EARLY CRETACEOUS BELEMNITES
FROM
SOUTHERN INDIA

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MSc BY RESEARCH

EARLY CRETACEOUS BELEMNITES FROM SOUTHERN INDIA

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A PROJECT REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE UNIVERSITY OF GREENWICH FOR THE DEGREE OF MSC BY RESEARCH.

DECLARATION

This project report is the result of the independent work of Emma Victoria Shakides. All other work reported in the text has been attributed to the original authors and is fully referenced in the text, and listed in the Reference Section.

IN MEMORY OF MY DADDY,

WHO WAS THE ONE WHO INTRODUCED ME TO BELEMNITES

- ALL THOSE YEARS AGO.

ACKNOWLEDGEMENTS

I would like to thank Professor Peter Doyle for being my supervisor, giving me helpful advise, criticism and encouragement throughout this dissertation. Also, Dr Ian Slipper for the use of the SEM, Patrick Brown who helped me with photography and the resin blocks and showed me how to use the cutting and grinding machinery, Dr Florence Lowry who helped me find the correct equipment, Hilary Foxwell for 'de-coding' the stratigraphy which was produced by Dr Ben Hathway and Lee Gooderam for showing me how to do acetate peels. I would also like to thank the Natural History Museum, London, for allowing me to look at their collections of belemnites, Professor Malcolm Hart for sending me his work on the Cauvery Basin and Dr Dave Horne who found me a desk! I am indebted to my husband who helped enormously with behind the scenes support and encouraged me to continue, even when times got really tough, and lastly to my children who let me get on with my work in peace.

ABSTRACT

The Cauvery Basin has been the subject of intense research into the bio- and lithostratigraphies of the basin fill since Blanford and Stoliczka (1861-65). The Karai Formation ranges from the Early Albian through to the Late Turonian in age. The belemnites in this study were collected from the sediments of Albian age. Over 3500 belemnites were collected of which, 2 families and three genera were identified. The belemnite fauna is rich and although not extremely diverse, it shows a range of species belonging to the three main genera. Three species of *Parahibolites* and seven species of *Neohibolites* of the family Belemnopseidae were identified along with two new subspecies of *Tetrabelus* of the family Dimitobelidae. The study of fossils found in the sediments of this basin provide an insight into the timing of the break-up of Gondwana and the formation of the seaways, over time. One group of belemnites, the dimitobelids, are only found in the Southern Hemisphere at about the time of the Gondwanan break-up, whereas, *Neohibolites* and *Parahibolites* are to be found throughout the World's seas at this time (Aptian-Albian), including those of southern India. *Neohibolites* seems to be constantly present in this formation, whereas *Parahibolites* and *Tetrabelus* appear and disappear periodically. This pattern may indicate some kind of climatic or geographic influence on the different genera. *Neohibolites* have so far been recorded from Europe, whereas the *Parahibolites* species have only been recorded from the Southern Hemisphere. *Tetrabelus* is characteristic of the Austral Realm and is never found outside of it.

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CHAPTER 1 – INTRODUCTION

1.1 INTRODUCTION

The Cauvery Basin, located in the Tamil Nadu Province, southern India, is one of several basins formed on continental India during the break-up of the Gondwanan landmass in the Late Jurassic/Early Cretaceous. Studies in the Cauvery Basin over the last 30 years have been restricted to detailed examination of the bio- and lithostratigraphies of the basin fill. This has increased our understanding of this important Cretaceous succession and provides a framework for further study.

Belemnites are a common component of the Cretaceous (Aptian - Albian) of the Cauvery Basin, southern India. Even though these fossils are numerous, especially so in the Karai Formation of the Uttatur Group, the study of these belemnites has not been undertaken for nearly 100 years (Blanford & Stolitzka, 1861-65; Kossmat, 1895, 1897; Spengler, 1910). More recently, during the 1970's, there was a spate of studies on the palaeontology of this area. The knowledge of the palaeontology thus far has mainly been used to produce biostratigraphies of the area that have been compared to the biostratigraphies around the world, along with the recognition of sea level changes (Hart *et al.* 2000; Hart *et al.* 2001). The palaeobiogeography of the region during the Aptian-Albian has been indicated through biostratigraphy (Hart *et al.* 2001).

The purpose of this new research is to examine the belemnite fauna of the Karai Clay Formation, and to discuss its palaeobiogeographic importance.

1.2 METHODS USED

The methods used for this dissertation are detailed below. The basic fieldwork had already been carried out by others studying the Cauvery Basin and therefore will not be detailed here, although a basic review is presented based on published and unpublished work. The work completed for this dissertation is entirely laboratory based.

1.2.1 *Stratigraphy*

Fossils used in this study were collected by A.S. Gale and P. Doyle from a well exposed, low relief section of the Karai Clay Formation at a location 1.5km south east of the village of Karai. This involved systematic collection of over 3500 belemnites on a relatively flat surface, and although collected up-stratigraphy, the production of standard logs was difficult. Comparison with later work (B. Hathway, pers. comm.) allows for the placement of this stratigraphy in vertical log. As such, because the fossils had already been collected from the field, the stratigraphical information is to be in the form of a review of the stratigraphies of other authors. The author will originate no field logs or data and the main stratigraphy of the Karai Clay Formation at this location was compiled by Dr B. Hathway.

1.2.2 *Statistical Data*

Statistical data has been collected from the belemnites in the form of measurements. The measurements have been taken from the overall length (L), maximum ventral diameter (Dvmax), maximum lateral diameter (Dlmax), length from apex to Dvmax (xv) and length from apex to Dlmax (xl). The measurements were made by using Vernier callipers. The data were then recorded in Excel. Identification processes were made easier by plotting the Dvmax against the Dlmax in a scatter diagram to see the correlation between them.

1.2.3 *Lateral and Transverse sections*

For this method, each species of belemnite and those belemnites that are pathologically different were set into a block of polyester resin with the apical line horizontal and the lateral side up. To do this, the resin was mixed with 2% hardener and mixed thoroughly. It was then poured into a plastic container and left for approximately 15 minutes. The resin would then become tacky and the belemnites could then be placed in the correct position. More resin was poured to just above the apical line area. This was left to set hard for at least 24 hours. The blocks of resin were then extracted from the plastic containers and the excess resin was cut off with a diamond cutter. The surface of the block was ground down to the apical line by using a grinding machine and completed with a carborundum lap. Once the apical line became clear, the belemnite was then polished with optical paste. The features that were revealed by this method include: the distance from the protoconch to the apex of the guard (l); the alveolar angle (α); the course of the apical line; the growth stages; the phragmocone (if still intact); and pathological conditions experienced by some belemnites in the collection. Transverse sections reveal: the nature of the apical line and the growth stages. The transverse and lateral sections were then placed in the scanning electron microscope and inspected.

1.2.4 *Scanning Electron Microscope*

Belemnites that have been identified as having external borings have been examined under the SEM, as well as the polished lateral and transverse sections. The SEM was set up with a low vacuum at 10 pascals pressure with a working distance of 16mm. The compositional back-scattered electron image had artificial shadow to enable a conception of depth to the external borings (Pl. 12). These borings have not been investigated further in this study.

1.2.5 *Acetate Peels*

Acetate peels have been taken of the transverse sections of each species of belemnite (Pl. 7, figs 1-9; Pl. 8, figs 1-2). This enabled the internal morphological aspects of the rostrum to be seen more clearly. Acetate peels were made by the following process: A bath of Hydrochloric acid (15%) and water (85%) was used to immerse the resin block containing the transverse section of a belemnite. The dilute acid etched the cut surface and using distilled water, the excess hydrochloric solution was rinsed off. The belemnite resin block was then left to dry. Next, the block was placed in a bath of sand to keep it horizontal. Acetone was washed over the surface and a thin sheet (0.3mm thick) of acetate, cut to size, was placed on the surface while the acetone was still liquid. This was left for about 30 minutes, by which time, the surface of the belemnite become attached to the acetate sheet. This was peeled back slowly and placed between two sheets of glass slide and secured (Pl. 7, figs 1-9; Pl. 8, figs 1-2).

1.2.6 *Photographs*

Typical examples of each species were photographed in outline and profile with a digital camera, as well as those that have pathological deformities, and were organised as plates.

1.2.7 *Systematic Study*

Because the topic of this research was so subject specific, and new to the author, a steep learning curve was observed. Large amounts of literature were collected together and an intense period of reading commenced. During this initial period of the research, the Indian belemnites were being collated. Each belemnite received its own number. The number consisted of the sample number and an individual number, for example: in sample bag number 10, the belemnites were numbered 10/1; 10/2; 10/3 etc. The number of belemnites labelled totalled 3523. This information was input into Excel. The next stage was to measure the whole belemnites. Each belemnite was inspected and a decision was made if the belemnite was complete or not. Those that were, were measured with callipers and the measurement (L) was logged in both Excel and on a sheet. A following 4 different measurements were made on these select few. These measurements were the maximum dorso-ventral diameter (Dvmax); maximum lateral diameter (Dlmax); the length from the apex to Dvmax (xv); length from the apex to Dlmax (xl). This data was also collected into Excel. A total of 3380 measurements were made on 676 belemnites (Appendix 1).

CHAPTER 2 - STRATIGRAPHY OF THE CAUVERY BASIN

2.1 INTRODUCTION

During the Late Jurassic – Early Cretaceous, rifting between India and Australia-Antarctica caused the development of a series of NE-SW trending basins in the Indian Precambrian crystalline basement (Powell, *et al.* 1988). The Cauvery basin is the southern most basin along the eastern seaboard of India (Fig. 1), and has been subject to much research in the last twenty years, which has attempted to redefine its stratigraphy.

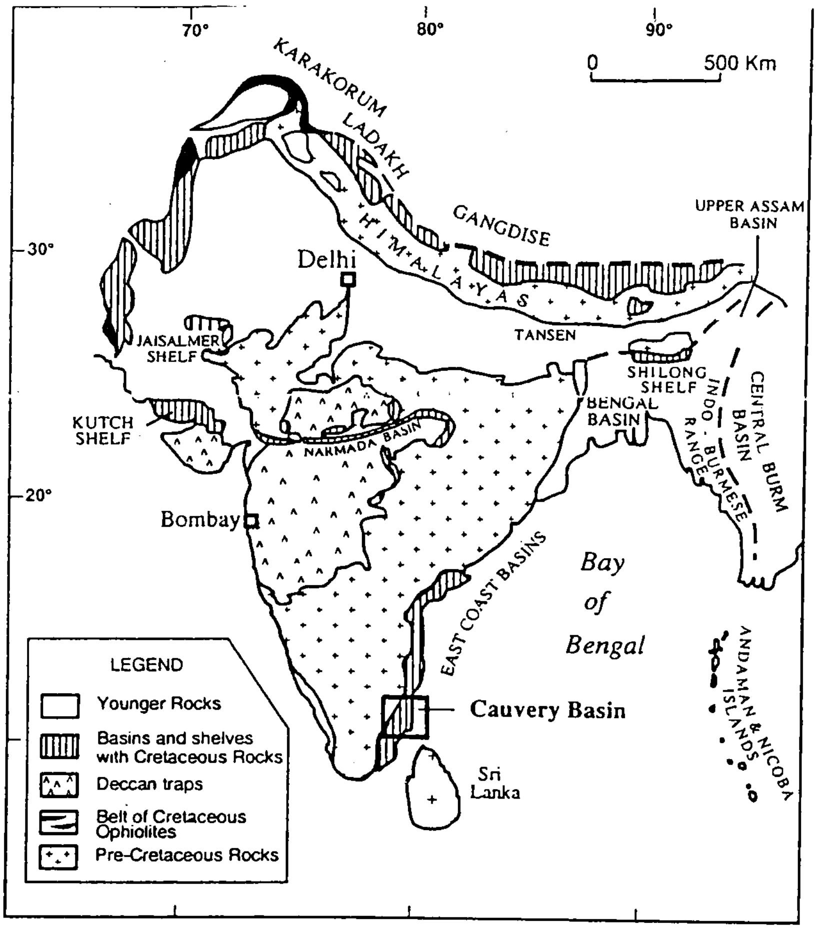


Fig. 1 Distribution of the Cretaceous rocks in the Indian subcontinent (Hart *et al.* 1996). The box indicates the approximate position of the Cauvery Basin.

The Cauvery Basin covers an area of 25000km^2 of the Tamil Nadu region (Prabhakar and Zutshi, 1993) and contains an almost complete succession of Cretaceous (Albian –

Maastrichtian) shallow marine sediments that become progressively younger towards the east.

2.2 GEOLOGICAL SETTING OF THE CAUVERY BASIN

The break-up of Gondwana which commenced in the Permian and continued into the Early Cretaceous this contributed to the production of five sedimentary basins on the east coast of India namely: Bengal, Mahanadi, Godavari-Krishna, Palar and Cauvery (Sastri, *et al.* 1981) (Fig. 2).

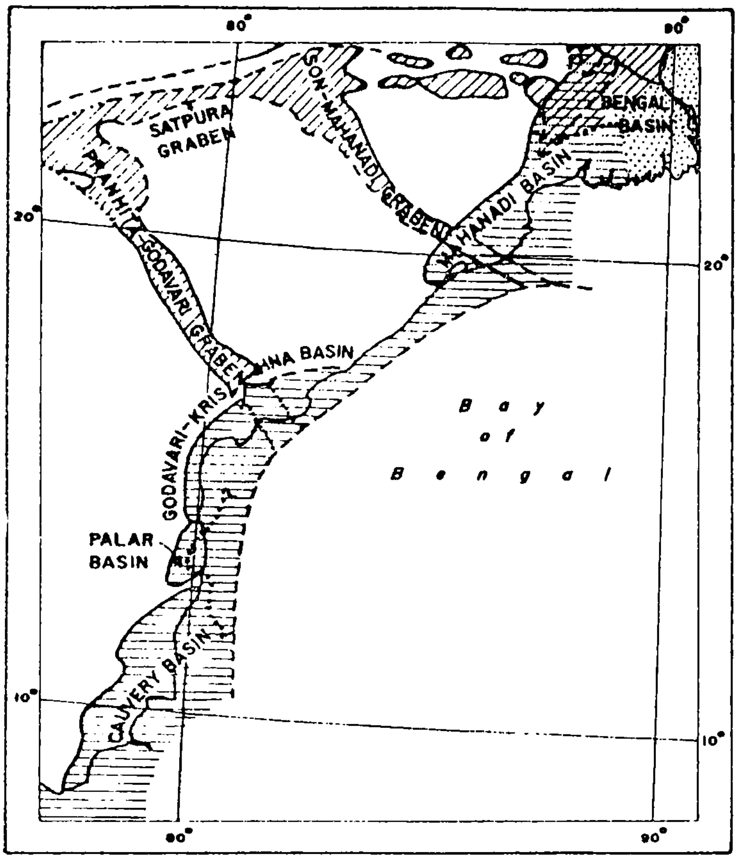


Fig. 2 Sedimentary basins along the east coast of India (Sastri *et al.* 1981)

The setting of the Cauvery Basin has been most recently reviewed by Sastri *et al.* (1981). In their review, they demonstrated that the western edge of the Cauvery basin is marked by steep faults that separate the Archaean shield from the Cretaceous and Tertiary sediments. Archaean metamorphic and volcanic rocks also constitute the basement for the basin. In this basement are several depressions separated from each other by ridges

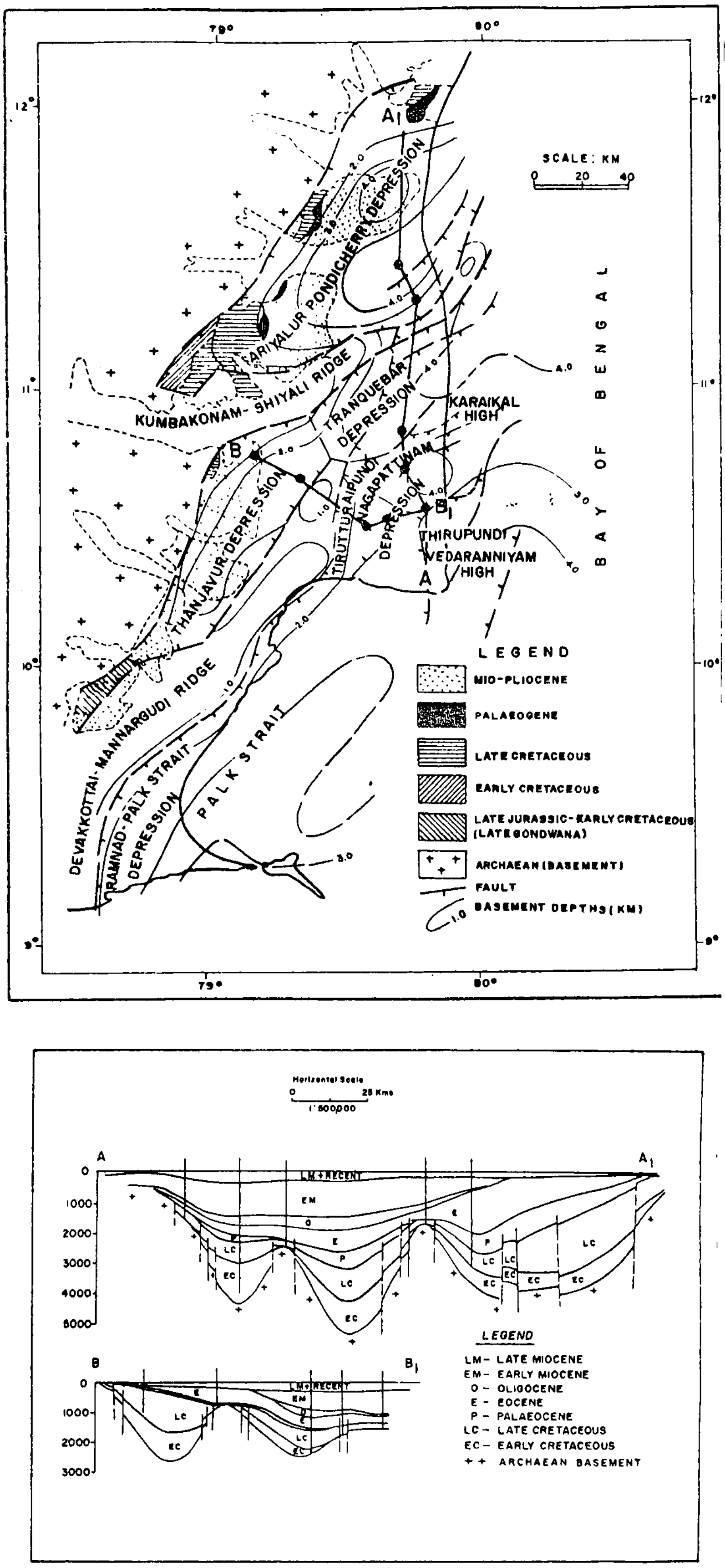


Fig. 3 Geological map showing the location and diagrammatic sections across the Cauvery Basin (Sastri *et al.* 1981).

trending NE-SW in the basin, and has subsequently been filled by Early Cretaceous sediments through to the Recent (Sastri *et al.* 1981) (Fig. 3). The sediments of this basin are approximately 5500m thick (Sastri *et al.* 1981), with approximately 2500m of Jurassic to Cretaceous sediments resting on a crystalline basement. These sediments become progressively younger towards the east, with the Early Cretaceous sediments being exposed in the west of the Cauvery Basin (Sastri *et al.* 1981) (Fig. 4). An appraisal of the literature on the stratigraphy and the fauna of this area will follow.

2.2.1 *Lithostratigraphy*

Blanford and Stolitzka (1861-65) were the first to initiate the Uttatur and Trichinopoly groups. A basic outline of this is presented in Table 1, and these have been used by most subsequent authors. In Nair (1974), only the Uttatur Group was maintained, a new Ariyalur Group was generated, whilst the Trichinopoly Group was discarded, being incorporated as a Formation in the Uttatur Group (Table 1). The lithostratigraphic classification of Sundaram and Rao (1979), which was revised in 1986, instigated three groups, establishing all three groups (Uttatur, Trichinopoly and Ariyalur) in succession, subdivided into formations (Table 1). The most recent review has been that of Tewari *et al.* (1996) who set about revising the lithostratigraphic classification of the Cauvery Basin (Table 1). A further lithostratigraphical revision of this area has been undertaken by Sundaram *et al.* (2002). Both have taken into consideration the existing nomenclature of groupings and formations. Sundaram *et al.* (In press) has divided the Uttatur Group into formations and members following Srivastava and Tewari (1967), Bhatia and Jain (1969), Banerji (1973) and Sundaram and Rao (1986). As the work of Tewari *et al.* (1996) is currently the most accepted, it is used here as the basis of the stratigraphy.

2.2.2 *Biostratigraphy*

There are a number of ammonite biozonations based on the work of Blanford and Stoliczka (1861-65) and Kossmat (1897), and subsequently revised by Sastri et al. (1968) and Chiplonkar and Ghare (1979). These are still under discussion. Other biozonations include foraminifera (Banerji, 1970, 1973; Narayanan, 1977; Banerji and Sastri, 1979;

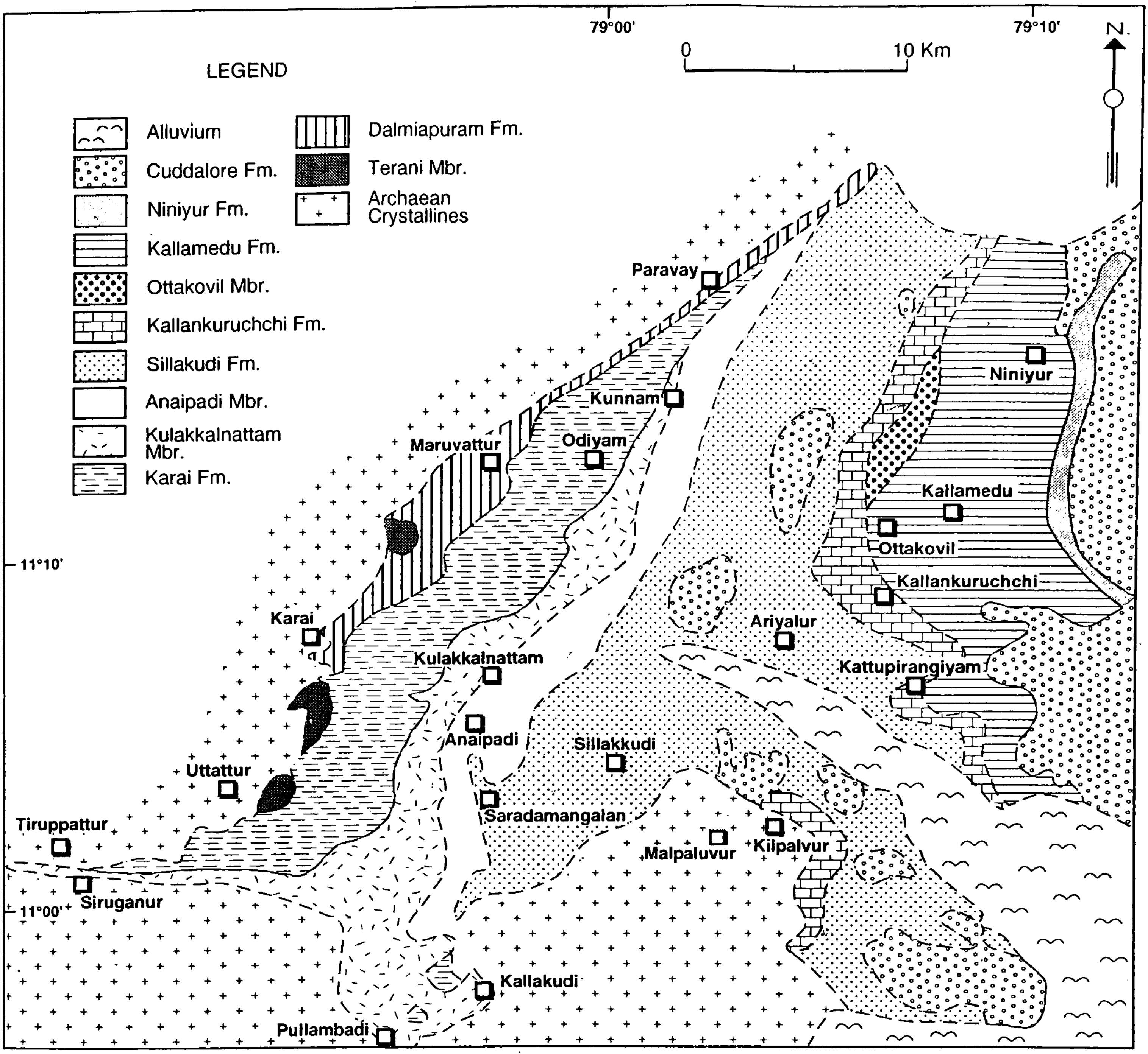


Fig. 4 Geological map of the exposed part of the Cauvery Basin (Tewari *et al.* 1996).

Chidambaram, 1985; Venkatachalapathy and Ragothaman, 1995; Hart *et al.* 2000; Hart *et al.* 2001), ammonites (Blanford and Stolitzka, 1861-65; Kossmat, 1897; Sastry *et al.* 1968; Chiplonkar and Ghare, 1979; Ayyasami, 1990), bivalves (Chiplonkar and Tapaswi, 1979). These belemnites are not found throughout the full range of the Karai Clay

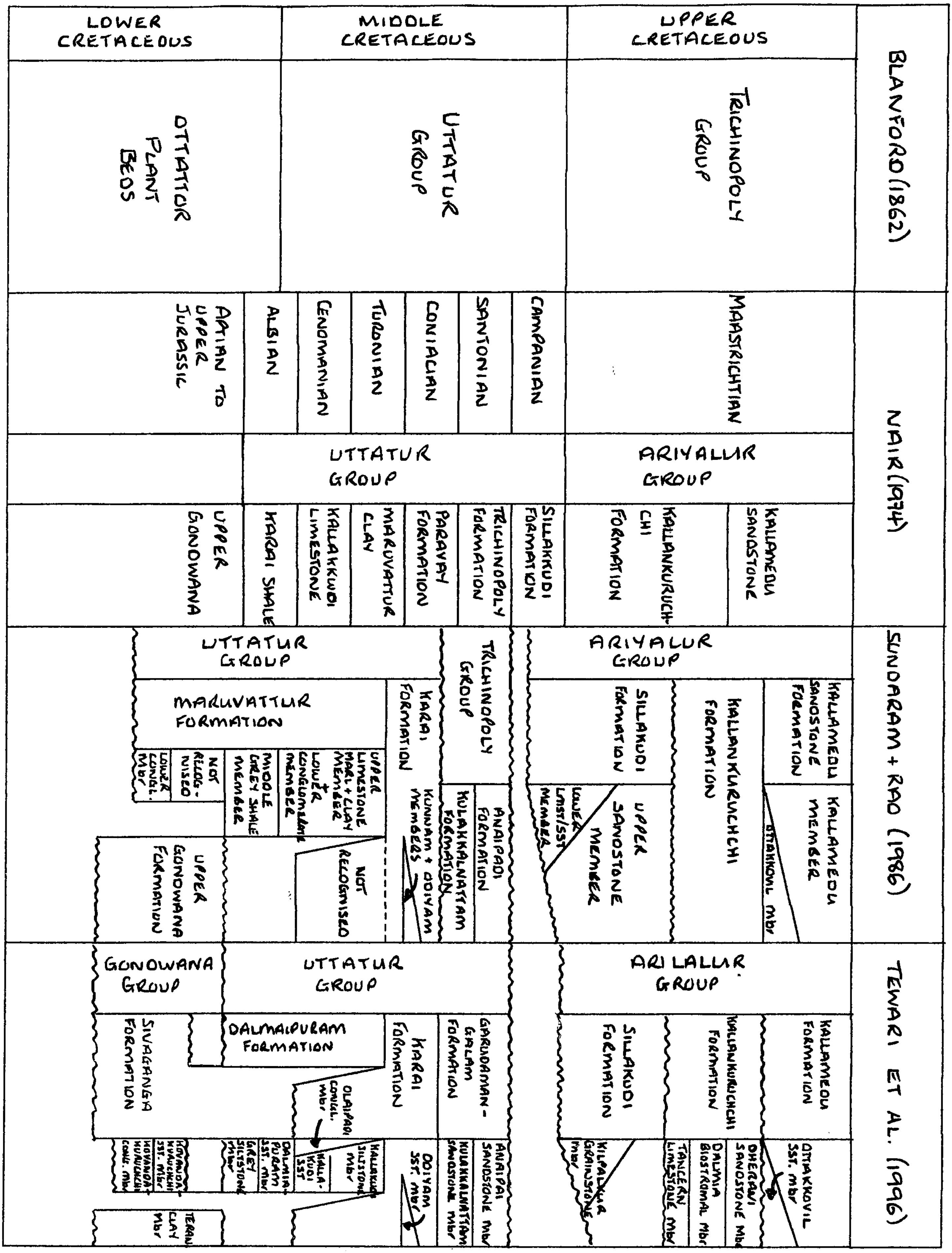
Formation (Albian to Turonian). The absence of distinct guide fossils in this work, hampers the exact placement of the belemnite fauna, but it thought to be in the earliest to Late Albian (Hart *et al.* 2001).

