely apparent or actual is not known. Text-fig. (18) is a group of histograms, all of the Gayle Limestone, illustrating the distribution of the conodonts compared with that of the "Icthyodus" fish teeth, Scolecodonts and the percentage soluble and insoluble in HCl, in each limestone sample. Other groups of microfossils have not been included since their distribution would be greatly affected by the digestion process of the acetic acid. Text-fig. (18) indicates that the Gayle Limestone is very pure and contains up to 99% of soluble in HCl and that the 3 most impure horizons are the top and bottom bedding planes and the sample from 9ft below the top, which is the sample immediately below the shale band. The conodonts are therefore most common in the purest limestones but superimposed upon this there is some second influence which causes the conodonts to be much more abundant in the pure limestone in the upper part of the bed than in the pure limestone in the lower part of the bed.

"Icthyodus" does not appear to have been subject to this second influence to the same extent, since although it is most abundant near the top of the Gayle Limestone, it is an important fossil in the lower 6ft of the bed, where conodonts are uncommon. Also the distribution of this fossil is not as regular as that of the conodonts, since it is absent from 5 samples and varies considerably in numbers in the remaining samples.

Scolecodonts were found only in 10 of the 26 samples and were concentrated in the middle part of the bed. They were nevertheless also absent from the sample 9ft. below the top of the limestone and were therefore fairly restricted to the horizons which contained very little terrigenous material. Sample GB15, beneath the shale band, was the most barren sample of the Gayle Limestone and contained only 3 Ostracods and 15 Bryozoa.

The iron pyrites was separated from the conodont fraction from a number of Gayle Limestone samples, by means of Bromoform. This mineral was present, when not replacing calcareous fossils, mainly as masses of minute cubes but pyrite spheres were also fairly common. The amount of iron pyrites in the conodont fraction, varied between 0·5 and 3·0 gms. and seemed to bear little or no relation to the distribution of the microfossils, in particular the conodonts. This would not however be a true representation of the amount of pyrite in each sample since the bulk of this mineral, in the form of single cubes, would be lost through the 100 mesh sieve.

The actual residues consisted primarily of clay minerals, occasional quartz grains, undigested calcite, and iron pyrites, plus occasional uncommon minerals such as Glauconite. The quartz grains were usually fairly well rounded, but the residue from one sample in the Hardraw Scar Limestone (MG35) was composed chiefly of masses of radiating euhedral quartz crystals.

4. MAJOR FACTORS INFLUENCING THE DISTRIBUTION OF CONODONTS IN THE YOREDALE SERIES

The following section of this thesis consists of a discussion of some of the general characteristics of conodont distribution plus a discussion of the characteristics displayed in particular by the conodonts of the Yoredale Series. A comparison of these characteristics indicate that the Yoredale conodonts are somewhat unique and a discussion of the factors which are considered to have affected their distribution is given. Several of these factors are outlined in various other sections of this report.

(a) Some Characteristics of Conodont Distribution

As yet there has been no direct evidence discovered indicating the form or habit of the conodont animal (conodontifer). Natural conodont assemblages have, however, indicated that this animal was well organised and bilaterally symmetric. Conodonts are also known to range from Upper Cambrian to Triassic or possibly Cretaceous strata. The very wide distribution of these fossils, plus the simultaneous appearance of new forms in various parts of the world indicate that the conodontifer was certainly not benthonic but it is not known to which of the nektonic or planktonic habitats it belonged. No matter which was the case the animal was capable of living in a wide range of environments. It seems extremely unlikely that the conodontifer could exist under fresh-water conditions but there is a growing opinion that it could exist in brackish water. The vast majority of conodontifers, however, were undoubtedly marine and as such conodonts are found in a wide range of lithologies. Rexroad (1958) has shown that limestone faunas show very little variation from shale faunas. He reported that out of 27 species in the Glen Dean Formation (1958, p.13), 21 were common to both shale and limestone. The 2 species found only in the shale were each represented by less than 4 specimens and he considered the 4 species found only in the limestone to reflect the method of sampling rather than environmental factors. For many years shales and calcareous sandstones were considered capable of producing the most prolific faunas but nowadays limestones, particularly thin impure bands in shales, are considered very important. Rexroad (1958) for instance, found larger, better preserved faunas in the limestones than in the shales, even though their content was practically identical.

In view of the lack of direct evidence about the conodont animal, a consideration of the associated fauna has been an important aspect in the study of conodonts, as an indication of the environments which they preferred. Conodonts are commonly found in association with Cephalopods, Ostracods and Fish remains and are rarely found associated with Corals, Brachiopods and Crinoids. It must be remembered, however, that the distribution of conodonts is very wide and the above statement is a broad generalisation. Conodonts have also been found, sometimes abundantly, in black fissile shales, which lack any associated fauna and which, according to Rhodes (1954) may represent lagoonal conditions.

(b) Some Characteristics of Yoredale Conodont Distribution.

The distribution of conodonts in the Yoredale Series is of even greater interest after a consideration of the foregoing section. The majority of Yoredale conodonts originated from an unknown natural assemblage with the result that there is no direct evidence available as to the relative proportions and abundances of the various form genera and species involved. The associated fauna is also somewhat unorthodox, since the conodonts are not associated with Cephalopods, except in the Mirk Fell Beds but are associated, in addition to the microfauna described earlier, with Corals, Brachiopods and Crinoids. As has already been seen, conodonts are most abundant in the purer horizons of the limestones, horizons which are typically crinoidal and contain a Coral/Brachiopod fauna. Certain horizons in the Gayle and Middle Limestones, contain abundant Corals and Brachiopods.

The lithology is also an important consideration in the Yoredale Series. The only shales which received a detailed examination were the Mirk Fell shales but other shale samples have been broken down from many horizons and all have been barren. In addition all the thin shale bands within productive limestones have also been barren. It is thus considered that in the Yoredale Series, conodont distribution is strongly influenced by lithology and is therefore contrary to the results given by Rexroad (1958) and the opinions of several authors. On a smaller scale, Yoredale conodonts appear to have been influenced to some extent by changes in lithology within a limestone. For instance, soft impure limestones are usually only poorly productive, pure crystalline, crinoidal limestones are strongly productive and dark compact limestones are in general barren. These differences in lithology must reflect differences in environment, however slight and it therefore appears that, contrary to popular opinion, the distribution of conodonts in the Yoredale Series was influenced by changes in environment. The genus Apatognathus?, in particular, appears to have been actually restricted to the type of environment represented by the Yoredale Limestones during the Carboniferous Period.

(c) Factors affecting Conodont Distribution in the Yoredale Series.

There are two main considerations involved in a study of this sort, i.e. the distribution of genera, species and numbers of individuals through the succession and also their distribution through individual beds. Both were probably influenced by the same factors, although the overall effect may have differed in each case.

(i) Changes in Environment:-

Variations in the speed of accumulation may have been important in producing the large faunas of a number of the thinner limestones compared with the relatively smaller faunas of a number of the thicker limestones. Thus on the assumption that the conodontifer was of fairly uniform abundance through time (which is undoubtedly an erroneous assumption), a limestone which is $\frac{1}{3}$ the thickness of its lateral equivalent should in theory contain three times the concentration of conodonts. Unfortunately a direct comparison of this nature has not been possible in the present study, since although there should have been opportunity to compare the Great Limestone, which is 23ft. thick and contains large faunas, with the Main Limestone, which is 68ft. thick, the figures for the number of conodonts in the latter limestone are not complete. If speed of accumulation was the only factor involved in the varying size of conodont faunas, then it would be assumed that not only were there great fluctuations in the speed of accumulation of the various limestones but also in the various horizons within a limestone. The latter fluctuations would consist of a relatively rapid accumulation of the base of the limestone, with the rate decreasing upwards, to be at its slowest at some point in the upper $\frac{1}{3}$ of the bed, from where it would increase once more to the top of the bed. If this was the only factor involved, the whole fauna might tend to show its effect and this is not the case. Therefore, although the speed of accumulation of the limestones undoubtedly fluctuated and this is bound to be reflected in the conodont distribution, its overall effect is considered to have been small.

It is unlikely that speed of accumulation could explain the sudden disappearance of abundant conodonts below the lower shale band of the Middle Limestone but this could be explained by other changes in environment. There is a change in lithology at this horizon but possibly the most important control was salinity. As has already been explained, about 5ft. of dark limestone plus the 1ft. of shale at this horizon in the Middle Limestone are considered to represent up to 100ft. of beds on the Alston Block, consisting of shales, siltstones, sandstones and possibly also seat-earth and coal. The delta was therefore not far to the north of Wensleydale after the deposition of the Single Post Limestone (= lower unit of the Middle Limestone) and although very little terrigenous material reached this area, it is possible that the non-marine influence of the delta did extend to this region resulting in the extinction of the marine fauna. An overwhelming of the delta and the beginning of limestone deposition in the north would result in the return of more "normal" limestone conditions in Wensleydale, accompanied by the return of the conodont animal.

(ii) Transgression and Regression:-

The question of transgression and regression in some respects overlaps the above discussion on changes in environment. The idea of the horizon of maximum abundance of conodonts representing a "time-plane" has already been outlined. In this discussion it is assumed that the Cockle Shell and Single Post Limestones, like the Scar Limestone, each have their own conodont distribution pattern with a horizon of maximum concentration of conodonts somewhere near the top. It would therefore be possible, by tracing the "time-planes" laterally, to determine gradual changes in environment and possibly also the amount of erosion, if any, which had taken place.

(iii) Original Abundance of Conodonts (Conodontifers):-

This has undoubtedly been an important factor in the distribution of conodonts. Ignoring their distribution through

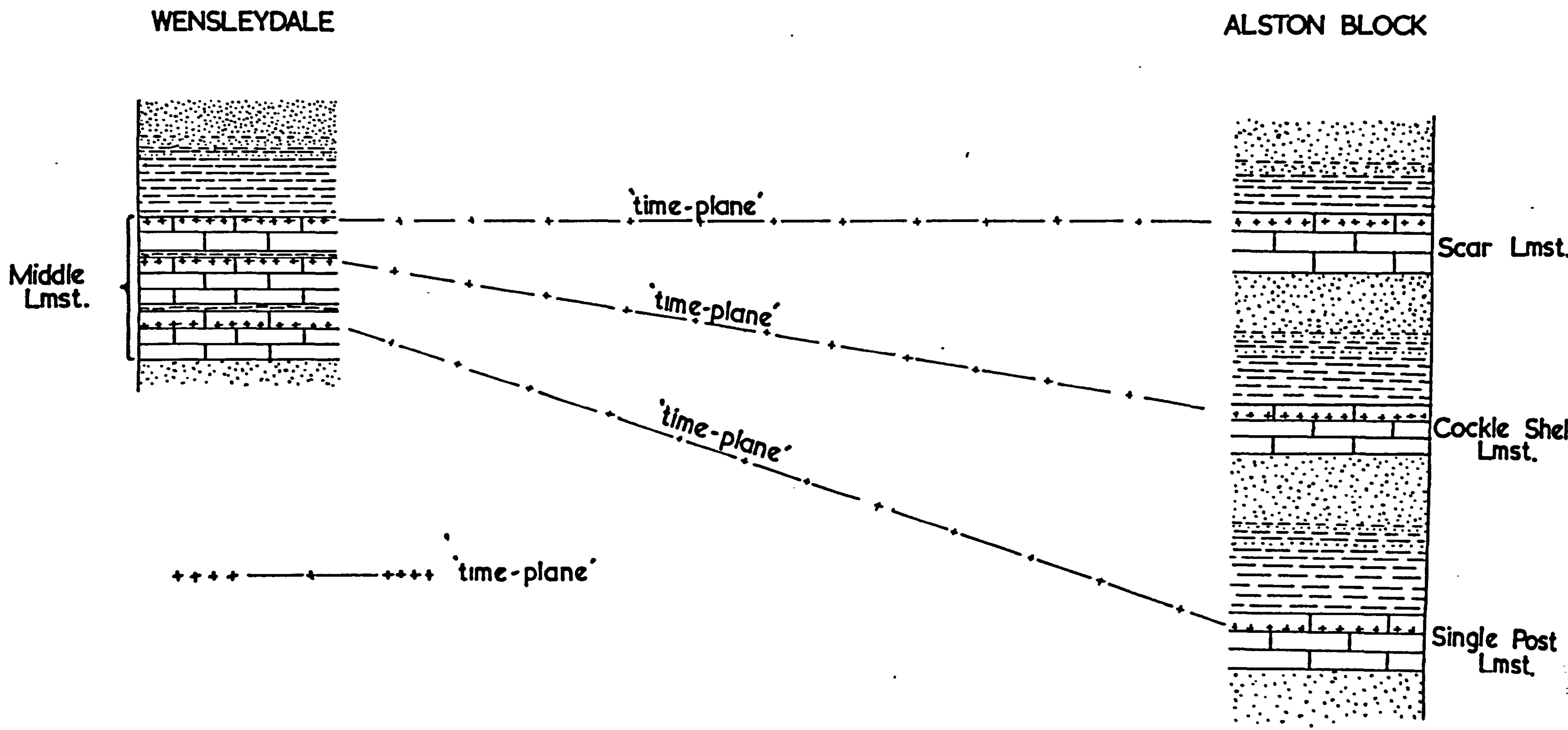


Fig. 19. Diagrammatic Representation of the Use of the Horizon of Maximum Abundance of Conodonts as Correlation 'Time - Planes'

individual beds, this could have been a major factor in the Hardraw Scar Limestone, for instance, which is characterised by small faunas, whereas the Underset Limestone, which is only 2ft. thinner, has obviously larger faunas even though their full extent is not known. Variations in original abundance could also have been an important factor in producing the distribution pattern seen in individual beds. Conodonts would come into the area with the marine conditions at the base of the limestone but at first would not be abundant in view of the adverse, although tolerable conditions. Sometimes these conditions were intolerable, in which case the base of the limestone would be barren. As limestone conditions became well-established and conditions became more favourable for conodonts, their numbers would increase. At the same time, the rate of deposition of the limestone would decrease thus exaggerating the concentration of the conodonts. Before limestone deposition ceased, the effects of the oncoming delta would be felt, the amount of terrigenous material would increase causing an increase in the rate of deposition and the conodonts would decrease in numbers as they migrated southwards. The factor which first caused the decline in numbers of the conodonts is unknown, since this decline often began before there was any real deterioration in the purity of the limestone.

(iv) Evolution of Genera and Species:-

This is a factor which must have been of prime importance in the distribution of conodonts through the Yoredale Series but it is considered in detail elsewhere in this report and need be considered no further at this stage.

(v) Post-Depositional Effects:-

There are a number of other effects, of only minor importance in the present discussion, which could have affected the present distribution of conodonts.

Differential Compaction is usually an important consideration but in this study the majority of samples have been of limestone and there has been no direct comparison between limestone and shale except to point out that the shale bands in the limestones were barren. This is all the more surprising since the shale has undoubtedly been compacted to a much greater extent than the limestone and would therefore contain an increased concentration of conodonts, were they present, due to this fact.

Another factor which has probably caused a certain amount of error is that the beds were not randomly sampled.

Finally, although all the samples were of standard weight, the volume of limestone involved would vary slightly since specific gravity was not taken into consideration. Once again however, the only lithology to be directly involved was limestone so the error would not be great.

The major influence in controlling the distribution of conodonts in the Yoredale Series is therefore considered to have been changes in environment, although this has been combined with a number of other influences of variable effect. The main reason for such a complicated set of influences is probably the very wide range of environments represented in the Yoredale Series, from marine to terrestrial, all of which, except the terrestrial environment, represent shallow water, where changes in conditions are swift and the influences of large rivers and deltas strong.

5. THE DISTRIBUTION OF CONODONTS THROUGH THE YOREDALE SERIES

Reference to Chapter Three indicates that there are a large number of genera, species and varieties of conodonts in the Yoredale Series. Unlike a fully marine succession where faunal zones are deduced from evidence of the varied and overlapping ranges of individual species from the whole succession, conodonts were obtained only from the limestones and the Mirk Fell Beds of the Yoredale Series. These horizons are each separated by a varied series of rocks whose total thickness exceeds that of each productive horizon and which were deposited under very different environments. The conodont distribution to be described is therefore the distribution of species through the succession of limestones and the Mirk Fell Beds rather than through the complete succession. These productive horizons are therefore described individually and complete faunal lists are given in the appendix.

(a) The Conodont Fauna of the Hawes Limestone

This limestone was characterised by small faunas, representing 13 species and 2 varieties from 7 genera. The dominant genus was Gnathodus, which represented 24% of the total number of specimens from the limestone. The most common species of this genus was G. commutatus, followed by G. girtyi girtyi and G. homopunctatus which were of equal importance, whilst G. bilineatus and G. girtyi sulcatus were uncommon.

The genus Apatognathus? was also an important constituent and comprised the two species A? chaulioda and A? gemina of which the latter was twice as common as the former.

The remaining forms were present in smaller numbers. Lonchodina sp.B, Hindeodella brevis and H. ibergensis were each in fact represented by only a single specimen. Only 7 specimens of Hindeodella were specifically identified but the genus was probably much more abundant than this number suggests since 27 of the unidentified specimens from this limestone belonged to either Hindeodella or Angulodus. It is therefore possible that Hindeodella might have been the most common genus in the Hawes Limestone faunas. If this were so H. undata would have been relatively less important than the identified specimens suggest since its distinctive morphology has enabled it to be identified even in a fragmentary state.

The more important aspects of the Hawes Limestone conodont faunas are shown on page (219).

(b) The Conodont Fauna of the Gayle Limestone

Five of the conodont faunas obtained from this limestone exceeded the largest Hawes Limestone fauna and ranged up to 182 specimens per sample. The range in forms was also very much wider since no species had disappeared (although Lonchodina sp.B and Gnathodus girtyi sulcatus have only a conjectured range through this limestone) between the Hawes and Gayle Limestones and the fauna of the former was joined by 31 species which appear in the Gayle Limestone for the first time. The complete conodont fauna of the Gayle Limestone was therefore very varied and consisted of 43 species from 17 genera. The fauna was not however so greatly different from that of the Hawes Limestone since 13 species were each represented by only a single specimen from the whole of the limestone. In addition, the single specimen of Lonchodina sp.A was the only record of this species in the whole of the study.

As in the Hawes Limestone, the dominant genus was Gnathodus, which comprised 26% of the total number of specimens and 41% of the identified specimens. The most important species, however, was G. girtyi (var girtyi) which made up ⅔ of the total number of specimens for this genus. Most of the remaining specimens were divided roughly equally between G. commutatus and G. homopunctatus since G. bilineatus and G. nodosus nodosus were present in only very small numbers.

Also as in the Hawes Limestone, the second most abundant genus in the Gayle Limestone was Apatognathus?, representing 12·7% of the total number of specimens. A? gemina and A? chauliodа were still the dominant species, the former twice as common as the latter, but were joined by A? petila and A? librata in small numbers.

Although 4 species of Neoprioniodus appeared in the Gayle Limestone for the first time, N. singularis was still the most important species and comprised more than half the total specimens for the genus. Spathognathodus scitulus had also become an important accessory form and was found in 10 samples at a maximum of 5 specimens per sample. Hindeodella was once again an important genus in spite of the small number of identifiable specimens which consisted mainly of H. ibergensis.

The dominant elements of the Gayle Limestone fauna were therefore forms which had already appeared in the Hawes Limestone. It is thus possible in view of the small number of faunas studied from the latter limestone, plus their small size, that many of the species which first appeared in the Gayle Limestone may have been present in the Hawes

Limestone, particularly the uncommon species.

(c) The Conodont Fauna of the HardrawScar Limestone

The Hardraw Scar Limestone was characterised by very small conodont faunas which yielded only 9 species from 6 genera. This was in spite of the fact that the only species present in the Gayle Limestone which was not found higher in the succession was Lonchodina sp.A. 37 of the Gayle Limestone species were thus given conjectured ranges passing through the Hardraw Scar Limestone. The 9 species obtained from the latter included Spathognathodus cristula, which first appeared at this horizon and was definitely not present in the much larger faunas of the Gayle Limestone below.

The Hardraw Scar Limestone faunas thus differed in many respects from those of the Gayle and Hawes Limestones. Apart from the drastic reduction in numbers and the appearance of Spathognathodus cristula the dominant genus was Apatognathus? and not Gnathodus. A? chaulioda was absent but A? gemina was still the most important species, representing more than 50% of the genus. Only two species of Gnathodus were present, of which the most common was G. commutatus and only 2 specimens of G. girtyi girtyi were obtained from the 11 samples spread over 50ft. of limestone. Neoprioniodus singularis and Hindeodella undata were the only representatives of their respective genera.

(d) The Conodont Faunas of the Simonstone Limestone.