2.3 LITHOSTRATIGRAPHY OF THE CAUVERY BASIN

Tewari, *et al.* (1996) proposed a lithostratigraphic classification that utilised three Groups and these are accepted here as the basis of this study.

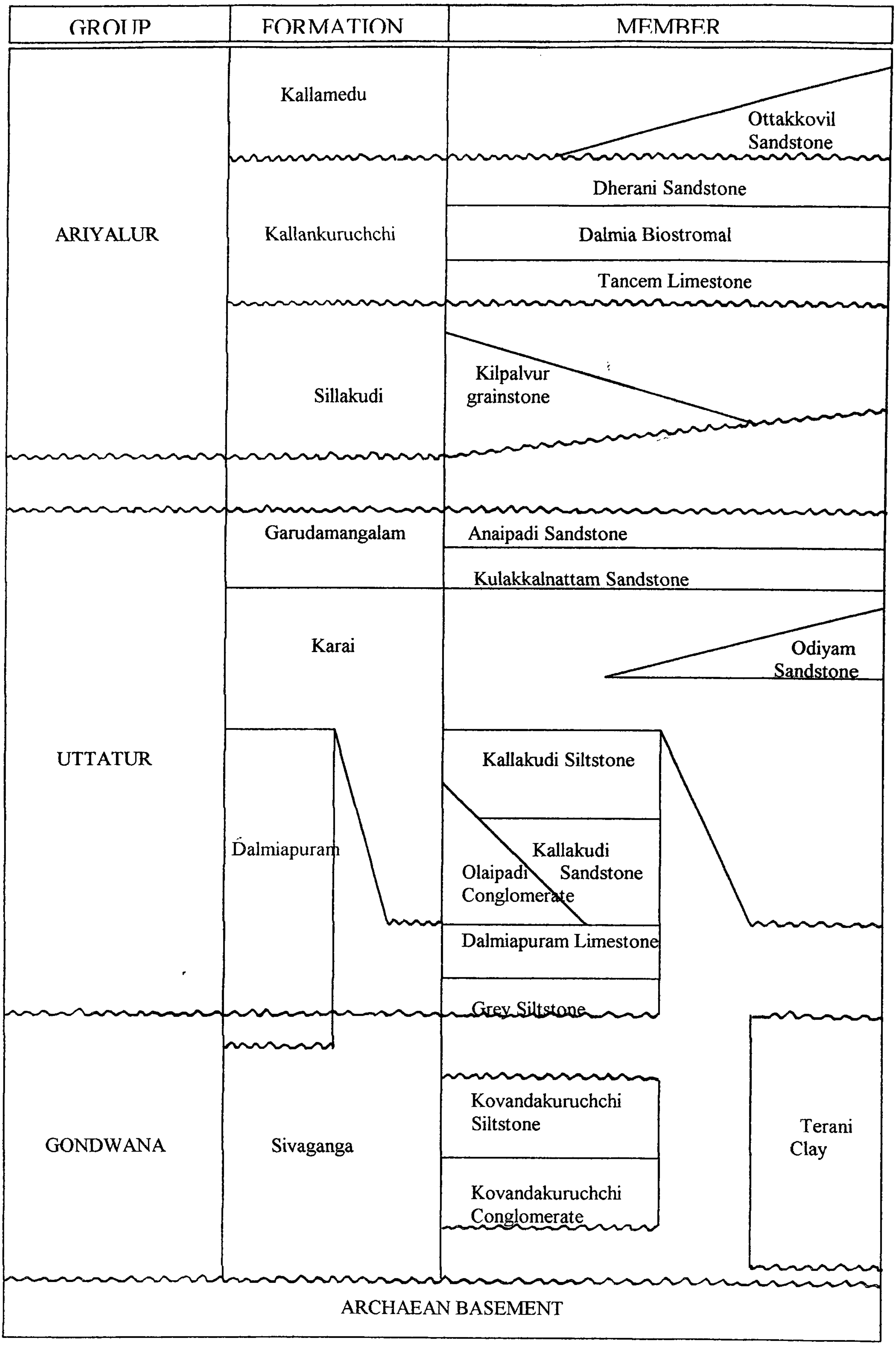
Ariyalur Group (Stratigraphically youngest)
Uttatur Group
Gondwana Group (Stratigraphically oldest)

A total of three groups, seven formations and seventeen members have been used by Tewari, *et al.* (1996) to describe the lithology of the Cretaceous of the Cauvery Basin (Table 2). A brief description of the lithologies, palaeontology and palaeoenvironmental interpretations can be found in Tables 3, 4 and 5, based on the recent work by Tewari *et al.* (1996). The belemnites currently being studied all come from the Karai Formation of the Uttatur Group.



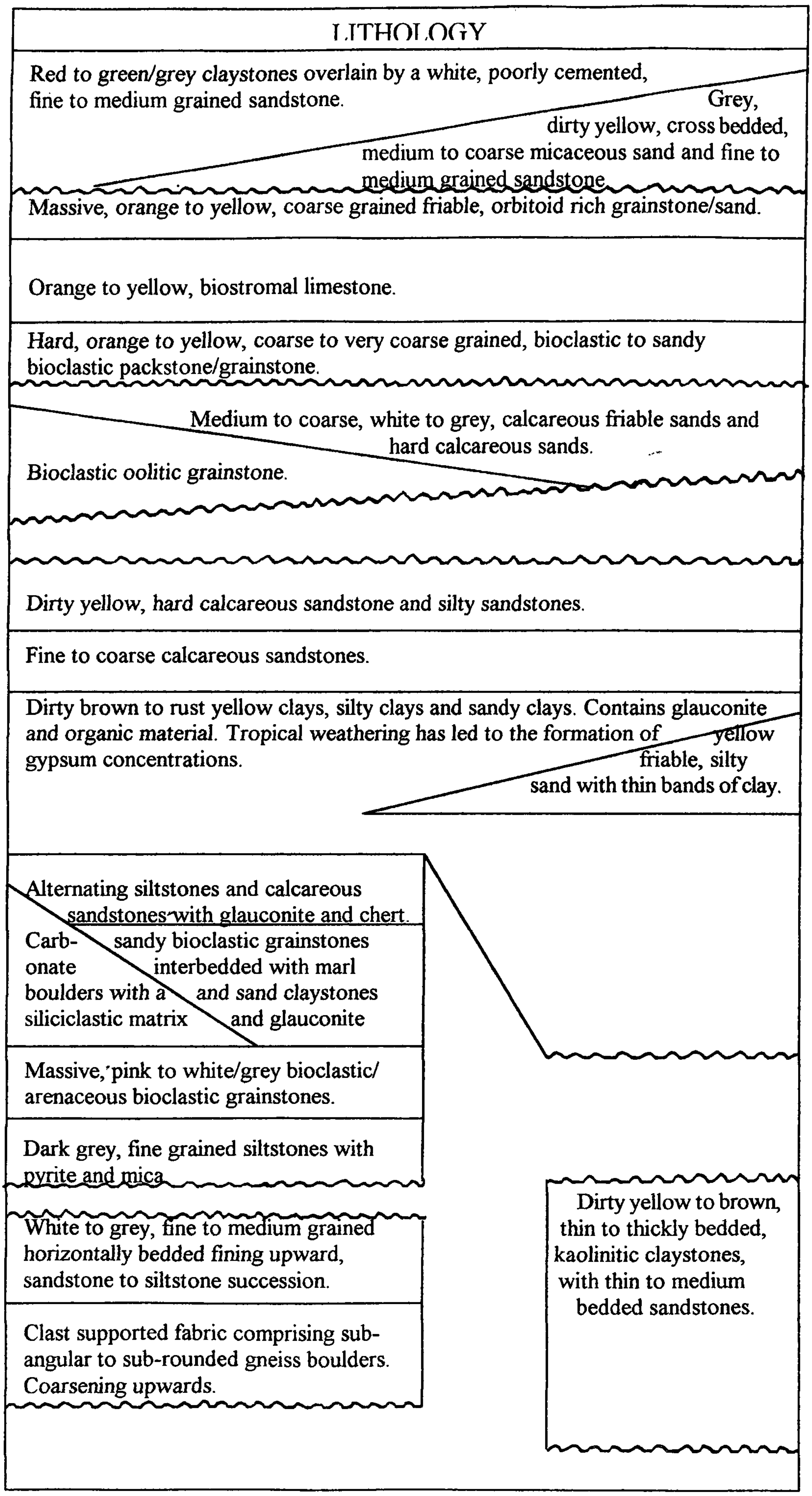
	LOWER CRETACEOUS	MIDDLE CRETACEOUS	UPPER CRETACEOUS
BLANFORD (1862)	OTTATOOR PLANT BEDS	UTTATUR GROUP	TRICHINOPOLY GROUP
NAIR (1974)	APTIAN TO UPPER JURASSIC ALBIAN	CENOMANIAN TURONIAN CONIACIAN SANTONIAN CAMPANIAN	MAASTRICHTIAN
		UTTATUR GROUP	ARIYALLUR GROUP
	UPPER GONDWANA KARAI SHALE	KALLAKKUDI LIMESTONE MARUVATTUR CLAY PARAVAY FORMATION TRICHINOPOLY FORMATION SILLAKKUDI FORMATION	KALLANKURUCHCHI FORMATION KALLAMEDU SANDSTONE
SUNDARAM + RAO (1986)	UTTATUR GROUP	UTTATUR GROUP TRICHINOPOLY GROUP	ARIYALUR GROUP
	MARUVATTUR FORMATION	MARUVATTUR FORMATION KARAI FORMATION KULAKKALNATTAM FORMATION ANAIPADI FORMATION	SILLAKUDI FORMATION KALLANKURUCHCHI FORMATION KALLAMEDU SANDSTONE FORMATION
	LOWER CONGL. Mbr NOT RECOG-NISED MIDDLE GREY SHALE MEMBER	LOWER CONGLOMERATE MEMBER UPPER LIMESTONE MARL + CLAY MEMBER KUNNAM + ODIYAM MEMBERS	LOWER LMST/SST MEMBER UPPER SANDSTONE MEMBER OTTAKOVIL Mbr KALLAMEDU MEMBER
	UPPER GONDWANA FORMATION	NOT RECOGNISED	
TEWARI ET AL. (1996)	GONDWANA GROUP	UTTATUR GROUP	ARILALUR GROUP
	SIVAGANGA FORMATION	DALMAIPURAM FORMATION KARAI FORMATION GARUDAMANGALAM FORMATION	SILLAKUDI FORMATION KALLANKURICHCHI FORMATION KALLAMEDU FORMATION
	KOVANDAKURICHCHI CONGL. Mbr KOVANDAKURICHCHI SST. Mbr TERANI CLAY Mbr	GREY SILTSTONE Mbr DALMIAPURAM SST. Mbr KALLAKUDI SST OLAIPADI CONGL. Mbr KALLAKKUDI SILTSTONE Mbr ODIYAM SST. Mbr KULAKKALNATTAM SANDSTONE Mbr ANAIPADI SANDSTONE Mbr	KILPALUVAR GRAINSTONE Mbr TANCEM LIMESTONE Mbr DALMIA BIOSTROMAL Mbr DHERANI SANDSTONE Mbr OTTAKOVIL SST. Mbr

Table 1. A comparison between the main lithostratigraphies published, from Blanford (1862) through to Tewari *et al.* (1996).



GROUP	FORMATION	MEMBER
ARIYALUR	Kallamedu	Ottakkovil Sandstone
	Kallankuruchchi	Dherani Sandstone
		Dalmia Biostromal
		Tancem Limestone
	Sillakudi	Kilpalvur grainstone
UTTATUR	Garudamangalam	Anaipadi Sandstone
		Kulakkalnattam Sandstone
	Karai	Odiyam Sandstone
	Dalmiapuram	Kallakudi Siltstone
		Kallakudi Sandstone
		Olaipadi Conglomerate
		Dalmiapuram Limestone
		Grey Siltstone
GONDWANA	Sivaganga	Kovandakuruchchi Siltstone
		Kovandakuruchchi Conglomerate
		Terani Clay
ARCHAEAN BASEMENT		

Table 2.The Lithostratigraphy of the Cauvery Basin (Tewari *et al.* (1996)).



LITHOLOGY

Red to green/grey claystones overlain by a white, poorly cemented, fine to medium grained sandstone.

Grey, dirty yellow, cross bedded, medium to coarse micaceous sand and fine to medium grained sandstone.

Massive, orange to yellow, coarse grained friable, orbitoid rich grainstone/sand.

Orange to yellow, biostromal limestone.

Hard, orange to yellow, coarse to very coarse grained, bioclastic to sandy bioclastic packstone/grainstone.

Medium to coarse, white to grey, calcareous friable sands and hard calcareous sands.

Bioclastic oolitic grainstone.

Dirty yellow, hard calcareous sandstone and silty sandstones.

Fine to coarse calcareous sandstones.

Dirty brown to rust yellow clays, silty clays and sandy clays. Contains glauconite and organic material. Tropical weathering has led to the formation of gypsum concentrations.

yellow friable, silty sand with thin bands of clay.

Alternating siltstones and calcareous sandstones with glauconite and chert.

Carbonate boulders with a siliciclastic matrix

sandy bioclastic grainstones interbedded with marl and sand claystones and glauconite

Massive, pink to white/grey bioclastic/ arenaceous bioclastic grainstones.

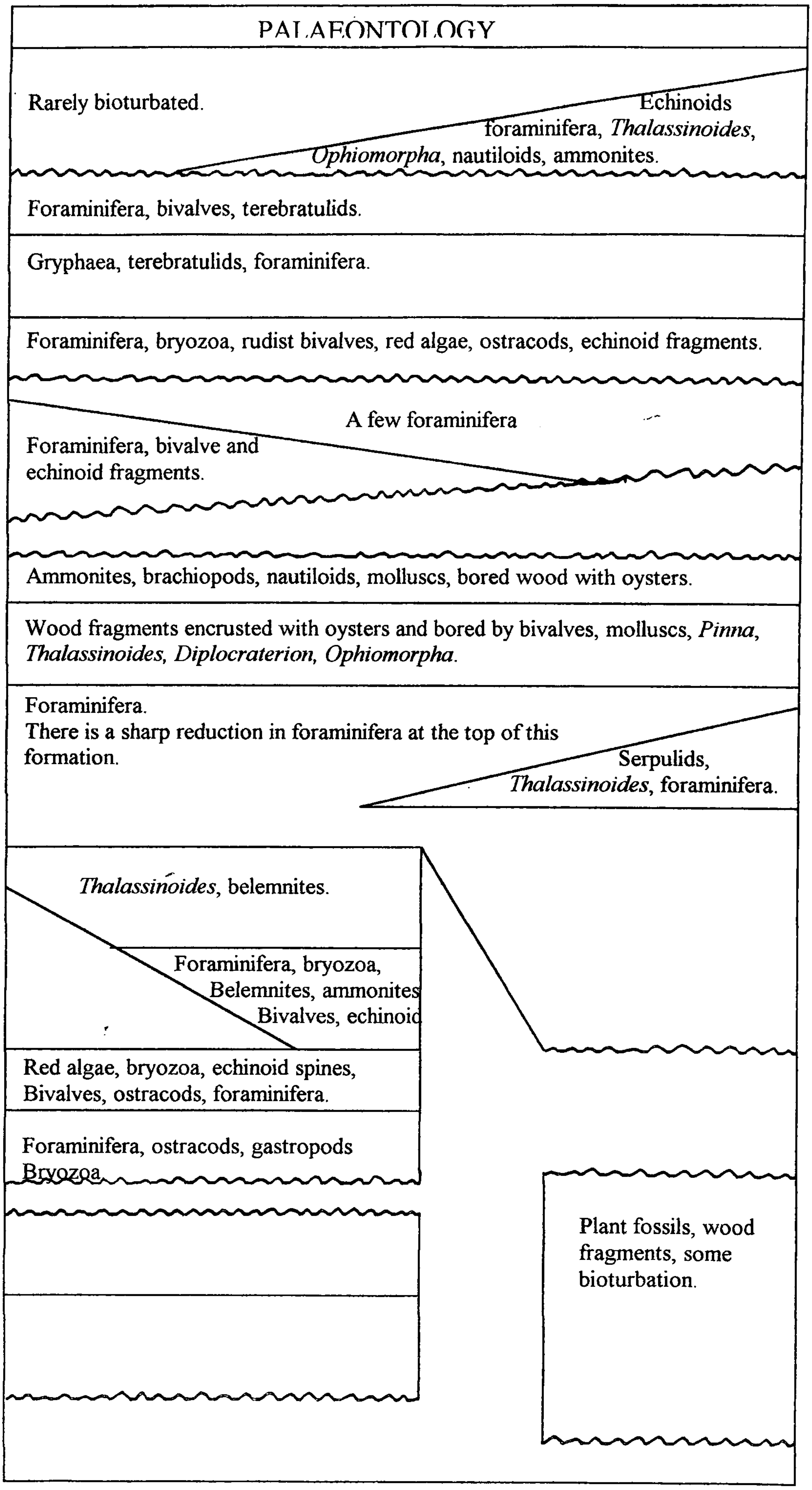
Dark grey, fine grained siltstones with pyrite and mica.

White to grey, fine to medium grained horizontally bedded fining upward, sandstone to siltstone succession.

Clast supported fabric comprising sub-angular to sub-rounded gneiss boulders. Coarsening upwards.

Dirty yellow to brown, thin to thickly bedded, kaolinitic claystones, with thin to medium bedded sandstones.

Table 3. The lithology of the Cauvery Basin, summarised, and taken from Tewari *et al.* (1996). The descriptions correspond to the members of table 2.



PALAEONTOLOGY

Rarely bioturbated.

Echinoids
foraminifera, *Thalassinoides*,
Ophiomorpha, nautiloids, ammonites.

Foraminifera, bivalves, terebratulids.

Gryphaea, terebratulids, foraminifera.

Foraminifera, bryozoa, rudist bivalves, red algae, ostracods, echinoid fragments.

A few foraminifera

Foraminifera, bivalve and
echinoid fragments.

Ammonites, brachiopods, nautiloids, molluscs, bored wood with oysters.

Wood fragments encrusted with oysters and bored by bivalves, molluscs, *Pinna*, *Thalassinoides*, *Diplocraterion*, *Ophiomorpha*.

Foraminifera.
There is a sharp reduction in foraminifera at the top of this formation.

Serpulids,
Thalassinoides, foraminifera.

Thalassinoides, belemnites.

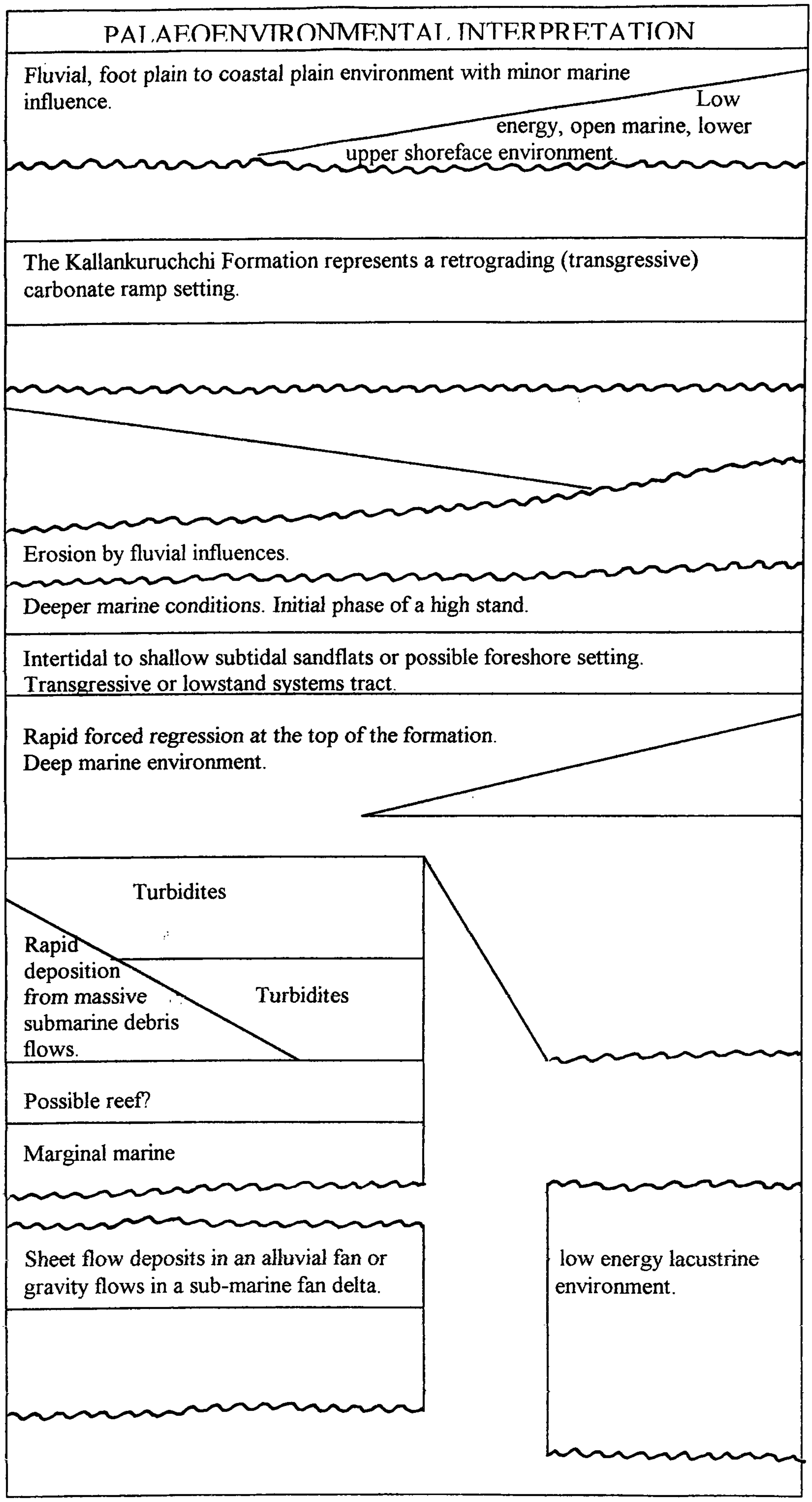
Foraminifera, bryozoa,
Belemnites, ammonites
Bivalves, echinoi

Red algae, bryozoa, echinoid spines,
Bivalves, ostracods, foraminifera.

Foraminifera, ostracods, gastropods
Bryozoa

Plant fossils, wood
fragments, some
bioturbation.

Table 4. A summary of the palaeontology of the Cauvery Basin, as described in Tewari *et al.* (1996). The descriptions correspond to the members in table 2.



PALAEOENVIRONMENTAL INTERPRETATION

Fluvial, foot plain to coastal plain environment with minor marine influence.

Low energy, open marine, lower upper shoreface environment.

The Kallankuruchchi Formation represents a retrograding (transgressive) carbonate ramp setting.

Erosion by fluvial influences.

Deeper marine conditions. Initial phase of a high stand.

Intertidal to shallow subtidal sandflats or possible foreshore setting. Transgressive or lowstand systems tract.

Rapid forced regression at the top of the formation.
Deep marine environment.

Turbidites

Rapid deposition from massive submarine debris flows.

Turbidites

Possible reef?

Marginal marine

Sheet flow deposits in an alluvial fan or gravity flows in a sub-marine fan delta.

low energy lacustrine environment.

Table 5. A summary of the palaeoenvironmental interpretation of the Cauvery Basin, as described by Tewari *et al.* (1996). The descriptions correspond to the members in table 2.

The belemnites were collected from an area 1.5 km south west of the village of Karai (approximately 11°08'N, 78°45'E) (Fig. 5), which has a typical 'badlands' topography and has been interpreted as being deposited in a deep marine environment (Tewari *et al.* 1996). The exposed Karai Formation is 480m thick (data from stratigraphical log originated by Dr B. Hathway, not published) with a steady dip of 5 - 10° to the east (Sastri *et al.* 1981). Two collections were made throughout the thickness of the Karai Clay Formation, near Karai, and the first of these, made in 1999, forms the basis for the study. A second collection was made in 2000 by B. Hathway and others, and has been used as a check on the first.

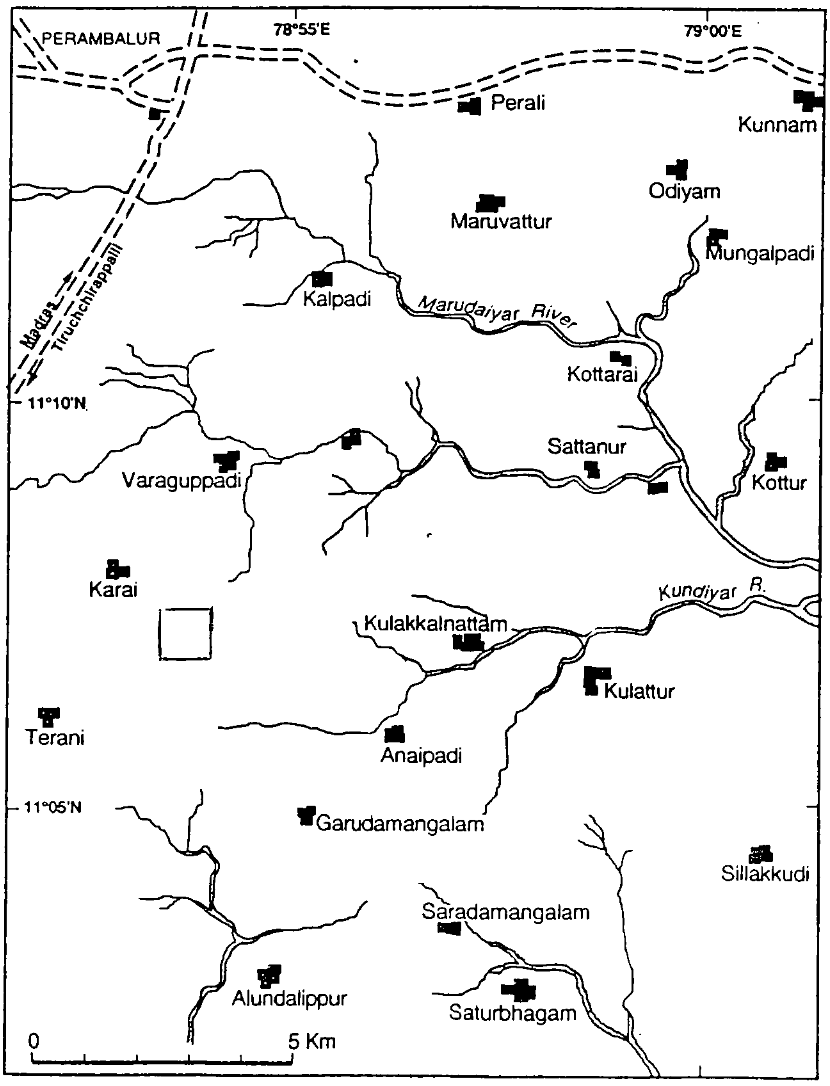


Fig. 5 Sampling area for belemnites (enclosed by box) (Hart *et al.* 1996)

CHAPTER 3 - BELEMNITE MORPHOLOGY

3.1 INTRODUCTION

The evolutionary history of belemnites is generally thought to have started with the aulococerids. Aulacocerida are the most ancient group of belemnites that first appeared in the Devonian or Carboniferous (Doyle 1993, 1999; Clarkson, 1994) and continued into the Jurassic. Bandel *et al.* (1983) recorded the earliest known 'family' of aulocoerids in the Devonian, from the Emsian of Hunsruck, Germany. However, Doyle *et al.* (1994) feel that this has doubtful coleoid similarities. Belemnites proper may have evolved from the Aulocoerida in the early Jurassic (Doyle, 1993, 1999; Clarkson, 1994; Doyle *et al.* 1994) in which the body chamber of the aulococerid was reduced to the pro-ostracum of the belemnite (Clarkson, 1994). These belemnites continued to flourish and diversify throughout the Jurassic and Cretaceous, but then, at the end of the Cretaceous, they began to decline. A few survived into the Tertiary, but they became extinct shortly afterwards (Clarkson, 1994).

The purpose of this chapter is to present an overview of the belemnite morphology which is to be used in the systematics chapter.

The morphology of belemnites has been widely discussed by many authors such as Swinnerton (1936-1955), Schwegler (1961), Pugaczewska (1961), Stevens (1965), Jeletzky (1966), Barskov (1970, 1972, 1973), Spaeth (1971), Riegraf (1980), Mutterlose (1983), Doyle, (1984, 1988, 1990, 1999), Combemorel (1988), Saelen (1989), Clarkson (1994). Belemnites are squid-like creatures, the skeleton of which can be divided into three distinct parts: the rostrum, the phragmocone and the pro-ostracum. The rostrum is used most widely in systematics due to its abundance and preservation. The phragmocone is much less widely preserved and used only at higher taxonomic levels (Jeletzky, 1966). The pro-ostracum is, in the majority of cases, rarely preserved. The rostrum has occasionally been called the 'guard'. Many authors prefer to use the term 'rostrum' (Stevens 1965; Doyle 1984, 1990, 1999), as the 'guard' refers to the protection of the phragmocone, which is situated in the alveolus at the anterior end of the rostrum. The rostrum at this point is at its thinnest, and most fragile, and can therefore, not be expected to protect the phragmocone.

The morphology of each skeletal part shall be described below.

3.2 ROSTRUM

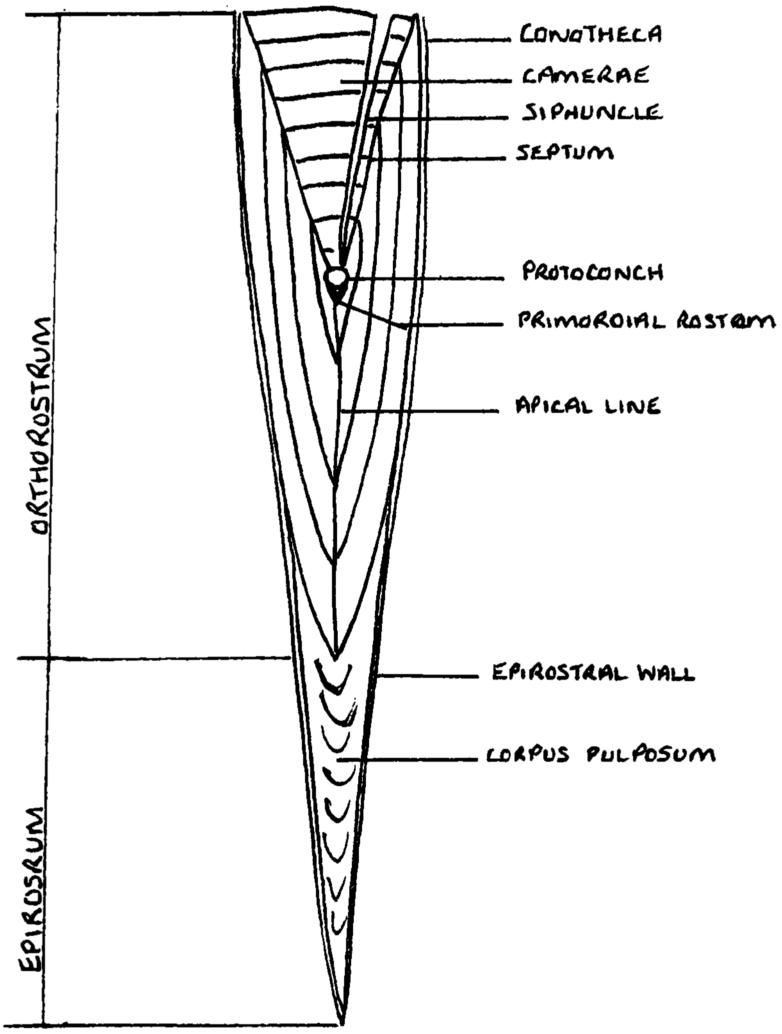


Fig. 6 Sketch of a model rostrum (including epirostrum), which illustrates the morphological terms used here (adapted from Doyle, 1984).

The rostrum is the most commonly preserved part of the belemnite skeleton and is found in most Jurassic and Cretaceous marine sediments around the world. The rostrum is the most posterior part of the belemnite skeleton. It is a solid, low magnesium calcite cylinder (Bandel *et al.* 1984; Saelen, 1989; Doyle, 1999) with a conical hollow, called the alveolus, situated at the anterior end in which the phragmocone sits. The rostrum is made up of radiating prismatic calcite crystals that seem to grow from the apical line (Doyle, 1990) with concentric growth lines (Fig. 6). These growth lines have been recognised to show at least three years of growth (Stevens, 1965; Barskov & Weiss, 1992), each major growth ring probably represents a year in the life of the belemnite. Stevens (1965) and Barskov & Weiss (1992) have compared the life span of the belemnite animal with that of modern squid, concluding that the belemnite had a typical life span of between three and four years. The rostrum can be divided into two structural elements: the orthorostrum and the epirostrum (Doyle, 1990, 1999) (Fig. 6).

3.2.1 *Orthorostrum*

The orthorostrum can be divided in to two parts in relation to the alveolus (Doyle, 1999): the *rostrum solidum* and the *rostrum cavum*. The *rostrum solidum* is that part of the rostrum from the base of the alveolus to the apex of the rostrum. The *rostrum cavum* is the part of the rostrum that contains the alveolus (Doyle, 1999). The orthorostrum is very similar in many species of belemnite, however, distinguishing features such as shape, grooves and lateral lines enable the palaeontologist to differentiate between them.

Shape

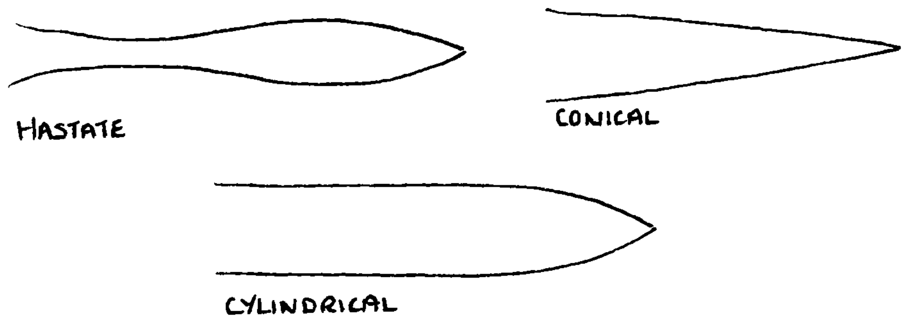


Fig. 7 Sketch of the three typical shapes of belemnite rostrum (adapted from Doyle, 1984).

The shape of the rostrum is very important when it comes to the systematics. It can help identify down to specific level (Doyle, 1990). All belemnites will fit into one of three categories, although some belemnites may demonstrate gradation from one to the other (Schumann, 1974) (Fig. 7);

- hastate (spear-like)
- conical (cone-shaped)
- cylindrical (parallel-sided)

A description of the outline or profile of the rostrum is usually given which includes the shape.

Outline

The outline is the form of the rostrum seen in dorsal or ventral view, and is always symmetrical (Swinnerton, 1936-55; Stevens, 1965; Doyle, 1990). The shape of the outline is described above and is an important specific character.

Profile

The profile is the form of the rostrum seen in lateral view. This may be either symmetrical or asymmetrical except where pathologically deformed (Swinnerton, 1936-55; Stevens, 1965; Doyle, 1990). If the profile is symmetrical, it generally resembles the shape of the outline, whereas, if the profile is asymmetrical, the dorsal margin is usually more inflated than the ventral margin.

Transverse sections

The transverse sections show an important specific character when used with the shape of the rostrum (Swinnerton, 1936-55; Pugaczewska, 1961; Schwegler, 1961; Stevens, 1965; Doyle, 1984, 1990). The amount of depression or compression varies between species. The depressed rostrum will have a greater lateral diameter than ventral diameter, and the compressed rostrum will have a greater ventral diameter than lateral (Doyle, 1984, 1990). The terms used to describe the sections are;

- circular
- elliptical

- pyriform
- subquadrate (Fig. 8)

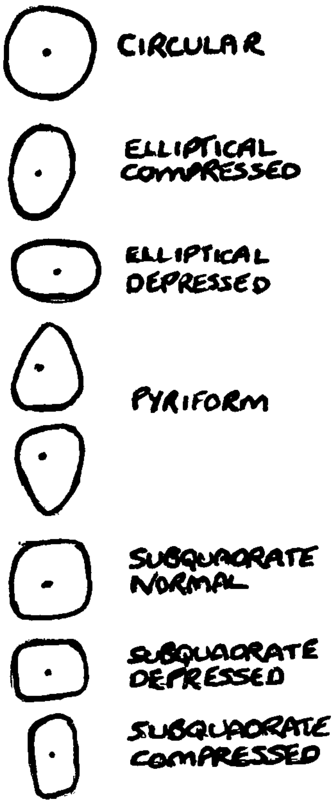


Fig. 8 Forms of transverse sections (adapted from Doyle, 1984).

Grooves

Swinnerton (1936-55) stated that apical grooves were of little systematic value, whereas, the ventral grooves, both anterior and posterior, were of considerable value, as they do not appear together in any one species. The nature and type of grooves are of great importance at generic level (Stevens, 1965; Doyle, 1990). All of the belemnite genera used in this study have ventral alveolar grooves. These grooves commence in the alveolar region and gradually taper out toward the apex of the rostrum. These are not always easily found as erosion may wear away the rostrum and flatten the groove, or the alveolar region may break, leaving no trace of the groove. The ventral alveolar grooves in *Neohibolites* and *Parahibolites* are very short, so if the alveolar region is not preserved, the groove will not be seen.

The grooves of belemnites have been a focus for discussion for many authors such as Swinnerton (1936-55) and Stevens (1965). Various theories as to the nature of the grooves have been raised and include:

- the groove is the site of a fin (Abel, 1916)
- a prominent muscle attachment (Stevens, 1965)
- a blood vessel (Stevens, 1965; Bandel, 1985a, b; Doyle, 1999)

The idea that the ventral groove is the site of a single unpaired fin (Abel, 1916) has been dismissed by authors (Stevens, 1965; Gustomesov, 1975; Hanai, 1981) as being an unnecessary appendage. When the belemnite animal is compared to the present day cephalopods, an unpaired fin is absent, as only paired fins are noted (Stevens, 1965).

Another explanation for the ventral groove has been suggested, then dismissed by Stevens (1965) as being the site of attachment for a large muscle or tendon. This large muscle served to attach a funnel that was used for locomotion. Stevens (1965) concluded that there was no likelihood of the groove being an attachment for such a muscle, as in modern squid and cuttlefish, the attachment for the highly developed funnel is a pair of muscles running back to the pen or cuttle bone.

The last explanation is widely accepted as the function for the ventral groove in the belemnite rostrum. It was the site of a blood vessel (Stevens, 1965; Bandel, 1985a, b; Doyle, 1999). The interpretation of the function of this blood vessel as serving the lateral lines (sites of fin attachments) has been generally agreed upon. If the belemnite were to swim through the water, the fins would need a supply of blood. The situation of the ventral alveolar groove is ideal for this purpose. If the skin of the belemnite was thin, the development of the groove was to protect the blood vessel from damage by lowering it below the level of the skin. Stevens (1965) explains that the groove would get deeper as the belemnite got bigger by the non-deposition or resorption of rostral material. This is at least one possible explanation for the ventral grooves, but as Stevens (1965) points out that, it is difficult to understand why the grooves are so straight and why there are no markings for the distributary and tributary vessels (although they are seen in the Late Cretaceous Belemnitellidae). He explains that the smaller vessels, leaving the main blood vessel, were too small to make any impression on the surface of the rostrum and that they may have plunged into the soft tissue of the skin.

Lateral Lines

Lateral lines are found on the surface of all belemnites (Gustomesov, 1962). They are closely spaced, parallel, longitudinal ridges and depressions on the lateral sides of the rostrum. These have a taxonomic value for taxa higher than genus (Gustomesov, 1962; Jeletzky, 1966), and Doyle (1990) believes they are only useful for differentiation at family and higher taxonomic levels. Stolley (1911) made use of these lateral lines in his systematic studies and described them in detail. The lateral lines are not always easy to see. In some genera, such as *Neohibolites* and *Parahibolites*, the lateral lines are very easy to see, although in some more poorly preserved and older specimens, they are absent, possibly due to erosion after death.

The function of these lateral lines has long been suggested as the sites of termination of fins against the rostrum (Naef, 1922; Gustomesov, 1962; Stevens, 1965; Doyle, 1984; 1999). Stevens (1965) also suggested that they may be the course of longitudinal blood vessels on the surface of the flanks of the rostrum, but concluded that they must be the continuations of blood vessels associated with the lateral fins.

Apical Line

The apical line is the central axis of the belemnite rostrum. It represents each successive growth stage of the apex (Stevens, 1965; Doyle, 1984; Saelen, 1989). This central axis has radiating calcite prisms, which may be a primary (Saelen, 1989) or secondary diagenetic feature of the rostrum (Muller-Stoll, 1936; Jeletzky, 1966; Barskov, 1970; Spaeth, 1971, 1973; Spaeth *et al.* 1971; Hanai, 1981; Bandel *et al.* 1984; Dauphin, 1991). Bandel *et al.* (1984) regarded the apical line as an originally organic feature, and the development of an apical canal in some forms (Naef, 1922) is considered to be a secondary, diagenetic feature (Doyle, 1984). For taxonomic purposes, the lateral line is considered a useful character for taxa higher than genus (Doyle, 1984). Stevens (1965) studied the apical line and how it is affected by the morphology of the rostrum. He found that a well developed groove would influence the direction of the apical line. If the groove is ventral, then each growth lamina of the rostrum will meet its maximum thickness on the dorsum and minimum thickness on the venter. This means the apical line will be deflected towards the venter. There are three main types of apical line (Schumann, 1974) (Fig. 9);

- ortholineate
- goniolineate
- cyrtolineate

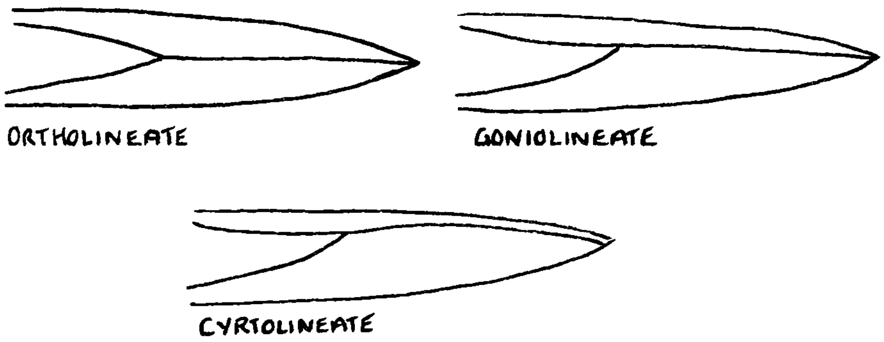


Fig. 9 Sketch of the three main types of apical line (adapted from Doyle, 1984).

Apex

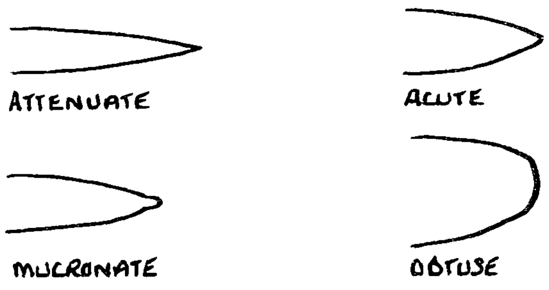


Fig. 10 Sketch of the different shapes of apex (adapted from Doyle, 1984).

The apex is the term used for the posterior end of the rostrum. It may show differing shapes such as(Swinnerton, 1936-1955; Doyle, 1984) (Fig. 10);

- attenuate
- mucronate
- acute
- obtuse

3.2.2 *Alveolus*

The alveolus is the conical cavity at the anterior end of the rostrum. This housed the phragmocone during life. The phragmocones of the belemnites in this study have not survived. This may be due to the decay of a material that lay between the phragmocone wall and the alveolus (Stevens, 1965) and may be facies linked. There is also a suggestion that this may be related to resorption in life. The specimens in this study were collected from marine clays and silts, but had no phragmocones intact. This contrasts with other studies (Doyle, 1984) in such facies where there is a high proportion of phragmocones intact and therefore this may not necessarily be a purely preservational character. A number of *Neohibolites* from this collection have shown a feature known as the psuedoalveolus. This is when the anterior rostral parts have been resorbed, leaving a corroded depression (Christensen, 1975; Spaeth, 1971; Saelen, 1989).

3.2.3 *Epirostrum*

The epirostrum is an elongation of the orthorostrum (Schwegler, 1961), and is only found in the mature belemnite as part of its last growth stage (Muller-Stoll, 1936; Doyle, 1999), although, Spaeth (1971) suggested that the epirostrum construction began in the juvenile stage and that it was unreliable to use for ageing the belemnite.

The epirostrum has thin walls and is filled with a calcitic granular mass called the '*corpus pulposum*' (Muller-Stoll, 1936). This *corpus pulposum* has been found to be a secondary diagenetic recrystallisation of an originally aragonitic epirostrum (Engeser and Reitner, 1983; Bandel, 1985b; Bandel and Spaeth, 1988), although Naef (1922) thought that the *corpus pulposum* was the diagenetic infill of an originally organically filled cavity, interlayered with thin calcareous material. The growth of the calcite crystals would disrupt the organic layering (Muller-Stoll, 1936).

The epirostrum has been found on many unrelated groups of belemnite. It is because of this that Doyle (1984) has concluded that epirostra are not of great taxonomic value and should not be used as such. Some species have been subdivided because of the epirostra, for example, *Neohibolites minimus* is known to have two forms, one with and one without epirostra (Spaeth, 1971). Those *Neohibolites minimus* in this study do not have epirostra, whereas, approximately 30% of *Neohibolites minimus* observed at Folkestone, Kent, have epirostra. Riegraf (1980) subdivided *Dactyloteuthis* into two subgenera (*D, (Cuspiteuthis)* and *Dactyloteuthis*). Also, Doyle (1984, 1985) whilst studying Toarcian belemnites, discovered that *Youngibelus tubularis* and *Y. levis* were in fact morphospecies and sexual dimorphs, with one having an epirostrum.

There has been a long standing school of thought that belemnites that have an epirostrum have reached sexual maturity and the epirostrum is a sexual adaptation (d'Orbigny, 1842-45; Lissajous, 1925; Doyle, 1984, 1985, 1990, 1999). The *Neohibolites* in this study do not have epirostra, therefore concluding that these belemnites have not reached sexual maturity or that they are of one sex. This is compounded by the fact that *N. minimus* possess epirostra in typical European locations (Spaeth, 1971)

3.2.4 *Rostrum Function*

The function of the rostrum has been a topic for discussion, the most recent being Monks *et al.* (1995) and Doyle (1999). There have been four proposed functions of the rostrum:

- streamlining for the backward motion of the animal
- a protection for the phragmocone
- a support for musculature and/or fins
- a counterweight (Doyle, 1999)

Bandel (1985b) has suggested that the different shapes of belemnite rostra were the result of varying styles of swimming and the buoyancy of the phragmocone was to counteract the weight of the rostrum. Both Bandel (1985b) and Monks *et al.* (1995) thought the rostrum necessary as a rigid support to the body to control the flexibility of the soft parts when swimming.

An unlikely function of the rostrum was proposed by Blanford and Stolitzka (1861-65) as a protection to the phragmocone and then called the rostrum the 'guard'. This, however, has not been thought correct (Stevens, 1965; Doyle, 1984, 1999), as the rostrum in the alveolar region is at its thinnest and therefore its weakest. There would be little protection for the fragile phragmocone here. The phragmocone is also, not entirely enveloped in the rostrum, more than half protrudes from the alveolus and therefore would have had no protection.

The rostrum may have been used as a support for musculature or fins, as many authors have suggested in recent years (Bandel, 1985b; Bandel and Spaeth, 1988; Monks *et al.* 1996). This is seen in the lateral lines and the grooves of the belemnite rostrum. The attachment to a rigid body is probably more favourable than to a flexible body.

The final hypothesis as to the function of the belemnite rostrum is that it was a counterweight to the soft parts. This is the favoured school of thought by many authors (Stevens, 1965; Jeletzky, 1966; Spaeth, 1975; Doyle, 1984, 1999; Engeser, 1990; Monks *et al.* 1995). The chambered phragmocone which probably contained gas and liquid (Stevens, 1965), so that it could change its density, would have acted as a buoy and the head and soft parts, being supposedly heavier, would have pointed vertically downwards, leaving the belemnite in a vertical position in the water column. The rostrum, acting as a counterweight to the soft parts, with the phragmocone as the pivot in the middle, would have kept the belemnite animal in a horizontal position (Stevens, 1965; Doyle, 1984, 1999; Monks *et al.* 1996). Spaeth (1975) agreed that the rostrum was a counterbalance, but determined that the rostrum would have been too heavy and the belemnite animal would have a vertical position in the water column. Many authors have looked at the hastation in some belemnites, suggesting that the calcite is removed from the alveolar region and replaced onto the posterior end of the belemnite, therefore, shifting the centre of gravity adapically (Doyle, 1984). The shape of the rostrum is also determined by the amount of counterweight needed as in the club-shaped belemnite *Duvalia* (Doyle, 1999). Epirostra are noted as being an extra counterweight system to counteract sexual adaptations (Doyle, 1984, 1985).

3.2.5 *Rostrum Diagenesis*

The debate over the original mineralogy of the belemnite rostrum is an ongoing topic for researchers. The rostrum is made of concentric growth rings of alternating laminae pellucidae (light, organic poor layers) and laminae obscurae (dark, organic rich layers) (Muller-Stoll, 1936). Spaeth (1971) considered these concentric growth lines to be primary, although the laminae obscurae may be considered altered by diagenesis (Muller-Stoll, 1936; Jeletzky, 1966; Barskov, 1970; Spaeth, 1971). The fine radially orientated compact latticework of calcite needles in the laminae pelucidae, which alternated with thinner layers of higher organic content (laminae obscurae) (Muller Stoll, 1936), were altered by diagenesis by the intergrowth of the massive calcite prisms that radiate from the apical line. This hypothesis by Muller-Stoll (1936) has been acknowledged by other authors such as Jeletzky (1966), Spaeth (1971, 1973), Spaeth *et al.*(1971) and Bandel *et al.* (1984), Doyle (1984, 1999). Saelen (1989), disputes the presence of alternating inorganic and organic layers of Muller-Stoll (1936). Instead he suggests that organic material is distributed throughout the rostrum. Barskov (1970) stated that the rostrum was calcified during life and that the calcite crystals were arranged in tabular layers orientated parallel to the boundaries of the layers. He visualised an original aragonitic rostrum after which the prismatic calcitic concentric structure was a secondary diagenetic feature and lastly the massive prismatic radial features were tertiary. According to some authors (Barskov, 1970; Spaeth, 1971, 1973; Bandel *et al.* 1984) the rostrum was at least partly calcified during life, although, other authors suggest that the rostrum was originally partly aragonitic ((Barskov, 1970; Spaeth, 1971). These theories of the original mineralogy of the rostrum indicate that the rostrum was a rigid structure. This conflicts with the thoughts of Kabanov (1959) who thought the rostrum was an elastic structure that was completely organic.

3.3 PHRAGMOCONE

The phragmocone is not preserved as readily as the rostrum, although, it is quite often found attached and sometimes complete. However, none of the specimens in this collection have a phragmocone preserved. This is possibly due to the decay of a thin membrane of tissue, which it has been suggested, lies between the alveolus and the phragmocone (Stevens, 1965) although, Hewitt and Pinckney (1982) propose that this is probably facies controlled. This review is therefore from published sources.

The phragmocone in composed of two layers as described by Barskov (1972). An inner prismatic layer is the continuation of the first septa and an outer nacreous layer. The phragmocone sits inside the alveolus, which contains the protoconch and the primordial rostrum.

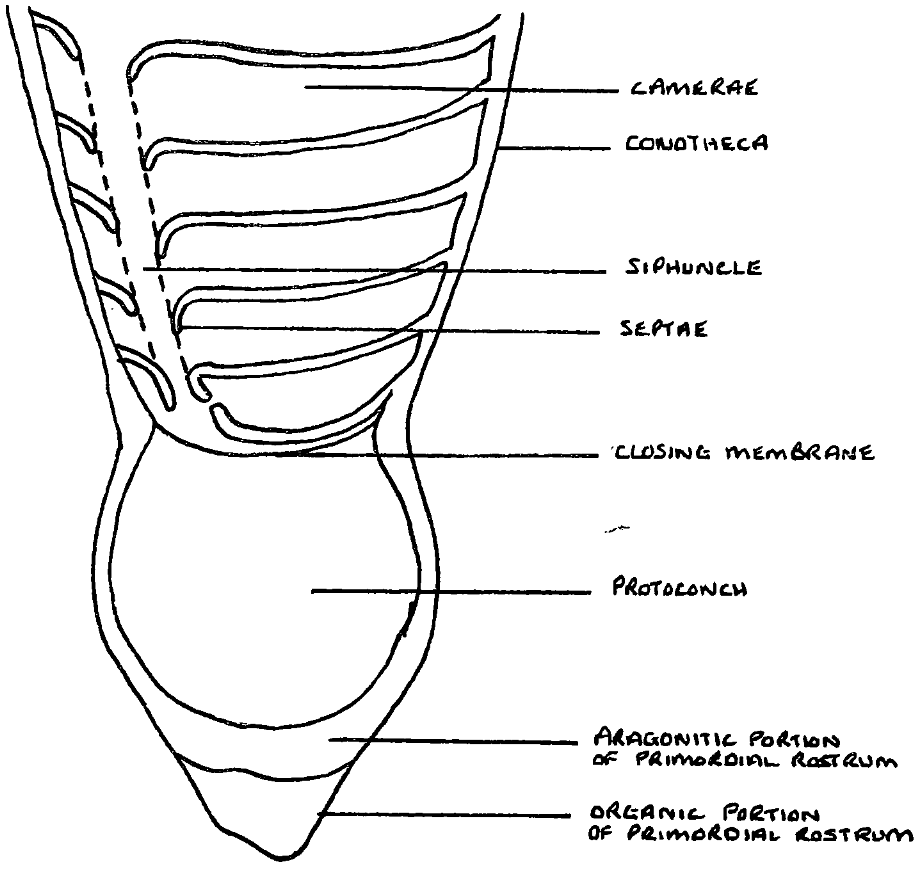


Fig. 11 Sketch of a typical belemnite phragmocone, showing the morphological terms used here (adapted from Doyle, 1984).

The phragmocone is composed of (Fig. 11):

- the protoconch
- the primordial rostrum
- camerae and septae
- the siphuncle
- conotheca

3.3.1 *Protoconch*

The protoconch is a bulbous body at the anterior end of the phragmocone representing the first formed shell. Most authors consider the protoconch to be made of two layers (Christensen, 1925; Jeletzky, 1966; Barskov, 1972, 1973). Muller-Stoll (1936) considers only one layer, but Bandel *et al.* (1984) report four layers. Barskov (1972) studied the protoconch and discovered how the newly hatched belemnite developed. The inner layer was the first formed and was an external shell (Barskov, 1972). The soft parts of the newly hatched belemnite enveloped this outer shell making it an endoskeleton, then the second layer of the protoconch was formed (the outer layer). The next stage in development was the posterior end of the body moved forward and formed the closing membrane. This then allowed the protoconch to fill with gas acting as a buoyancy aid and a planktonic way of life (Barskov, 1972).

3.3.2 *Primordial Rostrum*

The protoconch is bound at the posterior by the primordial rostrum. This is the first rostrum-like structure of the newly hatched belemnite animal (Saelen, 1989). Bandel *et al.* (1984) consider the primordial rostrum as being made up of an anterior aragonitic and a posterior organic part. This initial rostral stage is followed by the growth of the rostrum as seen in the concentric growth lines preserved in the low magnesium calcitic rostrum (Doyle, 1999).

3.3.3 *Camerae and Septae*

The phragmocone consists of chambers separated from each other by septae. The first septae is the organic closing membrane of the protoconch (Jeletzky, 1966; Barskov, 1972, 1973; Bandel *et al.* 1984). Through each septum, passes a siphuncle through septal necks. (Doyle, 1984). The structure of the septae has been widely debated with Jeletzky (1966) and Barskov (1972) realising that there were three inner layers and that two outer layers were diagenetic. Grandjean (1910) and Christensen (1925) regarded each septum as having five layers; a thin middle layer, two middle layers and two external layers.

3.3.4 *Siphuncle*

The siphuncle has been described by Grandjean (1910), Christensen (1925), Jeletzky (1966), Mutvei (1971) and Bandel *et al.* (1984). Essentially, the siphuncle is composed of the septal necks and the connecting rings. Both the septal necks and the connecting rings are composed of two layers. An inner nacreaous layer and an outer semiprismatic layer (Christensen, 1925; Jeletzky, 1966; Mutvei, 1971). The siphuncle ends in a 'foot' at the closing membrane (Grandjean, 1910; Christensen, 1925; Jeletzky, 1966).

3.3.5 *Conotheca*

The conotheca was applied to the outer wall of the phragmocone by Huxley (1864). Research completed on the number of layers attributed to the conotheca has been inconclusive due to the authors not being able to agree. Huxley (1864) and Grandjean (1910) agree that there is only one layer, Naef (1922), Christensen (1925), Mutvei (1964), Barskov (1972) and Hewitt and Pickney (1982) all agree that there are two layers, Muller-Stoll (1936) identified three layers and Bandel *et al.* (1984) concluded that there were four layers. The outer layer of Bandel *et al.* (1984) agrees with the suggestion of Stevens (1965) that there was a thin membrane between the alveolar and phragmocone.

3.4 PRO-OSTRACUM

The pro-ostracum is the most rarely preserved part of the belemnite skeleton, due to its fragile nature (Hewitt and Pinckney, 1982; Doyle and Shakides, in press). The term 'pro-ostracum' was originated by Huxley (1864). It is a spatulate, dorsal elongation of the conotheca (Jeletzky, 1966; Hewitt and Pinckney, 1982), which has been thought to provide support for the musculature of the head and to give definition to the body (Doyle, 1999). The pro-ostracum has been used as an important character in higher taxa (Jeletzky, 1966), but may be useful when identifying lower taxa (Doyle, 1984; Doyle and Shakides, in press). No pro-ostracum were found in this study.