The Simonstone Limestone contained moderately large conodont faunas consisting of 35 species from 17 genera. Six of these species first appeared in this limestone whilst Mestognathus bipluti and Ozarkodina cf hindei were restricted to this horizon. The former is a very large, highly distinctive species which is rare in its occurrence generally but was found in three samples in this limestone and was not recorded elsewhere in the succession. This species is therefore regarded as an excellent indicator of the horizon in the Yoredale Series. Ozarkodina cf hindei was represented by only a single specimen.

A single specimen of Lonchodina sp. B, only the second for the species, represented its highest occurrence but a more important highest occurrence was that of Neoprioniodus spathatus, which was fairly common in the upper part of this bed but of which only one other specimen was recorded in the present study, from the Gayle Limestone.

The faunas were once more dominated by the genus Gnathodus, the most common form being G. girtyi girtyi, which was twice as common as G. commutatus. Only 3 specimens of G. nodosus nodosus were obtained.

The second most common genus was in this case Neoprioniodus, which comprised 5 species, thus equalling Apatognathus? in variation of form. N. singularis was still the most common species and represented ½ the total number of specimens for the genus, whilst N. conjunctus was the least common species and was represented by only 2 specimens from the whole of the Simonstone Limestone.

Apatognathus? was still an important genus even though superceded by Neoprioniodus in this limestone and its most common species A? librata was twice as abundant as its nearest rival A? petila. A? scalena and A? cuspidata, which first appeared in this limestone, were relatively uncommon.

Apart from Hindeodella, which was once more a fairly common element of the faunas, the remaining forms were present in small numbers.

(e) The Conodont Faunas of the Middle Limestone

The Middle Limestone contained some large conodont faunas and these had the widest variation of forms seen in any limestone of the study. Only 3 species of conodonts had disappeared up to the Middle Limestone, but 48 had appeared since the Hawes Limestone. A total of 50 species from 18 genera was described from this limestone, including 8 species which appeared in this limestone for the first time. Lambdagnathus sp.B, Magnilaterella recurvata and Neoprioniodus camurus, were each represented by a single specimen in the whole of the study and were therefore restricted to the Middle Limestone. Spathognathodus minutus first appeared in the middle unit of the Middle Limestone and was absent from the much larger faunas of the lower unit of the same limestone. Its appearance is therefore considered to coincide with the horizon which is equivalent to the Cockle Shell Limestone of the Alston Block.

The Middle Limestone also represented the highest occurrence of 6 species (see tab.220), the most significant of which were Apatognathus? gemina, Gnathodus homopunctatus and Hindeodella undata each of which were major constituents of the faunas in the lower part of the succession up to and including the present limestone.

The faunas of the Middle Limestone were once again dominated by the genus Gnathodus, with G. girtyi girtyi the most common form. The ratio of abundance of the 4 species of Gnathodus were as follows:-

G. girtyi girtyi	:	G. nodosus nodosus	:	G. homopunctatus	:	G. bilineatus
7	:	1·75	:	1·25	:	1

G. nodosus nodosus had thus increased considerably in importance from lower in the succession.

The Middle Limestone was the only horizon in which Apatognathus?, second in abundance after Gnathodus, contained all 6 species. A? petila and A? librata were the dominant species, each being twice as abundant as their nearest rivals A? cuspidata and A? gemina, whilst almost 4 times as abundant as the 2 remaining species.

After Apatognathus? in order of abundance were Neoprioniodus, consisting of 5 species but with over 80% of the specimens represented by N. singularis and N. peracutus and Spathognathodus, of which S. scitulus was still the dominant species although S. minutus and S. cristula were relatively more important than in lower horizons.

These genera were followed by several of about equal abundance, including Ligonodina, Magnilaterella and Hindeodella, the remaining genera and species being relatively uncommon.

Therefore, in spite of the wide variety of forms present, the order of priority of genera was still Gnathodus, Apatognathus? and Neoprioniodus but with Spathognathodus fourth for the first time.

The conodont faunas of the Scar Limestone were smaller and contained no forms which were not found in the Middle Limestone.

(f) The Conodont Fauna of the Five Yard Limestone

The Five Yard Limestone contained small conodont faunas, which were more than usually fragmentary, consisting of only 18 species from 8 genera and therefore showed a drastic reduction from the large faunas of the Middle Limestone. 30 species found at lower horizons have however a conjectured range through this limestone in view of further occurrences higher in the succession.

Only one species, Ligonodina sp., of which only one specimen was obtained, was restricted to the Five Yard Limestone and no other species appeared at this horizon for the first time. The proportion of unidentifiable specimens was 40%, rather higher than for most of the limestones.

The most common genus was Apatognathus? of which 5 species were present, representing 32% of the identified specimens, with A? librata as the most common species.

As in the Hardraw Scar Limestone, Gnathodus had been pushed into second place but G. girtyi girtyi was still the most common form present, being twice as common as G. bilineatus, whilst only a single specimen of G. nodosus nodosus was obtained from the whole limestone. G. commutatus was absent but was one of the numerous species with a conjectured range through the Five Yard Limestone.

Ligonodina (3 species) and Neoprioniodus (2 species) were each about ½ as common as Gnathodus, the dominant species being L. ultima and N. peracutus. Of the remaining genera Spathognathodus was the most important but all were uncommon.

(g) The Conodont Fauna of the Three Yard Limestone

The largest single conodont fauna of the whole of the study was obtained from the Three Yard Limestone in its Swaledale locality but the Weardale locality was also characterised by very large faunas. The total number of species recognised from 15 genera was 38, of which G. girtyi consisted of 2 varieties. There were therefore 12 species and 3 genera fewer in the very large faunas of the Three Yard

Limestone than there were in the Middle Limestone, although the number of forms with conjectured ranges through the former was 11, as opposed to 7 in the latter.

Only Cavusgnathus middlehopensis was restricted to the Three Yard Limestone and was in fact only found in one sample. The several specimens involved were however very distinctive and this species could represent a useful indicator of horizon.

Lonchodina cf projecta, ranging up to the Main Limestone and L. paraclarki, of which only 2 specimens were found in the whole of the study, both first appeared in this limestone. The Three Yard Limestone represented the highest occurrence of four species (see table page 219), the most significant of which were Synprioniodina forsenta, which was the only species recorded of a fairly distinctive genus, and Hindeodella brevis, which had probably been more common in the lower part of the succession than the actual figures suggested.

The faunas from the Swaledale and Weardale localities of this limestone were almost identical and are considered together in this summary.

In great contrast to the Five Yard Limestone below, the faunas of the Three Yard Limestone were strongly dominated by the genus Gnathodus which represented 55% of the total number of specimens. Well over 1,000 specimens of G. girtyi girtyi alone were studied from this limestone but G. girtyi sulcatus was represented by only 23 specimens. The species as a whole was 4 times as abundant as its nearest rival, G. commutatus. The latter in turn, was almost twice as common as G. nodosus nodosus and G. bilineatus, each of which were represented by about 120 specimens.

Another contrast between this limestone and those below was that the second most common genus was Neoprioniodus, which comprised 10% of the identified fauna and was composed of 3 species, of which N. singularis was much the most abundant and N. scitulus was very uncommon.

Neoprioniodus was in fact almost 3 times as common as Apatognathus? in spite of the fact that the latter was represented by 5 species. Once again A? librata was the most common species but for the first time A? cuspidata was the second most important species, closely followed by A? petila.

The remaining genera were present in much smaller numbers. Spathognathodus, Ligonodina and Ozarkodina were the most important and were present in roughly equal numbers.

One interesting feature of the Three Yard Limestone conodont faunas was that the genus Hindeodella had suffered a great decline in abundance from the lower part of the Yoredale Succession where it was a major constituent of the faunas. Only 8 specimens of this genus were identified out of nearly 2,000 and this was not because they were largely broken since the unidentified specimens consisted primarily of broken gnathodid blades.

(h) The Conodont Fauna of the Underset Limestone.

The Underset (= Four Fathom) Limestone contained a number of moderately large conodont faunas consisting of 11 genera, 34 species and 2 varieties. Four species first appeared at this horizon and of these only Ligonodina cf ultima was not restricted to this limestone. Probably the most important of the restricted species was Spathognathodus cf minutus, which although present in small numbers and closely related to S. minutus, was a very distinctive form.

The Underset Limestone (= Four Fathom) also represented the highest occurrence of five species (see table page 219).

The make up of the faunas of the Underset and Four Fathom Limestones was practically identical and was interesting since it contrasted in a number of ways with those from lower in the succession.

Firstly, although the most abundant genus was once again Gnathodus, there was not the complete dominance of G. girtyi girtyi, although it was the most common form, since it represented only 40% of the total number of specimens for the genus. There was also an unexpected abundance of G. bilineatus, which shared second place with G. commutatus. This was the most prominent position reached by G. bilineatus in the whole of the succession. The only other forms of this genus present were G. nodosus nodosus and G. girtyi sulcatus, of which the latter was the least common.

The second most common genus was once again Apatognathus? but unlike its appearances in lower limestones, the 5 species were fairly uniformly distributed, although A? librata was still slightly the most common.

Perhaps the most striking contrast with the earlier faunas was that the third most common genus, representing over 10% of the identified fauna was Spathognathodus and that within this genus the most important species was not S. scitulus, which was found throughout the succession and was the most common species of this genus in the lower limestones but S. minutus. S. cristula and S. cf minutus were present in only small numbers.

Of the remaining genera the most important were Neoprioniodus in which Neoprioniodus peracutus had superceded N. singularis as the most common species, Ligonodina, in which L. levis and L. tenuis represented the majority of the specimens and Cavusgnathus, which was a major constituent of the faunas for the first time.

The trend of the gradual disappearance of Hindeodella which was noticed in the Three Yard Limestone had been carried a stage further in this limestone and only 2 specimens of H. ibergensis and 1 of H. hamatilis were recognised.

(i) The Conodont Fauna of the Iron Post Limestone

Unfortunately the Iron Post Limestone was extremely siliceous and of the 4 samples taken, only one, from the upper bedding plane, could be broken down sufficiently for any conodonts to be obtained. The preservation of the 9 conodonts obtained was poor since the Acetic Acid was of much stronger concentration than that normally used but they included 4 identifiable specimens, 3 of which were Spathognathodus scitulus and the fourth Neoprioniodus singularis.

(j) The Conodont Fauna of the Main Limestone

The fairly small conodont faunas from the Main Limestone of Swaledale closely agreed with the much larger faunas from the Great Limestone of Borrowdale Beck, and the following remarks combine the two localities. 14 genera were recorded, comprising 39 species, of which Gnathodus nodosus and Gnathodus girtyi each consisted of two varieties.

Only 3 forms appeared at this horizon for the first time but these alone rendered the Main Limestone Faunas highly distinctive and were as follows:- Cavusgnathus navicula

Gnathodus nodosus radiolus

Hibbardella apsida.

The first was the most common species of Cavusgnathus and ranged from the Main Limestone to the top of the sequence. The remaining 2 forms were restricted to this limestone and are thus excellent indicators of horizon. Gnathodus nodosus radiolus was found in association with G. nodosus nodosus in a ratio of about 1:4 and the species as a whole narrowly exceeded G. girtyi as the most common in the limestone. Hibbardella apsida was a distinctive form, although not abundant.

The Main Limestone represented the highest occurrence in the succession of 23 forms. A drastic change in the conodont faunas therefore took place between the Main Limestone and the Mirk Fell Beds. Unfortunately the exact horizon of this change, or its exact nature are unknown since only a very small fauna has been obtained from the Little Limestone and no conodonts have been obtained from the Crow Limestone.

The genus Gnathodus strongly dominated the Main Limestone faunas once again but unlike the other large faunas of the succession, the most common species was G. nodosus and not G. girtyi. G. girtyi girtyi was however slightly the most common single form since only a small number of specimens of G. girtyi sulcatus were obtained. G. commutatus and G. bilineatus were each as common as G. nodosus radiolus.

The second most common genus was Apatognathus?, which with Gnathodus comprised 60% of the identified specimens. This genus had been reduced to 4 species by Main Limestone times and all were present, A? librata and A? petila being the most common species and A? scalena the least common.

Neoprioniodus and Spathognathodus then followed, the former consisting of only two species, N. peracutus and N. singularis in roughly equal proportions and the latter consisting of 4 species, of which S. scitulus comprised 90% of the genus.

Of the remaining genera several occurred in about equal numbers and included Ligonodina, Ozarkodina, Hindeodella, Cavusgnathus and Magnilaterella.

(k) The Conodont Fauna of the Little Limestone.

Only a single small fauna was obtained from the Little Limestone and it included single specimens of Cavusgnathus navicula, Apatognathus? librata and Ligonodina cf. ultima.

(l) The Conodont Fauna of the Mirk Fell Beds.

The fauna of the Mirk Fell Beds was the most distinctive fauna of the study. As already outlined, a great change had taken place between the Main Limestone and the Mirk Fell Beds, during which numerous species had disappeared and their places taken by a few forms which were restricted to this horizon. Of the 44 forms seen in the Main Limestone or having a conjectured range through it, only 15 extended up into the Mirk Fell Beds where they were joined by the following species:

Geniculatus claviger
Gnathodus confixus
Hindeodus sp.B.
Metalonchodina bidentata
Streptognathodus unicornis

It is remarkable that 3 of these forms represent genera which had not been recorded in the whole of the succession below the Mirk Fell Beds. The fauna of this horizon was therefore very much different from any so far described.

The Mirk Fell Bed fauna was strongly dominated by the genus Gnathodus, which comprised 75% of the identified specimens. The most important element was the new species G. confixus, closely related to G. girtyi and probably an intermediate stage between that and a new genus or genera higher in the Namurian. Only slightly less abundant was

G. girtyi girtyi itself and these 2 forms represented 95% of the genus, the remaining 5% being occupied by G. girtyi sulcatus.

Gnathodus was about 12 times more abundant than its nearest rival, Cavusgnathus, comprising 2 species, of which C. navicula was slightly the most common. The third most common genus was Geniculatus, a readily recognisable form.

This fauna was therefore very different from the more typical Yoredale faunas below and the ratios of the most important genera were roughly as follows:-

Gnathodus	:	Cavusgnathus	:	Geniculatus	:	Neoprioniodus	:	Ligonodina
21	:	1·75	:	1	:	1	:	1

The remaining genera were each represented by small numbers of specimens.

6. CONCLUSIONS TO THE STRATIGRAPHIC PALAEONTOLOGY

Having established in earlier sections of this thesis that conodonts are not only present in the Yoredale limestones but are abundant and ubiquitous in these horizons, which are the most easily recognised bands of cyclothems, easily extracted and well preserved, it remains necessary to consider their usefulness. The detailed study which these fossils have been given has shown them to be useful in at least two respects. The first is that conodonts have added to the knowledge of both the Yoredale limestone palaeogeography and the palaeoecology of the animal. The second respect is that conodonts can be used as a tool in the recognition, dating and correlation of Yoredale horizons.

(a) Palaeogeography and Palaeoecology

A record of the number of conodonts present in each uniform sized sample has indicated a gradual increase in the concentration of conodonts from the base to a point in the upper $\frac{1}{3}$ of each bed and from there a decrease to the top bedding plane, except when the horizon of maximum abundance is in this position. Caution must be observed in

TABLE ILLUSTRATING THE MOST IMPORTANT FEATURES OF THE CONODONT FAUNAS FROM EACH HORIZON

Horizon	Dominant genus and species	Restricted Genera or species	Lowest Occurrence of:-	Highest Occurrence of:-	Other Characteristic Species
Mirk Fell Beds.	Gnathodus G. confixus	Geniculatus Hindeodus sp.B. Metalonchodina Streptognathodus			Cavusgnathus navicula C. unicornis
Main Limestone	Gnathodus G. nodosus	Gnathodus nodosus radiolus Hibbardella apsida	Cavusgnathus navicula	See Appendix	Spathognathodus cristula Roundya subacoda
Underset Limestone	Gnathodus G. girtyi girtyi	Cavusgnathus convexa Ozarkodina cf. curvata Spathognathodus cf. minutus	Ligonodina cf. ultima	Apatognathus? chaulioda Magnilaterella alternata Neoprioniodus scitulus N. varians Hibbardella abnormis	Spathognathodus minutus
Three Yard Limestone	Gnathodus G. girtyi girtyi	Cavusgnathus middlehopensis	Lonchodina paraclarki L. cf. projecta	Hindeodella brevis Lambdagnathus macrodentata Ozarkodina sp.B. Synprioniodina forsenta	Neoprioniodus singularis
Five Yard Limestone	Apatognathus? A? librata	Ligonodina sp.			Gnathodus bilineatus Ligonodina ultima Neoprioniodus peracutus

Middle Limestone	Gnathodus G. girtyi girtyi	Lambdagnathus sp.B. Magnilaterella recurvata Neoprioniodus camurus	Hindeodus sp.A. Magnilaterella robusta M. sp.A. Ozarkodina sp.B. Spathognathodus minutus	Angulodus walrathi Apatognathus? gemina Gnathodus homopunctatus Hindeodella undata Lambdagnathus n.sp.A. Ozarkodina laevipostica	Apatognathus?-sixspecies Neoprioniodus singularis N. peracutus Spathognathodus scitulus
Simonstone Limestone	Gnathodus G. girtyi girtyi	Mestognathus bipluti Ozarkodina cf. hindei	Apatognathus? cuspidata A? scalena Lambdagnathus macrodentata Neoprioniodus conjunctus Roundya subacoda Spathognathodus sp.A.	Lonchodina sp.B. Neoprioniodus spathatus	Neoprioniodus singularis
Hardraw Scar Limestone	Apatognathus? A? gemina		Spathognathodus cristula		Gnathodus commutatus
Gayle Limestone	Gnathodus G. girtyi girtyi	Lonchodina n.sp.A.	See Appendix		
Hawes Limestone	Gnathodus G. commutatus		See Appendix for faunal list.		

placing too much emphasis upon the variation in size of faunas from limestone to limestone but the distribution of conodonts through the individual beds is important and has led to a number of questions particularly concerning the mechanism involved in producing this distribution pattern.

It seems fairly certain that no single factor has been responsible. A number of factors, the most important of which have been described, must have combined their influences to produce the remarkably constant distribution pattern. It is possible that the absence of a decline in numbers of conodonts at the top of the Three Yard Limestone indicates that this limestone suffered erosion before the deposition of the shale above it. A sample of shale from 1 inch above the Three Yard Limestone, which contained the highest concentration of conodonts in the whole study, was barren.

The triple distribution pattern in the Middle Limestone substantiates the northward splitting of this horizon into three separate limestones. It also indicates the difference in overall importance between the shale bands in the Middle Limestone and the apparently identical shale band in the Gayle Limestone. The former thus represent that part of the cyclothems between the relevant limestones, reflecting a major change in palaeogeography from south to north, whilst the latter is not a constant feature and has no effect upon the outcrop of the Gayle (= Smiddy) Limestone. A complete sampling of the Middle Limestone and its lateral equivalents over their geographical extent could thus be an interesting study in the reconstruction of the palaeogeography of Middle Limestone times, using the horizons of maximum abundance of conodonts as "time-places" or "correlation planes" from one locality to the next.