3.5 ARM HOOKS

The arms of belemnites contained a double row of arm hooks for the capture of their prey, although these arm hooks are mostly found disconnected from the belemnite itself. Belemnites have been found with the arm hooks associated with the soft parts of belemnite bodies (Reitner and Engeser, 1982; Reitner and Urlichs, 1983; Doyle and Shakides, in press). The different arm hooks found were associated with different species of belemnite. Even so, the use of arm hooks in taxonomy is extremely restricted (Doyle and Shakides, in press). No hooks were found in this study.

3.6 SOFT PARTS

The belemnite animal is said to have ten arms and ink sacs (Reitner and Urlichs, 1983), and the soft parts have been reconstructed by a few authors (Huxley, 1864; Donovan, 1977; Phillips, 1980). The skin of the belemnite over the rostrum is thought to be very thin (Jordan *et al.* 1975; Spaeth, 1983) due to the colour banding found on some belemnite rostra (Phillips, 1865-70; Jordan *et al.* 1975). Seilacher (1968) even went as far to say that the skin may have been removed during life. No soft parts were sncountered in this study.

3.7 SEXUAL DIMORPHISM

Sexual dimorphism in belemnites has been a widely touched upon subject (d'Orbigny, 1842; Phillips, 1865-70; Lissajous, 1925; Roger, 1952; Stevens, 1965; Doyle, 1984, 1985, 1990, 1999). Studies by Doyle (1985) and Bandel and Spaeth (1988) have shown that the growth stages in the belemnite rostrum are the same for the first two stages, then at the third growth stage, a divergence of growth occurs, one of the dimorphic pair will show rapid growth whilst the other will show a thickening of the rostrum. It is not known which of the dimorphic pair is male or female. This hypothesis does not agree with that of Stevens (1965). His theory suggests that the sexual dimorphism would not occur in the rostrum, that if there was any dimorphism between the sexes, it would be evident in the pro-ostracum region where the gonads were probably housed. As discussed above, epirostra have been identified as potential indicators of sexual dimorphism. However, none were encountered in this study and sexual dimorphism was therefore not clearly definable in the material.

3.8 PATHOLOGICAL CONDITIONS IN BELEMNITE ROSTRA

Some belemnites have fractures and morphological irregularities that are shown in the shape and growth lines of the rostrum. The belemnite was apparently able to regenerate the rostrum well in life (Stevens, 1965), continuing its life cycle. Specimens in this collection show some pathological peculiarities and some irregularities that are obviously not pathological (Pl. 8, figs 3-9; Pl. 9, figs 1-9; Pl. 10, figs 1-9; Pl. 11, figs 1-2). Some of the specimens illustrated in Plate 10 (figs 4-5), Plate 9 (figs 8-9) and Plate 11 (fig. 1), show swellings along the rostrum which may indicate a possible disease during life or deformity that may have handicapped the belemnite, but it was still able to grow and reach maturity. For example, in specimen 900/169, Plate 9 (figs 3-5), however, there can be seen a prominent bite mark on the ventral side of the rostrum. This may have been a fatal bite from a bigger fish or shark, as it does not seem to have healed (Doyle *et al.* In Prep.) and is worthy of further study, but is not discussed further here.

CHAPTER 4 – SYSTEMATICS

4.1 INTRODUCTION

This chapter will examine the systematics of the belemnites found in the Karai Shales. There are a total of two families, three genera, and eleven species. This collection of belemnites will be housed in the Oxford University Museum.

4.2 IDENTIFICATION OF THE BELEMNITES

The belemnites were initially identified to generic level. To do this the belemnites were sorted into groups such as type A, type B, type C, etc. This was to stop confusion with identification and to address the features of the belemnites that were of generic importance. The belemnites were then compared to the literature and the generic names were allocated. A total of three genera were found, belonging to two families of the Suborder Belemnopseina Jeletzky, 1965. These are:

Family **Belemnopseidae** Naef, 1922.
Genus ***Neohibolites*** Stolley, 1911.
Genus ***Parahibolites*** Stolley, 1915.
Family **Dimitobelidae** Whitehouse, 1924
Genus ***Tetrabelus*** Whitehouse, 1924

A total of 3475 belemnites have been identified to generic level, of which, 1313 are *Parahibolites*, 1541 are *Neohibolites* and 621 are *Tetrabelus*.

Identification to species level took the same format as the identification of the genus. This was to appreciate the differences within each genus and to locate the specific characteristics of each species. Each presumed species was given a letter, for example: *Tetrabelus* sp. *A*; *Neohibolites* sp. *G*; *Parahibolites* sp. *B* etc. *Parahibolites* are lettered A – E; *Neohibolites* are lettered A – H and *Tetrabelus* are lettered A – F. A total of 2831 specimens have been identified to species level, of which, there are 1134 *Parahibolites* sp.; 1114 *Neohibolites* sp.; 591 *Tetrabelus* sp.

The collections of belemnites at the Natural History Museum, London have been studied for the purpose of identifying the Indian belemnites in this collection. Most of the *Neohibolites* in this collection were identified in this way, but unfortunately, the Natural History Museum does not hold collections which include the species of the genera *Parahibolites* and *Tetrabelus*.

Whilst the identification process was being carried out, identification of unusual features were noted, such as those belemnites with borings on the surface and pathological deformities. Those with borings have been placed in the Scanning Electron Microscope and examined. Those with pathological deformities were photographed and set in resin for lateral and transverse sectioning.

4.3 SPECIFIC DESCRIPTIONS

Specific descriptions are in the following form:

Synonomy

v (*vide*) in front of the year: specimens cited have been checked.

non in front of the year: this reference does not apply to the species under discussion.

? in front of the year: there is some doubt whether this is the species under discussion.

Diagnosis

- size and shape
- outline and profile
- transverse sections
- additional features

Type Specimens

Type specimens have been suggested where possible. Identification of most of the type specimens has not been possible within the duration of this work.

(NHM= Natural History Museum, London.)

Locality and material

- zone and subzone
- Geographical range

- Material

Typical dimensions.

L, Dvmax, Dlmax ,xv, xl.

Description

- size and shape
- length: diameter proportions
- outline (dorso-ventral aspect)
- profile (lateral aspect)
- transverse sections
- apex (form and grooves)
- lateral lines
- phragmocone
- apical line
- other observations

Discussion

- general observations
- differential diagnosis: species of other genera, species of same genus
- taxonomic

4.4 SYSTEMATIC DESCRIPTIONS

Class CEPHALOPODA Cuvier, 1794
Subclass COLEOIDEA Bather, 1888
Order BELEMNITIDA Zittel, 1895
(*non* MacGillivray, 1840 *vide* Riegraf *et al.* 1998)

Suborder BELEMNOPSEINA Jeletzky, 1965
(*non* Pachybelemnopseina *vide* Riegraf *et al.* 1998)

Diagnosis: Belemnitida with longitudinal alveolar canals; double dorso-lateral or lateral lines, which do not seem to be accompanied by ether splitting surfaces or open fissures (except possibly in Dimitobelidae) characteristic and may extend to apex of rostrum.

Family BELEMNOPSEIDAE Naef, 1922

Diagnosis: Slender, conical, clubate or cylindrical rostrum with a deep ventral alveolar groove often extending to the end of the alveolar region. Two parallel lateral lines run the entire length of the rostrum.

Neohibolites Stolley, 1911

Type Species: *Belemnites ewaldi* Strombeck, 1861, by subsequent designation of Gorn (1968, p.383).

Diagnosis: The size of the guard varies from medium to small. Cross sections are practically always circular. The apical line is centrally placed and is enveloped in a succession of compact growth lamellae of uniform thickness. The rostrum may be cylindrical with parallel sides, but more usually it tends to be more spindle shaped with a relatively thick anterior end.

Range: *Neohibolites* range from the Aptian to the Cenomanian (Doyle, 1988; Doyle and Bennett, 1995). From the Aptian of Germany (Mutterlose, 1987), Alicante, Spain (Bevia, 1975), Trinidad (identified by Stolley *in* Liddle, 1946), Mexico (Burckhardt, 1930), Mozambique (Doyle, 1987b) and Turkey (Doyle and Mariotti, 1991). Albian of Argentina (Doyle, 1988). Both the Aptian and Albian of Japan (Hanai, 1953), Germany (Stolley, 1911), Europe (Combemorel *et al.*, 1981), England (Swinnerton, 1936-55) Madagascar (Combemorel, 1988), Antarctica, South America, Malagasy Republic, New Guinea (Doyle, 1988) and southern India (Blanford and Stoliczka, 1861-65). It also has its last appearance in the Cenomanian of South America and the Malagasy Republic (Doyle, 1988). Stevens (1965) acknowledged that *Neohibolites* does not appear in the Cretaceous sediments of New Zealand or Australia.

Neohibolites minimus (Miller, 1826)

Plate 11, figs 3-4

Type Species: Lectotype selected by Swinnerton (1936-55), p.71, text fig. 8 (NHM C.44579).

Diagnosis: Length is 6-8 times the maximum diameter. Outline is elongate with the maximum diameter towards the apical region and is slightly clavate, and symmetrical. The profile is asymmetrical with a slightly inflated venter. The ventral alveolar groove is clearly defined and can extend backwards beyond the alveolar region. Double lateral lines are developed along the flanks of the rostrum, but may be seen only in small specimens. Transverse sections show that the alveolar region is slightly compressed, whereas, in the apical region, it is circular.

Discussion: The species *Belemnites minimus* was established for a group of Albian belemnites by Miller (1826). This species had previously been identified by Mantell (1822) who named it *Belemnites listeri*. Swinnerton (1936-55) applied to the International Commission of Zoological Nomenclature to have the name *Neohibolites minimus* recognised and to suppress that of *Belemnites listeri* due to *N. minimus* being more widely recognised. This is followed here. Stolley (1911) studied the forms of *Neohibolites minimus* and established a number of varieties for this species, which include: *N. minimus oblonga; N. minimus obtuse; N. minimus media; N. minimus pinguis; N. minimus attenuata.* Miller (1826) listed Mantell's (1822) specimens in his synonomy and so they are the syntypes for Miller's species. Swinnerton (1936-55) chose a lectotype from these syntypes which best agrees with the central point of the range of variation in Stolley's (1911) varieties of *N. minimus*. This central type is *N. minimus media* (NHM C.44579). In agreement with Swinnerton (1936-55) and Spaeth (1971), Stolley's varieties are upheld here as subspecies.

Range: *Neohibolites minimus* occurs mainly in Europe. Stolley (1911), discussed *N. minimus* from the Late Albian of Germany, Swinnerton (1936-55) found *N. minimus* in England, and Bevia (1975) talks about *N. minimus* in the Aptian-Albian from Alicante, Spain.

Neohibolites minimus minimus (Miller, 1826)

Plate 1, figs 1-6; Plate 6, figs 8-9; Plate 9, figs 8-9; Plate 10, figs 1-3.

Synonomy:

1826 *Belemnites minimus*, Miller, p.62.

1861 *Belemnites stilus*, Blanford, p.4, Pl.1, figs 2-3, *non* 1, 4-11 [fig. 4 = *N. semicaniculatus*; fig. 15 = *N. stoliczkai*]

v1955 *Neohibolites minimus* var *minimus* (Miller), Swinnerton, Pl. 17, figs 23, 30. [NHM C44589, C44549].

v1971 *Neohibolites minimus minimus* (Miller), Spaeth, p.58, Pl. 2, fig. 1; Pl.3, fig. 5. [NHM C45804].

v1971 *Neohibolites minimus minimus* (Miller), Spaeth, p. 33, Pl. 5, figs 2, 3, 4. [NHM C45848].

v1973 *Neohibolites minimus minimus* (Miller), Spaeth, pp. 163-174, Pl. 27- 29. [NHM C45848].

Diagnosis: Length 6-8 times the dorso-ventral diameter, outline and profile are symmetrical and slightly hastate; transverse sections are subquadrate; ventral alveolar groove up to ¼ of length of rostrum, double lateral lines along the entire length of the rostrum.

Type Specimen: Lectotype: *Belemnites listeri*, designated by Swinnerton (1955). [NHM C42926, *non* C42564].

Locality and Material: 574 specimens from the Karai Formation, Cauvery Basin.

Typical Dimensions:

N. minimus minimus					
SAMPLE NO.	**L**	**DLMAX**	**XL**	**DVMAX**	**XV**
KA30	28.7	8	20.4	7.9	24
KA60	32.6	5.8	17.9	5.9	17.8
KA110	30	6.3	17.9	6.5	17.6
KA120	39.3	8.2	19.5	8.8	19
KA150	25.6	4.4	11.4	4.6	13.5
KA240	43.6	9	21.9	8.3	36.8
KA690	46.6	7.8	27.8	7.3	32.4
KA720	42	7	23	6.8	23.6
KA720	36.2	6.1	16.4	5.9	16
KA760	35.3	6.8	16.6	6.2	15.5
KA820	29.4	4	19	4.3	20.3
KA840	34.4	5	15.4	4.9	17.9
KA840	34.5	7.2	22.4	6.9	22.5
KA870	32.8	5.5	7.9	5.7	16.7
KA990	44	7	31.6	7	30.5
KA990	41.4	5.5	25.4	5.7	25.7
KA1020	49.6	6.6	29.3	7	34.6
KA1020	45.5	7.3	31.1	7.3	29.4
KA1020	43.3	5.8	23.9	6.1	35
KA1020	39.7	5.2	29.9	5.5	28.3
KA1020	43.9	6.4	29.1	6.5	28.3
KA1050	40.7	6.7	25.8	7.2	27.2
KA1150	46.1	7.1	20.5	7.8	23
KA1150	49.3	7.2	23.2	7.7	25.6
KA1150	37.8	6.4	21.6	7.3	21
KA1260	41.4	8.8	23.6	8.6	26.4
KA1360	43.1	6.2	26.8	6.7	28
KA1670	47	7.5	27.4	7.3	29.5
KA1680	44.6	7	23.7	6.9	32.8

KA1690	43.2	6.4	26.1	6.5	28.5
KA1690	46.6	7	31.4	6.8	29.9
KA1690	41.7	6.4	21.4	6.6	23.7
KA1690	41.8	7.2	24.3	7.1	26.7
KA1690	44	6.7	23.9	6.9	23.2
KA1730	35.4	4.4	18.5	4.9	18.2
KA1730	34.9	4.6	15.5	4.9	18.1
KA1730	37	5.3	17.8	5.7	18.5
KA1730	33.5	5.2	21.1	5.4	24.1
KA1770	36.5	5.9		6.2	
KA1770	40.1	6.4	25	6.2	25.5
KA1770	34.6	6.2	18.2	6.7	21.9
KA1770	32.6	6.2		6.3	
KA1770	28.4	6.7		7	
KA1790	41.6	6		6.1	
KA1790	35.6	7.5		7.4	
KA1840	35.5	6.6	19.3	6.5	17.7
KA1840	34.7	6.2		6.6	
KA1840	39.4	6.5		6.7	
KA1840	28.7	5.4	15.7	5.5	13.9
KA1850	28.8	5.5	10.5	5.8	10.9
KA1900	30.9	5	16.3	5	16.8
KA1920	37.7	6.7	22	6.6	24
KA1930	37.4	6.7		6.4	
KA1940	28.2	5.4	18.9	5.4	17.8
KA1940	40.8	7	22.6	7.3	27.1
KA1950	39.9	7.2	23	6.9	25.4
KA1950	38.8	7.2	21.7	7.3	23.3
KA1960	31.6	5.9	19.1	6	16.8
KA1960	35.9	7.6		7.1	
KA1970	27.2	4.3		4.5	
KA1970	23.2	4		4	
KA1970	25.5	5.4		5.4	
KA1980	31.2	6		6.1	
KA1980	33.8	6.3	22.6	6.2	20.1
KA1980	32.6	6.3		6.2	
KA2040	27.7	6.5	22.9	6.6	24.5
KA2050	36.1	6.3	25.2	6.3	22.5
KA2070	36.1	5	13.7	4.8	13.2
KA2140	39.2	7	25.6	6.9	27.7
KA2140	31.1	5	17.1	4.8	14.3
KA2170	40.2	7.5		7.2	
KA2180	23.2	4.4	15.2	4.2	14.4
KA2180	28.9	5.6		5.8	
KA2180	28.9	5.4		5.4	

Description: Rostrum is very slightly hastate to cylindrical, with a total length approximately 5.5 times the maximum dorso-ventral diameter (Dvmax). The outline and profile are slightly hastate to cylindrical and symmetrical. Transverse sections are subquadrate and slightly depressed. The apex is obtuse with a slight mucro. The alveolar ventral groove is small, very similar to *N. strombecki. Doppellinien* present. No phragmocones have been observed in this species. The apical line is ortholineate.

Discussion: Blanford recognised the genus *Neohibolites* from southern India and named them all *Belemnites stilus*. Only Plate 1 (figs 2-3) (Blanford and Stolitzka, 1861-65) represent *N. minimus minimus*. This species is not as hastate as the others on this plate and represent different subspecies of *N. minimus*. *Nadlespitze* (Muller-Stoll, 1936) is seen in some of these specimens. The apex in this species is more sharply pointed than in *N. minimus pinguis*, but is very similar to *N. strombecki.*

Range: This subspecies is known from the Cretaceous (Aptian-Albian) of southern India (Blanford and Stoliczka, 1861-65) and England (Swinnerton, 1936-55).

Neohibolites minimus pinguis Stolley, 1911

Plate 1, fig. 9; Plate 2, figs 1-3; Plate 7, fig. 2.

Synonomy:

1911 *Neohibolites minimus pinguis* Stolley, p. 61, Pl. 6, figs 11-14.
v1955 *Neohibolites minimus pinguis* Stolley, Swinnerton, p. 74, Pl. 18, figs 7-12.
[NHM C58014].

Diagnosis: Rostrum length 5-6 times the maximum dorso-ventral diameter, outline and profile subhastate and symmetrical, transverse sections slightly depressed, apex very obtuse, short deep ventral alveolar groove not exceeding ¼ length of rostrum.

Type Specimen: Designated by Swinnerton (1936-55), Stolley, 1911. pl. 6, fig. 14.

Locality and Material: 8 specimens from Karai Formation, Cauvery Basin.

Typical Dimensions:

Neohibolites minimus pinguis					
SAMPLE NO.	**L**	**Dvmax**	**Dlmax**	**xv**	**xl**
ka20	37.4	8.3	8.6	21.8	19.2
ka110	33.3	7	7.4	20.9	19.3
ka290	34.9	6.5	6.9	13.5	13.6
ka1250	36.2	6.6	6.8	16.5	12.3

Description: Medium sized, slightly subhastate, *Neohibolites*, with a total length approximately 5 times the maximum dorso-ventral diameter (Dvmax). The outline and profile are similar, slightly subhastate and symmetrical. Transverse sections are circular to subquadrate, slightly depressed. The apex is very obtuse. *Doppellinien* are not observed due to poor preservation. A short, deep, ventral, alveolar groove appears longer than *N. strombecki*. The phragmocone does not appear to have been preserved. The apical line is ortholineate.

Discussion: The rostrum has developed a pseudoalveolus which is seen on the transverse sections. This may be caused by the resorption of the calcite by the belemnite animal back into the body. The apex is distinctly obtuse and even rounded in some specimens, but not as much as in *N. mimimus oblongatus* Swinnerton, 1955.

Range: *N. minimus pinguis* has been recognised from the Albian of South America (Gerth, 1932) and England (Swinnerton, 1936-55).

Neohibolites minimus submedius Swinnerton, 1955

Plate 1, figs 7-8; Plate 7, fig. 1; Plate 11, figs 5-6.

Synonomy:

v1955 *Neohibolites minimus* var *submedius*, Swinnerton, p. 77, Pl.17, fig. 21. [NHM

C44710 = illustrated here, Pl. 11, figs 19, 20].

Diagnosis: Slender, slightly hastate in outline and profile, slightly depressed, length of rostrum being 7-10 times the maximum dorso-ventral diameter; ventral alveolar groove short up to ¼ length of rostrum, double lateral lines.

Type Specimen: Holotype: From the Gault Clay, Folkestone. [NHM C44710].

Locality and Material: 80 specimens from Karai Formation, Cauvery Basin.

Typical Dimensions:

Neohibolites minimus submedius					
SAMPLE NO.	**L**	**Dvmax**	**Dlmax**	**xv**	**xl**
ka710	26.8	4	4	17.8	17.1
ka830	30.5	3.4	3.5	13.3	16.3
ka910	35.2	4.2	4.1	19.9	20.8
ka1720	32.5	5.3	5.2	19.4	17.7
ka1810	35.2	4.2	4	21.5	21.8
ka1850	29.4	4.6	4.5		
ka1850	24.6	4.4	4.2		
ka1930	33.5	5.3	5.2	24.9	20.7

Description: Rostrum is very slender, cylindrical to subhastate and slightly depressed, with a total length approximately 7 times the maximum dorso-ventral diameter (Dvmax). The outline and profile are subhastate and symmetrical. The transverse sections are subquadrate and slightly depressed. The apex is very acute and to some extent attenuate, although not in all specimens. The ventral alveolar groove is very small and is not preserved on many specimens due to the preservation of the alveolar. The *Doppellinien* (double lateral lines) are observed in a straight line from the alveolar region to the apex. The phragmocone is not seen in these specimens. The apical line is ortholineate.

Discussion: Swinnerton (1955) created this new variety because it was a transitional type between *N. minimus minimus* and *N. minimus attenuatus*. Here, the variety is changed to a subspecies, following Spaeth (1971). This subspecies is much more slender than *N. ernsti* and is very similar to *N. spicatus*. One specimen with a possible epirostrum.

Range: *N. minimus submedius* has only been recognised from the Aptian-Albian of England (Swinnerton, 1936-55). The specimens in this collection resemble this subspecies better than any other species of *Neohibolites*.

Neohibolites semicanaliculatus (Blainville, 1827)

Plate 2, figs 4-5; Plate 7, fig. 3.

Synonomy:

1827 *Belemnites semicanaliculatus*, Blainville, p. 27, Pl. 1, fig. 13.
1861 *Belemnites stilus*, Blanford, p.4, Pl.1, fig. 4, *non* 1-3, 5-12.
1919 *Neohibolites semicanaliculatus* (Blainville), Stolley, p. 9, Pl.1, figs 1-8.
1981 *Neohibolites semicanaliculatus* (Blainville), Hanai, p.68, Pl.5, fig. 9

Diagnosis: Rostrum length is 3-7 times the width, cylindrical in profile and outline, the apex is acute to obtuse; short, deep alveolar groove not extending further than 1/3 of rostrum; double lateral lines extending from alveolus area to apex region; transverse sections show a slightly depressed character.

Type Specimens: Lectotype here designated, the original of Blainville (1827, pl.1, fig. 13).

Locality and Material: 198 specimens from the Karai Formation, Cauvery Basin.

Typical Dimensions:

Neohibolites semicanaliculatus					
SAMPLE NO.	**L**	**Dvmax**	**Dlmax**	**xv**	**xl**
ka90	43.7	8.2	8	28	26.3
ka130	51.9	8.9	8.4	30.4	32.1

ka230	41.2	7.7	7.7	21.4	21.9
ka780	36.9	6.5	6.5	16	20.7
ka830	45.8	7.1	7.4	21.1	22.5
ka1200	47.4	10.8	9.9	30.9	29.2
ka1280	49.4	7.9	8.2	35.9	29.3
ka1330	33.2	5.3	5.2		
ka1680	41	8.5	8.6	34.2	31
ka1680	45.5	8.3	8.1	36.6	28.8
ka1690	38.3	7.2	7.5	24.9	23
ka1690	46.4	8.9	8.7	38.7	36.3
ka1700	43.5	8.4	8.4	34.1	31.5
ka1720	33.3	5.8	5.5	23	22.6
ka1740	38.6	7.3	7.3		
ka1750	44.9	7.2	7.1		
ka1770	47.7	8.7	8.5	25.5	24.5
ka1770	39.6	6.5	6.4		
ka1780	37.7	7.2	7		
ka1780	32.3	5.7	5.5		
ka1780	36.5	5.6	5.5	19.3	20.4
ka1790	4.05	7.6	7.6	31.2	31.9
ka1800	40.6	6.9	7		
ka1810	38	7.5	7.8		
ka1820	32.8	5	4.8	23.5	28.9
ka1820	31.4	4.6	4.4	14.6	17.3
ka1820	31.6	5.6	5.3	17.8	17.9
ka1820	29.4	4.9	4.6		
ka1820	32.6	4.6	4.6	17.8	19.4
ka1830	45.5	8.5	8.4	29	25.3
ka1830	37	6.6	6.4	24.5	24.4
ka1840	38.6	6.4	6.4		
ka1840	45.5	7	6.9	32.8	21.6
ka1840	48.5	9	9.5	31.9	30.2

Descriptions: Rostrum is cylindrical and large for *Neohibolites*, with a total length approximately 5.5 times the maximum dorso-ventral diameter (Dvmax). The outline and profile are cylindrical and symmetrical. Transverse sections in the alveolar region are subquadrate and slightly compressed, in the apex region, the section is less quadrate. The apex is acute to moderately obtuse. The ventral alveolar groove is deep and relatively short. The *Doppellinien* are distinct and clear, continuing in a straight line from the apex to the alveolar region. The phragmocone has not been preserved in these specimens. The apical line is ortholineate/ slightly cyrtolineate.

Discussion: Stoliczka (1861-65) identified *Belemnites stilus* Blanford as being identical to *Belemnites semicanaliculatus* Blainville. Blanford and Stoliczka (1861-65) recognised this species from the Lower Chalk of Maidstone, Kent as being identical to those from India (Blanford and Stolitzca, 1861-65, Pl.1, figs 2-4). In France, Germany and Switzerland, the species occurs in the 'middle strata of the Cretaceous Formation' (Blanford and Stolitzca, 1861-65). Combémorel *et al.* (1981) have placed *N. semicanaliculatus* into the genus *Mesohibolites*. This confusion is probably due to the species being slightly depressed. This species is very similar to *N. minimus minimus*, but is not hastate.

Range: *N. semicaniculatus* has been recognised from both the Northern Hemisphere, from the Aptian-Albian of Alicante, Spain (Bevia, 1975) and from the Lower Aptian to Lower Albian of Japan (Hanai, 1953), to the Southern Hemisphere, from the Upper Aptian of Trinidad, which was identified by Stolley in Liddle (1946), the Aptian of Mexico (Burckhardt, 1930) and the Albian (Gerth, 1932) of South America (Stolley, 1912).

Neohibolites strombecki Muller, 1895

Plate 2, figs 8-9; Plate 3, figs 1-2; Plate 7, fig. 4.

Synonomy:

1895 *Belemnites strombecki* Muller, p.106.

1911 *Neohibolites strombecki* Stolley, p.252, Pl. 4, fig. 5-20.

1911 *Neohibolites strombecki* Stolley, p.183.

1955 *Neohibolites strombecki* Stolley, Swinnerton, p.68, Pl.XVII, figs 10-12.

Diagnosis: Medium to short rostrum. Rostrum length is usually 5-6 times the maximum diameter. Maximum diameter is behind the middle of the rostrum. The profile and outline are symmetrical and cylindrical. Transverse sections are almost circular. Double lateral grooves extend the whole length of the rostrum. The ventral groove may extend to the end of the alveolar region.

Type Specimen: Lectotype here designated the original of Stolley, Pl.XXXI, fig. 5.

Locality and Material: 48 specimens from Karai Formation, Cauvery Basin.

Typical Dimensions:

Neohibolites strombecki					
SAMPLE NO.	**L**	**Dvmax**	**Dlmax**	**xv**	**xl**
ka10	28.3	4.7	4.9	13.5	13.9
ka80	30.8	8	8.4	13	12.9
ka100	30.7	5	5.1	19.4	18.4
ka2040	43.3	4.6	4.5	16.3	18.1

Description: Medium sized, slightly hastate *Neohibolites*, with a total length approximately 4.8 times the maximum dorso-ventral diameter (Dvmax). Both the outline and profile are slightly hastate and symmetrical. Transverse sections are circular throughout the length of the belemnite. The apex is obtuse, being short and blunt with no mucro. A short, deep, well defined, ventral, alveolar groove is seen. *Doppellinien* are seen, although not clearly, due to poor preservation. The phragmocone is not preserved in this species. The apical line is ortholineate.

Discussion: The apex of these specimens and the shape is very similar to that of *N. ewaldi*, although *N. ewaldi* is much smaller and the length of the rostrum is 6 times that of the maximum diameter. This species is also differentiated from *N. wollemani* due to its smaller size and less elongate outline (Swinnerton, 1936-55). The preservation of the alveolar end is not good, which is why only four of the 48 specimens in this study were measured.

Range: This species has so far only been identified from the Middle Albian of Germany (Stolley, 1911) and the Aptain-Albian of England (Swinnerton, 1936-55), although, can now be identified from the Karai Clay Formation of southern India.

Neohibolites ernsti Spaeth, 1971

Plate 2, figs 6-7.

Synonomy:

1971 *Neohibolites ernsti* Spaeth, p.68, Pl. 7, figs 8-9.

Diagnosis: A slim/slender *Neohibolites*. The younger growth stages show a clavate orthorostrum. The transverse sections shows a slightly compressed ventral side which makes it subquadtrate in appearance. The apex is acute with the occurrence of a mucro in some cases. The ventral alveolar groove is very short. *Doppellinien* are observed on the lateral sides of the belemnite.

Type Specimen: Holotype designated by Spaeth 1971, Pl. 7, fig. 7.

Locality and Material: 70 specimens from Karai Formation, Cauvery Basin.

Typical Dimensions:

Neohibolites ernsti					
SAMPLE NO.	**L**	**Dvmax**	**Dlmax**	**xv**	**xl**
ka280	26.2	4.6	4.9	14.4	14
ka730	36	6.4	6.7	26.9	21.5
ka750	26.4	4.6	4.4	12.5	10
ka830	30	4.5	4.6	15.2	16.3
ka1270	27	4.2	4.4		
ka1720	30.7	6	6	17.9	17.5
ka1800	25.4	4.1	3.9		
ka1840	27.8	4.6	4.7	14	16.3
ka1930	23.2	3.8	3.8		
ka2160	28.4	4.6	4.8	16.2	16.2

Description: A group of small sized, hastate, *Neohibolites*, with a total length approximately 6 times the maximum dorso-ventral diameter (Dvmax). The outline and profile are hastate and symmetrical. Transverse sections are subquadrate at the alveolar end, becoming more circular toward the apex. The apex is acute to moderately acute. The ventral alveolar groove is not always seen due to its short length and preservation detail of the alveolus. *Doppellinien* are present and create a slight depression on the lateral sides of the rostrum. Phragmocone not seen in these specimens. Apical line is ortholineate.

Range: Spaeth (1971) identified this species from the Late Albian of Germany and England in the *cristatum* and *inflatum* zones.

Neohibolites spicatus Swinnerton 1935

Plate 3, figs 3-4; Plate 7, fig.5.

Synonomy:

1935 *Neohibolites spicatus* Swinnerton, p.30, Pl. I, figs 9, 9a.
1955 *Neohibolites spicatus* Swinnerton, p.69, Pl. XVII, figs 13-16.

Diagnosis: An elongate, conical *Neohibolites* with a well developed ventral groove. Elongate with maximum diameter at the anterior end. The length is 7 times the maximum diameter. In transverse section it is slightly compressed in the alveolar region, becoming circular later. The compression is due to a ventral groove which extends through the alveolar region. It flattens out during the initial part of the apical region. Double lateral lines are seen on the alveolar region and is absent in the apical region.

Type Specimens: Swinnerton elected the holotype from the Swinnerton collection, Geological Survey Museum, no. 91634.

Locality and Material: 136 specimens from Karai Formation, Cauvery Basin.

Typical Dimensions:

Neohibolites spicatus					
SAMPLE NO.	**L**	**Dvmax**	**Dlmax**	**xv**	**xl**
ka820	40.7	5.7	5.7	21.6	21.5
ka830	26.9	3.8	3.4	21.7	16.5
ka930	34.4	4.8	4.5	25.4	21.8
ka990	32.6	5.5	5	21.9	19.5

ka990	38.2	5.3	5.1	22	28.8
ka1030	49.4	6.7	6.4	30.4	29.4
ka1140	48.1	7.5	7		
ka1140	42.3	6.1	5.9	30.1	30.8
ka1140	40.8	5.5	5.3		
ka1160	37.3	5.5	5.2	18.6	19.8
ka1180	40.9	5.8	28.9	5	25.3
ka1710	39.6	5.9	5.8		
ka1790	36.6	5.4	5.4		
ka1830	33.6	4.9	4.8	18.9	19
ka1850	30.3	4.7	4.3	21.3	20.3

Description: Rostrum is medium sized, slightly subhastate and slender with a total length approximately 6.9 times the maximum dorso-ventral diameter (Dvamx). The outline and profile are similar, slightly subhastate, slender and symmetrical. The transverse sections are slightly compressed at the alveolar end, becoming rounded toward the apex. The apex is very acute. A faint ventral alveolar groove may be seen in some specimens, which indicates that the groove was very short and that it is mainly only found on the fragile part of the alveolar which in most cases does not preserve well. *Doppellinien* (double lateral lines) are observed clearly on most specimens, sometimes becoming faintly depressed. There are no phragmocones preserved in these specimens. The apical line is ortholineate and shows the development of a pseudoalveolus. One specimen may have an epirostrum.

Discussion: This species is not seen in any of Blanford's (1861-65) figures. Swinnerton (1936-55) noted that this species was very rare in European Albian deposits, but is however, quite common in the Indian collection. This species resembles *N. wollemani*, but its maximum diameter is much more forward in position giving the conical, rather than spindle shape. *N. strombecki* is similar, although, they are much shorter and the ventral groove does not extend as far along the rostrum.

Range: Found in the Albian of England (Swinnerton, 1936-55), and the Albian of southern India.

Parahibolites Stolley, 1919

Type Species: (by original designation) *Neohibolites duvaliformis* Stolley, 1911.

Diagnosis: Small, slender, hastate to cylindriconical, compressed member of the Belemnopseidae. Outline symmetrical, cylindriconical to subhastate. Apex acute. Profile asymmetrical, hastate to cylindriconical. Venter commonly inflated to very inflated. Transverse sections notably compressed, elliptical to subquadrate. A single ventral alveolar groove extends adapically one sixth to one fifth of the total length of the rostrum and is accompanied by a well defined splitting surface. Deeply incised lateral lines consist of a double line (*Doppellinien*) extending for the full length of each flank. Phragmocone penetrates one third to one half of the rostrum. Pseudalveolus and *Nadelspitze* may be developed. Apical line is ortholineate.

Range: Although very closely related to *Neohibolites*, *Parahibolites* is not found as frequently around the world as *Neohibolites*. *Parahibolites* lived from the Aptian through to its extinction in the Cenomanian (Doyle, 1985; Doyle and Bennett, 1995). Found in Europe (Combemorel *et al.*, 1981; Doyle, 1985), Aptian of Turkey (Doyle and Mariotti, 1991), Aptian of South America (Stolley in Richter, 1925; Doyle, 1985), the Albian of Argentina (Doyle and Pirrie, 1999), the Malagasy Republic (Lemoine, 1906), USSR, Antarctica and southern India (Doyle, 1985).

Parahibolites stoliczkai (Spengler, 1910)

Plate 3, figs 5-9; Plate 4, figs 1-3; Plate 7, figs 6-7; Plate 10, figs 4-9;
Plate 11, figs 1-2; Plate 12, figs 1-11.

Synonomy:

1861 *Belemnites fibula* Forbes, Blanford, p. 3, Pl.1, fig. 15, *non* figs 13-14, 16-39.
1865 *Belemnites fibula* Forbes, Stoliczka, p.201.
1910 *Belemnites (Pseudobelus) Stoliczkai*, Spengler, p.156, Pl. XIV, fig. 8a-c.
1920 *Parahibolites stoliczkai* (Spengler), Bulow-Trummer, p. 166.

Diagnosis: Robust *Parahibolites* with a slightly subhastate and symmetrical outline and profile. The transverse section is oval, becoming more circular towards the apex, which is acute.

Type Specimen: Here designated *Belemnites fibula* Blanford, Pl.II, fig. 7.

Locality and Material: 1002 specimens from Karai Formation, Cauvery Basin.

Typical Dimensions:

Parahibolites stoliczkai					
SAMPLE NO.	L	DLMAX	XL	DVMAX	XV
KA160	44.5	8.6	20.5	10	17.6
KA175	49.5	7.3	30.8	9.1	36.8
KA175	38	7	30.7	8.8	30.8
KA990	44.9	6.2	18.7	6.7	23.5
KA990	50.5	7.1	23.8	7.7	27.5
KA990	42.3	5.9	25.8	6.1	23.3
KA1000	40.7	5.7	25.2	6.1	27.9
KA1040	45.1	7.2	32.5	7.9	33.3
KA1040	45.5	6.2	28.4	6.6	33
KA1050	48.7	7.8	33.4	8.9	37.5
KA1140	37.3	5.6	22.7	6	20.6
KA1200	42.3	7.8	17.7	8.7	17.8
KA1230	45.7	6.5	23.4	7.6	30.8
KA1250	42.4	7	24.8	6.6	17.9
KA1250	45	6.4	22.9	7	21.2
KA1250	47.3	6.3	26.6	7.5	27.4
KA1250	40.6	5.9	27	6.6	25.9
KA1250	40.5	6	26.2	6.6	23.7
KA1260	46.5	6.2	21.6	7.2	29.7
KA1260	48.4	6.3	28.7	7.1	25
KA1260	44.8	6.6	25.5	7.3	24.4
KA1260	38.1	5.5	22.4	6.1	21.2
KA1270	53.7	8	32.5	8.8	28.5
KA1270	37.7	4.6		5	
KA1270	40.6	5.8	27.1	5.9	28.7
KA1280	41.9	6.9	25.7	7.8	25.2
KA1280	35.2	5		5.7	
KA1290	46.9	9.7	34.1	10.4	31.3
KA1290	45.4	6.3	26.4	6.7	23.6

KA1290	43.2	6.3		7.1	
KA1300	46.8	6.2	23.7	6.8	34.1
KA1310	43.1	6.5		7.1	
KA1310	40.2	5.8	25.2	6.1	22.8
KA1350	39.3	5.9	26.1	7.2	24.5
KA1350	42.3	6.1	20.7	7	24.2
KA1350	43	5.6		6.2	
KA1350	39.6	5	23.5	5.6	25.7
KA1360	44.4	5.9	21.8	6.5	21.6
KA1360	45.3	6.3	25.8	7	24.3
KA1360	43.1	6.1	24.2	6.8	23.9
KA1360	40.9	7	30.5	7.6	31.7
KA1370	49.2	6.5	24.3	7.3	25.6
KA1370	48.9	6.9	26.5	7.6	24.7
KA1370	43.1	6.4		6.9	
KA1380	48.9	6.5	25.9	7.3	24.3
KA1410	41.8	7.3	30.5	9.1	25.9
KA1420	50.9	8	27.3	9.3	26.2
KA1440	43.7	7.5	23.9	8.5	26.7
KA1440	43.5	7.2	29.8	8.2	30.9
KA1440	49.6	7.4		8	
KA1450	49.6	6.6	36.8	7.4	34.3
KA1480	44.6	6.5	27.9	6.9	28.7
KA1480	42.5	6	27.8	7	28.9
KA1480	34.7	5.1	20.2	5.5	20.6
KA1480	40.1	5	29.6	5.7	30.3
KA1480	31.2	4.3	19.6	4.7	16
KA1490	44.5	6.9	35.1	7.6	31.5
KA1490	53.1	6.9	35.7	7.9	31.8
KA1490	45.9	6.5	32.8	7.1	30.7
KA1490	54.2	6.5	45.4	7.3	29.3
KA1490	38.6	5.8	26.8	6.7	26
KA1490	39.8	5	25.8	5.6	25.5
KA1500	42	5	24.7	5.9	27.2
KA1500	39.8	5.2	26.4	5.9	29.3
KA1500	34.2	4.6	21.1	5	22.4
KA1500	49.2	7.6	33.3	9.9	33.8
KA1500	45.5	5.5	31.2	6.3	26.5
KA1520	30.6	4.9		6	
KA1520	27.5	4	17.4	4.8	16.6
KA1530	41.4	5.7	28.4	6.5	26.9
KA1530	34.9	5.2	19.4	6	22.3
KA1540	46.8	6	23.4	6.8	23.8
KA1580	34.3	4.9	20	5.7	19.1
KA1590	42.8	5.7		6.9	
KA1600	44.5	5.5	29.7	6.7	28.4
KA1600	43.3	6.1	33.5	7.4	30.8
KA1600	42.2	5.3	22.2	6.3	21.3

KA1600	48.5	6.2	35	6.9	32.4
KA1600	39.1	4.5		5.3	
KA1600	44	5.6		5.9	
KA1620	35.8	4.1	21.3	5.4	19.3
KA1620	42.4	5.3	31.2	6.5	25.8
KA1620	33.7	3.8		4.7	
KA1620	45.5	5.7	28.6	7	28.9
KA1630	26.3	3.6	18.2	4.3	26.9
KA1630	35.1	5.1	23	6.6	20.9
KA1630	41	5.7		6.9	
KA1630	40.4	5.2	24.9	6	24.5
KA1630	36.3	5		6.3	
KA1640	39.4	5.2		6.2	
KA1640	45.8	5.6	27.6	6.4	26.2
KA1640	28.8	3.4	14.2	4.3	11.7
KA1640	40.1	5.5		6.4	
KA1640	36.9	4.8		5.7	
KA1640	26	3.5		4	
KA1640	36.8	5	26.6	5.8	23.7
KA1640	42.8	5.4		6.4	
KA1650	24.3	4.1		4.6	
KA1650	32.6	4.7	18.7	5.3	16.9
KA1650	32.7	5.1	19.1	6.1	19.7
KA1650	30.5	4.8		5.5	
KA1660	25.1	5.5	19.9	6.1	18.2
KA1720	28	3.8	17.2	4.1	14.3
KA1730	32.7	5		5.5	
KA1730	43.4	6	32.1	7.2	35.4
KA1750	33.6	5.1		6.1	
KA1820	43.7	5.8	26.6	6.2	32.3
KA1820	31.5	4.7	15.4	5	17.6

Description: Rostrum is cylindrical to slightly subhastate and compressed, with a total length approximately 6.2 times the maximum dorso-ventral diameter (Dvmax). The outline is more slender than the profile, both are slightly subhastate and symmetrical. Transverse sections show a compressed rostrum. The transverse section at the alveolar end is oval to subquadrate, becoming more circular toward the apex. The apex is acute. The ventral alveolar groove is short but clear in specimens with the alveolar end in tact. Double lateral lines are observed along the entire length of the rostrum. No phragmocones have been preserved in these specimens. The apical line is ortholineate.

Discussion: *Belemnites fibula* of Forbes (1845) and Kossmat (1897) are found in the Santonian (Late Cretaceous) of the Pondicherry District, southern India, and are quite different to the *Belemnites fibula* of Blanford (1861). The specimens of Forbes (1845) and Kossmat (1897) cannot be *Belemnites fibula*, as this species has a range from the Aptian to the Albian.

Range: Found only in the Aptian-Albian of southern India (Blanford and Stoliczka, 1861-65; Stevens, 1965).

Parahibolites fuegensis Stolley *in* Richter, 1925

Plate 4, figs 6-7

Synonomy:

1925 *Parahibolites fuegensis* Stolley *in* Richter, p. 541, Pl. VII, figs 12-13.
1949 *Parahibolites fuegensis* Stolley, Camacho, p.253, Pl. 1, fig. 8.
v in Press *Parahibolites fuegensis* Stolley, Doyle *et al.* p. 23, Pl. 3, figs 2-4.

Diagnosis: Large *Parahibolites*. The outline is symmetrical and slightly subhastate. The profile is asymmetrical and slightly subhastate. The apex is acute. Transverse sections are strongly compressed. Ventral alveolar groove is short. The double lateral lines are well developed.

Type Specimen: Lectotype designated by Doyle *et al.* (in press), the original of Stolley *in* Richter, Pl. VII, figs 12-13.

Locality and Material: 35 specimens from the Karai Formation, Cauvery Basin.

Typical Dimensions:

Parahibolites feugensis					
SAMPLE NUMBER	L	DLMAX	XL	DVMAX	XV
KA220	30.8	5.9	25.4	7.3	23.5
KA1630	34.5	4.8		5.8	
KA1630	39.9	4.6		6.1	

KA1630	47.3	5.2		6.5	
KA1640	28.9	3.6	14.9	4.5	14.9
KA1640	33.9	4.6	17.6	5.6	18.1
KA1640	36	4.9	21.3	5.9	18.7
KA1640	35.5	5	22.8	5.9	25.5
KA1650	26.4	3.9	17.8	4.1	26.5

Description: A large subhastate *Parahibolites* with a total length approximately 6 times the dorso-ventral diameter (Dvmax). The outline is symmetrical and slightly subhastate. The profile is asymmetrical and subhastate. The transverse sections are very compressed, sometimes the lateral sides become straight to slightly concave. The apex is acute. The lateral lines are clear the entire length of the rostrum, they are sometimes so well developed they produce the concave effect of the transverse section. No phragmocones were preserved in this species. The apical line has also not been observed.

Discussion: The typical dimensions shown here, of this species, are not of adults. These measurements are of juveniles. One incomplete adult specimen in this collection. This species is differentiated from *P. stoliczkai* and *P. blanfordi* by the exaggerated compression and the much broader profile.

Range: This species is only known from the Hito XIX Beds of Tierra del Fuego, Argentina (Stolley *in* Richter, 1925; Camacho, 1949; Stevens, 1965; Doyle & Pirrie, 1999; Doyle *et al.* in press) and now from the Uttatur of southern India. There has been some debate over the age of this species, an Aptian age is suggested by Stolley in Richter (1925), Macellari (1979) and Doyle *et al.* (in press), but an Albian age is suggested by Camacho (1949) and Doyle and Pirrie (1999).

Parahibolites blanfordi (Spengler, 1910)

Plate 4, figs 4-5; Plate 12, figs 1-2.

Synonomy:

non 1845 *Belemnites fibula* Forbes, p.119, Pl.9, fig.3.

1861 *Belemnites fibula* Forbes, Blanford, p.63, Pl.1, figs 13, 16-19, 23-38.

1865 *Belemnites fiblua* Forbes, Stoliczka (in Blanford and Stoliczka, 1861-65), p.201.

non 1897 *Belemnites* sp. (= *Belemnites fibula*) Forbes, Kossmat, p.87, Pl.7, fig.7.

1910 *Belemnites (Psuedobelus) blanfordi* Spengler, p.155, Pl.12, fig.6; Pl.14, fig. 6.

1920 *Parahibolites blanfordi* (Spengler), Bulow-Trummer, p.164.

1985 *Parahibolites blanfordi* (Spengler), Doyle, p.26, text fig. 2b-d *non* 2a.

Diagnosis: Small, slender subhastate to cylindrical *Parahibolites*. Outline symmetrical, cylindriconical. Profile asymmetric, subhastate, venter weakly inflated to inflated. Transverse sections compressed, eliptical to subquadrate. Ventral alveolar groove short. Lateral lines form shallow depressions in the rostral flanks (Doyle, 1985).

Type Specimens: Lectotype designated by Doyle, 1985, the original of Spengler (1910), Pl. XIV, fig. 16.

Locality and Material: 132 specimens from Karai Formation, Cauvery Basin.

Typical Dimensions:

Parahibolites blanfordi					
SAMPLE NO.	**L**	**Dvmax**	**Dlmax**	**xv**	**xl**
ka860	47.6	5.5	5.4	27.1	27.9
ka1020	44	6	5.6	36.5	34.8
ka1200	43.5	7.7	7.3	30.2	27.9
ka1260	40.7	5	4.5	31.7	25.3
ka1480	33.7	4.7	4.3	27.8	28
ka1490	37.4	4.8	4.3	30	26.7
ka1490	37.3	5	4.6	32.3	24.5
ka1500	50	6.8	6	41.6	42.2
ka1760	41.2	5.2	4.9	23.8	23.4

Description: Medium sized *Parahibolites*, slender, cylindrical, with a total length approximately 7.4 times the maximum dorso-ventral diameter (Dvmax). The outline and profile are similar, cylindrical to slightly conical at the alveolar end, and symmetrical. Transverse sections are compressed. The apex is very acute Ventral alveolar groove short. Lateral lines are clear on all specimens. There are no phragmocones preserved in these specimens. The apical line is ortholineate.

Discussion: *Parahibolites blanfordi* is much more slender and elongate than *P. stoliczkai*, having a more acute apex and longer rostrum.

Range: Found throughout the Southern Hemisphere in the *Stoliczkaia dispar* zone, Late Albian of southern India (Glaessner, 1943), Antarctica (Doyle, 1985), southern India (Stevens, 1965; Doyle, 1985) and New Guinea (Glaessner, 1945).

Family **DIMITOBELIDAE** Whitehouse, 1924

Diagnosis: The family Dimitobelidae contains those cylindrical and clavate belemnites provided with lateral grooves on the anterior portion of the rostrum, but devoid of antero-ventral or apical grooves.

Tetrabelus Whitehouse, 1924

Type Species: (by original designation) *Belemnites seclusus* Blanford, 1861.

Diagnosis: Hastate belemnites provided with dorso-lateral grooves and lateral lines, but having in addition, independent ventro-lateral grooves (Whitehouse, 1924). Small, moderately robust to slender, hastate to cylindriconical, compressed Dimitobelidae. Outline symmetrical, subhastate to cylindriconical. Apex acute. Profile asymmetrical to nearly symmetrical, hastate to cylindriconical. Venter commonly inflated to very inflated. Transverse sections compressed to very compressed, subquadrate to pyriform. Two pronounced ventro-lateral alveolar grooves with splitting surfaces extend adapically for one third of the rostrum. Ventro-lateral grooves straight in alveolar region, becoming shallow and curving ventrally. Dorso-lateral depressions presents. Lateral lines (Doppellinien) close to and parallel with the dorsum, extending adapically from the dorso-lateral depressions. Fine striae may be present on venter and dorsum. Phragmocone penetrates one quarter to a third of rostrum, ventrally deflected. Apical line ?goniolineate to ?cyrtolineate. (Doyle, 1985).

Discussion: Glaessner (1958) and Stevens (1965) both argue that *Tetrabelus* should not be a separate genus, and that it should belong to that of *Dimitobelus* on the grounds of the ventro-lateral grooves, dorso-lateral depressions and lateral lines. However, Doyle (1988) has confirmed its separate identification. *Tetrabelus* is clearly as species in its own right due to its compression, whereas *Dimitobelus* is depressed.

Range: As with all the Dimitobelidae, *Tetrabelus* is only to be found in the Southern Hemipshere from the Aptian-Albian (Doyle and Bennett, 1995) of Antarctica and southern India (Doyle, 1988). Some relict specimens may have survived into the Cenomanian of southern India (Doyle, 1988).

Tetrabelus seclusus (Blanford, 1861)

Type specimen: No type specimen was designated by Blanford (1861), lectotype, the original of Blanford fig. 44, was subsequently designated by Doyle (1985).

Diagnosis: Small hastate *Tetrabelus*. Outline symmetrical, subhastate to hastate. Venter inflated. Transverse section compressed elliptical to rounded, subquadrate, pyriform in alveolar region. Ventro-lateral alveolar grooves display sharp ventral curvature in stem region. Dorso-lateral depressions broad.

Discussion: Blanford and Stolitzka (1861-65) recognised that a new species *Belemnites seclusus* was only found in India (at the time). Nothing like it has ever been found in the Northern Hemisphere. This species was to become known as *Tetrabelus seclusus* when Whitehouse (1924) introduced a new family of belemnites, Dimitobelidae, although Stolley (1919) and Bülow-Trummer (1920) suggested that *Belemnites seclusus* was probably a member of Stolley's genus *Parahibolites.* However, the ventral groove distinguishes it from this genus (Doyle, 1985). Glaessner (1957, 1958) discussed the significance of the genus *Tetrabelus*, remarking that it it could not be a genus in its own right, and that it is a subgenus of *Dimitobelus*. However, *Tetrabelus seclusus* has recently been described from James Ross Island of Antarctica by Doyle (1985), placing the species firmly into the genus *Tetrabelus*, not *Dimitobelus*. *Dimitobelus* is a depressed dimitobelid, whereas *Tetrabelus* is markedly compressed (Doyle, 1988). Some of the specimens in this collection have more pronounced mucros, and some may be more slender than others.

Range: Found in the Aptian-Albian of Antarctica (Doyle, 1988) and southern India (Stevens, 1965; Doyle, 1988) and the Albian of the Malagasy Republic (Lemoine, 1906).

Tetrabelus seclusus seclusus s.s. nov.

Plate 4, figs 8-9; Plate 5, figs 1-8; Plate 7, figs 8-9; Plate 8, figs 1-9; Plate 9, figs 1-2.

Synonomy:

1861 *Belemnites seclusus* Blanford, p.4, Pl. I, figs 43-46, 48-51, Pl. II, fig. 8.
1865 *Belemnites seclusus* Blanford, Stolitzca, p.202.
1910 *Belemnites seclusus* Blanford, Spengler, p.153, Pl. XIV, fig. 7.
1920 *Parahibolites* (?) *seclusus* (Blanford), Bülow-Trummer, p.166.
1924 *Tetrabelus seclusus* (Blanford), Whitehouse, p.413, fig. 4.
?1985 *Tetrabelus seclusus* (Blanford), Doyle, p.29, text fig. 5a.
?1987 *Tetrabelus seclusus* (Blanford), Doyle, p.156, Pl.21, figs 3-6.

Diagnosis: *Tetrabelus seclusus* with elongated straight mucro, positioned centrally on the apex.

Type Specimens: Pl. 5, figs 3-4.

Locality and Material: 542 specimens from Karai Formation, Cauvery Basin.

Typical Dimensions:

Tetrabelus seclusus seclusus SAMPLE NO.	L	DLMAX	XL	DVMAX	XV
KA 10	25	6	10.3	6.4	11
KA 40	27.3	6.6	13.1	6.2	11.6
KA280	25.4	6.4	11.5	6.1	11.5
KA290	18.8	4	6.9	5	8
KA390	19.7	4	8	4.2	8.4
KA610	28.5	6	14	6.4	11.5
KA610	29.3	5.4	11	6	11.7
KA610	29	5.4	14	5.6	12.2
KA610	23.4	4.2	10.4	4.9	10.9
KA610	21.9	4.4	10.4	5	7.9
KA610	16.9	3.3	8.6	3.8	7.9
KA610	28.1	5.4	12.8	5.5	12.5
KA610	23.2	4.7	10.3	5.1	9.6
KA610	27.1	6.8	14	6.9	14.2
KA610	26.6	5.7	11.1	5.6	14
KA610	28.9	5.3	12.9	5.5	12.4
KA620	31.4	7	15	8.1	14
KA620	28.3	5	11.3	5.5	11.8
KA620	21.6	4.8	9.3	5.5	9.6
KA620	23	4.6	9	5.2	9.4
KA620	24.9	4.9	11.1	5.3	10.5
KA620	25.5	4.5	10	4.9	8.5
KA620	27.6	4.7	11.7	5	11.6
KA630	25.8	4.1	8.2	4.7	9.5
KA630	22.1	3.6	8	4.1	9.3
KA680	29.9	4.3	7.8	4.8	7.7
KA690	19.6	3.6	7.7	4	7.3
KA710	19.9	3.7	7.8	4.1	7.2
KA710	23.4	3.6	7.1	4.1	7.7
KA710	21.4	3.5	8.5	4.3	8.9
KA720	20.6	3.5	8	3.9	8.7
KA720	17.9	3.5	10	3.6	7.8
KA730	23.5	3.9	9.2	4.5	8.9
KA730	20.8	3.5	7.2	4.1	7
KA740	20	3.4	8.5	3.9	8.7
KA740	20.1	3.5	6.5	4.3	6.6
KA740	20.2	3.5	7.9	3.9	6.9
KA740	25.7	4.3	12.4	4.8	10.7
KA740	22.3	4	9.7	4.3	8.7
KA750	21.4	3.4	9.4	4	7.3
KA750	23	4.1	13.1	4.5	11.3

KA750	18.7	3.5	8	4.1	8.5
KA750	22.4	3.5	8.5	4.3	7.9
KA750	20	4	8.7	4.4	8.9
KA750	19.7	3.7	9.2	4.2	9.3
KA750	19.1	3.7	8	4.3	6.7
KA750	19.8	3.1	9.9	3.6	7.4
KA770	22.3	3	9.5	3.7	8
KA770	20.1	3.6	7.9	4.3	8.4
KA770	28.5	4.6	10.5	5	9.3
KA770	21.7	3.4	7.3	3.9	7.5
KA790	21.8	3.1	6.8	4	7.6
KA800	22.7	3.4	8.3	4.5	7.3
KA810	28.5	5	10.3	6.2	10.4
KA810	23.9	3.6	6.3	3.9	6.9
KA810	22.1	3.8	7	4.3	7.9
KA810	29.7	5.8	12.8	6.1	9.9
KA810	23.6	5.2	11.8	5.5	10.4
KA810	22.1	5.2	11.5	5.8	9.1
KA810	29	5.9	10	6.2	11.6
KA820	25.3	5.5	10.7	5.8	9.1
KA820	28	3.6	8.1	3.9	8.2
KA830	24.4	4.3	10.4	5	9.4
KA830	19.5	3.7	7.1	3.9	8
KA830	28.4	4.9	9.7	5.2	9.1
KA830	24.9	4.6	11.9	4.9	12.4
KA830	20.8	4.7	9.4	5.4	10.5
KA830	22	4	7.3	4.9	8.9
KA830	18.9	3.4	9.1	3.6	8.5
KA830	20.6	4.5	8.4	5	8.6
KA840	19.9	3.5	7.6	4	6.7
KA840	24.9	3.3	8.1	3.9	9
KA840	23.5	4.1	12.7	4.6	8.5
KA840	21.4	3.7	9.9	4.2	7.9
KA850	24.2	5	11.9	5	11.8
KA850	22	4.6	9.8	5.2	8.7
KA850	22.1	4.6		5	
KA850	23.5	4.7	8.3	5.5	10.9
KA850	18	3.5	6.7	3.8	5.9
KA860	25.6	5.7	9.6	5.9	14.7
KA860	20.4	3.8	9.6	4.4	10.1
KA860	24.7	4.9	10.4	5.1	10
KA860	24.3	4.2	8.1	4.7	8.1
KA860	23.8	4.5	8.9	4.9	7.8
KA870	28.9	5.2	12.4	5.8	11.4
KA870	26.6	4.9	12	5.2	10.9
KA870	23.7	4.7	15	5.2	13.3
KA870	26	5	11.2	5.5	11.3
KA870	22.8	5	11.1	5.3	11.9