A brief study of the associated microfauna has shown that this is very variable and includes numerous fossil groups, none of which were as universally distributed in the Yoredale Series as the conodonts and none of which exhibited the same degree of regularity in distribution. The nearest comparison which could be made was between the fish remains and conodonts although this is not in any way considered as an indication

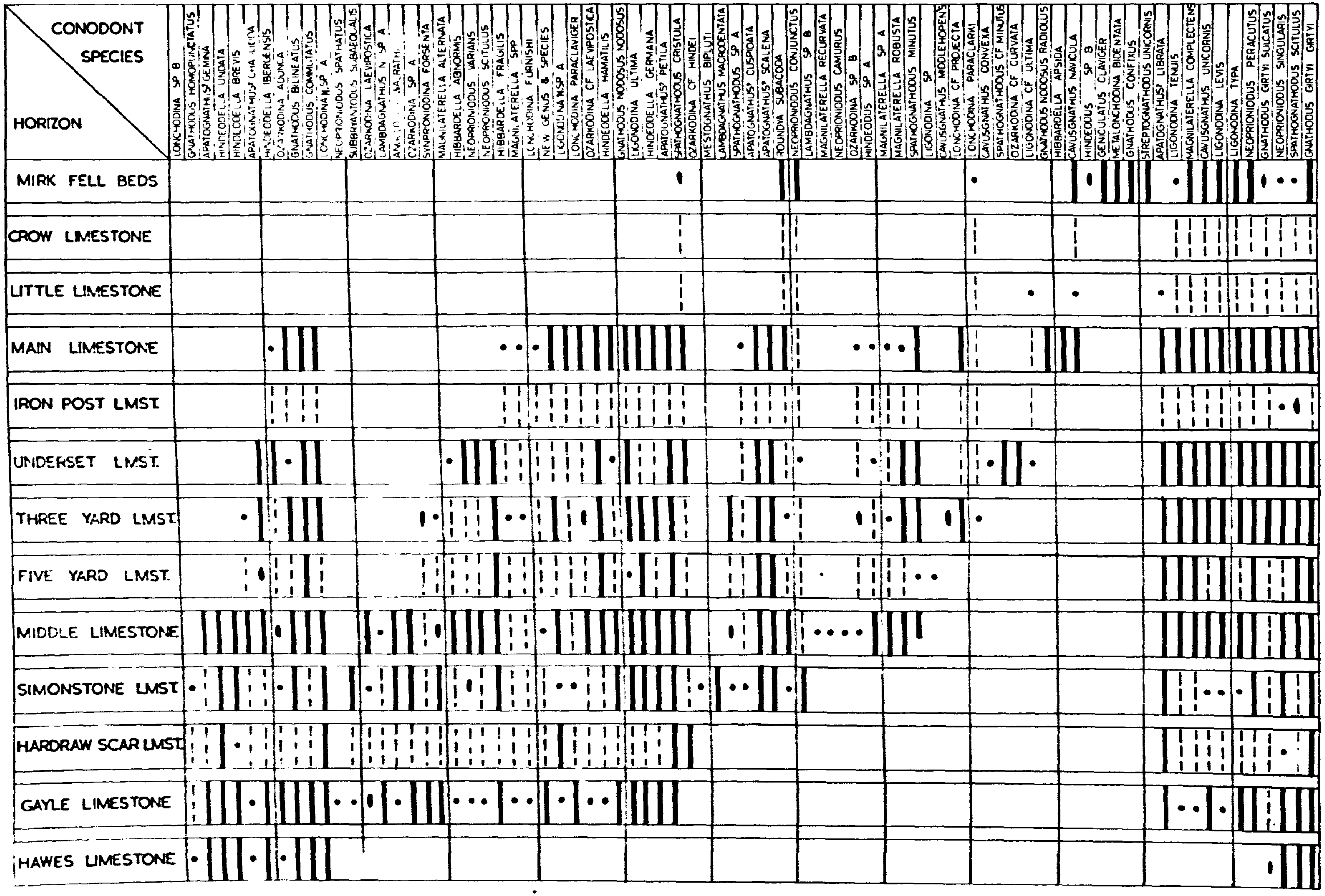


FIG. 20 Range Chart of the Conodont Species occurring in the Yoredale Limestones and Mirk Fell Beds. SYMBOLS AS IN FIG 21

of the zoological affinities of the latter. The several reasons for this conclusion include the fact that fish remains are in general uncommon above the Five Yard Limestone but there is no reduction in the number of conodonts. Also, both the fish remains and the conodonts may be abundant whilst the other is absent. In common with the other groups, the numbers of fish remains fluctuated strongly and it was impossible to forecast even their presence.

The macrofauna seems to have been affected to some extent by factors which may have been those governing the conodont distribution. For instance the base of the limestones often contained large numbers of corals, often in the position of growth, brachiopods were most common in the lower part of the limestone and there was sometimes an algal phase at the top, but this was not invariably the case. Some limestones which showed a strong distribution pattern of conodonts were practically devoid of a macrofauna, e.g. the Great Limestone of Borrowdale Beck.

The present study has also shown that two of the known natural conodont assemblages could have been present in the Yoredale Series but that at least one or probably several unknown assemblages were also involved. The reason for considering that perhaps more than one other natural assemblage contributed to these faunas is the relationship between the two most common genera. In all except the Hardraw Scar and Five Yard Limestones, Gnathodus was the most common genus but in these two limestones Apatognathus was the most common genus. Gnathodus girtyi girtyi is a large form which would be among the last to be destroyed or removed by erosion, etc. and yet only 2 specimens were obtained from the Hardraw Scar Limestone. This therefore suggests a different source, i.e. natural assemblage, for G. girtyi girtyi and Apatognathus, although the latter may well have originated from the same natural assemblage as the Gnathodus commutatus/nodosus/ homopunctatus group of species.

(b) Stratigraphy.

A wide variety of genera and species of conodonts have been described in the present report, involving every major limestone except the Crow, plus the Mirk Fell Beds. Although the distribution of

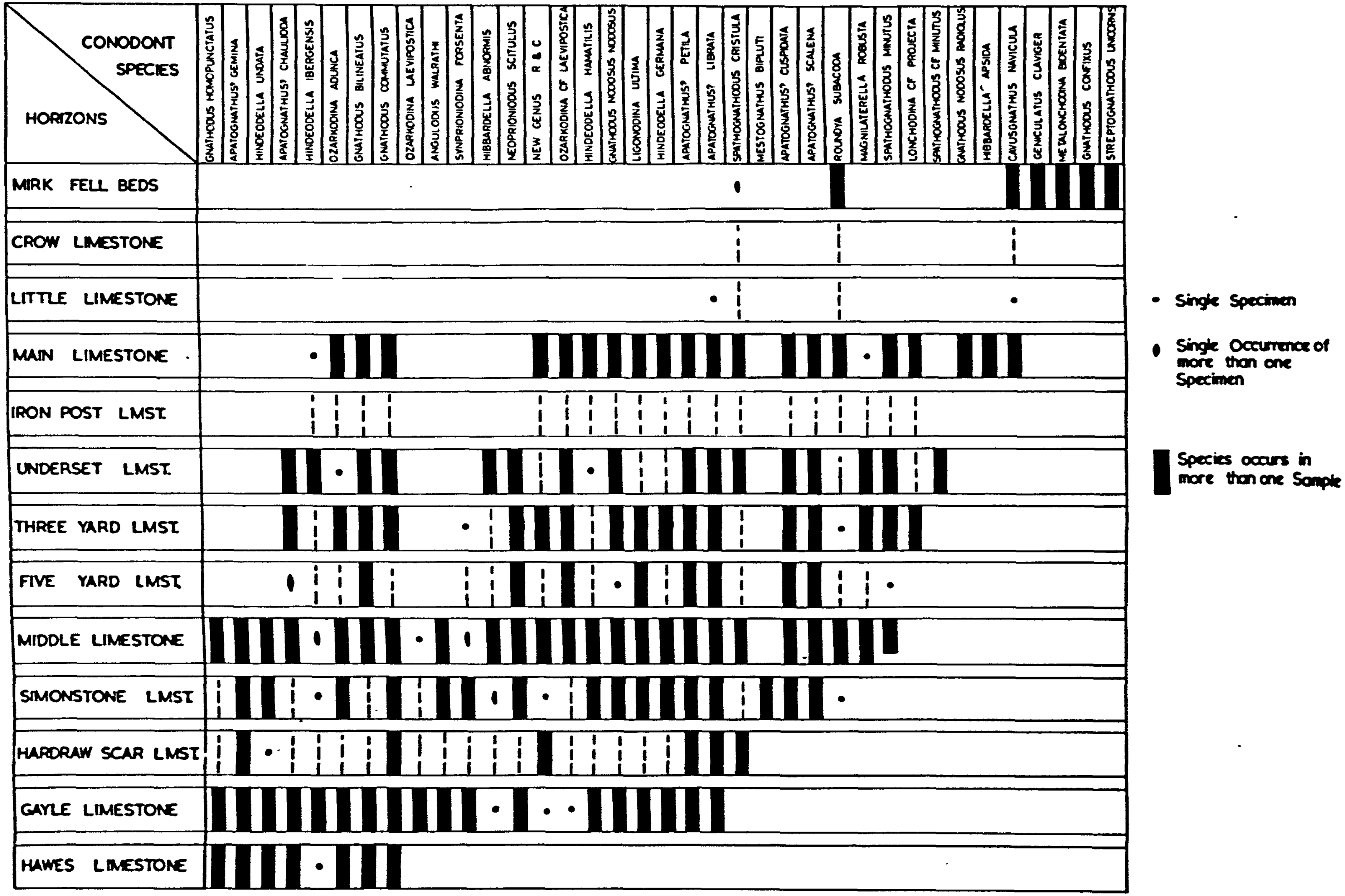


FIG. 21 Range Chart of Selected Conodont Species

conodonts in the latter appears to be somewhat random, the distribution pattern described for the individual limestones makes it possible to forecast, to some extent the horizon of maximum concentration of conodonts. This is an obvious asset, particularly in preliminary sampling, which would be concentrated on the upper $\frac{1}{3}$ of the limestone except where it was complicated lithologically, in which case samples would be taken from each limestone unit. Even in the latter case, however, unless there are obvious lithologic changes in the limestone, the conodonts are liable to be concentrated in the upper part of each unit.

As has already been described, no two limestones contain the same conodont fauna. The most important question is therefore whether or not the changes are significant to the stratigraphy of the Yoredale Series. Text fig.(20) has shown the ranges of all the species involved in the study but text fig. (21) shown the ranges of selected species, i.e. species which are restricted in range and or present in sufficient numbers to be useful. A summary of the distinctive features of the fauna from each limestone is given in table p. (219). This indicates that conodonts may be used in the stratigraphy of the Yoredale Series for the recognition of horizons, based upon an association of forms rather than single species. Not all of the limestones have a very distinctive fauna, normally because of the restricted number of forms present, but such horizons are usually interspersed by limestones which are easily recognised.

C H A P T E R F I V E

COMPARISON OF YOREDALE CONODONT FAUNAS WITH OTHERS OF SIMILAR AGE

CHAPTER V

COMPARISON OF THE YOREDALE CONODONT FAUNAS WITH OTHERS OF SIMILAR AGE

Reference to Chapter Three indicates that studies of Viséan/Namurian conodonts are fairly numerous. It would therefore be a difficult and laborious task to compare directly the Yoredale faunas with all those of similar age. However, since many works merely record the presence of conodonts and others describe them from beds which have not been precisely dated by other fossils, only important and especially interesting studies will be considered. In addition other works have considered conodonts as natural assemblages but since these are so rare and the source of the Yoredale faunas is unknown, little could be gained by such a comparison.

(a) Belgium

The only records of Viséan/Namurian conodonts from Belgium consist of lists of species. Upper Viséan species were listed by Serre and Lys (1960) and in common with the Yoredale Series were dominated by Gnathodus, which represented 4 of the 9 species present. Only Ozarkodina delicatula and Prioniodina cassilaris were not present in the Yoredale Series but the biggest difference was the extremely restricted number of species in Belgium, which did not include many of the most common Yoredale forms.

The only record of Belgian Namurian conodonts is a chart of species and occurrences by Bouckaert and Higgins (1963) from the E_2 horizon of the Dinant Basin. Of the 26 forms listed, 22 are common to Belgium and the North of England. The main difference however is the result of distribution since of the 22 forms common to both areas, only 9 actually occur in the E_2 horizon of the Yoredale Series. In addition the E_2 Yoredale faunas include genera such as Geniculatus and Streptognathodus which are absent in Belgium.

(b) France

Lys, Mauvier and Serre (1962) included short lists of conodonts in their study of the microfauna of the Upper Viséan and Namurian of Northern France. The lists were, however, so brief that little could be gained from a comparison, except that, in the Upper Viséan, two of the five forms recorded were Gnathodus girtyi and G. commutatus.

Remack-Petitot (1960) also included a short section on French conodonts in her work which mainly concerned North Africa but only Gnathodus bilineatus and G. girtyi were recorded from horizons equivalent to the Yoredale Series.

French conodont faunas therefore appear to have been dominated by Gnathodus as in the Yoredale Series but the faunas were extremely small and it is unlikely that they are representative of faunas of this age from France.

(c) Germany

Conodont research in Germany has been mainly concentrated on the Upper Devonian and Lower Carboniferous and as a result there are no records of Namurian conodonts and the descriptions of Viséan faunas are relatively few in number. Although 5 works are to be considered, only that of Meischner (1962) specifically concerned the Goniatites-Stufe.

Meischner's distribution chart included 2 forms of Gnathodus girtyi, plus G. bilineatus, G. commutatus, G. homopunctatus and G. nodosus, all of which are present in the Yoredale Series. G. homopunctatus occurred mainly at a lower horizon than G. nodosus as in the Yoredale Series but the latter species was less common than in the North of England. In addition three other species were recorded by Meischner, i.e. G. texanus, G. semiglaber and Mestognathus beckmanni, none of which occurred above the lower part of the cu III/β zone and each of which was absent in the Yoredale Series. A correlation of the Yoredale Series with the Goniatites-Stufe of Germany would therefore place the base of the Yoredale succession at about midway through the cu III/β zone (Goniatites striatus).

Of the several species in Böger's range charts, which ranged from the Upper Devonian to zone cu III/β, only G. bilineatus and G. commutatus were found in the upper horizons. This is also in agreement with the conodont zones described by Voges (1959). Three zones occur in the Viséan, the anchoralis zone at the base and the bilineatus zone at the top, between which there is an intermediate zone where both forms are found. Flügel and Ziegler (1957) recorded seven species of Gnathodus from the Viséan, the most common of which was G. girtyi.

Bischoff (1957) described 104 forms of conodonts ranging from the Upper Devonian to the top of the Goniatites-Stufe, of which 57 occurred in the latter stage. Of the 19 short ranging forms, which were restricted to any one of the three zones of the Goniatites Stufe, only 3 occurred in the Yoredale Series. However 17 of the forms which ranged through part or all of this stage were found in the Yoredale Series and included four species of Gnathodus. The ranges given by Bischoff are thus in agreement with the base of the Yoredale Series correlating with a midway position in the cuIIIβ zone, since G. semiglaber which is absent from the Yoredale Series disappeared at this horizon in Germany. In addition several species of Hindeodella common to both localities disappeared at the top of the cuIIIβ zone thus corresponding with the reduction in this genus in the middle part of the Yoredale succession.

The German faunas have therefore much in common with the Yoredale conodont faunas, particularly in the dominance of the genus Gnathodus. The relative importance of the species of this genus does show some differences however, since G. bilineatus and G. commutatus are among the most important species in Germany, where there is not such a complete dominance of the fauna by G. girtyi, and G. nodosus is much less common than in the North of England where G. texanus is absent.

Another difference is the almost complete lack in Germany of Apatognathus?, of which only a single specimen was recorded by Bischoff (1957). In addition Geniculatus, which ranged throughout the Goniatites-Stufe in Germany, was restricted to the E_2 horizon in the Yoredale Series.

(d) Great Britain

The Yoredale conodont faunas represent an interesting link between the faunas of the Midland Valley of Scotland (Clarke 1960) and those of the Southern Pennines (Higgins 1961 and in manuscript). In each of these three areas the dominant genus was Gnathodus and the forms present were the same, although there were some differences in nomenclature between the Scottish and English species. Consequently G. smithi has been placed in synonomy with G. bilineatus, G. clavatus with G. girtyi and G. cruciformis with G. nodosus nodosus. In addition the dominant species in each locality was G. girtyi (clavatus). One difference, however, was the presence in the Yoredale Series of G. nodosus radiolus, which was restricted to the Main Limestone.

The intermediate position of the Yoredale Series between Scotland and the Southern Pennines is indicated in a study of the genus Spathognathodus. This genus was represented by a single species, S. campbelli in the Southern Pennines and by four species, S. exodentatus, S. minutus?, S. pusilis and S. scitulus in Scotland. S. minutus and S. scitulus were the most important species of this genus in the Yoredale Series, where they were joined by S. cristula plus a number of other forms present in small numbers.

Greater differences are evident between the three localities in a study of Apatognathus?. A? gemina and A? porcata were both present in the Lower and Upper Limestone Groups of Scotland. The former was also present in the lower part of the Yoredale succession and the Viséan of the Southern Pennines. The Yoredale Series, however, contained 5 other species, each of which was new and combined with A? gemina to make this genus the second most abundant of the study. The presence of abundant Gnathodus and Apatognathus? would therefore appear to be a characteristic and distinguishing feature of Yoredale conodont faunas.

Clarke recorded a total of 18 genera and 40 species from the Midland Valley of Scotland and of these 15 genera and 17 species have been found in the Yoredale Series and 13 genera and 10 species in the Southern Pennines. There is thus a strong similarity between the 3 areas, although the effect of geographic separation is obvious. There is also an appreciable variation in the number of forms present in the 3 areas. Compared with the 18 genera and 40 species of Scotland, the Yoredale Series contained 22 genera, 76 species and 4 varieties, whilst 23 genera, 51 species and 4 varieties were recorded in the Southern Pennines. The range in variety of forms is therefore greatest in the Yoredale Series, particularly when it is remembered that the 51 species of the Southern Pennines spanned from the Upper Viséan to the Lower Coal

Measures and therefore included several which could not possibly have been found in the Upper Viséan and Lower Namurian. 21 genera, 39 species and 4 varieties thus occurred in the Southern Pennines at equivalent horizons to the Yoredale Series, and of these 17 genera, 31 species and 2 varieties have been found in the latter area. The comparison between the two areas is thus much closer than the total figures suggested. The Yoredale conodont faunas therefore appear partly as a mixture of the faunas from Scotland and the Southern Pennines but also contain forms which are indigenous to the North of England.

(e) North Africa

The conodont faunas of North Africa, covering an extremely wide range of beds from Silurian to Pennsylvanian, have been studied by Remack-Petitot (1960). Beds of relevant age to this study yielded 5 genera, 9 species and 1 subspecies, of which only Gnathodus roundyi, G. texanus and Cavusgnathus cristata were absent from the Yoredale Series. However there was a marked lack in the North African faunas of Gnathodus commutatus, G. homopunctatus and G. nodosus and also genera such as Apatognathus? and Neoprioniodus, both of which were common in the Yoredale Series.

(f) North America

The difficulties involved in a comparison of the Yoredale conodont faunas with those of North America are mainly the result of difficulties in intercontinental correlation. The reason for the difficulties in correlation is the absence of useful zonal fossils common to the two areas. Conodonts are however proving extremely useful and numerous correlations have been based upon these fossils. The problem is enhanced by the fact that even within North America correlations from one part of the continent to another are by no means certain. Correlation charts produced by Weller et. al.,1948 and Moore et al.,1944 equate the Lower Namurian with the Chester Series. The Upper Viséan is therefore probably equivalent in part to the Chester Series and also the Meramec or Upper Valmeyeran Series. Several Upper Mississippian horizons have been studied in America from areas other than the Illinois/Mississippi Basin, including the Barnett Formation of

Texas, the Stanley Shale of Arkansas and Oklahoma and the Caney Shale of Oklahoma, but their exact age is still uncertain. A comparison of the conodonts however indicates that they are roughly equivalent to the Chester Series of Illinois.

The Barnett Formation was described by Hass (1953), who considered that the upper of its two faunal zones was probably partly Meramec and partly Chester age whilst the lower zone was Osage (Keokuk) in age. If this is correct, the upper faunal zone is probably equivalent to at least part of the Yoredale succession.

Hass did not describe the lower faunal zone, although he did list the genera present. These included Gnathodus, Hibbardella, Hindeodella, Ligonodina, Neoprioniodus, Roundya and Subbryantodus, all of which were present in the Yoredale Series and apart from Roundya were typical of the lower part of the Yoredale succession. There is therefore a strong similarity at a generic level between the lower faunal zone of the Barnett Formation and the lower part of the Yoredale succession but the most pronounced difference is the lack in the former of the genus Apatognathus?

The upper faunal zone of the Barnett Formation yielded a relatively larger and more varied fauna of conodonts comprising 10 genera and 18 species but was nevertheless extremely limited in variety for such abundant material. All the forms ranged through the upper faunal zone except Gnathodus texanus which was absent from the top of the zone and Neoprioniodus singularis which was restricted to the top. Of the 18 species present, 8 were common and included Gnathodus commutatus, G. bilineatus, Geniculatus claviger, Lonchodina paraclarki and Roundya subacoda, each of which was found in the Yoredale Series. The presence of Geniculatus might suggest a correlation of this fauna with that of the Mirk Fell Beds but as has already been seen, this genus has been found throughout the Goniatites-Stufe in Germany.

Hass also compared the Barnett Formation with the Stanley Shale and the Caney Shale. The latter was described by Elias (1956) and divided into the Ahlosa, Delaware Creek and Sand Branch members, in ascending order, the upper of which was considered to be of Chester age and the lower two Meramec. Elias considered the Barnett Formation to be of Chester age, slightly younger than the Delaware Creek member of the Caney Shale and equivalent to the Stanley Shale. All were considered equivalent to the Lower Namurian of Europe. This was supported by the fact that the most important conodont genus in all these areas, plus the Yoredale Series, was Gnathodus. The three most common species were G. bilineatus, G. girtyi and G. commutatus and in this respect the Yoredale faunas were unusual in the relative unimportance of G. bilineatus and the complete absence of G. texanus.

Comparisons of the major elements of the faunas of North America and Northern England are not as direct when considering the alternating sediments of the Illinois Basin, where, in the standard succession of the Chester Series, the place of Gnathodus as the dominant genus is taken by Cavusgnathus. There is nevertheless a strong resemblance between the faunas of the two areas, in composition if not in relative proportions.