KA870	17.4	3.4		3.9	
KA870	24.5	5	9.4	5.7	9.5
KA870	23	4.7	11.2	5.3	10
KA870	29.3	5.4	13	5.8	7
KA870	19.6	3.8	9.3	3.9	7.8
KA870	30.3	5.5	9.6	6.4	9
KA870	20.6	3.7	8.1	4.3	8.1
KA870	21.3	4.5	10	4.6	8.9
KA870	22.9	4.9	12.3	5.5	9.9
KA870	21.4	4.5	8	5	10.1
KA870	18.9	4.3	8.7	4.5	6.9
KA870	20	3.5	7.6	4.2	8.3
KA870	18.9	3.8		4.1	
KA880	27.9	5.3	13.7	5.6	12.5
KA880	26.4	5.6		5.8	
KA880	21.1	3.5	7.4	4.1	6.8
KA880	18.5	3.8	9.3	4.4	8
KA880	25.6	4.6	11.5	5.1	9.6
KA880	22.2	4.6	9.9	5.2	9.4
KA880	27.1	5.1	12.4	5.3	10.1
KA880	26.8	5.4	11.3	5.9	8.8
KA880	22.3	5.5	10.6	6	9
KA880	26.6	5.1	12.3	5.7	11.5
KA880	23	4.6	9.1	5.1	8.8
KA880	20.4	3.4	8.9	3.7	7.2
KA890	27.9	4.9	15.5	5.2	15.8
KA890	22.2	4.7	9.6	5.1	9.1
KA890	22.3	5	8.6	5.6	8.5
KA890	25.5	5	12.7	5.5	11.2
KA890	24.6	5.2	11	5.5	11.9
KA890	22.8	4.3	9.1	4.8	7.9
KA890	26.5	5.4	9.4	6	8.4
KA890	19.9	3.8	7.6	4.1	7.7
KA890	17.6	4.3	7.8	4.7	7.3
KA890	25.7	5.3	9.8	5.4	8.2
KA900	20.9	4.7	7	5.1	8.3
KA900	23.7	5.2	8.2	5.5	7.9
KA900	19.5	4	7.8	4.5	10.6
KA900	24.9	5	9.4	5.5	10.2
KA900	25.7	5.5	12.2	6	10.5
KA900	31.9	5.7	12.8	6.2	13.1
KA900	25.4	4.9	10.6	5.2	8.4
KA900	17.1	3.9	9.1	4.2	7.1
KA900	17.6	3.1	6	3.3	6.2
KA900	25	4.3	11.5	4.7	9.8
KA900	22.7	4.1	9.8	4.6	6.7
KA910	18.6	3.1		4	
KA910	21.5	3.8	8	4.5	7.9

KA910	20.3	3.5		3.8	
KA910	20.1	3.7	7.9	4.1	8.6
KA910	31.8	5	13.3	5.7	14.8
KA910	18.4	3.7	5	4.4	7.6
KA910	22.8	4.2	10.5	4.9	9.3
KA910	21.4	4	9.6	4.6	10.2
KA910	22	3	5.6	3.6	7
KA910	24.3	4.9	10.3	5.4	9.3
KA910	24.5	4.6	8.9	5.3	6.9
KA910	18.7	3.3	5.2	3.8	5.8
KA910	22.2	5	9.1	5.9	7.8
KA910	23.7	4.5	9.8	4.7	8.1
KA910	24.6	4.9	8.5	5.2	8.3
KA910	26.5	4.9	11	5.4	10.2
KA910	25.7	4.5	12.1	5	11.6
KA910	21.5	5.1	8.7	5.4	8.7
KA910	19.5	3.3	7.2	3.6	6.9
KA910	24.9	4.4	8.8	4.9	9.3
KA910	24.9	5	13.1	5.4	11.2
KA910	31.2	5.6	12.6	6.4	12.5
KA910	22.6	4.3	8.5	4.7	7.3
KA910	22.7	4.7	10	5	8.1
KA910	19.9	4.5	9	4.8	9
KA910	23.3	5	10.3	5.5	10.1
KA910	26.5	4.8	11.5	5.5	10.9
KA910	22.3	4.8	9.2	5.3	10
KA910	24.1	5.1	8.5	6.7	9.3
KA910	19.2	4	8.8	4	5.9
KA910	19.8	4	7.4	4.6	7.4
KA910	21	4.9		6.4	
KA910	28.6	6.5	10.5	5.7	8.5
KA910	27.3	5.4	8.7	6	10.3
KA910	22.8	5.5	10.2	6	9.1
KA910	23.2	5		5.6	
KA910	23.7	5	9.1	5.5	6.9
KA920	25.4	5.1	8.2	5.5	7.8
KA920	24.8	5.1	10	5.5	8.9
KA920	24.6	4.3	7	4.6	8.9
KA920	21.2	4		4.7	
KA920	20	3.7	7.3	4.4	7.3
KA920	29.3	4.6	10.8	5.6	8
KA920	31.6	5	11.9	6.1	13.3
KA920	20.8	3.6	8.7	4	8.5
KA920	23.2	4.4	10.5	4.8	9.1
KA920	25.6	4.9	10.9	5.6	11.3
KA920	30.7	5.5	12.9	5.9	11.4
KA920	16.9	2.9	6.2	3.2	6.3
KA920	27.4	4.5		5.4	

KA930	22.2	3.7	3.7	4	7.2
KA930	23.6	4.1	9.7	4.6	7.3
KA940	27.3	5.6	13.7	5.8	10.5
KA940	26.6	5.4	10	6	9
KA940	23.2	4.5	8.6	5	9
KA950	29.3	5.3	10.9	5.7	10.1
KA950	24.2	3	10.6	4.9	9.3
KA960	24.9	4.4	10.9	4.9	9.7
KA970	26	5.6	13.2	6.2	14.2
KA970	32	5.2	14.3	6	14.2
KA970	32.2	5.2	12.1	5.2	9.4
KA970	28.2	5.4	12.5	6.1	11.2
KA970	28.7	4.8	11.4	5.4	9
KA970	25.4	4.7	9.6	5.5	10.4
KA970	24.5	5.6	10.6	6.3	9.1
KA970	24.4	4.5	9.9	5.1	10.1
KA970	27.2	4.8	8	5.1	11.6
KA970	21.3	3.5	10	4.2	7.6
KA980	29.9	5.8	11	6.2	9.7
KA980	22.7	4.2	7.7	4.8	7.8
KA990	20.2	4.9	8.4	5.3	7.4
KA990	21.2	4.1	7	4.9	6.7
KA1000	20.2				
KA1000	24	4.4	9.7	5	8.4
KA1000	26.9	4.8	10.5	5.4	10.5
KA1000	19.8	5.4	9.3	5.9	8.5
KA1010	28.7	5.7	12.4	5.8	11
KA1010	21.6	4.9	9.9	4.9	8.8
KA1010	25.9	5.8		5.7	
KA1010	23.6	6.5	11.7	6.2	10
KA1010	20.9	4.4	8.6	4.8	7.8
KA1010	32.8	5.9		5.9	
KA1010	22.1	3.8	7.2	4.1	7.3
KA1020	25.1	4.9		5.3	
KA1020	20.5	4.4	8	4.7	8.4
KA1030	24.5	5	8.2	5.4	8.9
KA1030	18.1	3.6	6.1	4.1	8.1
KA1040	17.8	3.7	7.1	4	6.8
KA1040	22.1	4.1	7.8	4.6	8.8
KA1040	21.9	4.9	10.6	5	8.4
KA1050	24.9	5		5.7	
KA1050	22	4.9		5.2	
KA1050	26	5	12.3	5.7	12.6
KA1050	23.3	4.5	9.2	5	9.6
KA1050	22.9	4.7	11.8	5.1	10
KA1050	21.7	4.3	9.2	4.8	8
KA1050	24.7	4	9.5	4.6	9
KA1050	22.4	4		4.8	

KA1050	22.9	4.1	9.6	4.3	7.9
KA1050	22.9	4.1	8.6	4.8	8.9
KA1060	25.2	4.1	10.5	4.9	11
KA1060	25.2	4.3	10.9	5	10.4
KA1060	23.4	4.6	11.1	5.5	12.6
KA1060	25	6.2	10.9	6.5	12.6
KA1060	29.6	5.7		6.4	
KA1060	21.2	3.7		4	
KA1070	24	5	9.9	5.5	10.8
KA1070	27	5.5	13.1	5.8	9.9
KA1070	26.9	4.6	14.8	5.6	11.2
KA1070	25.7	4.2	12.7	5	12.9
KA1070	30.3	6.3	11.5	6.8	14.3
KA1070	19	4	11.1	4.3	9.1
KA1070	22.2	3.9	10.6	4.5	12.4
KA1080	22.8	3.3	9.3	4.4	10
KA1080	19.5	3.2	7.9	3.8	10.3
KA1080	25.2	5.1		6.2	
KA1080	26.6	5.5	15.3	6.3	15.7
KA1090	24.3	5.2	12.9	5.9	11.6
KA1090	24.8	4.9	11.9	5.7	12.6
KA1090	20.6	4.2	10.9	5	12
KA1090	22.9	4.5	8.8	5.4	8.8
KA1090	25	5.2	15.6	5.9	13.4
KA1090	25.6	4.3	14.3	5.3	12.6
KA1090	21.1	3.9	9.6	4.8	10.1
KA1090	18.3	3.4	8.6	4.1	8.2
KA1090	20.4	4	7.2	4.8	7.3
KA1090	23.2	3.7	9.4	4.7	7.9
KA1090	21.3	4.1	8.7	5.2	9.3
KA1090	22	3.9		4.5	
KA1090	21	4.3	7.8	4.7	9
KA1100	20.7	3.8		4.5	
KA1100	17.1	3	7.7	3.7	8.2
KA1100	22.5	3.7	11.5	4.5	9.8
KA1100	19.7	2.9	8.6	3.7	8.8
KA1100	22.6	4.8	11	5	10.6
KA1100	21.4	3.6	7.6	4.3	8.2
KA1100	26.7	4.9	12	5.3	11
KA1100	27.7	4.9	13.3	5.7	12.5
KA1110	21.2	4.6	11	5.2	12.9
KA1110	20.8	3.9		4.7	
KA1120	22.8	3.9	9	4.5	10.6
KA1120	18.8	4	8	5	8.8
KA1120	29.5	6.4	16.5	7.3	13.7
KA1120	26	6	15.9	6.6	15.3
KA1120	23.1	5	12.9	5.9	11.7
KA1120	28.7	5.2	13.4	6.1	10.7

KA1130	21.1	4.3	7.3	5	8.8
KA1130	19	3	6.2	3.5	6
KA1130	17.8	3.7		4.3	
KA1140	20	4.1	11.7	5	11.9
KA1140	21.4	3.3	7.1	4.3	8.1
KA1140	17.3	3.2		3.9	
KA1140	23.6	3.8	10.5	4.5	10.4
KA1140	23.7	3.9	10	4.8	9.6
KA1140	21	4.3	10.9	4.9	10.2
KA1140	32.4	6.7	16	7.3	16.5
KA1140	19.4	4.1	9.1	4.5	7.8
KA1140	18.7	4.5	8	5.4	9.7
KA1150	24.8	4.7	12.2	5.5	12.7
KA1150	23.6	4.8		5.9	
KA1170	27.2	4.7	13.9	5.9	13.2
KA1170	18.6	3.2	8.5	4.6	9.4
KA1170	24.8	4.3	12.6	4.6	13.3
KA1180	28.4	4.3		5.2	
KA1180	27.4	3.7	10.8	4.8	10
KA1190	29.4	5	11.9	6.1	11.3
KA1190	16.4	3.6	7.1	4.6	6.9
KA1200	26.6	5.5		6.3	
KA1200	29.2	5.6	14.8	6.3	14.9
KA1210	18.5	3.6	8.9	4.3	8.5
KA1210	28.1	4.4	12.3	5.4	15.5
KA1210	35	6.1	16.6	7	16.8
KA1520	25.5	4.5	10.4	5.2	12.8
KA1530	25.7	4.5	10	4.9	9.6
KA1560	29.4	5	13.5	5.4	14.3
KA1590	22.1	3.8	8.7	4.5	7.1
KA1590	26.2	4.4	11.1	5.2	12.1
KA1620	26.4	4.8	12.2	5.2	11.3
KA1630	21.9	4.7	12	5	9.9
KA1640	17.8	3.7	8.4	4.3	8.5
KA1660	16.8	3.4	7.7	3.7	7.2
KA1660	18.6	3.4	7.6	4	7
KA1660	20.5	3.5	9.9	4.3	10.4
KA1660	20.1	3.5	9	4.5	11.7
KA1670	23.5	4	10.7	4.8	10.7
KA1670	22.6	4.7	11.9	5.2	10.2
KA1670	23.4	4.9	10.9	5.6	11.5
KA1670	25.5	4.9	13.4	5.7	13.6
KA1670	21.9	4.7	11.9	5	12.3
KA1670	25.4	4.9	13	5.6	14.3
KA1670	25.5	5.1	14.4	5.5	11.8
KA1670	18.4	3.9	9	4.3	8.9
KA1680	24.1	4.4	10.3	4.9	12.3
KA1680	18.4	3.7	7.4	4.4	7.5

KA1680	23.5	4.6	11.6	5.1	11.3
KA1680	25.4	5	11.5	5.6	13.8
KA1690	20.7	3.7	8.8	4.4	8.7
KA1700	24	3.4	9.1	3.8	8.4
KA1700	23.7	3.9	10.3	4.3	9.4
KA1700	23.2	4	9.6	4.6	9.9
KA1700	20.7	3.4	8.4	4	7.6
KA1720	25.3	4.2	15.9	5	14.5
KA1730	19.8	3.7		4.2	
KA1740	25.5	4.5	12	4.9	12.7
KA1750	19.4	4.5		4.9	
KA1760	20.8	5.4		5.8	
KA1780	18.8	4		4	
KA1780	21.6	3.4	12	4.3	10.6
KA1780	22	3.3	10.1	4	10.9
KA1780	23.1	3.7	10.6	4.1	11.1
KA1780	19.9	4.3	11.4	5.4	9.1
KA1780	21.3	4.3	10.3	5	10.4
KA1780	17.3	3.1	8.8	3.8	7.9
KA1780	18.7	3.2	9	3.6	9.1
KA1780	20.3	4.2	11.4	4.9	9.4
KA1790	30.4	5.2	15.4	5.8	13.7
KA1790	25.2	3.9	9.9	4.7	9.8
KA1790	20.1	3.6	9.9	4.4	10.2
KA1790	22.6	4.4	9.8	5.3	10.6
KA1790	21.8	4.5	11.3	5.2	11.1
KA1790	27.7	5	11.8	5.5	9.4
KA1790	27.8	6.3	13.1	6	10.9
KA1790	22.9	5	11.1	5.5	9.9
KA1790	20.5	4.5		4.9	
KA1800	22.6	4.5	8.7	5	8.9
KA1800	17.8	3.4	9	3.9	9
KA1800	24.2	3.7	11.6	4	9
KA1800	22.9	3.9	9.9	4.5	9
KA1800	23.3	5	12.9	5.9	11.4
KA1800	27.8	5.4	13.8	6.2	15.7
KA1810	23.9	4.6	11.7	5.3	11.4
KA1820	18.7	3.3	7.2	3.8	8.6
KA1820	22.8	3.8		4.2	
KA1820	17				
KA1830	24	4.6	11.6	5.2	10.5
KA1830	19.6	3.5	9.8	4.2	9.6
KA1830	21.7	4	9	5	9.9
KA1830	20.9	2.8	8.9	3.3	9.1

Description: Hastate rostrum is large for this genus, with a total length approximately 4.6 times the maximum dorso-ventral diameter (Dvmax). The outline differs from the profile in that the outline is hastate and symmetrical but the profile is hastate with a pronounced dorsal bulge in the apical region. Transverse sections are compressed, subquadrate to pyriform in the alveolar region, becoming oval to circular in the apical region. The apex is mucronate with a very defined and long mucro. Two prominent dorso-lateral grooves extend adorally 1/3 of the way from the alveolar end and continue dorsally. Two ventral-lateral furrows are faint and terminate approximately 1/6 of the way from the alveolar region. *Doppellinien* are evident in the alveolar region, but are not apparent toward the apex due to preservation detail. No phragmocone has been preserved in these specimens. The apical line is ortholineate.

Discussion: *Tetrabelus seclusus seclusus* has been distinguished due to its long, centrally positioned mucro. *T. seclusus lawrencei* has a long, dorsally pointing mucro.

Range: Found in the Aptian-Albian of southern India.

Tetrabelus *seclusus lawrencei* s.s nov.

Plate 5, fig. 9; Plate 6, figs 1-7; Plate 9, figs 3-5.

Synonomy:

1861 *Belemnites seclusus* Blanford, p.4, Pl. 1, fig. 47.

Diagnosis: Small to medium sized *Tetrabelus seclusus* with a dorsally upturned apex due to a bulge ¼ of the way from the apex on the venter, and a bulge a 1/3 from the apex on the dorsum.

Type Specimens: Holotype from the Uttatur Member, Cauvery Basin, southern India. Pl. 6, figs 6-7.

Locality and Material: 34 specimens from Karai Formation, Cauvery Basin.

Typical Dimensions:

Tetrabelus seclusus lawrencei					
SAMPLE NO.	**L**	**Dvmax**	**Dlmax**	**xv**	**xl**
ka610	22	5.9	5	11.1	11.5
ka880	25.8	6	5.3	12.5	12.2
ka880	25.9	5.6	5	11.7	10.3
ka880	21.5	4.1	3.9	9.2	8.4
ka880	24.4	5.7	5.1	9.8	11.2
ka880	23.5	4.3	3.7	9.9	10.4
ka890	28	6.5	5.4	10	10
ka890	21.9	4.3	3.9	8.2	7.8
ka890	25.3	5.6	5.2	9.1	9.7
ka900	21.7	5	4.2	9.7	9.2
ka910	19.4	4.3	3.8	6.3	8
ka910	24.9	4.9	4.6		
ka910	25.7	5	4.3	9.1	8.9
ka910	25.6	5.4	5		
ka910	26.4	5.8	4.8	12.8	11.4
ka910	26.7	5	4.4		
ka910	26.5	6.2	5		
ka910	20.9	4.4	3.8	8.1	7.8
ka910	20.6	4	3.4	8.8	8.8
ka910	29.6	5.9	5.2	10.8	10.7
ka910	19.9	3.6	3.2	7.2	6.9
ka910	21.8	4.1	3.5	7.3	7.6
ka920	18.4	4.8	3.9	6.8	7.1
ka940	24.4	4.6	4.3	11.1	9.9
ka1010	30	6.2	5.9	12.8	14.9
ka1690	28.1	5.8	5.5	12.6	13.4
ka1690	20	3.6	3.2	8.7	8.9
ka1800	27.2	5.5	5	11.8	13.9

Description: Small *Tetrabelus seclusus*, hastate, with a total length approximately 4.8 times the maximum dorso-ventral diameter (Dvmax). The outline is hastate and symmetrical. The profile has a ventral bulge approximately ¼ of the way from the apex and a dorsal bulge approximately 1/3 of the way from the apex this creates an apex which points towards the dorsum. Transverse sections are subquadrate to pyriform in the alveolar region and oval to subquadrate in the apex region. The apex is very acute with a prominent mucro which turns up toward the dorsum. Two ventro-lateral grooves are seen originating from the alveolar region, deflecting toward the ventral area and continuing to the apex. Two dorso-lateral furrows dissipate towards the end of the alveolus. *Doppellinien* (double lateral lines) are not observed. No phragmocones have been observed and the alveolar line is ortholineate.

Discussion: The subspecies created here is generally similar to *Tetrabelus seclusus* except that it has a peculiar apex. The dorsal side of the apex has a bulge a third of the way from the apex and the venter has a bulge a quarter of the way from the apex which characteristically turns the apex toward the dorsum creating an upturned bottle nose effect. Blanford and Stolitzka (1861-65) figured a specimen in their work, which resembles this new subspecies (Pl.1, fig. 47).

Range: Found in the Late Albian of southern India.

CHAPTER 5 – PALAEOGEOGRAPHY

5.1 BELEMNITES OF THE CAUVERY BASIN

The belemnites of the Cauvery Basin fall into two families, the Belemnopseidae (*Neohibolites* and *Parahibolites*) and Dimitobelidae (*Tetrabelus*).

The genera *Neohibolites* and *Parahibolites* are both known to range from the Aptian through to the Cenomanian (Christensen, 1976, 1992; Combemorel *et al.* 1981; Doyle, 1985, 1992; Mutterlose, 1988; Doyle and Bennett, 1995; Doyle and Pirrie, 1999). *Tetrabelus*, however, ranged from the Aptian of Antarctica (*T. willeyi* of Doyle 1988) through to the Late Albian of southern India (*T. seclusus seclusus* s.s. nov. and *T. seclusus lawrencei* s.s. nov.) and may continue into the Cenomanian of southern India (Doyle, pers. comm.). These specimens have been collected from the Albian, but no evidence has been found of belemnites from younger sediments from the Karai Clay Formation.

Neohibolites and *Parahibolites* are thought to be possible descendants of the earlier belemnopseid genus *Hibolites* (Mutterlose, 1988; Doyle and Pirrie, 1999), which dies out in the Early Cretaceous (Doyle and Pirrie, 1999). *Tetrabelus* has been closely associated with *Dimitobelus*, being interpreted incorrectly as a species of *Dimitobelus* by Glaessner (1958) and Stevens (1965). *Tetrabelus* is a direct descendant of *Dimitobelus* according to Whitehouse (1924). Doyle (1988) speculates that the family Dimitobelidae, and its Northern Hemisphere counterpart family Belemnitellidae, , both originate from a common ancestry in the Early Cretaceous (*Hibolites*), which concurs with the theory of Mutterlose (1988). However, Jeletzky (1966) proposed the Oxyteuthididae as being the ancestral stock for the Dimitobelidae.

There have been two separate collections of belemnites from the same location in the Karai Clay Formation (Fig. 5). The first collection is the basis of this study, with more than 3500 specimens, and the second was collected a year later by B. Hathway, with 1800 specimens. Both collections were considered relative to the stratigraphy. The first collection, when plotted against the stratigraphy (Fig. 12), shows an irregular pattern of appearance and disappearance of genera, which is replicated by the second collection of belemnites (Fig. 13) suggesting that it is stratigraphically significant.

However, there does not seem to be any connection between the lithology and the occurrence of the different genera or species, as the majority of the substrate was marl with only a few sandy levels.

A distinct trend is apparent in both collections with *Neohibolites* being present approximately 90% of the time throughout the formation forming a background to the fauna (Figs 12 and 13). There are three overlapping intervals throughout the formation, when all three genera are present. This overlapping appears to represent the cross over between the most abundant genera with the least abundant genera at the time. For example, from approximately 80m from the base of the section, through to 180m in the stratigraphy, *Neohibolites* and *Tetrabelus* are the most dominant genera with a few, if any, *Parahibolites* present (Figs 12 and 13). At about 180m, *Parahibolites* becomes more abundant in both collections and eventually becomes the dominant genus, whereas *Neohibolites* rapidly reduces in quantity, and *Tetrabelus* disappears altogether (see Figs 12 and 13). This pattern of generic abundance is almost cyclical, as the graphs show (Figs 12 and 13). This is demonstrated by an initial 'cross-over' interval, followed by *Neohibolites* and *Tetrabelus* dominance, a second 'cross-over' interval can be identified, enabling *Parahibolites* to become dominant, and a final 'cross-over' which has been recognised as a period of high stand (M. B. Hart, pers. comm..) followed by another *Neohibolites* dominated period, although this time *Tetrabelus* is lacking.

This generic pattern is not replicated by species abundances, although, *Parahibolites stoliczkai*, *Neohibolites minimus minimus* and *Tetrabelus seclusus seclusus* are the most abundant species/subspecies and occur whenever the respective genus is more dominant in the stratigraphy (Figs 14 and 15).

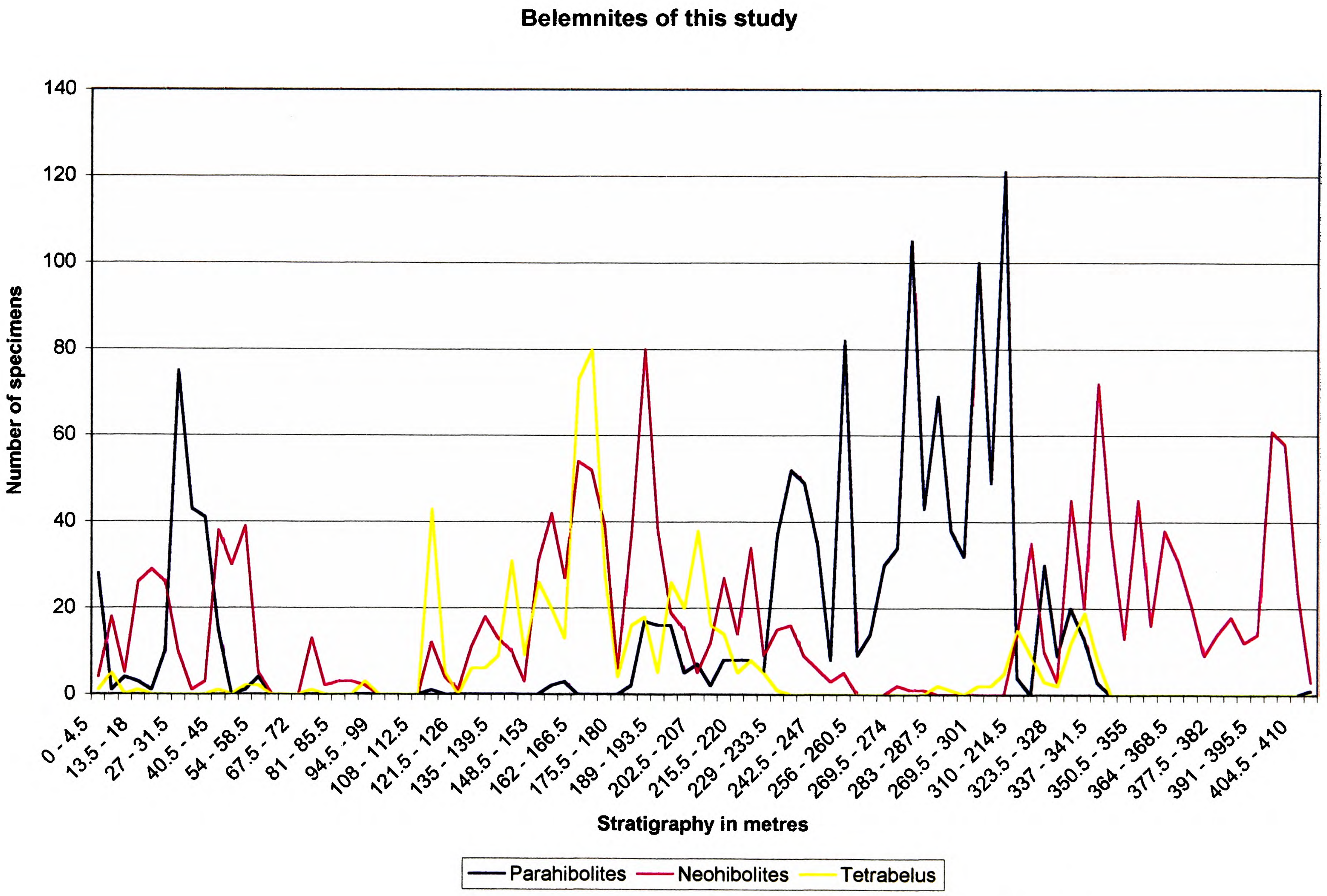


Fig. 12 The occurrence of belemnite genera in the Karai Clay Formation (this study).