The oldest fauna relative to this discussion is that of the St. Louis Formation of the Valmeyeran Series (Rexroad and Collinson, 1963). This fauna contained 11 genera, of which only Taphrognathus has not been found in the Yoredale Series and in common with the present study, also contained abundant specimens of Apatognathus? The occurrence of Taphrognathus was the youngest for this genus and was combined with the oldest occurrence of Cavusgnathus. In view of the absence of the former and the presence of the latter through the Yoredale Series, plus the fact that the common forms in the St. Louis Formation, including Spathognathodus scitulus, Apatognathus? gemina and Ligonodina levis all occurred in the lower part of the Yoredale succession, it is probable that the American horizon is equivalent to the base of the Yoredale Series or to the top of the Great Scar Limestone. This is also substantiated by the presence of Ozarkodina laevipostica in both areas but only common in the present study in the Gayle Limestone. The appearance of many new forms in the Gayle Limestone is therefore probably a reflection of the onset of true Yoredale conditions rather than an evolutionary trend. The major difference between the faunas of the St. Louis Formation and those of the Yoredale Series is therefore the relative unimportance in America of the genus Gnathodus, which was represented only by rare specimens of G. commutatus and G. texanus.

The fauna of the Pella Formation, redescribed by Rexroad and Furnish 1964 after Youngquist and Miller 1949, was correlated with that of the Ste. Genevieve Limestone of the standard succession. 14 genera and 25 species were described, of which 9 genera and 11 species have been found in the Yoredale Series. The two most common species were Cavusgnathus unicornis and Spathognathodus cristula, both of which have been found in the Yoredale Series. The latter species substantiates the correlation with the St. Louis Formation outlined above since it first appears in the Hardraw Scar Limestone, and is absent from the Gayle Limestone. Other species common to the two areas are Neoprioniodus scitulus, Ligonodina tenuis, L. levis, Neoprioniodus singularis, N. peracutus and Magnilaterella robusta, of which the latter was the most restricted, being recorded in small numbers from the Middle Limestone to the Main Limestone. The Pella and Ste. Genevieve Formations therefore roughly correlate with the horizon of the Hardraw Scar Limestone but possibly as high as the Middle Limestone. The Pella faunas were strikingly different from the St. Louis and Yoredale faunas in the lack of Apatognathus?

The whole of the Chester Series was studied by Rexroad (1957), who described 27 species belonging to 9 genera but the faunas of several of the formations involved have since been described in detail.

The oldest Chester fauna to be described was that of the Paoli Formation (Rexroad and Liebe 1961) of Indiana and Kentucky, which is equated with the Renault, Yankeetown and Downey Bluff Formations of Illinois. Once again Cavusgnathus unicornis and Spathognathodus cristula were the most common species and Gnathodus accounted for 8% of the fauna in the upper part of the formation. Of the 11 genera described 10 have been found in the Yoredale Series and the 11th, described as Elsonella? was both rare and uncertain. The relative proportions of the various elements of the faunas were different however since Cavusgnathus and

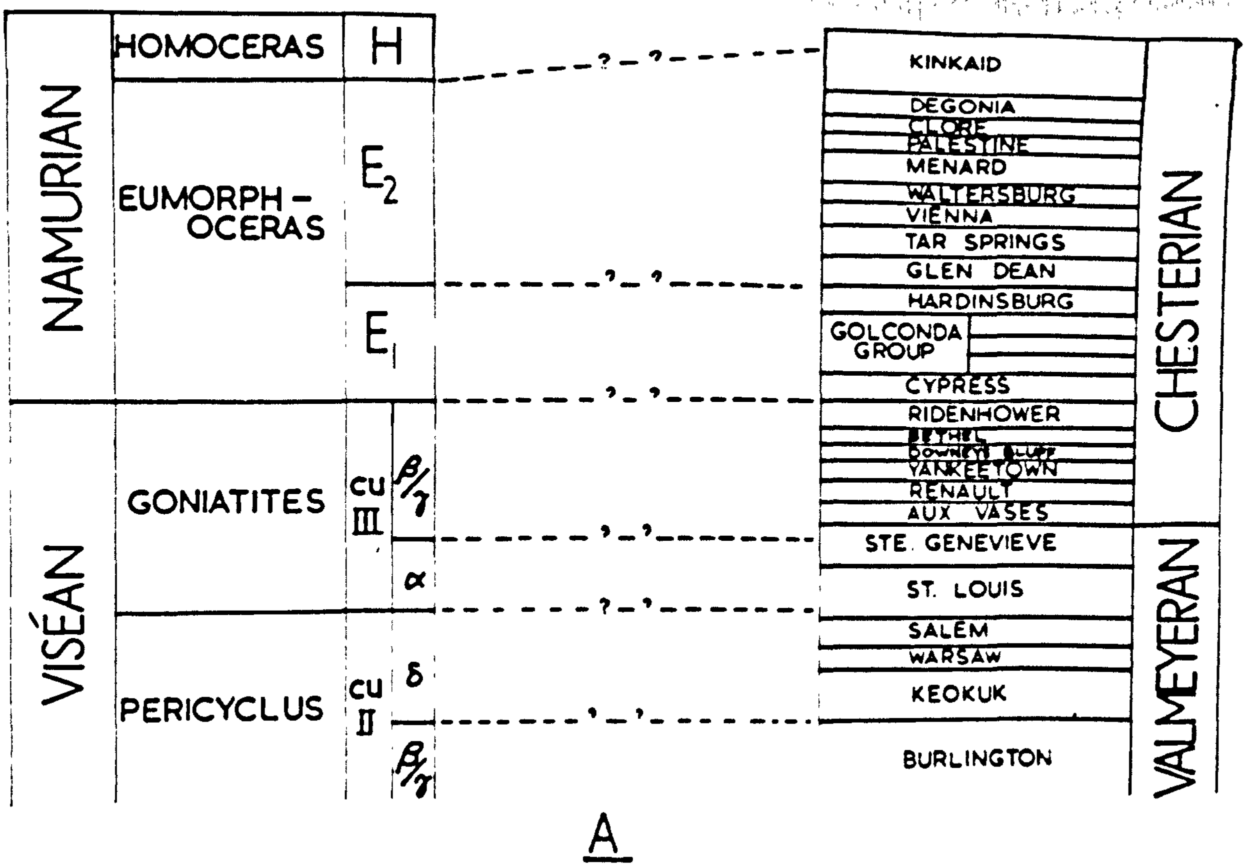
Spathognathodus were still the dominant genera in the Paoli Formation, followed by Neoprioniodus and Ligonodina. The presence of Hibbardella, Lambdagnathus, Synprioniodina and Hindeodus suggest a rough correlation with the middle part of the Yoredale succession.

The Golconda Group was described by Rexroad and Jarrell (1961). The lower of the three formations comprising the group was unusual for the Chester Series in that the dominant genus was Gnathodus. This genus, however, only represented 1% of the fauna in the upper formation, where it was once more replaced by Cavusgnathus. The lower or Beech Creek Formation therefore had strong similarities with the Yoredale faunas in its three most common forms - Gnathodus commutatus, G. bilineatus and Neoprioniodus singularis.

The Glen Dean Formation (Rexroad 1958) contained 27 species from 12 genera. The most important species were Cavusgnathus unicornis, Neoprioniodus scitulus, Ligonodina levis and Spathognathodus cristula, each of which have been found in the Yoredale Series. Thirteen of the Glen Dean species were present in the North of England. Collinson, Scott and Rexroad (1962) correlated the Glen Dean Formation with the base of E_2 in the European succession, the horizon of the Mirk Fell Beds. The Yoredale conodont faunas are not in agreement with this correlation, however, since the Mirk Fell (E_2) faunas were highly distinctive and closely resembled those of the Kinkaid Formation (upper part) at the top of the Chester Series and Mississippian.

The Kinkaid Formation (Rexroad and Burton 1961) contained 28 species from 12 genera and was divided into 4 units. The lower 3 units were typically Chesterian in aspect and contained 11 genera and 26 species of which 9 genera and 15 species occur in the Yoredale Series. The dominant genera were Cavusgnathus and Neoprioniodus and the most common species C. unicornis.

The upper unit of the formation was strikingly different from the lower 3 units in that Streptognathodus comprised one third of the fauna and there was a marked decrease in Cavusgnathus. Transitional forms between these two genera suggested that this was an evolutionary change rather than a migratory influx. The upper unit is thus correlated



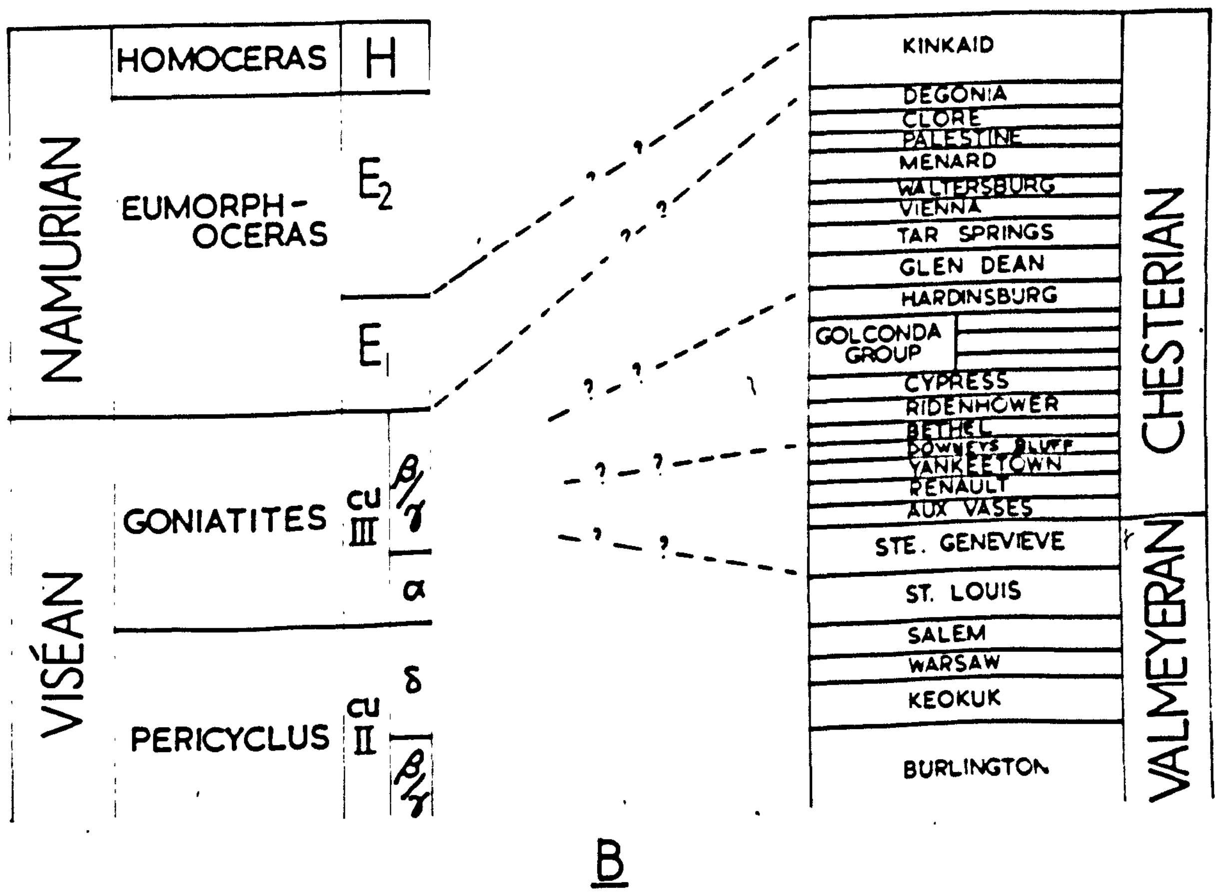


Fig.22. CORRELATION OF MISSISSIPPIAN FORMATIONS FROM THE MISSISSIPPI VALLEY WITH THE EUROPEAN GONIATITE ZONES.

Chart A shows the correlation suggested by Collinson, Scott & Rexroad 1962. Chart B shows the correlation suggested by the Yoredale Study.

with the Mirk Fell Beds on the basis of the transition from Cavusgnathus unicornis to Streptognathodus unicornis, which was observed in both areas. The three lower units of the Kinkaid Formation also correlate very satisfactorily with the E_1 horizons of the Yoredale succession, i.e. Main Limestone to the base of the Mirk Fell Beds. The basis of this correlation is primarily the appearance in the Main Limestone of Cavusgnathus navicula which Rexroad and Burton described as 1 of only 3 forms out of 26 in the Kinkaid Formation which have not been found in other formations lower in the sequence.

The correlations suggested by the Yoredale study and which are indicated in text fig.(22) are particularly important since they include the Mirk Fell Beds, the only Yoredale horizon containing a goniatite fauna. A definite lower E_2 age is thus known for these beds. The Kinkaid Formation, which is the uppermost formation of the Mississippian as well as of the Chester Series, does not contain goniatites and is in addition overlain by Middle Pennsylvanian in the type area of Illinois. In Oklahoma, where the succession is complete, the Mississippian/Pennsylvanian junction is considered to occur at the E_2/H horizon on the European Goniatite succession, hence Collinson, Scott and Rexroad's correlation of the top of the Kinkaid Formation with the base of H. The implications of the correlation suggested by the conodonts of the Yoredale Series are therefore twofold:-

either (a) Mississippian beds which are younger than the Kinkaid Formation occur in areas other than the type-area

or (b) the Mississippian/Pennsylvanian junction is placed too high in the succession in Oklahoma and Texas.

(g) Spain

Spanish conodonts of Middle Viséan to Lower Namurian age were described by Higgins (1962), from the "Griotte" Limestone. The faunas had much in common with those of the Yoredale Series, particularly in the abundance of species of Gnathodus. The following species were recorded:- G. bilineatus, G. commutatus, G. homopunctatus, G. nodosus, G. girtyi, G. delicatus, G. semiglaber, G. multinodosus and G. texanus, of which the latter 4 were absent in the Yoredale Series. Unlike the

Yoredale faunas, however, *G. bilineatus* was the most common species and ranged throughout the Spanish sequence.

Of the remaining fauna *Cavusgnathus* was short ranging in the Namurian and most of the other forms were relatively long ranging and consisted of many species common to Spain and the North of England.

(h) Conclusions

It is evident from the foregoing paragraphs that accurate comparisons and correlations of the Yoredale conodont faunas can only be made with those of the Southern Pennines, the Midland Valley of Scotland, Germany and the U.S.A. This is merely a reflection of the lack of sufficient knowledge of the faunas from other areas.

There are great similarities between the faunas of the three British areas and in most senses those of the Yoredale Series appear as an intermediate stage between the faunas to the south and north. In each area the dominant species was *Gnathodus girtyi*. In one respect however, the Yoredale Series was somewhat different, since the conditions represented by the limestones appear to have been the optimum conditions for the genus *Apatognathus?*, which was found in greater variety than has previously been recorded.

A comparison with Germany showed the main differences to be an almost complete lack of *Apatognathus?* plus a more diverse range of species of *Gnathodus*. Of particular interest was the absence of *G. texanus* in the Yoredale Series and the relative unimportance of *G. bilineatus* when compared with Germany. *Geniculatus* was also peculiarly restricted to the uppermost horizon of the Yoredale Series. The base of the Yoredale succession correlates with about the middle of the cuIII/β zone (*Goniatites striatus*) of Germany.

In many respects correlation of the Yoredale Series with the United States was easier than with Germany. Each fauna described from the Valmeyeran or Chester Series could, to varying degrees, be correlated with faunas in the Yoredale Series. The St. Louis Formation was of particular interest in its abundance of *Apatognathus?* but the most important correlation was between the Mirk Fell Beds, with an E_2 Goniatite fauna and the upper unit of the Kinkaid Formation. This has illustrated the difficulties experiencedin correlation within the U.S.A. since it is considered that either there must be younger Mississippian beds than the Kinkaid Formation outside the type area or that the Mississippian/Pennsylvanian junction must be somewhat lower than has been previously thought, i.e. E_1/E_2 as opposed to E_2/H.

CHAPTER SIX

CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

CHAPTER VI

1. CONCLUSIONS

The Yoredale Series has been shown to consist of a variable number of cyclothems, each of which contain a wide range of lithologies arranged in a regular order. These lithologies, ranging from fully marine limestones and shales to seat-earths and coals, reflect the great and rapid changes in environment, which took place during the deposition of the series. A great deal of controversy exists as to the actual control of these changes but many writers agree that deposition was strongly influenced by the formation and overwhelming of large deltas which covered much of the North of England during the Upper Viséan and Lower Namurian.

In a series of variable strata, where lithologies are repeated many times, recognition of particular horizons or even cyclothems is difficult, particularly in tectonically disturbed areas, and the fauna they contain is strongly influenced by the repeated changes in environment. Thus goniatites, which have proved extremely useful for the recognition, dating and correlation of equivalent horizons in other parts of the world, are so extremely rare in the Yoredale Series that they are of little or no "working value". In addition the alternative of the coral/brachiopod zonal scheme is relatively insensitive for the short period of time represented by the Yoredale Series.

An accurate and applicable method for recognition, dating and correlation in the Yoredale Series was therefore needed and in an effort to provide such a method a study of the conodont remains of these beds has been carried out. As a result of this study several facts have emerged:-

(a) Conodonts are present in the Yoredale Series.

(b) These fossils have been obtained from every limestone from which samples have been digested for this study.

(c) The only shales from which conodonts have been obtained were the Mirk Fell Shales but this may partly reflect the concentration of study upon the limestones.

(d) These fossils are generally present in great abundance, reaching a maximum of over 500 specimens per Kgm. of rock (Collinson, Scott and Rexroad 1962, considered a species abundant if its concentration was greater than 3 specimens per Kgm.)

(e) Over 9000 specimens were studied, representing 76 species and 4 varieties from 22 genera and these combined to make the Yoredale faunas unique, particularly in the abundance of Gnathodus and Apatognathus?

(f) The genus Apatognathus? appears to have been facies controlled during Carboniferous times and may have been restricted to the type of environment represented by the Yoredale limestones.

(g) Part of the fauna could have originated from two of the known natural conodont assemblages i.e. Westfalicus (Schmidt 1934) and Lewistownella Scott 1942.

(h) The majority of the conodonts present in the Yoredale Series originated from an as yet unknown natural assemblage.

(i) Conodonts are not sporadically or randomly distributed through individual limestones but occur in a regular pattern which with certain modifications, is repeated in each limestone.

(j) Except in the Middle Limestone, the maximum concentration of conodonts occurs in the upper third of each bed.

(k) In the Middle Limestone each limestone unit has a separate conodont distribution pattern and the horizons of maximum concentration may represent correlation "time-planes" with the three separate limestones, which are its lateral equivalents, on the Alston Block.

(l) The distribution pattern must be the result of several influences of which the most important were probably changes in the marine environment including speed of accumulation of sediment.

(m) No two limestones contain identical faunas since changes in composition of the faunas through the series are combined with marked fluctuations in their size. These fluctuations involve both the number of specimens and species, disregarding the effect of distribution through the individual beds.

(n) The conodont faunas are therefore stratigraphically useful since they are abundant, show rapid changes and are easily extracted from the dominant lithology of each cyclothem.

(o) The Yoredale conodont faunas show great similarities with the faunas of Scotland and the North Midlands but also contain forms which appear to be indigenous to the North of England.

(p) Many of the forms are very widely distributed and thus enable correlation on a very wide scale.

(q) Correlation with German faunas indicates that the base of the Yoredale Series occurs at about the middle of the Goniatites striatus zone (cuIII/β).

(r) A close correlation is possible between the Yoredale faunas and those of Illinois and this indicates that the type section of the Chester and Valmeyeran Series is more condensed than has been previously thought. The base of the Yoredale Series correlates with the horizon of the Ste. Genevieve and St. Louis Formations, and the Mirk Fell Beds, which are of basal E_2 age, with the upper division of the Kinkaid Formation. The implications are therefore that either Mississippian beds which are younger than the Kinkaid Formation occur outside of the type-area of Illinois or the Mississippian/Pennsylvanian junction should be placed at a lower horizon.

(s) Yoredale conodont faunas are associated with a large and varied microfauna.

(t) Contrary to the majority of occurrences of conodonts, the Yoredale faunas are associated with a coral/brachiopod/crinoid macrofauna.

The conodont faunas of the Yoredale Series therefore fulfil the requirements for the recognition, dating and correlation of horizons.

2. SUGGESTIONS FOR FUTURE WORK

A number of suggestions for future work have arisen, partly as a natural progression on to topics closely related to and resulting from the present study, and partly due to the relative success of the conodonts of the Askrigg and Alston Blocks.

It was stated in Chapter One that the Northumberland Trough is a well-defined tectonic area constituting a study in its own right. A study of the conodonts of this region would serve several purposes:-

(a) It would provide the last link between the faunas of the Midlands and Scotland.