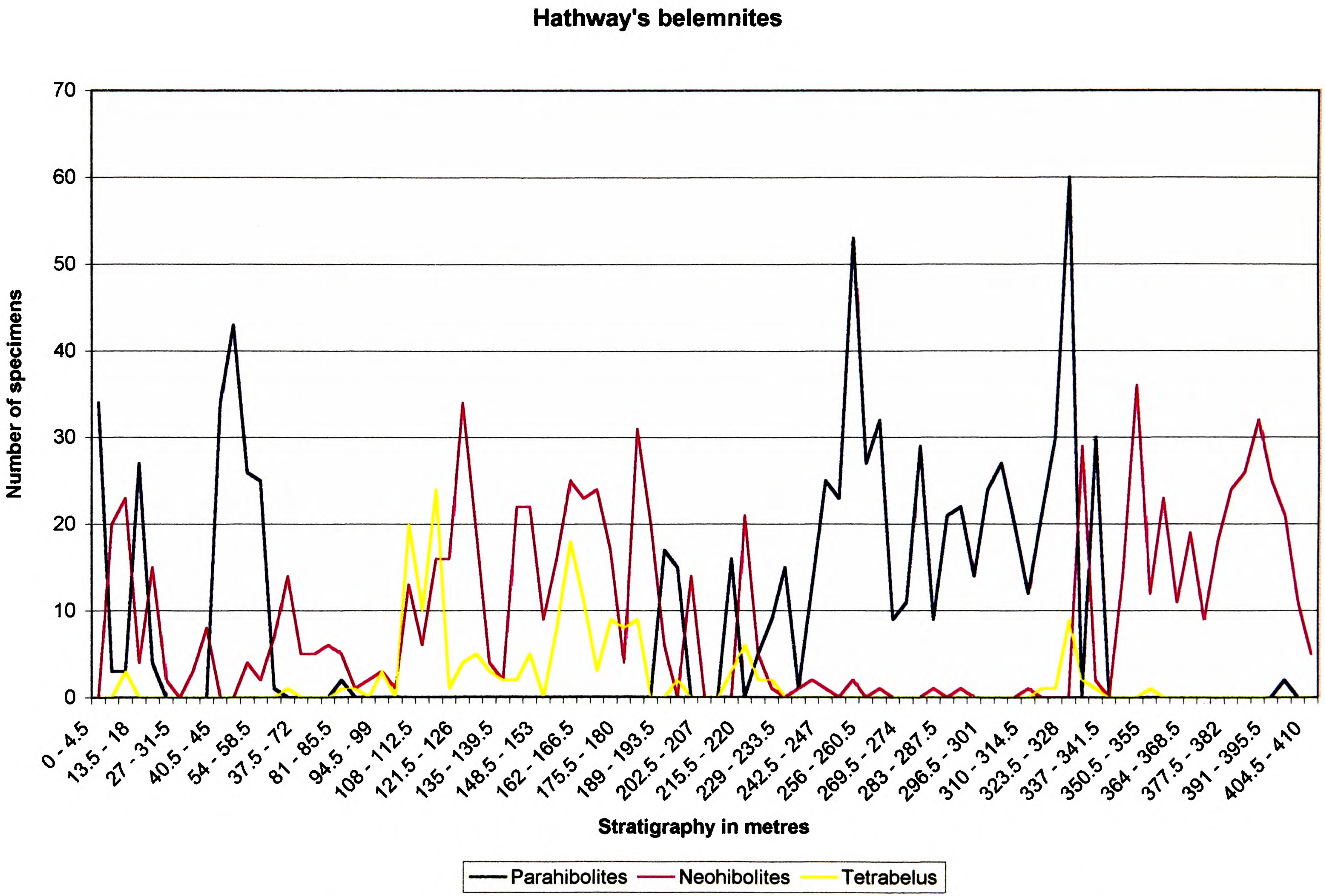
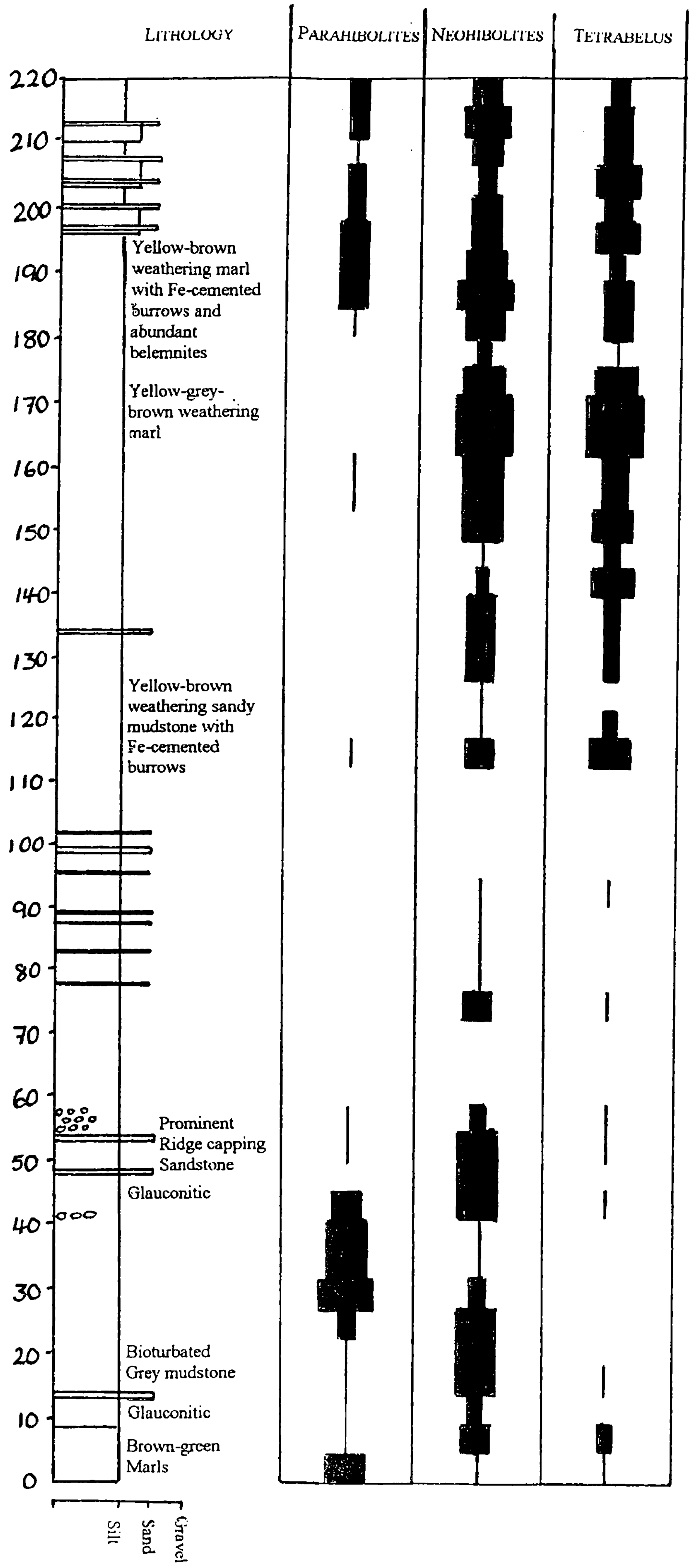


Fig. 13 The occurrence of belemnite genera in the Karai Clay Formation (B. Hathway collection).

ALBIAN OF THE KARAI FORMATION, NORTH SIDE OF KARAI-KULAKKALNATTAM ROAD.



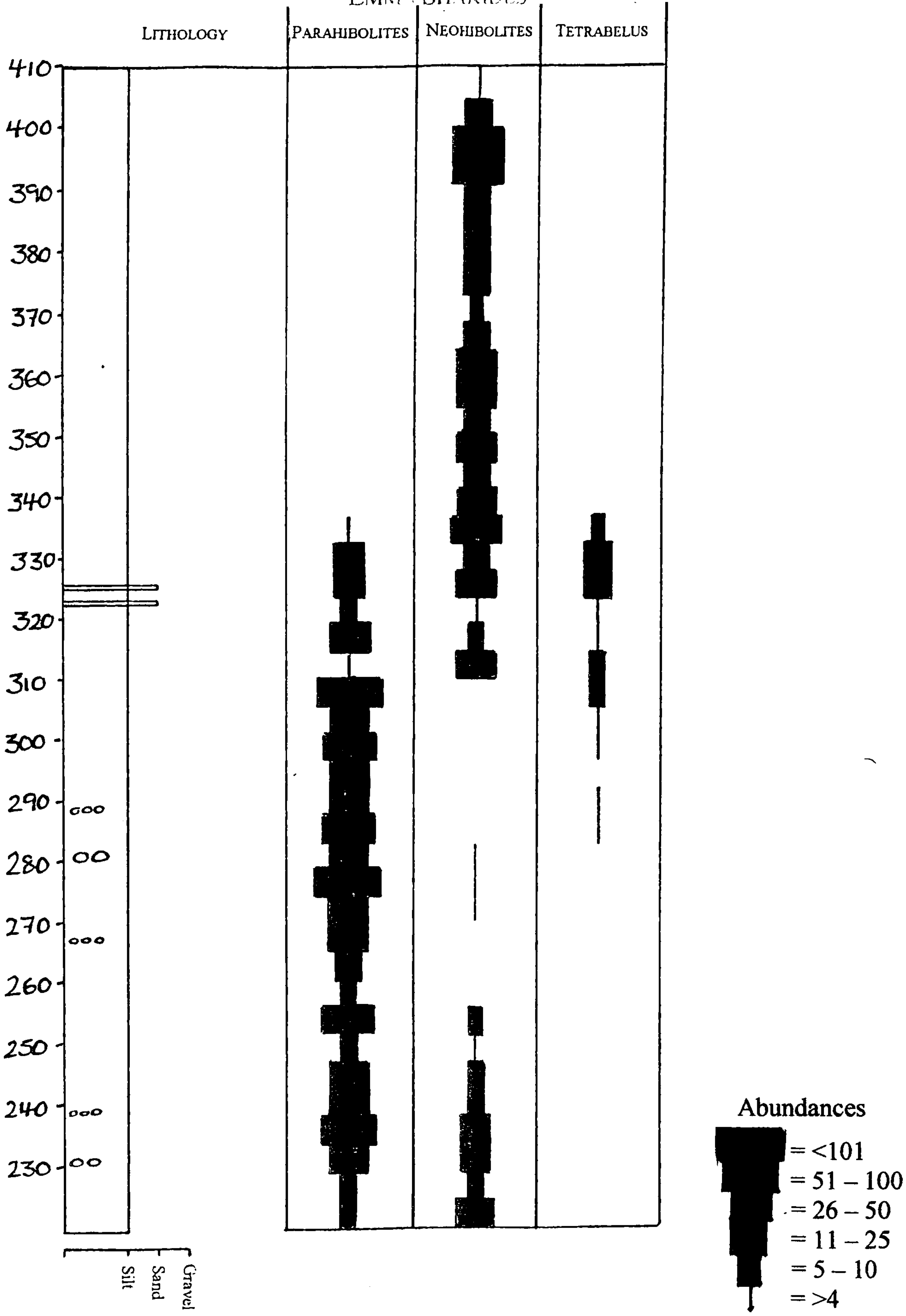
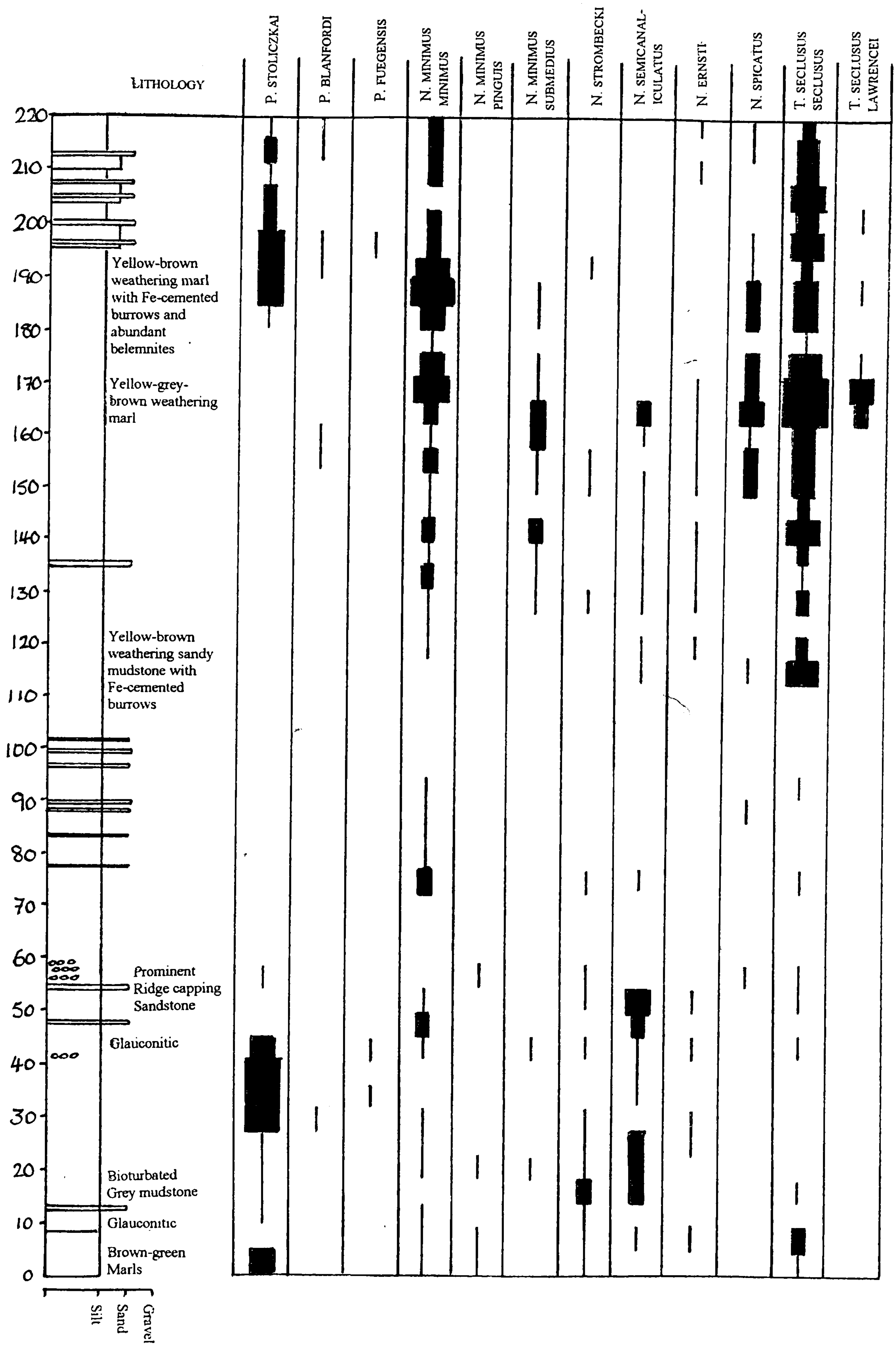


Fig. 14 The abundance of *Neohibolites*, *Parahibolites* and *Tetrabelus* in relation to the stratigraphy of the Karai Clay Formation (Log produced by B. Hathway, not published).

ALBIAN OF THE KARAI FORMATION, NORTH SIDE OF KARAI-KULAKKALNATTAM ROAD



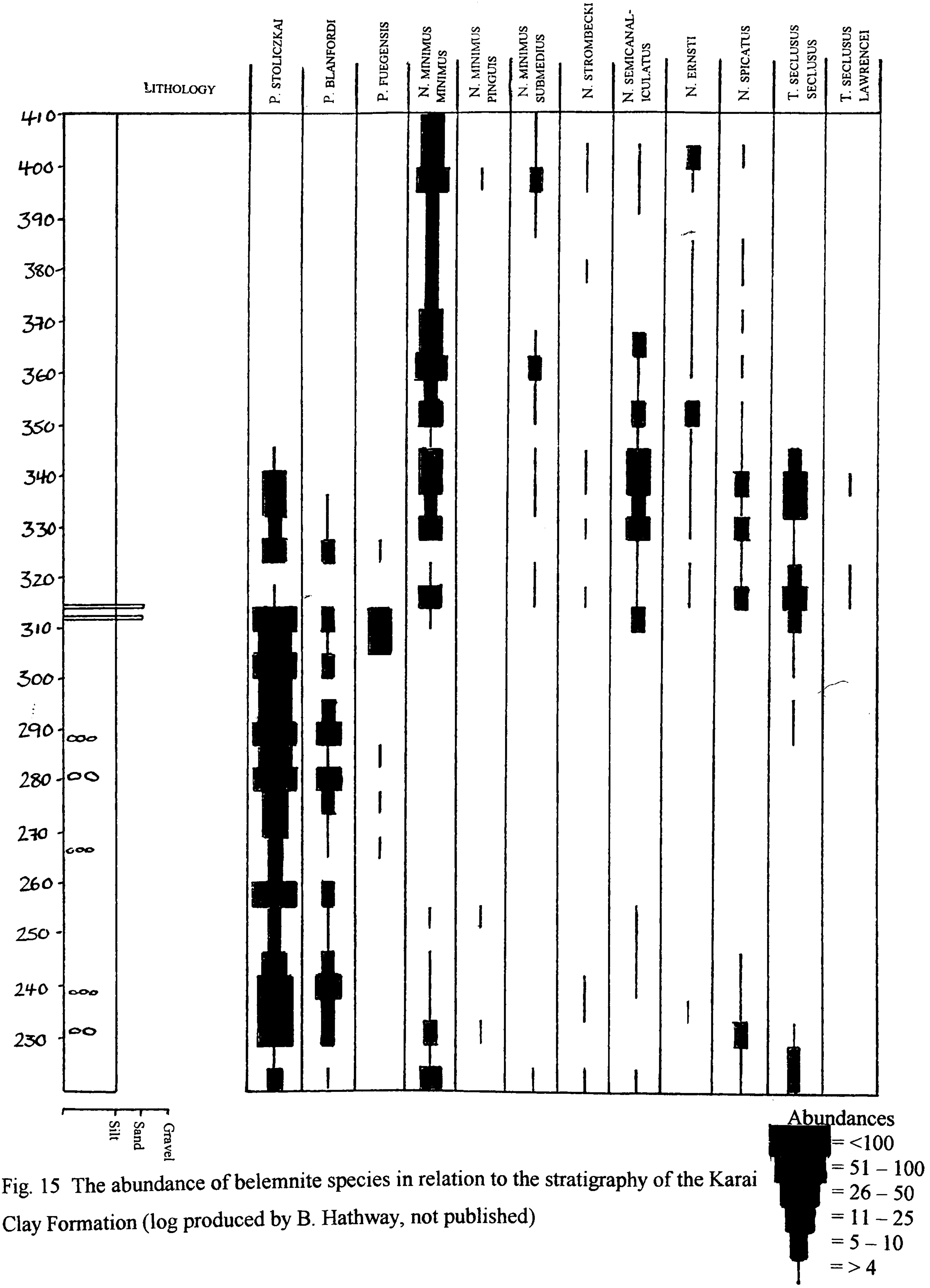


Fig. 15 The abundance of belemnite species in relation to the stratigraphy of the Karai Clay Formation (log produced by B. Hathway, not published)

5.2 PALAEOBIOGEOGRAPHY OF GONDWANAN BELEMNITES

Many studies have been carried out on the palaeobiogeography of belemnites (eg. Stevens, 1963, 1974; Combemorel *et al.* 1981; Doyle, 1987a, 1988, 1992; Doyle and Pirrie, 1999).

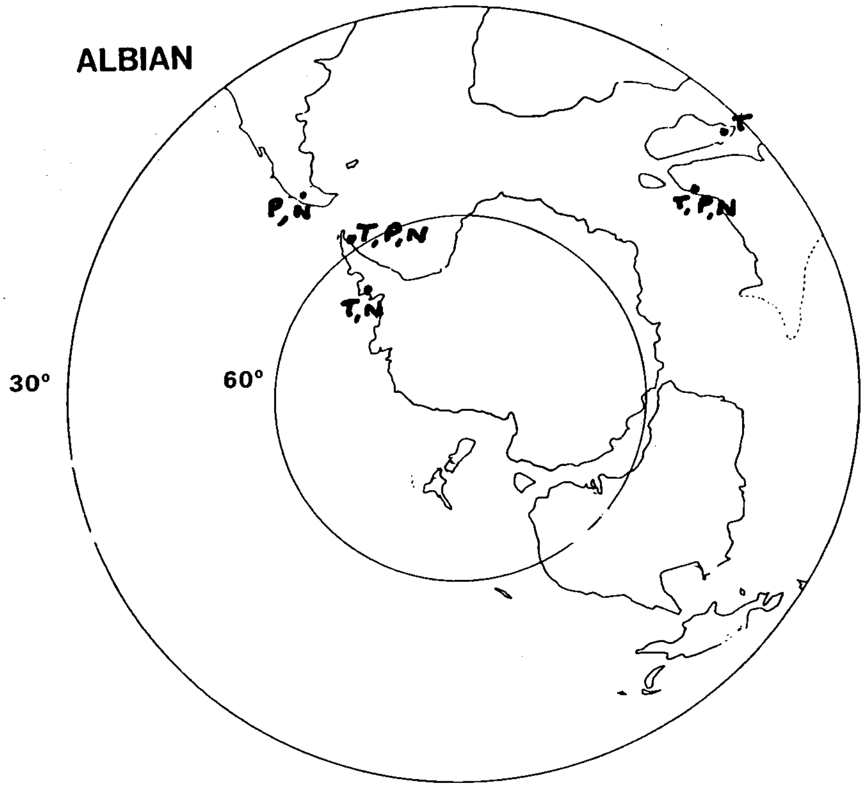


Fig. 16 Palaeogeographic map of the Albian (taken from Doyle, 1988) showing the locations of *Neohibolites* (N), *Parahibolites* (P) and *Tetrabelus* (T).

Faunal Realms were initiated in the Early Jurassic, and were best developed from the mid-Jurassic onwards (Doyle and Pirrie, 1999). The distribution of belemnites became worldwide in their distribution by the mid-Jurassic, with the development of the Boreal and Tethyan realms, and continued into the Cretaceous (Doyle, 1987a; Doyle and Pirrie, 1999). The Boreal Realm included Russia, through Central Europe, northern England, Greenland and North America (Stevens, 1963; Mutterlose, 1988) and was dominated by the suborder Belemnitina (Mutterlose, 1988). The Tethyan Realm was mainly situated over central and southern Europe, extending occasionally southward to east Africa, India, Madagascar and Australasia (Stevens, 1963), and is characterised by the suborder Belemnopseina (families Belemnopseidae, Duvaliidae and Dicoelitidae) (Mutterlose, 1988). The Boreal-Tethyan boundary was quite stable throughout the Jurassic, until the

Late Cretaceous, when the Tethyan belemnites became extinct, and the Boreal belemnites extended southward (Stevens, 1963).

Belemnopseid belemnites emerged in the Tethyan Realm during the Early Cretaceous, and during the Aptian, *Neohibolites* and *Parahibolites* were able to migrate both north into the Boreal, and south into the Gondwana shelf seas (Stevens, 1973; Doyle, 1985, 1987a; Combemorel, 1988; Doyle and Howlett, 1989; Doyle, 1992; Doyle and Pirrie, 1999).

The Tethyan belemnopseids *Neohibolites* and *Parahibolites* are characteristic of the Tethyan Realm (Christensen, 1976) but are also found globally (Stevens, 1963, 1965, 1974; Doyle, 1987a; Doyle and Pirrie, 1999). They are found throughout the world in rocks of Aptian to Cenomanian in age. During the Aptian, *Neohibolites* and *Parahibolites* make their first Gondwanan appearance in the Aptian of Argentina (*Parahibolites* and *Neohibolites*) (Doyle and Pirrie, 1999) and Antarctica (*Neohibolites*) (Stevens, 1965; Willey, 1973). Globally, they are found from Europe (Blanford and Stoliczka, 1861-65; Swinnerton, 1936-55; Spaeth, 1971, 1973; Stevens, 1965, 1974; Christensen, 1976, 1992; Combemorel *et al.* 1981; Doyle, 1985, 1987a, 1992; Doyle and Pirrie, 1999), through to India (Blanford and Stoliczka, 1861-65; Whitehouse, 1924; Stevens, 1965, 1974; Doyle, 1985, 1987a), Madagascar (Lemoine, 1906; Stevens, 1965, Doyle, 1987a), Mozambique (Doyle, 1987b), South America (Stolley, 1912, 1925 *in* Richter; Stevens, 1965; Doyle, 1985, 1987a; Doyle and Pirrie, 1999), Antarctica (Willey, 1973; Doyle, 1985, 1987a), Japan (Hanai, 1953; Stevens, 1965; Doyle, 1987a), and New Guinea (Glaessner, 1943; Stevens, 1965, 1974; Doyle, 1987a). Even though these genera are found throughout the world, they are not, however, found in the Aptian-Albian deposits of Australia and New Zealand (Stevens, 1965). Figure 16 shows the distribution of *Neohibolites*, *Parahibolites* and *Tetrabelus* in the Albian of the southern Hemisphere. The Cenomanian brought about the demise of *Neohibolites* and *Parahibolites*, making their last appearance in southern India, Argentina and the Malagasy Republic (Lemoine, 1906; Stevens, 1965; Doyle, 1988).

By the Aptian, two new, distinct faunal realms had been established (Mutterlose, 1988; Doyle and Bennett, 1995). The Belemnitidae of the Tethyan Realm were becoming extinct, being replaced by Boreal belemnites that were moving south (Stevens, 1963), and by the Cenomanian, the Tethyan Realm had disappeared. The remaining Boreal Realm was then characterised by the Belemnitellidae. In the Southern Hemisphere, at this time, the Austral Realm had developed and was characterised by the Dimitobelidae, a distinctive belemnite family that is only found in this realm. These belemnites continued into the Cenomanian, at which time they became extinct.

The formation of the Southern Hemisphere Austral Realm (Indo-Pacific Realm of Stevens (1963) and Mutterlose (1988)) in the Early Cretaceous was initiated by the break-up of Gondwana and its southward movement over the pole (Doyle and Pirrie, 1999). It encompassed the Indo-Pacific region, including Indonesia, Australasia, East Africa, Antarctica, India and South America (Stevens, 1963).

The Dimitobelidae is peculiar to the Southern Hemisphere and typical of the Austral realm, being found in only the Gondwanan continents (Stevens, 1963, 1965; Doyle, 1985) of southern India (Blanford and Stoliczka, 1861-65; Glaessner, 1957; Stevens, 1963, 1965; Doyle, 1985), Australasia (Etheridge, 1902; Glaessner, 1943, 1957; Stevens, 1963), Antarctica (Willey, 1972; Doyle, 1985), New Guinea (Glaessner, 1943, 1957), South America (Blanford and Stoliczka, 1961-65; Whitehouse, 1924; Doyle, 1992) and New Zealand (Glaessner, 1957). According to Stevens (1965, 1973), dimitobelids were not found north of the 30° south palaeolatitude for the Aptian-Albian, at this time (fig. 16). The segregation of the dimitobelids of the Southern Hemisphere from the Northern Hemisphere (Stevens, 1963; Doyle, 1987a, 1992) can possibly be explained by the timing of their appearance, the creation of the Austral Realm and the dissolution of the Tethyan Realm (Stevens, 1963; Doyle and Pirrie, 1999).

Tetrabelus is known only from Antarctica, India and possibly Madagascar (fig. 16). So far, three species have been identified in Antarctica (Doyle, 1985, 1988), and to date, only one has been found from India (Whitehouse, 1924; Glaessner 1957, 1958; Doyle, 1985, 1988; Doyle and Pirrie, 1999). The two new subspecies identified here are known only from India. The species of *Parahibolites* described from Antarctica and India are endemic to the region (fig. 16) and differ from their European counterparts. This contrasts with the *Neohibolites,* which are essentially European. The fact that many European species of *Neohibolites* are to be found in the Karai Clay Formation of southern India suggests that there was an open shelf seaway from the failing Tethys to the newly forming Austral Realm before the middle Albian, which enabled the Tethyan, and later pandemic species to migrate south and congregate in Gondwana, joining the endemic species of *Tetrabelus* and *Parahibolites.* The first *Tetrabelus* recorded is from the Fossil Bluff of Antarctica (Doyle, 1988) in the Aptian. The Indian belemnites are possibly of Late Albian age and are different species from the Antarctic species, although, Doyle (1985) found two complete specimens of *T. seclusus* from James Ross Island, Antarctica in association with *Parahibolites blanfordi. T. seclusus seclusus* may have evolved from *T. willeyi* of Antarctica establishing a more robust form, before it travelled west along the seaway created by the break-up of Gondwana. Once arriving in its new subprovince (southern India), *T. seclusus seclusus* and *T. seclusus lawrencei* were evolved. *T. seclusus lawrencei* did not survive for long enough to establish itself, and has therefore, only been found in the Cauvery Basin. From the data established in this study, we can see clearly that *Neohibolites* and *Tetrabelus* seem able to co-habit, as did *Neohibolites* and *Parahibolites*, but, it seems, *Parahibolites* and *Tetrabelus* could not, as their rostra are never found together without *Neohibolites.*

5.2.1 *Causes of Provinciality*

Many causes of provinciality have been considered, such as climate control (Doyle, 1987a, 1992) as confirmed by oxygen isotope studies (Stevens and Clayton, 1971), currents (Doyle, 1987a), sea level changes (Hancock, 1969, 1989; Hancock and Kauffman, 1979; Hart *et al.* 2001; Gale *et al.* 2002), environmental unsuitability (Stevens, 1965; Doyle, 1987a). *Neohibolites* is known to be abundant in Europe as well as in Gondwana. This indicates that it is unrestricted in its distribution through a widespread migration from the Tethyan Realm to the Austral Realm and that this genus can tolerate varying climatic temperatures (Doyle, 1987a, 1992). Stevens (1963) was of the opinion that the spread of *Neohibolites* and *Parahibolites* from the Tethyan Realm in to the Austral Realm is not associated with climatic fluctuations, but that migration became possible during the Aptian-Albian due to the absence of physical barriers. According to Mutterlose (1987), *Neohibolites* has a wide temperature tolerance enabling this genus to migrate *en masse* into a faunal realm different from the one in which it originated. Throughout the Cretaceous it is thought that the temperature zones in both hemispheres were much wider than today, penetrating further north/south enabling belemnites that were restricted by temperature, to migrate further (Stevens, 1963), although (as pointed out above), this does not apply to *Neohibolites* and *Parahibolites* (Stevens, 1963). The association of *Neohibolites*, *Parahibolites* and *Tetrabelus* together, has been compared to that of tha Albian belemnite associations of James Ross Island, Antarctica (Doyle, 1985), except that *Neohibolites* is replaced by *Dimitobelus*. The same types of belemnite assemblages occur in Mozambique (Doyle, 1987b), Argentina (Doyle and Pirrie, 1999) and New Guinea (Glaessner, 1943, 1957, 1958). This indicates that there was free, trans-Gondwanan belemnite migration at this time (Doyle, 1985).