(b) It would substantiate or refute the suggested correlation with the Mississippian/Pennsylvanian junction.

(c) It would be possible to recognise any Tournaisian strata which may be present.

(d) Concentrated collecting in the region of the Viséan/ Namurian junction would indicate its effect, if any, on the conodont faunas and this might, in turn, substantiate or refute its present placing between the Underset and Main Limestones.

A detailed study of the Middle Limestone and its lateral equivalents over their whole outcrop area would illustrate the palaeogeography of that time, indicate the extent of the deltas and the relative speeds of deposition of the various parts of the cyclothem(s) over their geographic extent.

Finally, a similar study could also be extended southwards into the Great Scar Limestone with the possibility of recognising the lateral equivalents of cyclothems in a massive limestone sequence by a study of the vertical distribution and abundance of conodonts.

APPENDIX

Faunal Lists of the Conodonts present in each Horizon, excluding those forms which appear in the table on pages 219 & 220

Mirk Fell Beds

Gnathodus girtyi Hass girtyi
G. girtyi Hass sulcatus Higgins
Ligonodina levis Branson and Mehl
L. tenuis Branson and Mehl
L. typa (Gunnell)
Lonchodina paraclarki Hass
Magnilaterella complectens (Clarke)
Neoprioniodus conjunctus (Gunnell)
N. peracutus (Hinde)
N. singularis (Hass)
Roundya subacoda (Gunnell)
Spathognathodus cristula Youngquist and Miller
S. scitulus (Hinde)

Little Limestone

Apatognathus? librata sp.nov.
Cavusgnathus navicula (Hinde)
Ligonodina cf. ultima Clarke

Main Limestone

* - forms which do not occur above the Main Limestone

*Apatognathus? cuspidata sp.nov.
A? librata sp.nov.
*A? petila sp.nov.
*A? scalena sp.nov.
Cavusgnathus unicornis Youngquist and Miller
*Gnathodus bilineatus (Roundy)
*G. commutatus (Branson and Mehl)
G. girtyi Hass girtyi
G. girtyi Hass sulcatus Higgins
*Hibbardella fragilis Higgins
*Hindeodella germana Holmes
*H. hamatilis sp.nov.
*H. ibergensis Bischoff
*Hindeodus sp.A.
Ligonodina levis Branson and Mehl

L. tenuis Branson and Mehl

L. typa (Gunnell)

*L. ultima Clarke

*L. n.sp.A.

*Lonchodina furnishi Rexroad

*L. paraclaviger Rexroad

*L. cf. projecta Ulrich and Bassler

Magnilaterella complectens (Clarke)

*M. robusta Rexroad and Collinson

*M. sp.A.

*M. spp

Neoprioniodus peracutus (Hinde)

N. singularis (Hass)

*New Genus - Rexroad and Collinson

*Ozarkodina adunca sp.nov.

*O. cf. laevipostica Rexroad and Collinson

*O. sp.B.

*Spathognathodus minutus (Ellison)

S. scitulus (Hinde)

*S. sp.A.

Iron Post Limestone

Neoprioniodus singularis (Hass)

Spathognathodus scitulus (Hinde)

Underset Limestone

Apatognathus? cuspidata sp.nov.

A? librata sp.nov.

A? petila sp.nov.

A? scalena sp.nov.

Cavusgnathus unicornis Youngquist and Miller

Gnathodus bilineatus (Roundy)

G. commutatus (Branson and Mehl)

G. girtyi Hass sulcatus Higgins

G. nodosus Bischoff nodosus

Hindeodella hamatilis sp.nov.

H. ibergensis Bischoff

Hindeodus sp.A.

Ligonodina levis Branson and Mehl

L. tenuis Branson and Mehl

L. typa (Gunnell)

Magnilaterella complectens (Clarke)

M. robusta Rexroad and Collinson

Neoprioniodus conjunctus (Gunnell)

N. peracutus (Hinde)

N. singularis (Hass)

Ozarkodina adunca sp.nov.

_O._ cf. _laevipostica_ Rexroad and Collinson

Spathognathodus cristula Youngquist and Miller

S. scitulus (Hinde)

Three Yard Limestone

Apatognathus? chauliodа sp.nov.

A? cuspidata sp.nov.

A? librata sp.nov.

A? petila sp.nov.

A? scalena sp.nov.

Cavusgnathus unicornis Youngquist and Miller

Gnathodus bilineatus (Roundy)

G. commutatus (Branson and Mehl)

G. girtyi Hass _sulcatus_ Higgins

G. nodosus Bischoff _nodosus_

Hibbardella fragilis Higgins

Hindeodella germana Holmes

Ligonodina levis Branson and Mehl

L. tenuis Branson and Mehl

L. typa (Gunnell)

L. ultima Clarke

Lonchodina paraclaviger Rexroad

Magnilaterella complectens (Clarke)

M. robusta Rexroad and Collinson

_M._ sp.A.

_M._ spp

Neoprioniodus peracutus (Hinde)

N. scitulus (Branson and Mehl)

New Genus - Rexroad and Collinson

Ozarkodina adunca sp.nov.

_O._ cf. _laevipostica_ Rexroad and Collinson

_O._ sp. B.

Roundya subacoda (Gunnell)

Spathognathodus minutus (Ellison)

S. scitulus (Hinde)

Five Yard Limestone

Apatognathus? chauliodа sp.nov.

A? cuspidata sp.nov.

A? petila sp.nov.

A? scalena sp.nov.

Gnathodus girtyi Hass _girtyi_

G. nodosus Bischoff _nodosus_

Ligonodina levis Branson and Mehl

L. tenuis Branson and Mehl

Magnilaterella complectens (Clarke)

Neoprioniodus scitulus (Branson and Mehl)

Ozarkodina cf. *laevipostica* Rexroad and Collinson

Spathognathodus minutus (Ellison)

S. scitulus (Hinde)

Middle Limestone

Cavusgnathus unicornis Youngquist and Miller

Gnathodus bilineatus (Roundy)

G. commutatus (Branson and Mehl)

G. nodosus Bischoff *nodosus*

Hibbardella abnormis Branson and Mehl

Hindeodella brevis Branson and Mehl

H. germana Holmes

H. hamatilis sp.nov.

H. ibergensis Bischoff

Lambdagnathus macrodentata Higgins

Ligonodina levis Branson and Mehl

L. tenuis Branson and Mehl

L. typa (Gunnell)

L. ultima Clarke

Lonchodina furnishi Rexroad

L. paraclaviger Rexroad

Magnilaterella alternata sp.nov.

M. complectens (Clarke)

Neoprioniodus scitulus (Branson and Mehl)

N. varians (Branson and Mehl)

New Genus - Rexroad and Collinson

Ozarkodina adunca sp.nov.

O. cf. *laevipostica* Rexroad and Collinson

Roundya subacoda (Gunnell)

Spathognathodus cristula Youngquist and Miller

Synprioniodina forsenta Stauffer

Simonstone Limestone

Angulodus walrathi (Hibbard)

Apatognathus? gemina (Hinde)

A? librata sp.nov.

A? petila sp.nov.

Cavusgnathus unicornis Youngquist and Miller

Gnathodus commutatus (Branson and Mehl

G. nodosus Bischoff *nodosus*

Hibbardella abnormis Branson and Mehl

Hindeodella germana Holmes

H. hamatilis sp. nov.

H. ibergensis Bischoff

H. undata Branson and Mehl

Lambdagnathus n.sp.A.

Ligonodina levis Branson and Mehl

L. typa (Gunnell)

L. ultima Clarke

L. n.sp.A.

Neoprioniodus peracutus (Hinde)

N. scitulus (Branson and Mehl)

New Genus - Rexroad and Collinson

Ozarkodina adunca sp.nov.

Subbryantodus subaequalis Higgins

Synprioniodina forsenta Stauffer

Hardraw Scar Limestone

Apatognathus? librata sp.nov.

A? petila sp.nov.

Gnathodus girtyi Hass girtyi

Hindeodella undata Branson and Mehl

Neoprioniodus singularis (Hass)

New Genus - Rexroad and Collinson

Gayle Limestone

* - forms not found below the Gayle Limestone

*Angulodus walrathi (Hibbard)

Apatognathus? chaulioda sp.nov.

A? gemina (Hinde)

*A? librata sp.nov.

*A? petila sp.nov.

*Cavusgnathus unicornis Youngquist and Miller

Gnathodus bilineatus (Roundy)

G. commutatus (Branson and Mehl)

G. homopunctatus Ziegler

*G. nodosus Bischoff nodosus

*Hibbardella abnormis Branson and Mehl

*H. fragilis Higgins

Hindeodella brevis Branson and Mehl

*H. germana Holmes

*H. hamatilis sp.nov.

H. ibergensis Bischoff

H. undata Branson and Mehl

*Lambdagnathus n.sp.A.

*Ligonodina levis Branson and Mehl

*L. tenuis Branson and Mehl

*L. typa (Gunnell)

*L. ultima Clarke

*L. n.sp.A.

*Lonchodina furnishi Rexroad

*L. paraclaviger Rexroad

*Magnilaterella alternata sp.nov.

*M. complectens (Clarke)

*M. spp.

Neoprioniodus peracutus (Hinde)

*N. scitulus (Branson and Mehl)

N. singularis (Hass)

*N. spathatus Higgins

*N. varians (Branson and Mehl)

*New Genus - Rexroad and Collinson

Ozarkodina adunca sp.nov.

*O. laevipostica Rexroad and Collinson

*O. cf. laevipostica Rexroad and Collinson

*O. sp.A.

Spathognathodus scitulus (Hinde)

*Subbryantodus subaequalis Higgins

*Synprioniodina forsenta Stauffer

Hawes Limestone

Apatognathus? chaulioda sp.nov.

A? gemina (Hinde)

Gnathodus bilineatus Roundy

G. girtyi Hass girtyi

G. girtyi Hass sulcatus Higgins

G. homopunctatus Ziegler

Hindeodella brevis Branson and Mehl

H. ibergensis Bischoff

H. undata Branson and Mehl

Lonchodina sp.B.

Neoprioniodus singularis (Hass)

Ozarkodina adunca sp.nov.

Spathognathodus scitulus (Hinde)

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PLATE 1

All Figures x 41

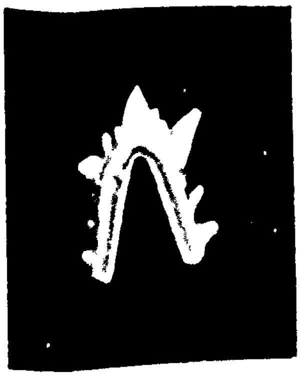
Apatognathus? chaulioda sp.nov.

Figs. 1 and 4	Type specimen, 26/5/GG202, outer and inner lateral views.
Figs. 2 and 3	34/3/GB8A, inner and outer lateral views.
Fig.5	23/1/MG285 inner lateral view.
Fig.6	24/6/SW182 outer lateral view of large incomplete specimen. Apical cusp broken and anterior bar missing.

Apatognathus? cuspidata sp.nov.

Fig.7	31/3/BB159, inner lateral view.
Figs. 8 and 9	25/4/SW182, inner and outer lateral views. Denticles broken but bars complete.
Fig.10.	Type specimen, 28/6/BB205, outer lateral view. showing complete cusp.
Fig.11.	29/2/BB204, inner lateral view.
Fig.12.	23/5/MG285, inner lateral view.
Fig.13	31/2/BB159, outer lateral view.

PLATE 1



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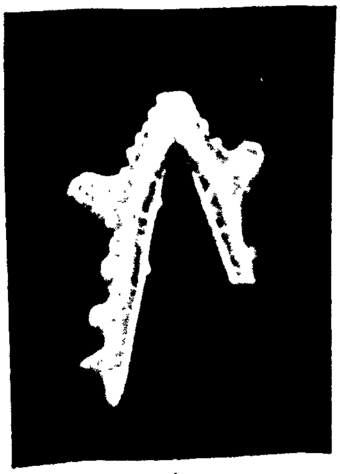

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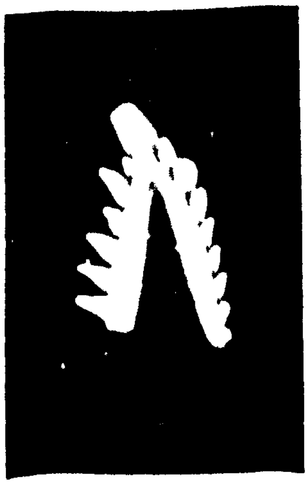

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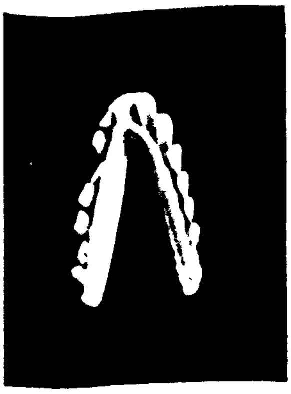

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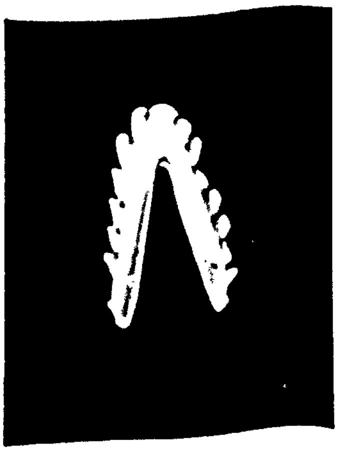

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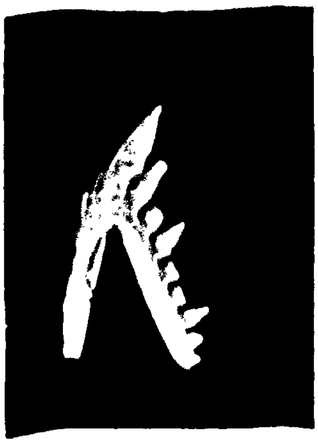

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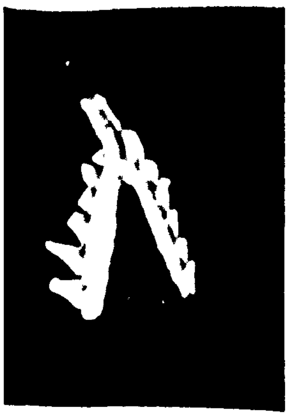

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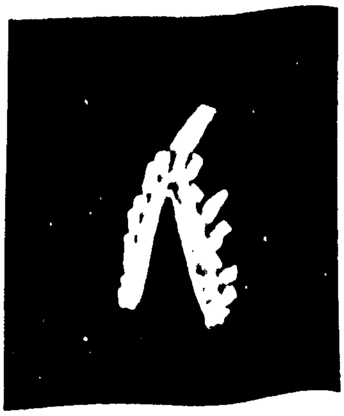

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PLATE 2

All Figures x 41

Apatognathus? gemina (Hinde 1900)

Figs. 1 and 2 80/5/GB110J, aboral and oral views of the posterior bar of a broken specimen showing the extent of lateral thickening and the position of the aboral groove.

Fig.3 81/1/GB110A, inner lateral view.

Apatognathus? librata sp.nov.

Figs. 4 and 7 30/2/BB212, inner and outer lateral view of an immature specimen.

Fig.5 29/5/BB159, inner lateral view of a juvenile specimen.

Fig.6 28/4/BB205, inner lateral view.

Fig.8 25/5/SW182, inner lateral view.

Fig.9 Type specimen, 18/2/MG132, inner lateral view of a large mature specimen.

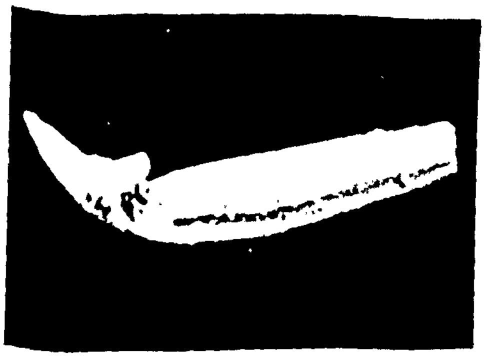
Figs.10 and 11 31/6/BB159, inner and outer lateral views of specimen with large denticle near apex.

Apatognathus? petila sp.nov.

Figs.12 and 13 24/4/SW182, outer and inner lateral views.

Fig.14. 34/5/GB110, inner lateral view.

PLATE 2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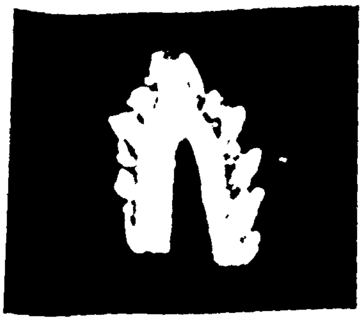
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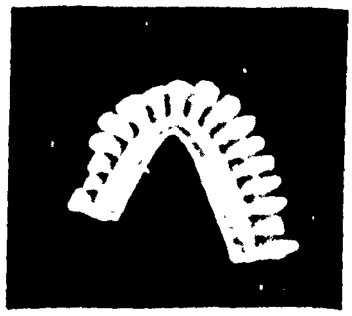
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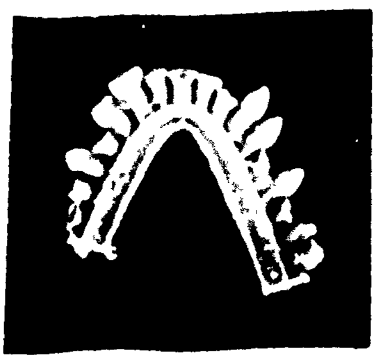
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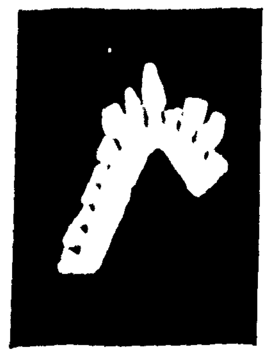
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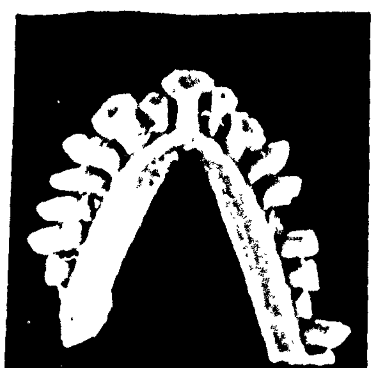
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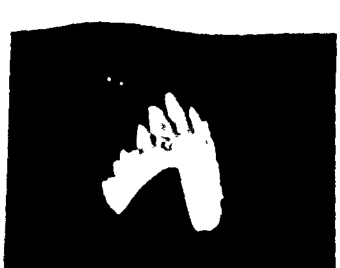
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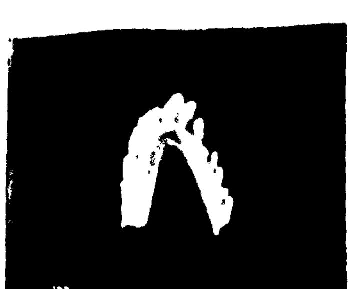
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PLATE 3

All Figures x 41

Apatognathus? petila sp.nov.

Fig.1	Type specimen, 16/6/MG39, outer lateral view.
Fig.2	20/5/MG259, inner lateral view of large broken specimen with thickening on the posterior bar.

Apatognathus? scalena sp.nov.

Figs. 3 and 4	Type specimen, 32/4/BB213, inner and outer lateral views showing the greater length of the anterior bar.
Fig.5	22/5/MG278, inner lateral view.
Fig.6	31/4/BB159, inner lateral view.
Fig.7	33/3/GG217, outer lateral view.
Fig.8	18/5/MG131, inner lateral view.

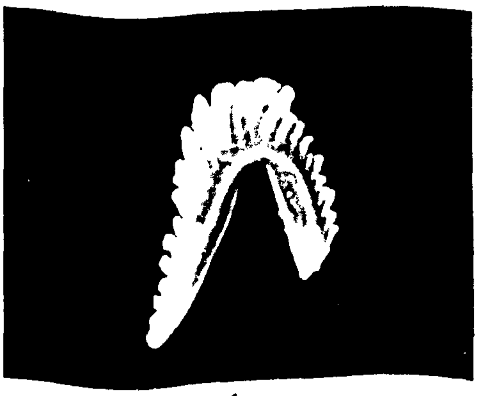
Geniculatus claviger Roundy 1926

Fig.9	65/2/MF191, oral view of a highly thickened specimen with a small cusp.
Fig.10	65/3/MF191, oral view of a specimen with a larger cusp.

Angulodus walrathi (Hibbard 1927)

Fig.11	35/2/GB111, inner lateral view.
Fig.12	35/1/GB117, inner lateral view.

PLATE 3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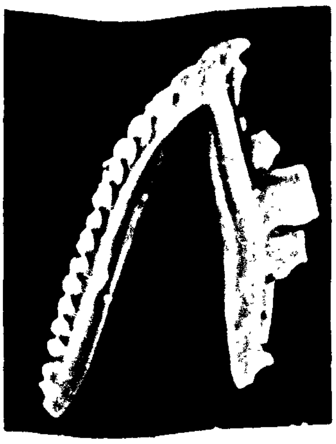
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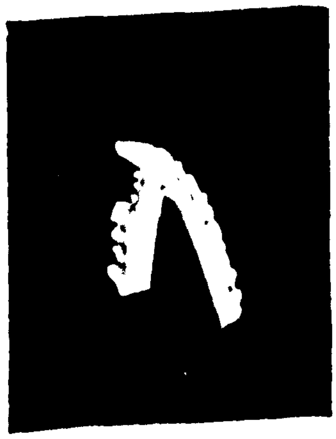
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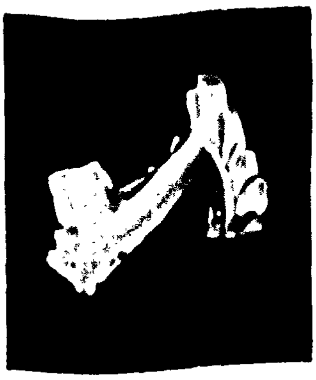
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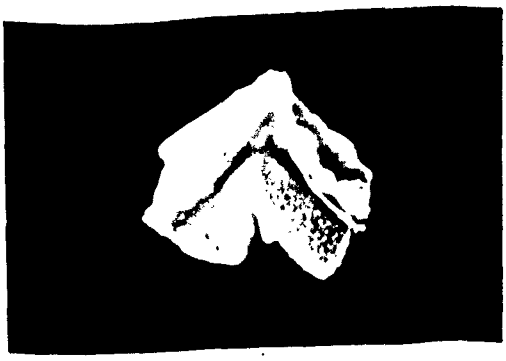
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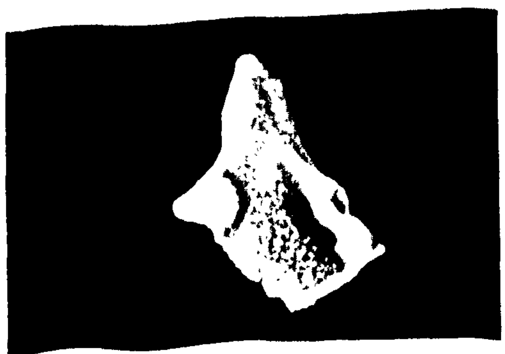
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PLATE 4

All figures x 41

Hindeodella brevis Branson and Mehl 1934.

Fig.1 65/6/MG144, outer lateral view.

Fig.2 66/1GB19, outer lateral view

Hindeodella germana Holmes 1928.

Fig.3 66/2/MG133, inner lateral view showing anterior bar and part of the posterior bar.

Fig.5 66/3/MG155, inner lateral view.

Hindeodella hamatilis sp.nov.

Figs. 4 and 7 Type specimen, 51/5/MG132, outer and inner lateral views.

Figs.6,8 and 9. 51/4/GB111, inner and outer lateral views and oral view, the latter showing the inward curvature of the anterior bar.

Hindeodella ibergensis Bischoff 1957

Fig.10 66/5/GB113, inner lateral view.

Fig.11 66/4/GB111, inner lateral view showing pronounced aboral curvature of anterior bar.

Hindeodella undata Branson and Mehl 1941

Figs.12 and 13 69/6/MG132, oral and lateral views.

Fig.14 70/1/MG132, oral view showing orientation of the major and minor denticles.

Hindeodus sp.B

Fig.15 52/2/MF190, inner lateral view.

Hindeodus sp.A.

Fig.16 52/1/MG259, inner lateral view, basal pit visible.

PLATE 4

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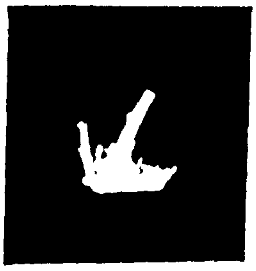

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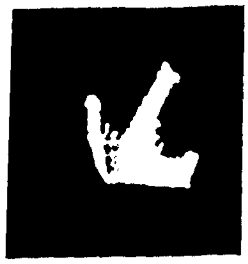

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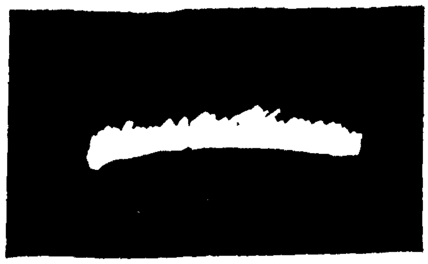

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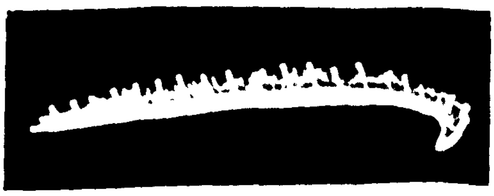

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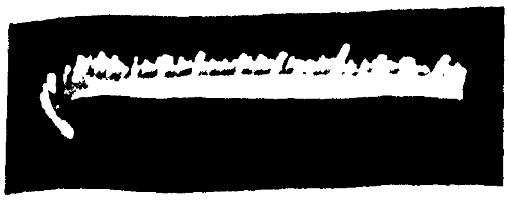

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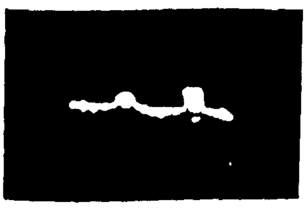

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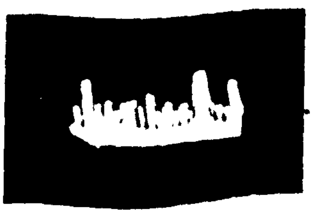

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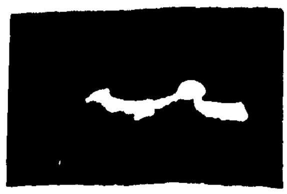

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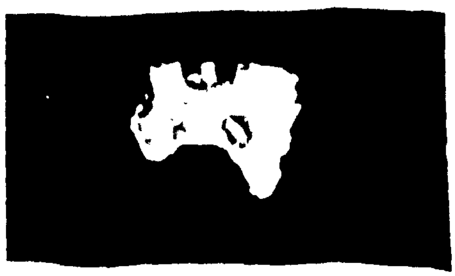

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PLATE 5

All Figures x 41

Lambdagnathus macrodentata Higgins 1961

Figs.1 and 2 64/6/MG132, inner lateral and aboral views.

Lambdagnathus n.sp.A.

Fig.3 52/3/GB112, inner lateral view. Aboral groove visible.

Lambdagnathus sp.B.

Figs.4 and 5 52/4/MG272, inner lateral and oral views.

Ligonodina tenuis Branson and Mehl 1941

Figs.6 and 9 70/4/GB117, inner and outer lateral views. Note denticle anterior to the cusp.

Ligonodina levis Branson and Mehl 1941

Figs.7 and 8 70/6/MG131, inner and outer lateral views. Note absence of denticle anterior to the cusp.

Ligonodina typa (Gunnell 1933)

Figs.10 and 11. 70/6/GB111, anterior and posterior views of a specimen with strong denticulation on the inner lateral process.

Fig.12 71/2/SW186, inner lateral view.

Ligonodina ultima Clarke 1960

Figs.12 and 13 62/5/MG155, outer and inner lateral views.

Fig.17 63/1/BB216, inner lateral view.

Ligonodina n.sp.A.

Figs.15 and 16 53/3/GB117, inner and outer lateral views.

PLATE 5

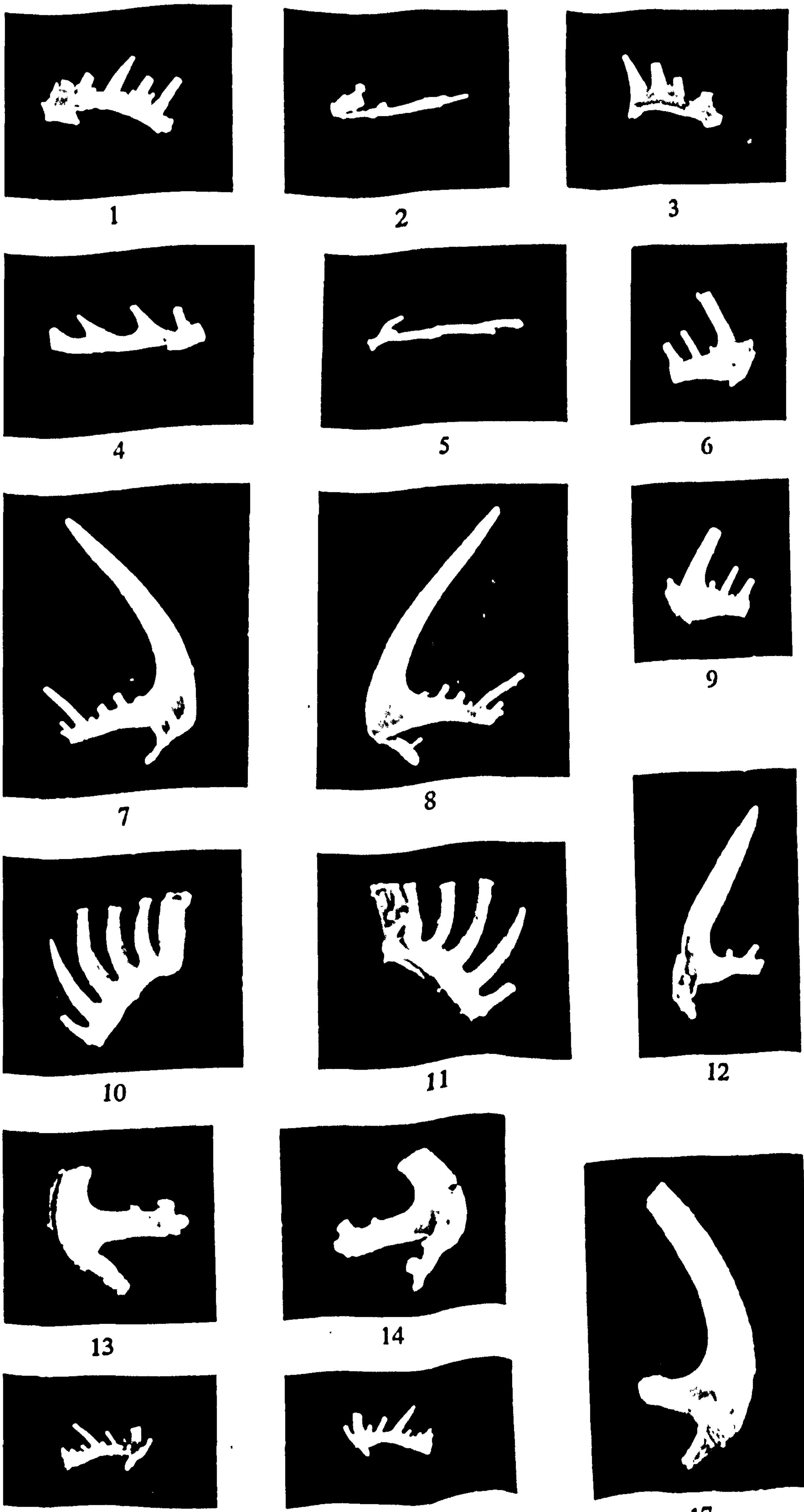


PLATE 6

All Figures x 41

Ligonodina of ultima Clarke 1960

Fig.1 62/3/BB123, inner lateral view.

Fig.2 62/4/BB202, inner lateral view.

Lonchodina paraclaviger Rexroad 1958

Fig.3 61/2/GG217, inner lateral view.

Lonchodina furnishi Rexroad 1958.

Figs.4 and 5 57/6/GB111, inner and outer lateral views.

Lonchodina n.sp.A.

Figs.6 and 7 52/6/GB117, inner and outer lateral views.

Lonchodina paraclarki Hass 1953

Figs.8 and 11 61/6/MF192, inner and outer lateral views.

Lonchodina cf. projecta Ulrich and Bassler 1926.

Fig.10 61/1/GG216, innerlateral view.

Magnilaterella recurvata (Bischoff 1957)

Fig.9 65/5/MG259, inner lateral view of lateral bar.

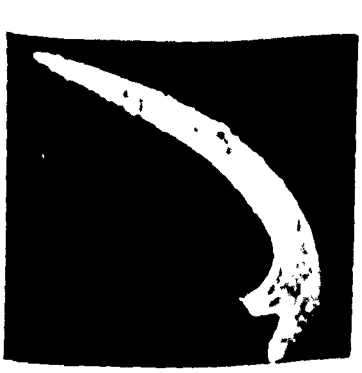
Magnilaterella complectens (Clarke 1960)

Figs.12 and 13 60/2/GB116, outer and inner lateral views.

Magnilaterella sp.A.

Fig.14 54/3/MG270, outer lateral view.

PLATE 6



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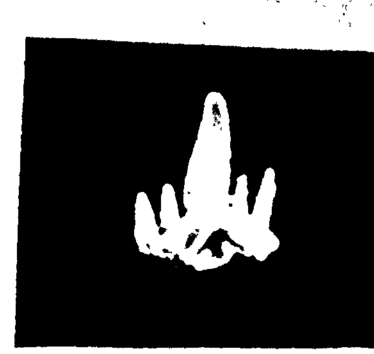

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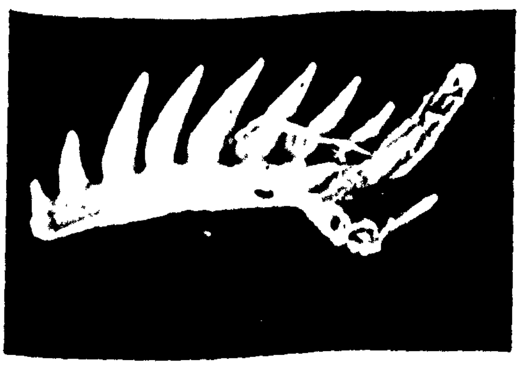

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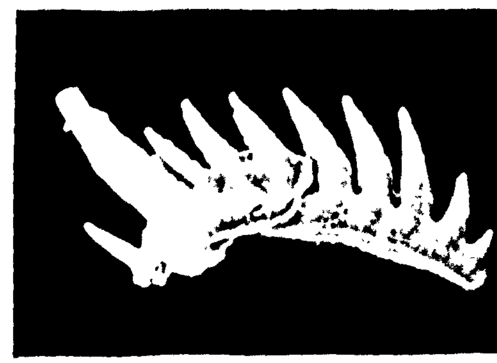

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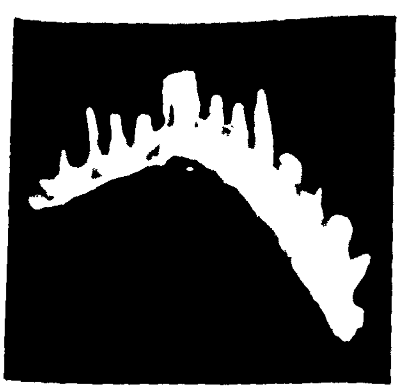

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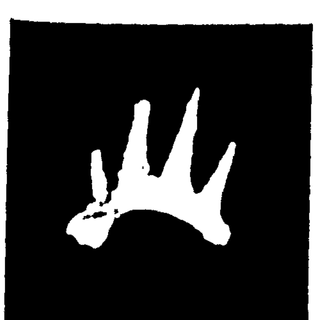

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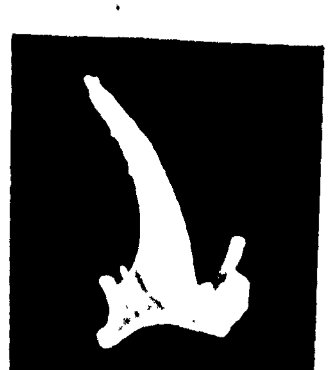

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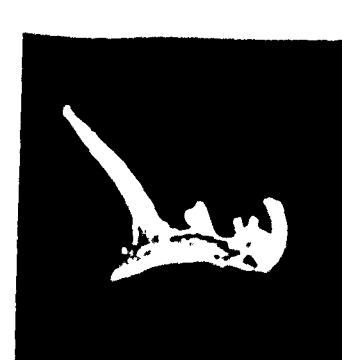

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PLATE 7

All Figures x 41

Magnilaterella robusta Rexroad and Collinson 1963

Figs.1 and 2 60/4/MG270, outer and inner lateral views.

Fig.3 60/6/MG272, outer lateral view of lateral bar.

Magnilaterella alternata sp.nov.

Figs.4 and 5. Type specimen, 54/1/MG155, inner and outer lateral views, showing prominent callus.

Neoprioniodus camurus Rexroad 1957

Fig.6 65/4/MG270, inner lateral view.

Metalonchodina bidentata (Gunnell 1931)

Fig.8 62/1/MF191, inner lateral view.

Fig.9 62/2/MF191, inner lateral view of thickened specimen.

Neoprioniodus varians (Branson and Mehl 1941)

Fig.7 72/6/GG211, inner lateral view.

Fig.10 73/1/GB116, inner lateral view.

Neoprioniodus conjunctus (Gunnell 1931)

Fig.11 71/3/MG132, inner lateral view.

Fig.12 71/4/MF191, thickened specimen, inner lateral view.

Neoprioniodus scitulus (Branson and Mehl 1941)

Fig.14 72/4/MG272, inner lateral view.

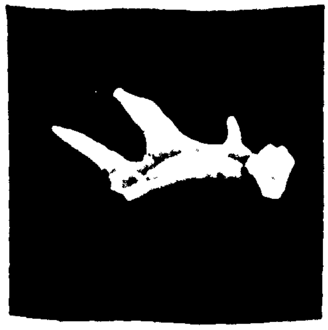
Fig.15 72/3/GB107, inner lateral view.

Neoprioniodus spathatus Higgins 1961.

Fig.13 55/5/GB108, inner lateral view of specimen with a denticle on the anticusp.

Fig.16 55/4/MG130, inner lateral view.

PLATE 7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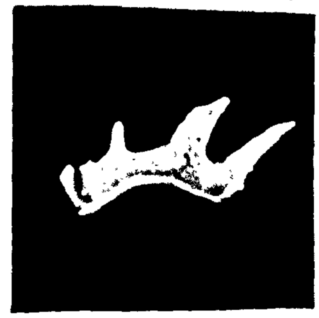
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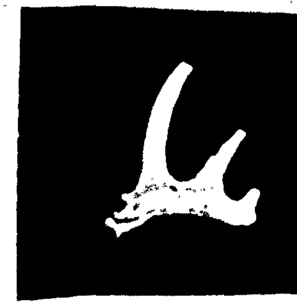
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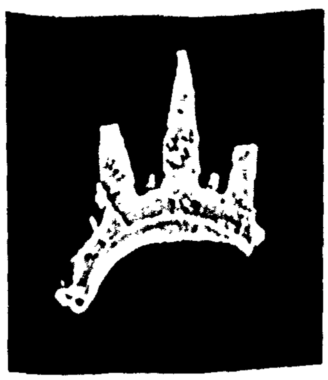
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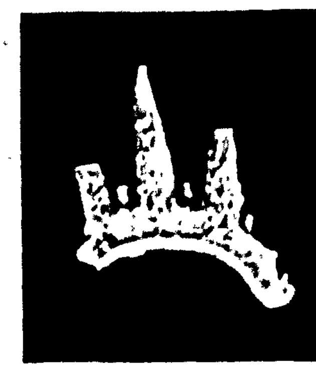
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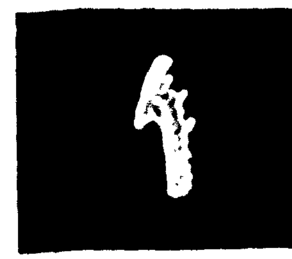
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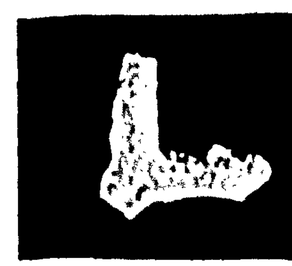
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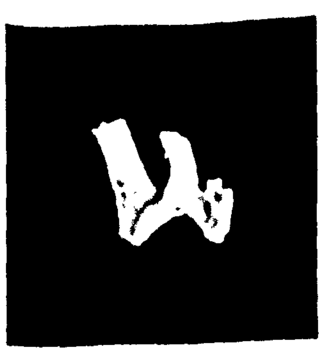
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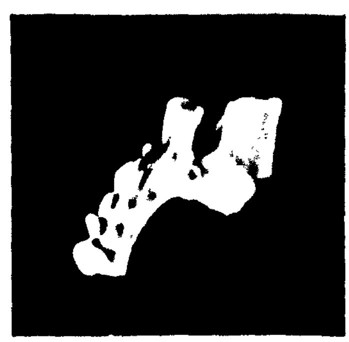
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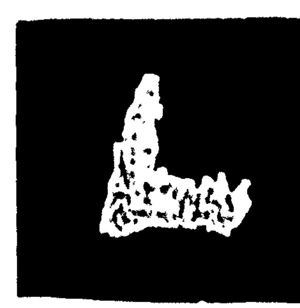
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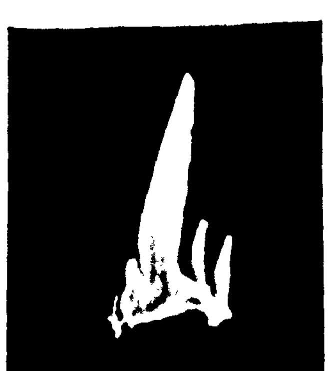
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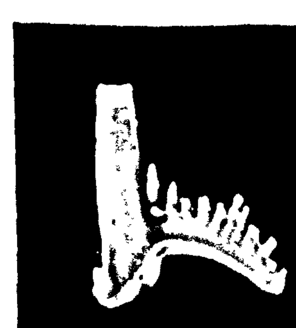
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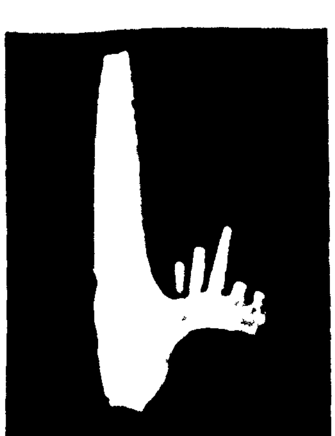
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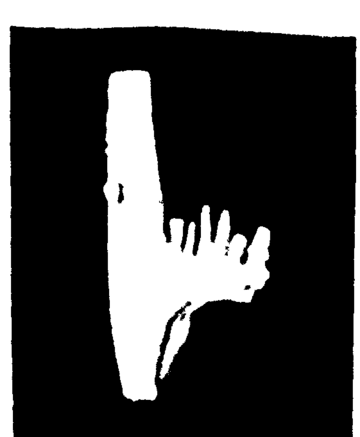
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PLATE 8

All Figures x 41

Neoprioniodus singularis (Hass 1953)

Fig.1 71/6/BB156, inner lateral view.

Fig.2 71/5/MG259, inner lateral view.

Neoprioniodus peracutus (Hinde 1900)

Fig.3 72/2/GB107, inner lateral view.

Fig.4 72/1/BB156, inner lateral view.

New Genus - Rexroad and Collinson

Fig.5 73/5/MG276, inner lateral view

Fig.6 73/4/MG272, inner lateral view

Fig.7 73/3/MG34, inner lateral view.

Fig.10 73/2/MG132, inner lateral view.

Ozarkodina adunca sp.nov.

Fig.8 Type specimen 55/6/GB111, inner lateral view.

Fig.9 54/4/MG270, inner lateral view of immature specimen.

Ozarkodina laevipostica Rexroad and Collinson 1963

Figs.11 and 12 63/5/GB111, inner and outer lateral views.

Ozarkodina sp.A.

Fig.13 74/1/GB109, inner lateral view.

Ozarkodina cf. hindei Clarke 1960

Fig.15 63/3/MG69, inner lateral view.

Ozarkodina cf. laevipostica Rexroad and Collinson 1963

Fig.14 64/1/BB204, inner lateral view

Fig.16 63/6/MG259, inner lateral view

Ozarkodina sp.B.

Fig.17 73/6/MG283, Inner lateral view.

Spathognathodus cristula Youngquist and Miller 1949

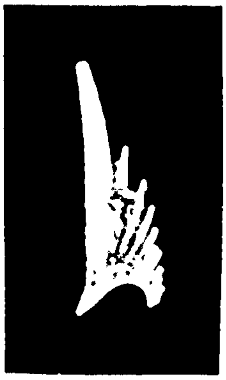
Fig.18 76/3/BB204, inner lateral view.

Fig.20 76/2/GG226, inner lateral view.

Spathognathodus cf. minutus (Ellison 1941)

Fig.19 76/6/BB204, outer lateral view.

PLATE 8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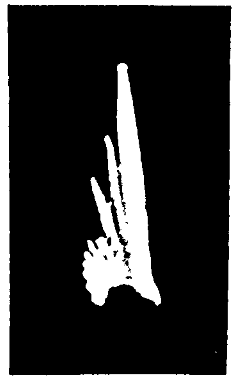
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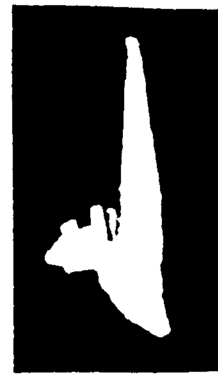
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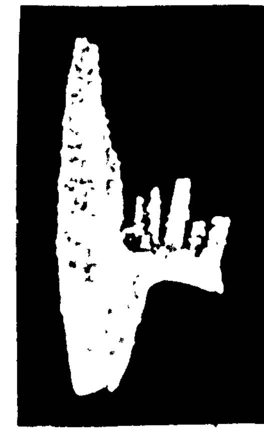
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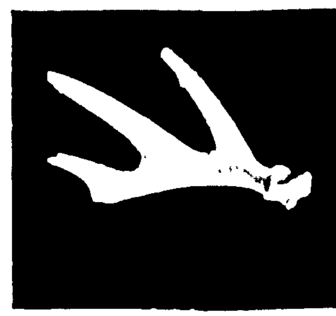
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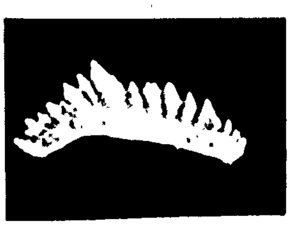
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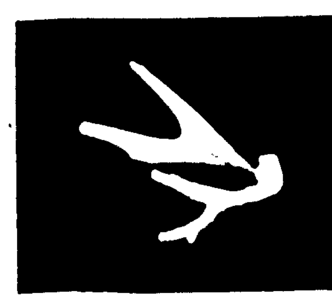
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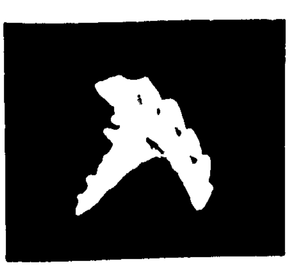
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PLATE 9

All Figures x 41

Spathognathodus cf. minutus (Ellison 1941)

Fig.1 77/1/GG211, outer lateral view.

Spathognathodus minutus (Ellison 1941)

Fig.2 76/4/MG285, outer lateral view.

Fig.3 76/5/MG285, outer lateral view.

Spathognatodus scitulus (Hinde 1900)

Figs4 and 6 77/2/GB107, outer and inner lateral views.

Spathognathodus sp.A.

Fig.5 76/1/MG132, outer lateral view.

Hibbardella apsida sp.nov.

Type specimen 50/3/BB213

Fig.7 Anterior view

Fig.8 Oral view

Fig.10 Posterior view.

Fig.11 Oblique anterior view.

Synprioniodina forsenta Stauffer 1940

Figs.9 and 10 74/4/GB111, inner and outer lateral views.

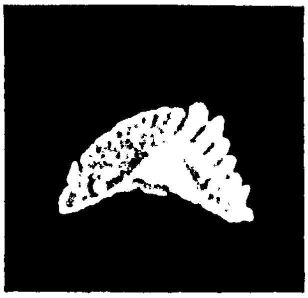
Subbryantodus subaequalis Higgins 1961

Fig.13 74/6/MG259, inner lateral view

Hibbardella abnormis Branson and Mehl 1940

Figs. 14 and 15.64/3/MG67, anterior and oblique posterior views.

PLATE 9



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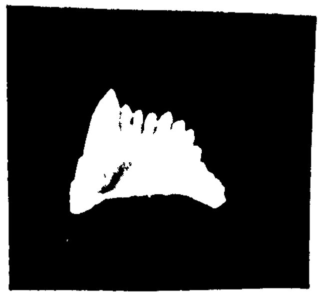

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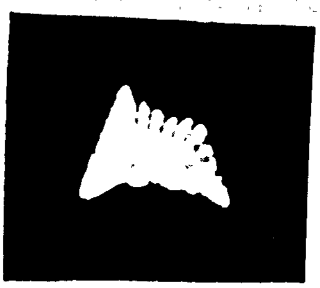

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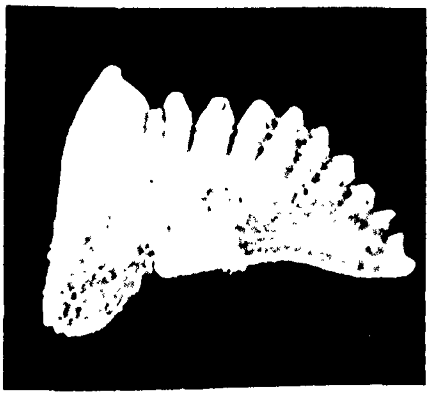

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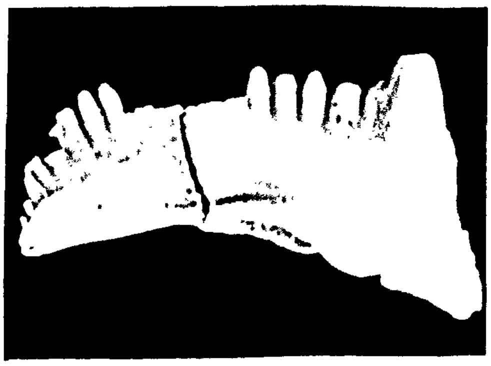

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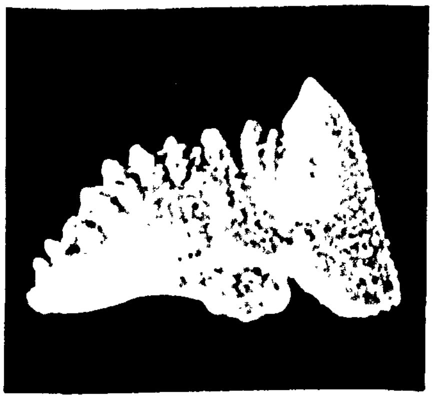

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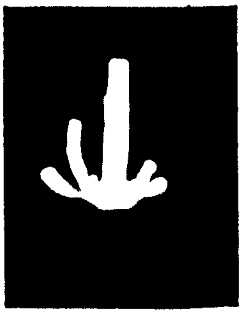

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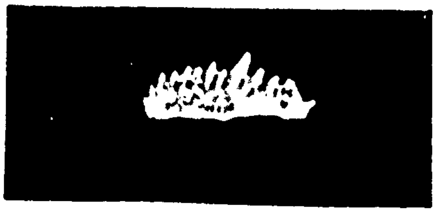

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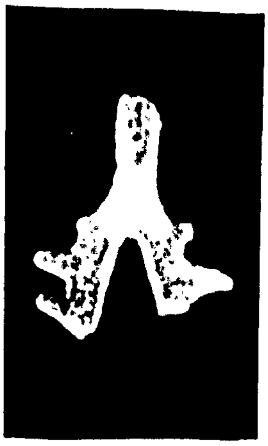

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PLATE 10

All Figures x 41

Hibbardella fragilis Higgins 1961

Fig.1 64/2/GB111, lateral view

Roundya subacoda (Gunnell 1931)

Fig.2 74/2/MG70, lateral view.

Fig.3 74/3/MG191, posterior view of large thickened form.

Mestognathus bipluti Higgins 1961

Fig.4 59/4/MG69, oral view.

Figs.5,6 and 7 59/6/MG130, inner lateral, aboral and oral views.

Cavusgnathus convexa Rexroad 1957

Figs.8 and 9 66/6/GG201, inner lateral and oral views.

Cavusgnathus middlehopensis sp.nov.

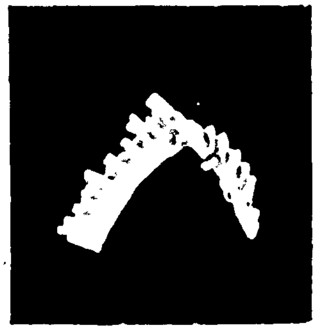
Type specimen 67/3/SW181

Fig.10 inner lateral view.

Fig.11 oral view

Fig.12 outer lateral/aboral view.

PLATE 10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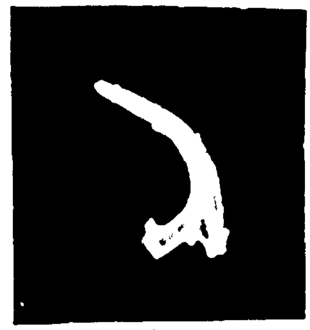
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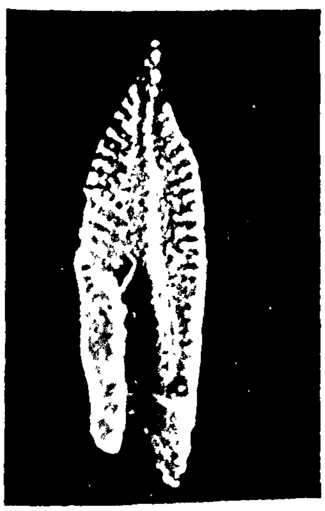
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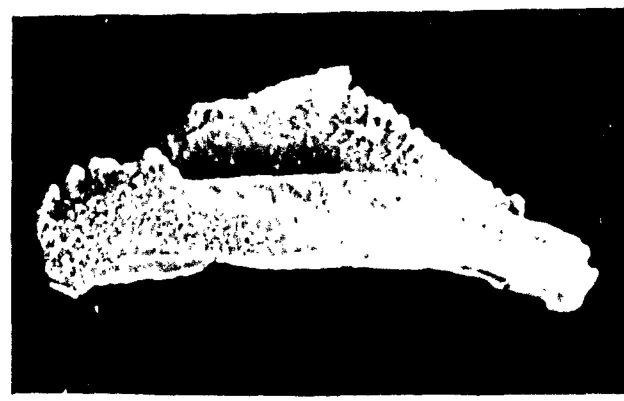
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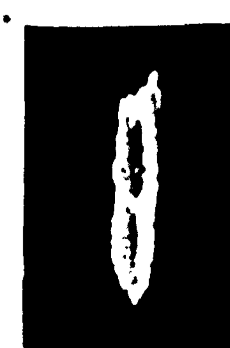
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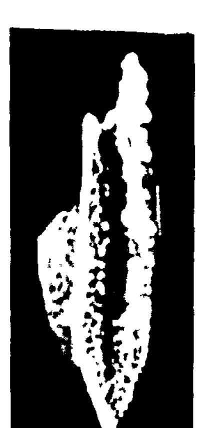
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PLATE 11

All figures x 41

Cavusgnathus navicula (Hinde 1900)

Fig.1	68/3/MF191, oral view of specimen with oral trough infilled.
Fig.2	68/4/BB214, oral view.
Fig.3	68/5/BB213, inner lateral view showing large posterior denticle of blade.

Cavusgnathus unicornis Youngquist and Miller 1949

Figs. 5 and 6	68/1/GG211, oral and outer lateral views.
Fig.7	67/6/GG211, outer lateral view.

Cavusgnathus/Streptognathodus transitions

Fig.4	75/3/MF190, oral view
Fig.8	75/4/MF190, oral view
Fig.9	75/1/MF190, oral view.
Fig.10	75/1/MF190, oral/lateral view.

Streptognathodus unicornis Rexroad and Burton 1961

Fig.11	75/6/MF190, oral view.
Fig.12	75/2/MF190, oral view.

Gnathodus commutatus (Branson and Mehl 1941)

Fig.13	56/1/GB113, oral view
Figs.14 and 15	56/2/GB113, oral and aboral views.

PLATE 11

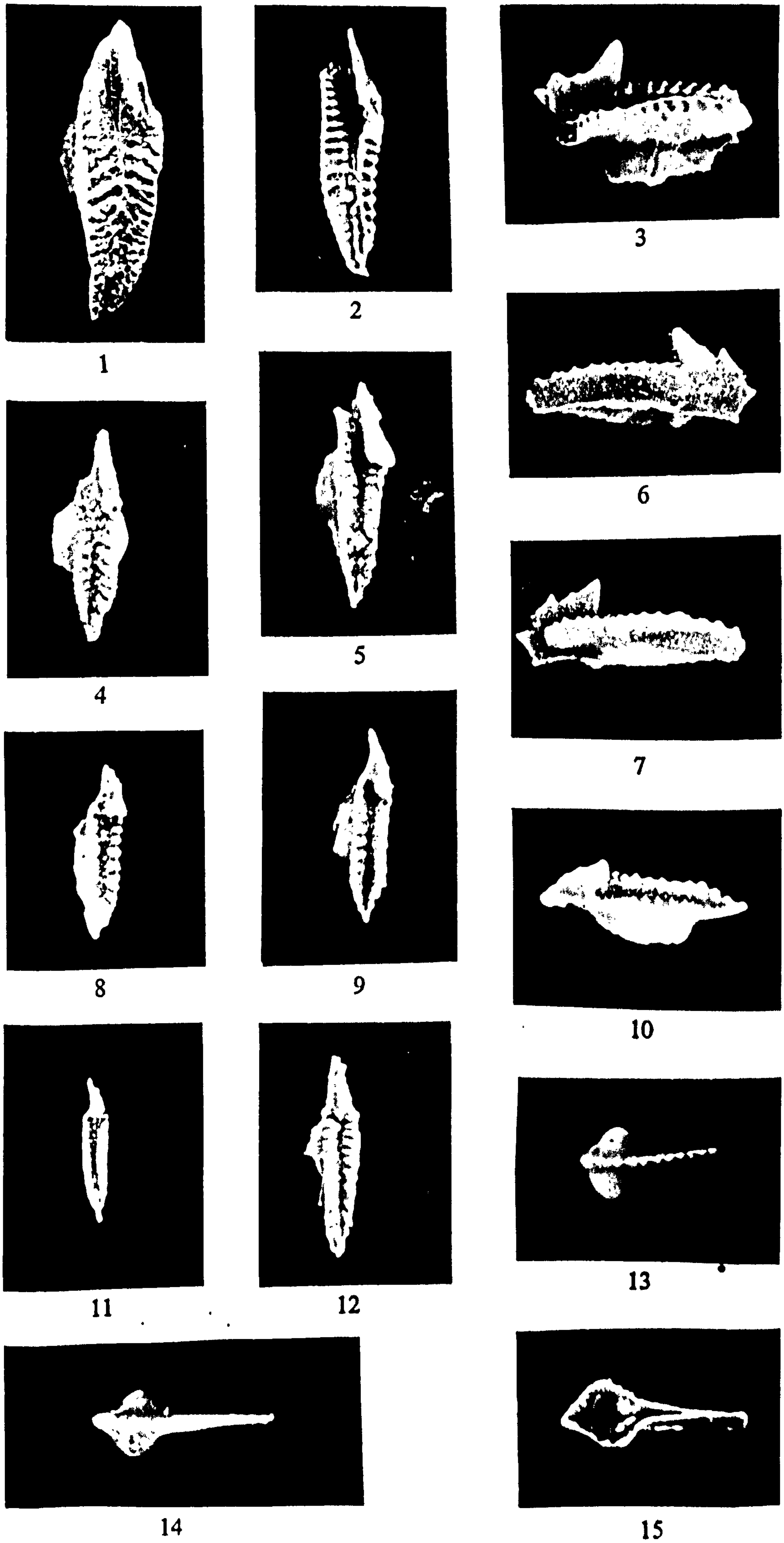


PLATE 12

All Figures Oral Views, x 41

Gnathodus homopunctatus Ziegler 1962

Fig.1	57/4/GB111
Fig.2	57/2/GB111
Fig.3	57/5/GB117
Fig.4	57/3/GB111

Gnathodus nodosus Bischoff var. nodosus

Fig.5	56/4/BB213
Fig.6	56/5/BB159
Fig.7	57/1/BB159

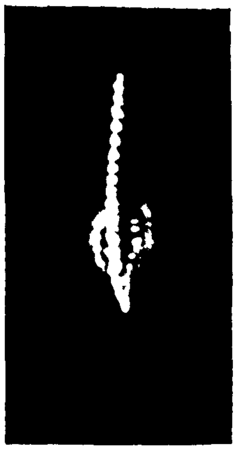
Gnathodus nodosus Bischoff var. radiolus nov.

Fig.8	56/6/BB159
Fig.9	68/6/BB159
Fig.10	69/1/BB159
Fig.11	69/2/BB159
Fig.12	69/4/GG214

Gnathodus confixus sp.nov.

Fig.13	77/6/MF191
Fig.14	Type specimen, 78/2/MF191
Fig.15	61/4/MF192.

PLATE 12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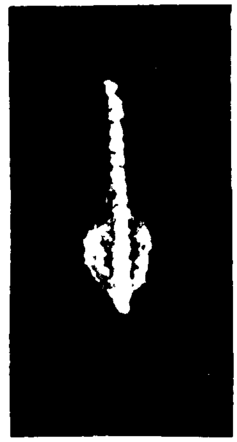
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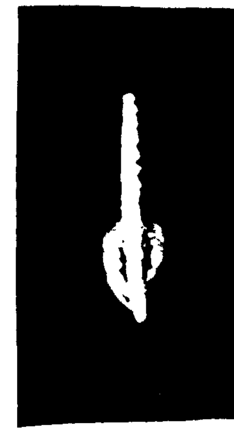
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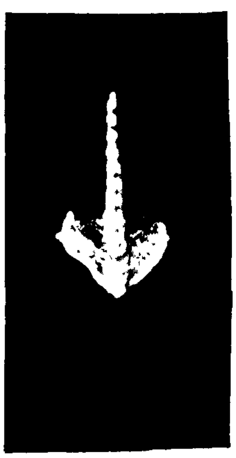
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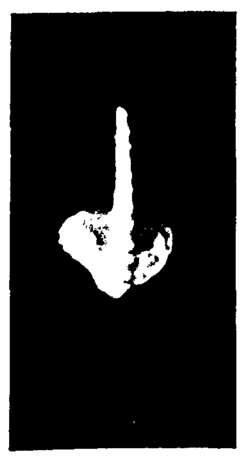
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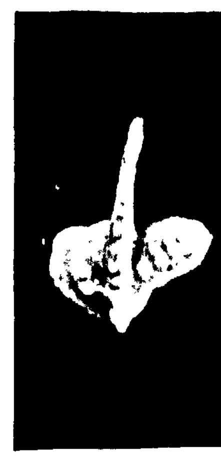
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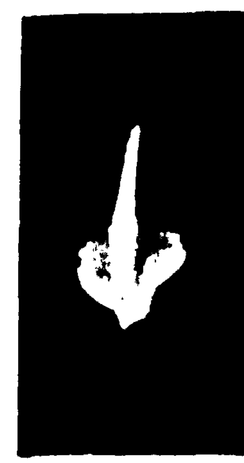
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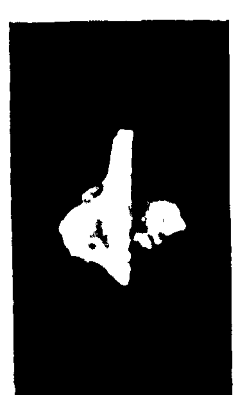
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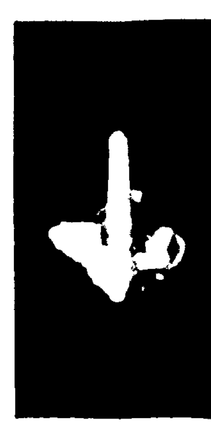
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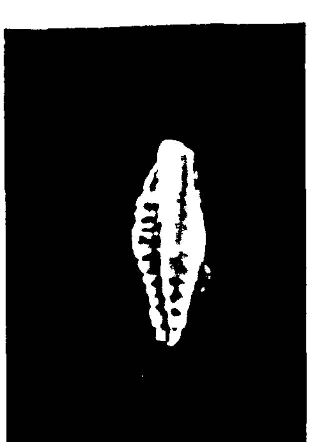
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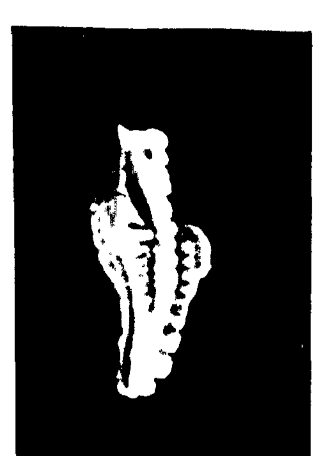
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PLATE 13

All Figures Oral Views, x 41

Gnathodus confixus sp.nov.

Fig.1	77/5/MF191
Fig.2	78/1/MF191
Fig.3	78/3/MF191

Gnathodus bilineatus (Roundy 1926)

Fig.4	59/3/BB205
Fig.5	58/5/MG285
Fig.6	58/2/GB111
Fig.7	59/2/BB205
Fig.8	58/4/MG285
Fig.9	58/6/SW184
Fig.10	59/1/SW184
Fig.13	58/3/GB109.

Gnathodus girtyi Hass var. *sulcatus* Higgins 1961 (in manuscript)

Fig.11	61/3/MF192
Fig.12	78/4/MF191
Fig.14	49/6/GB18
Fig.15	77/4/MF191

PLATE 13

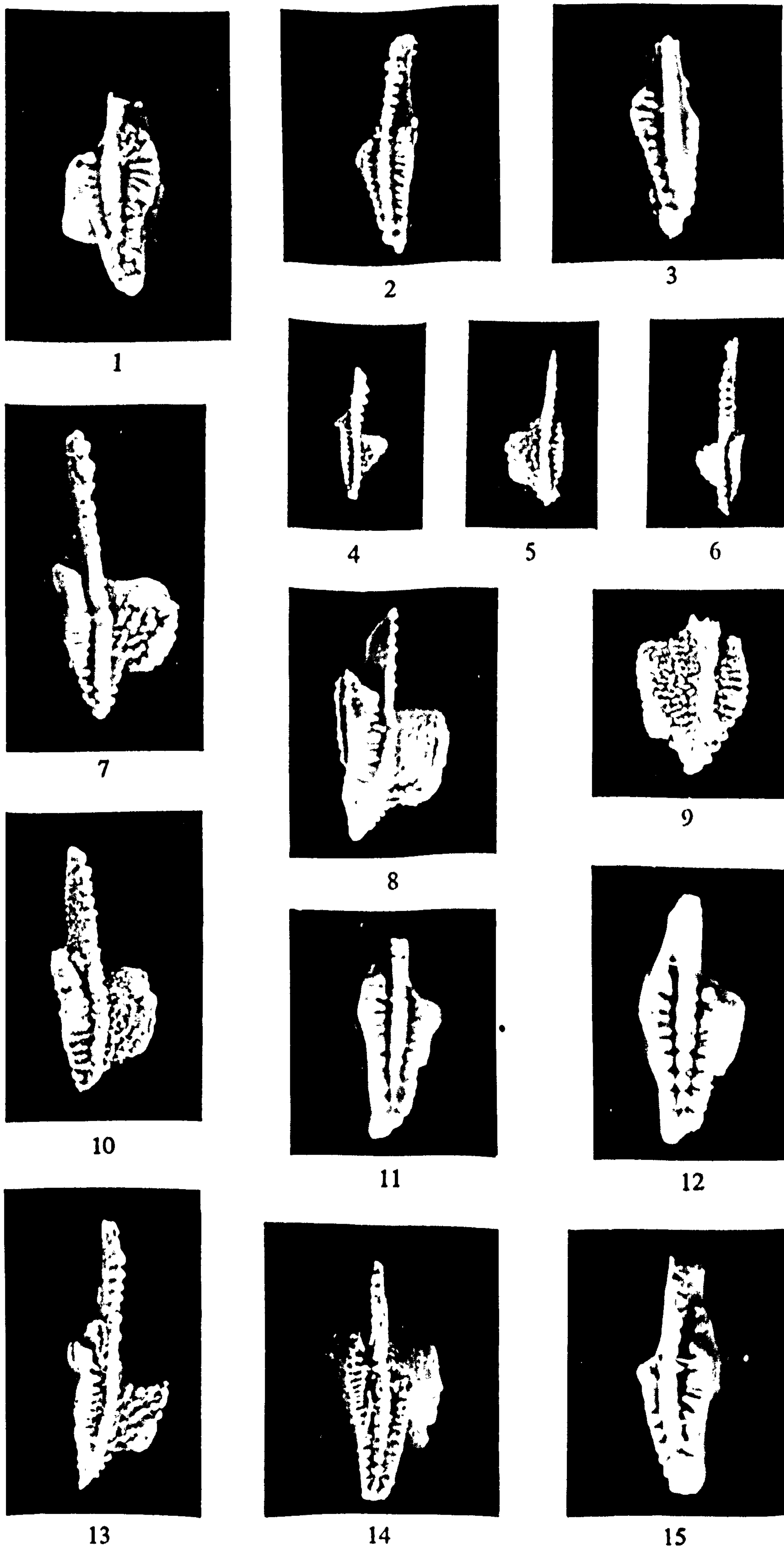

PLATE 14

All Figures *Gnathodus girtyi* Hass var. *girtyi*, x 41

Fig.1	79/2/GB109, outer lateral view
Fig.2	55/3/GB109, outer lateral view.

Oral View:-

Fig.3	55/2/GB109	Form 1
Fig.4	55/1/GB111	Form 2
Fig.5	78/5/GB111	Form5
Fig.6	79/1/GB111	Form5
Fig.7	78/6/GB111	Form5
Fig.8	54/6/GB113	Form 9
Fig.9	54/3/GB113	Form10
Fig.10	80/3/GB117	Form12
Fig.11	80/1/GG217	Form 12
Fig.12	79/3/MG130	Form 14
Fig.13	79/5/GG217	Form 16
Fig.14	80/2/GG217	Form 16
Fig.15	79/4/BB206	Form 18
Fig.16	79/6/GG217	Form 19
Fig.17	80/4/MF191	Form 20

PLATE 14

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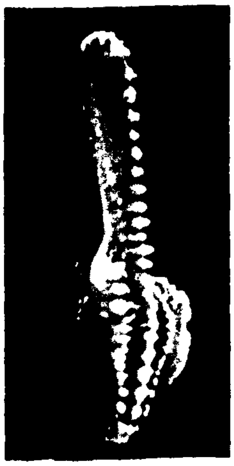

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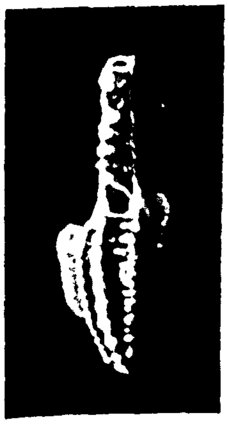

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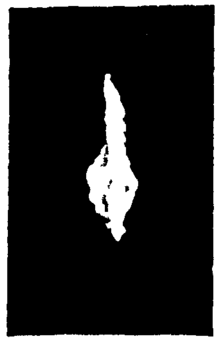

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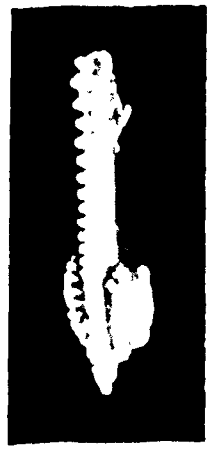

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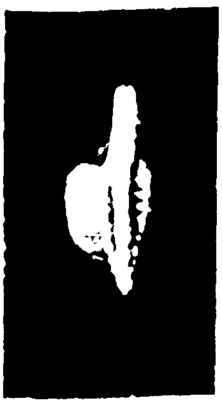

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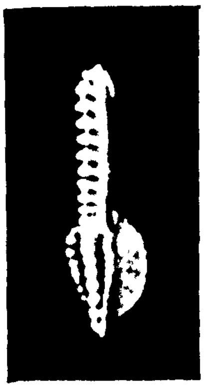

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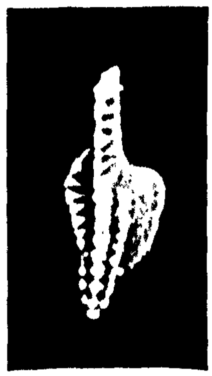

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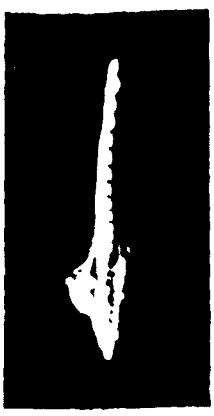

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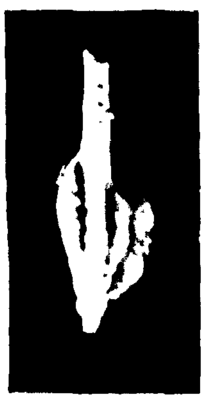

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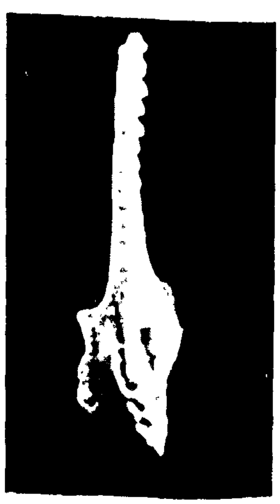

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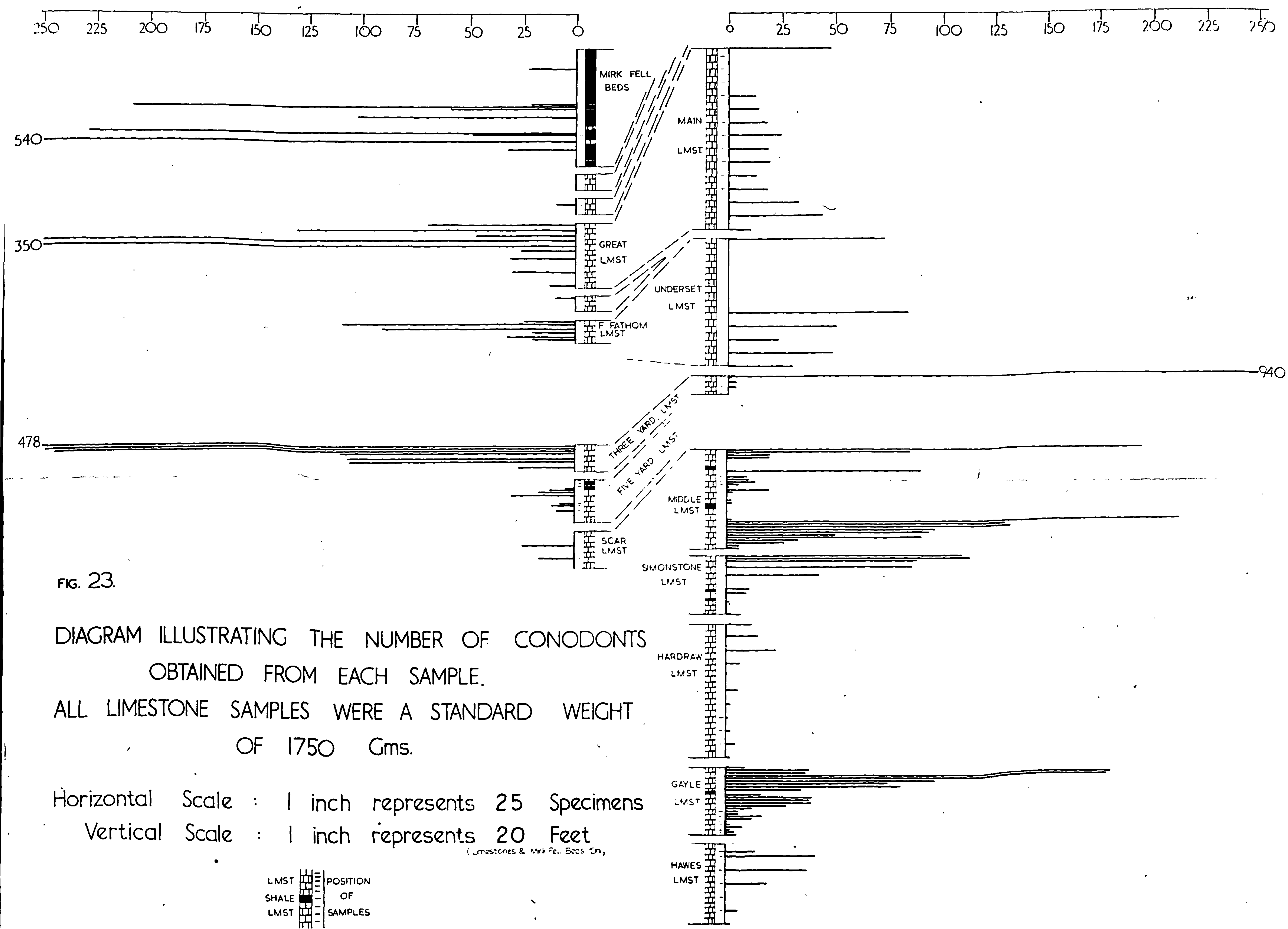

FIG. 23.

DIAGRAM ILLUSTRATING THE NUMBER OF CONODONTS OBTAINED FROM EACH SAMPLE.

ALL LIMESTONE SAMPLES WERE A STANDARD WEIGHT OF 1750 Gms.

Horizontal Scale : 1 inch represents 25 Specimens

Vertical Scale : 1 inch represents 20 Feet

(Limestones & Mirk Fell Beds Only)

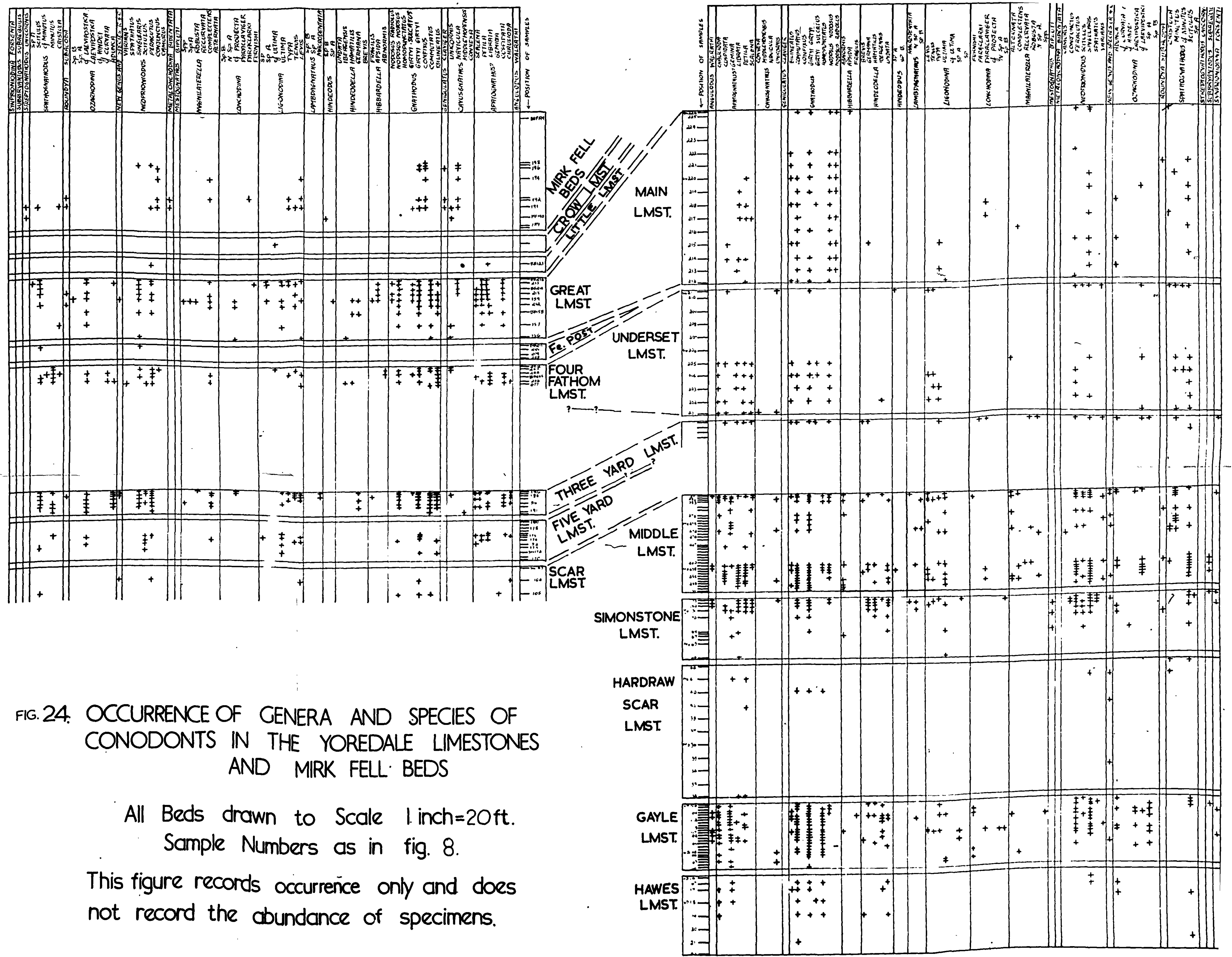

FIG. 24. OCCURRENCE OF GENERA AND SPECIES OF CONODONTS IN THE YOREDALE LIMESTONES AND MIRK FELL BEDS

All Beds drawn to Scale 1 inch=20ft.
Sample Numbers as in fig. 8.

This figure records occurrence only and does not record the abundance of specimens.