This new research into the Cretaceous belemnites of the Cauvery Basin has shown that belemnites played an important part in the faunal make-up of this basin. Many types of belemnites seem to have co-habited, although, *Tetrabelus* is not found without *Neohibolites* and never with just *Parahibolites* which may suggest that *Parahibolites* and *Tetrabelus* could not live together. The reasons for this are obscure. It is possible that successive migrations of *Parahibolites* led to the competitive exclusion of the smaller *Tetrabelus*. It is also feasible that such migration may be related to water mass changes, but this requires much further study, with particular emphasis on isotopic palaeotemperatures from skeletal carbonates.

CONCLUSION

- The Karai Clay Formation is made up of sediments dating from the Albian through to the Turonian. This research concentrated on the belemnites found in the Albian.
- Three belemnite genera were identified from the Albian of the Karai Clay Formation. Three species of *Parahibolites* and seven species of *Neohibolites* of the family Belemnopseidae, and two new subspecies of *Tetrabelus* of the family Dimitobelidae.
- *Tetrabelus* are only found in the southern Hemisphere, although *Parahibolites* and *Neohibolites* are to be found throughout the world's seas at this time (Albian).
- A generic pattern was observed, with *Neohibolites* being present approximately 90% of the time. *Parahibolites* and *Tetrabelus* never occur together without *Neohibolites* being present.
- Two overlapping intervals of genera have been observed within this stratigraphy. Further study needs to be carried out to explain why this has occurred, although it has been suggested that it appears at about the same time as a high stand. This may be the case as the different species and subspecies appearing at these intervals may tolerate living at different levels in the water column. For instance, *Tetrabelus seclusus seclusus* appears mainly on its' own, but during an overlapping interval (a high stand), *Tetrabelus seclusus lawrencei* is also present. Perhaps *Tetrabelus seclusus lawrencei* may require deeper water to live in than its counterpart.

To conclude, a number of important questions have been raised in this research, although, many have remained unanswered. Further research is needed to explain these.

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PLATE 1

1. *Neohibolites minimus minimus* (Miller, 1826), (x 1). Specimen number 2050/763. Lateral view, lateral lines are clearly seen, p. 49
2. *Neohibolites minimus minimus* (Miller, 1826), (x 1). Specimen number 2050/763. Ventral view, small alveolar groove seen, p. 49
3. *Neohibolites minimus minimus* (Miller, 1826), (x 1). Specimen number 2070/764. Lateral view, p. 49
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7. *Neohibolites minimus submedius* Swinnerton, 1955, (x 1). Specimen number 1810/714. Lateral view, this is a very slender subspecies of *Neohibolites minimus*, p. 53
8. *Neohibolites minimus submedius* Swinnerton, 1955, (x 1). Specimen number 1810/714. Ventral view, p. 53
9. *Neohibolites minimus pinguis* Stolley, 1911, (x 1). Specimen number 110/10. Lateral view, specimen exhibits very straight parallel sides, p. 52

PLATE 1

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PLATE 2

1. *Neohibolites minimus pinguis* Stolley, 1911, (x 1). Specimen number 110/10. Ventral view, p. 52
2. *Neohibolites minimus pinguis* Stolley, 1911, (x 1). Specimen number 110/10. Lateral view, p. 52
3. *Neohibolites minimus pinguis* Stolley, 1911, (x 1). Specimen number 110/10. Ventral view, p. 52
4. *Neohibolites semicanaliculatus* (Blainville, 1827), (x 1). Specimen number 1830/730. Lateral view, p. 55
5. *Neohibolites semicanaliculatus* (Blainville, 1827), (x 1). Specimen number 1830/730. Ventral view, the small alveolar groove is seen, p. 55
6. *Neohibolites ernsti* Spaeth, 1971, (x 1). Specimen number 2160/767. Lateral view, p. 59
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PLATE 2

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PLATE 3

1. *Neohibolites strombecki* Muller, 1895, (x 2). Specimen number 80/10. Lateral view, p. 57
2. *Neohibolites strombecki* Muller, 1895, (x 2). Specimen number 80/10. Ventral view, p. 57
3. *Neohibolites spicatus* Swinnerton, 1935, (x 1). Specimen number 1830/729. Lateral view, p. 60
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6. *Parahibolites stoliczkai* (Spengler, 1910), (x 1). Specimen number 1640/597. Ventral view, p. 62
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9. *Parahibolites stoliczkai* (Spengler, 1910), (x 1). Specimen number 1630/616. Lateral view, the double lateral lines are visible extending the full length of the rostrum, p. 62

PLATE 3

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PLATE 4

1. *Parahibolites stoliczkai* (Spengler, 1910), (x 1). Specimen number 1630/616. Ventral view, p. 62
2. *Parahibolites stoliczkai* (Spengler, 1910), (x 1). Specimen number 10/5. Lateral view, p. 62
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PLATE 4

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PLATE 5

1. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 1800/708. Lateral view, p. 71
2. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 1800/708. Ventral view, p. 71
3. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 1790/697. Lateral view, p. 71
4. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 1790/697. Ventral view, p. 71
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6. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 1820/715. Ventral view, p. 71
7. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 1790/691. Lateral view, p. 71
8. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 1790/691. Ventral view, p. 71
9. *Tetrabelus seclusus lawrencei* s.s. nov. (x 2). Specimen number 1800/703. Lateral view, p. 80

PLATE 5

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PLATE 6

1. *Tetrabelus seclusus lawrencei* s.s. nov. (x 2). Specimen number 1800/703. Ventral view, p. 80
2. *Tetrabelus seclusus lawrencei* s.s. nov. (x 2). Specimen number 1800/703. Lateral view, p. 80
3. *Tetrabelus seclusus lawrencei* s.s. nov. (x 2). Specimen number 1800/703. Ventral view, p. 80
4. *Tetrabelus seclusus lawerncei* s.s. nov. (x 2). Specimen number 610/28. Lateral view, p. 80
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6. *Tetrabelus seclusus lawrencei* s.s. nov. (x 2). Specimen number 910/182. Lateral view, p. 80
7. *Tetrabelus seclusus lawrencei* s.s. nov. (x 2). Specimen number 910/182. Ventral view, p. 80
8. *Neohibolites minimus minimus* (Miller, 1826), (x 1). Specimen number 120/12. Acetate peel of a lateral cross section showing an ortholineate apical line with resorption and a nadelspitze. P. 49
9. *Neohibolites minimus minimus* (Miller, 1826), (x 1). Specimen number 720/57. Acetate peel of a lateral cross section showing an ortholineate apical line which shows resorption. P. 49

PLATE 6

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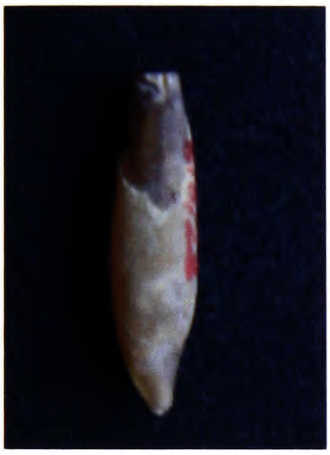

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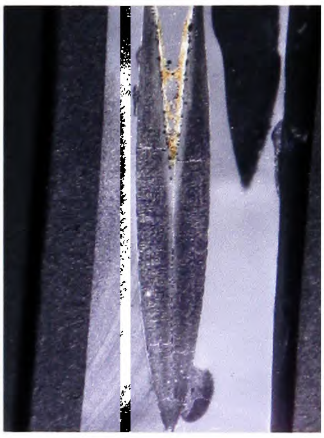

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PLATE 7

1. *Neohibolites minimus submedius* Swinnerton, 1955, (x 1). Specimen number 710/53. Acetate peel of a lateral cross section showing an ortholineate apical line which shows the resorption of calcite, and clearly visible are the major growth lines. P. 53
2. *Neohibolites minimus pinguis* Stolley, 1911, (x 1). Specimen number 20/3. Acetate peel of a lateral cross section showing an ortholineate apical line which shows signs of resorption, a nadelspitxe and the major growth lines are clearly visible. P. 52
3. *Neohibolites semicanaliculatus* (Blainville, 1827), (x 1). Specimen number 90/8. Acetate peel of a lateral cross section showing an ortholineate apical line with resorption and a nadelspitze. P. 55
4. *Neohibolites strombecki* Miller, 1895, (x 1). Specimen number 80/5. Acetate peel of a lateral cross section showing an ortholineate apical line with resorption. P. 57
5. *Neohibolites spicatus* Swinnerton, 1935, (x 1). Specimen number 820/91. Acetate peel of a lateral cross section showing an ortholineate apical line with resorption. P. 60
6. *Parahibolites stoliczkai* (Spengler, 1910), (x 1). Specimen number 175/17. Acetate peel of a lateral cross section showing an ortholineate apical line with resorption. A nadelspitze has formed and the major growth lines are visible. P. 62
7. *Parahibolites stoliczkai* (Spengler, 1910), (x 1). Specimen number 160/6. Acetate peel of a lateral cross section showing an ortholineate apical line. P. 62
8. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 710/53. Acetate peel of a lateral cross section showing an ortholineate apical line and radiating calcite prisms. P. 71
9. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 610/30. Acetate peel of a lateral cross section showing an ortholineate apical line with some resorption and radiating calcite prisms. P. 71

PLATE 7


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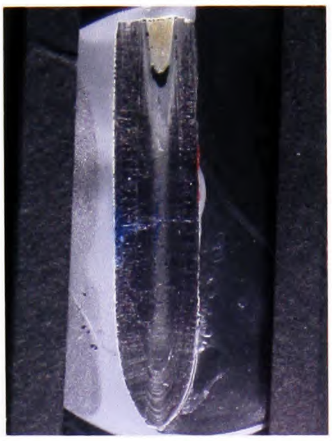
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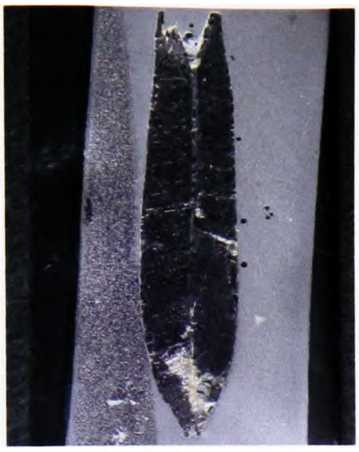
PLATE 8

1. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 40/5. Acetate peel of a lateral cross section showing an ortholineate apical line and radiating calcite prisms. P. 71
2. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 620/40. Acetate peel of a lateral cross section showing an ortholineate apical line and radiating calcite prisms. P. 71
3. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 830/92. A deformed rostrum in lateral view showing the double lateral lines. The rostrum has a deformed apex on the ventral side. P. 71
4. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 830/92. Ventral view showing the deformity and the dorso lateral grooves. P. 71
5. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 890/151. Deformed, p. 71
6. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 972/55. A lateral view showing a deformed alveolar region, p. 71
7. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 972/55. Ventral view of a deformed rostrum, p. 71
8. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 910/228. A lateral view showing the deformed alveolar which bends the alveolar region towards the venter, p. 71
9. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 910/228. A ventral view of a deformed *Tetrabelus*, p. 71

PLATE 8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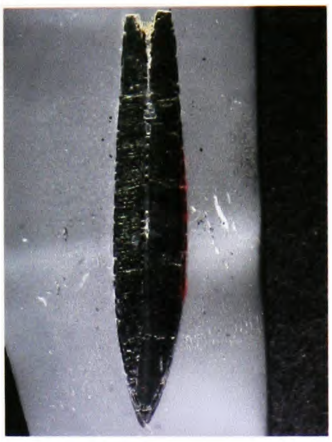
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PLATE 9

1. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 890/153. A lateral view showing that the alveolar region is deformed in this specimen, p. 71
2. *Tetrabelus seclusus seclusus* s.s. nov. (x 2). Specimen number 890/153. A ventral view of a deformed rostrum, p. 71
3. *Tetrabelus seclusus lawrencei* s.s. nov. (x 2). Specimen number 900/169. The lateral view of an injured *Tetrabelus*. The lateral groove is clearly seen and a prominent bite mark on the venter of the apical end. P. 80
4. *Tetrabelus seclusus lawrencei* s.s. nov. (x 2). Specimen number 900/169. The bite mark is clearly seen on the ventral view of this rostrum. P. 80
5. *Tetrabelus seclusus lawrencei* s.s. nov. (x 2). Specimen number 900/169. A close up of the ventral bite mark on this specimen. P. 80
6. *Neohibolites* sp. (x 2). Specimen number 180/10. Lateral view of a distinctly broken rostrum, perhaps broken in life and subsequently mended.
7. *Neohibolites* sp. (x 2). Specimen number 180/10. Ventral view.
8. *Neohiboltes minimus minimus* (Miller, 1826). (x 2). Specimen number 940/235. A lateral view of a very short, deformed rostrum. The alveolar groove is seen along with a bulge at the end of the alveolar region and at the apex of the rostrum. P. 49
9. *Neohibolites minimus minimus* (Miller, 1826). (x 2). Specimen number 940/235. A ventral view of the deformed rostrum. P. 49

PLATE 9

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PLATE 10

1. *Neohibolites minimus minimus* (Miller, 1826). (x 2). Specimen number 940/235. A view of the growth lines of this rostrum clearly show deformities during the life of this belemnite. P. 49
2. *Neohibolites minimus minimus* (Miller, 1826). (x 1). Specimen number 1000/321. A lateral view of a deformed rostrum showing a slight bulge midway along the rostrum. P. 49
3. *Neohibolites minimus minimus* (miller, 1826). (x 1). Specimen number 1000/321. A ventral view of the rostrum. P. 49
4. *Parahibolites stoliczkai* (Spengler, 1910). (x 2). Specimen number 1630/610. A lateral view of a deformed *Parahibolites* showing a swelling in the mid section of the rostrum indicating a desease or deformity during life. P. 62
5. *Parahibolites stoliczkai* (Spengler, 1910). (x 2). Specimen number 1630/610. Ventral view of the deformed *Parahibolites*, P. 62
6. *Parahibolites stoliczkai* (Spengler, 1910). (x 1). Specimen number 1370/535. A lateral view of a rostrum showing slight ridges along the ventral side. P. 62
7. *Parahibolites stoliczkai* (Spengler, 1910). (x 1). Specimen number 1370/535. Ventral view of the deformed rostrum, P. 62
8. *Parahibolites stoliczkai* (Spengler, 1910). (x 1). Specimen number 1620/587. A lateral view showing a deformed rostrum. P. 62
9. *Parahibolites stoliczkai* (Spengler, 1910). (x 1). Specimen number 1620/587. A ventral view showing a deformed rostrum. P. 62

PLATE 10

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PLATE 11

1. *Parahibolites stoliczkai* (Spengler, 1910). (x 1). Specimen number 1630/611. A lateral view showing a deformed rostrum. P. 62
2. *Parahibolites stoliczkai* (Spengler, 1910). (x 1). Specimen number 1630/611. A ventral view showing a deformed rostrum. P. 62
3. *Neohibolites minimus* (Miller, 1826). (x 1). Specimen number NHM. C.44579. Lateral view of the type specimen, p. 48
4. *Neohibolites minimus* (Miller, 1826). (x 1). Specimen number NHM. C.44579. Ventral view of the type specimen, p. 48
5. *Neohibolites minimus subnedius* Swinnerton, 1955. (x 1). Specimen number NHM. C.44710. Lateral view of the type specimen, p. 53
6. *Neohiboltes minimus submedius* Swinnerton, 1955. (x 1). Specimen number NHM. C.44710. Ventral view of the type specimen, p. 53

PLATE 11

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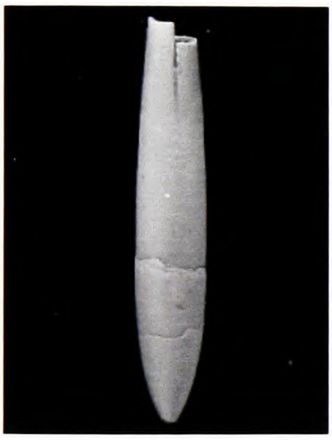

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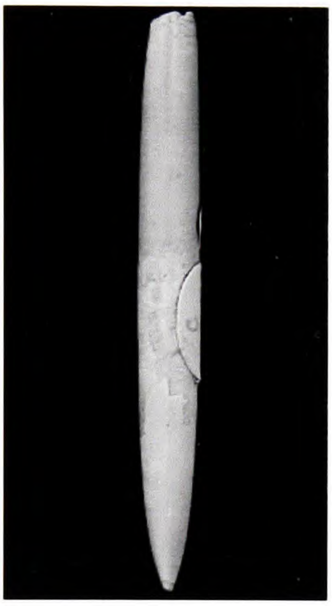

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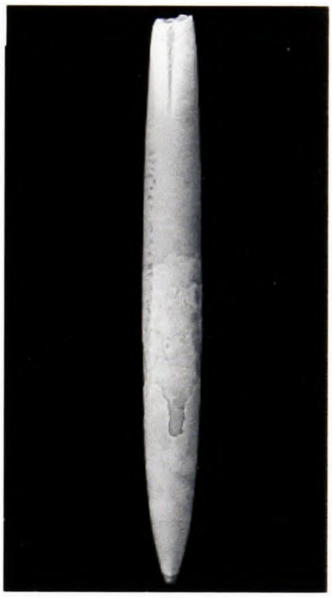

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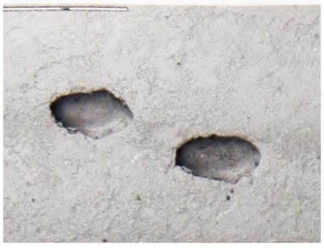
PLATE 12

These images of bore holes on the rostrums of certain belemnites were taken on the Scanning Electron Microscope (SEM) under a low vacuum of 10 pascals pressure at a working distance of 16mm. The images are compositional back scattered electron image with artificial shadow.

1. *Parahibolites blanfordi* (Spengler, 1910). (x 50). Speciemn number 1640/610. Two borings seen close together on the lateral side of the rostrum.
2. *Parahibolites blanfordi* (Spengler, 1910). (x 150). Specimen number 1640/610. A close up of one of the bore holes showing the concentric rings inside.
3. *Parahibolites stoliczkai* (Spengler, 1910). (x 50). Specimen number 1490/595. Two borings located on the lateral lines of this specimen. The lateral lines can be seen here.
4. *Parahibolites stoliczkai* (Spengler, 1910). (x 200). Specimen number 1490/595. A close up of one of the bore holes.
5. *Parahibolites stoliczkai* (Spengler, 1910). (x 50). Specimen number 1360/550. A different shaped bore hole into the rostrum.
6. *Parahibolites stoliczkai* (Spengler, 1910). (x 100). Specimen number 1360/550. This boring penetrates through an outer calcitic crust and the rostrum.
7. *Parahibolites stoliczkai* (Spengler, 1910). (x 150). Specimen number 1360/550. This bore hole penetrates through both the rostrum and the calcitic crust.
8. *Parahibolites stoliczkai* (Spengler, 1910). (x 35). Specimen number 1340/1. A cicular boring located in close proximity to the lateral lines (bottom of image).
9. *Parahibolites stoliczkai* (Spengler, 1910). (x 50). Specimen number 1340/1. A close up of the circular bore hole.
10. *Parahibolites stoliczkai* (Spengler, 1910). (x 150). Specimen number 60/1. A bore hole which has collapsed.
11. *Parahibolites stoliczkai* (Spengler, 1910). (x 35). Specimen number 60/1. A branching bore hole.

PLATE 12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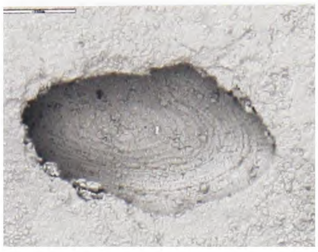
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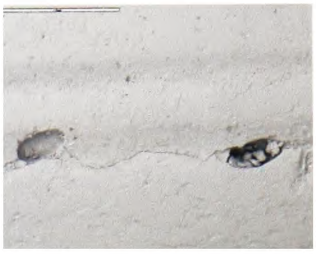
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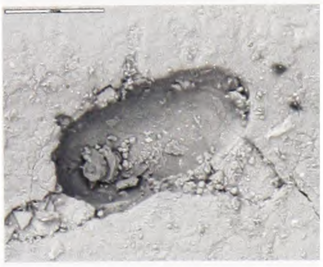
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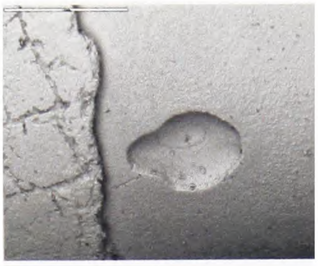
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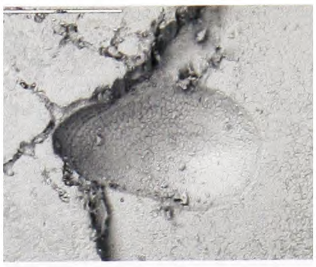
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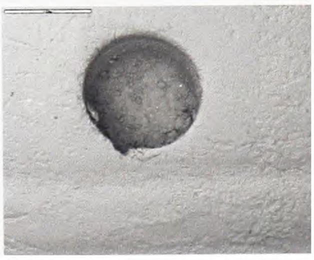
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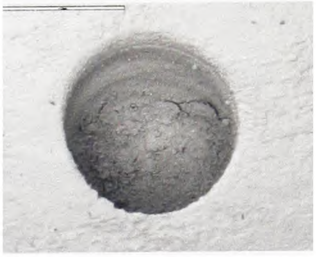
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APPENDIX 1

BELEMNITE MEASUREMENTS

Parahibolites stoliczkai				
L	Dlmax	Dvmax	xl	xv
44.5	8.6	10	20.5	17.6
49.5	7.3	9.1	30.8	36.8
38	7	8.8	30.7	30.8
44.9	6.2	6.7	18.7	23.5
50.5	7.1	7.7	23.8	27.5
42.3	5.9	6.1	25.8	23.3
40.7	5.7	6.1	25.2	27.9
45.1	7.2	7.9	32.5	33.3
45.5	6.2	6.6	28.4	33
48.7	7.8	8.9	33.4	37.5
37.3	5.6	6	22.7	20.6
42.3	7.8	8.7	17.7	17.8
45.7	6.5	7.6	23.4	30.8
42.4	7	6.6	24.8	17.9
45	6.4	7	22.9	21.2
47.3	6.3	7.5	26.6	27.4
40.6	5.9	6.6	27	25.9
40.5	6	6.6	26.2	23.7
46.5	6.2	7.2	21.6	29.7
48.4	6.3	7.1	28.7	25
44.8	6.6	7.3	25.5	24.4
38.1	5.5	6.1	22.4	21.2
53.7	8	8.8	32.5	28.5
37.7	4.6	5		
40.6	5.8	5.9	27.1	28.7
41.9	6.9	7.8	25.7	25.2
35.2	5	5.7		
46.9	9.7	10.4	34.1	31.3
45.4	6.3	6.7	26.4	23.6
43.2	6.3	7.1		
46.8	6.2	6.8	23.7	34.1
43.1	6.5	7.1		
40.2	5.8	6.1	25.2	22.8
39.3	5.9	7.2	26.1	24.5
42.3	6.1	7	20.7	24.2
43	5.6	6.2		
39.6	5	5.6	23.5	25.7
44.4	5.9	6.5	21.8	21.6
45.3	6.3	7	25.8	24.3
43.1	6.1	6.8	24.2	23.9
40.9	7	7.6	30.5	31.7
49.2	6.5	7.3	24.3	25.6
48.9	6.9	7.6	26.5	24.7
43.1	6.4	6.9		
48.9	6.5	7.3	25.9	24.3
41.8	7.3	9.1	30.5	25.9
50.9	8	9.3	27.3	26.2
43.7	7.5	8.5	23.9	26.7

43.5	7.2	8.2	29.8	30.9
49.6	7.4	8		
49.6	6.6	7.4	36.8	34.3
44.6	6.5	6.9	27.9	28.7
42.5	6	7	27.8	28.9
34.7	5.1	5.5	20.2	20.6
40.1	5	5.7	29.6	30.3
31.2	4.3	4.7	19.6	16
44.5	6.9	7.6	35.1	31.5
53.1	6.9	7.9	35.7	31.8
45.9	6.5	7.1	32.8	30.7
54.2	6.5	7.3	45.4	29.3
38.6	5.8	6.7	26.8	26
39.8	5	5.6	25.8	25.5
42	5	5.9	24.7	27.2
39.8	5.2	5.9	26.4	29.3
34.2	4.6	5	21.1	22.4
49.2	7.6	9.9	33.3	33.8
45.5	5.5	6.3	31.2	26.5
30.6	4.9	6		
27.5	4	4.8	17.4	16.6
41.4	5.7	6.5	28.4	26.9
34.9	5.2	6	19.4	22.3
46.8	6	6.8	23.4	23.8
34.3	4.9	5.7	20	19.1
42.8	5.7	6.9		
44.5	5.5	6.7	29.7	28.4
43.3	6.1	7.4	33.5	30.8
42.2	5.3	6.3	22.2	21.3
48.5	6.2	6.9	35	32.4
39.1	4.5	5.3		
44	5.6	5.9		
35.8	4.1	5.4	21.3	19.3
42.4	5.3	6.5	31.2	25.8
33.7	3.8	4.7		
45.5	5.7	7	28.6	28.9
26.3	3.6	4.3	18.2	26.9
35.1	5.1	6.6	23	20.9
41	5.7	6.9		
40.4	5.2	6	24.9	24.5
36.3	5	6.3		
39.4	5.2	6.2		
45.8	5.6	6.4	27.6	26.2
28.8	3.4	4.3	14.2	11.7
40.1	5.5	6.4		
36.9	4.8	5.7		
26	3.5	4		
36.8	5	5.8	26.6	23.7
42.8	5.4	6.4		
24.3	4.1	4.6		

32.6	4.7	5.3	18.7	16.9
32.7	5.1	6.1	19.1	19.7
30.5	4.8	5.5		
25.1	5.5	6.1	19.9	18.2
28	3.8	4.1	17.2	14.3
32.7	5	5.5		
43.4	6	7.2	32.1	35.4
33.6	5.1	6.1		
43.7	5.8	6.2	26.6	32.3
31.5	4.7	5	15.4	17.6
Parahibolites fuegensis				
L	**Dlmax**	**Dvmax**	**xl**	**xv**
30.8	5.9	7.3	25.4	23.5
34.5	4.8	5.8		
39.9	4.6	6.1		
47.3	5.2	6.5		
28.9	3.6	4.5	14.9	14.9
33.9	4.6	5.6	17.6	18.1
36	4.9	5.9	21.3	18.7
35.5	5	5.9	22.8	25.5
26.4	3.9	4.1	17.8	26.5
Parahibolites blanfordi				
L	**Dlmax**	**Dvmax**	**xl**	**xv**
47.6	5.4	5.5	27.9	27.1
44	5.6	6	34.8	36.5
43.5	7.3	7.7	27.9	30.2
40.7	4.5	5	25.3	31.7
33.7	4.3	4.7	28	27.8
37.4	4.3	4.8	26.7	30
37.3	4.6	5	24.5	32.3
50	6	6.8	42.2	41.6
41.2	4.9	5.2	23.4	23.8

Neohibolites minimus minimus				
L	**Dlmax**	**Dvmax**	**xl**	**xv**
28.7	8	7.9	20.4	24
32.6	5.8	5.9	17.9	17.8
30	6.3	6.5	17.9	17.6
39.3	8.2	8.8	19.5	19
25.6	4.4	4.6	11.4	13.5
43.6	9	8.3	21.9	36.8
46.6	7.8	7.3	27.8	32.4
42	7	6.8	23	23.6
36.2	6.1	5.9	16.4	16
35.3	6.8	6.2	16.6	15.5
29.4	4	4.3	19	20.3
34.4	5	4.9	15.4	17.9
34.5	7.2	6.9	22.4	22.5
32.8	5.5	5.7	7.9	16.7
44	7	7	31.6	30.5
41.4	5.5	5.7	25.4	25.7
49.6	6.6	7	29.3	34.6
45.5	7.3	7.3	31.1	29.4
43.3	5.8	6.1	23.9	35
39.7	5.2	5.5	29.9	28.3
43.9	6.4	6.5	29.1	28.3
40.7	6.7	7.2	25.8	27.2
46.1	7.1	7.8	20.5	23
49.3	7.2	7.7	23.2	25.6
37.8	6.4	7.3	21.6	21
41.4	8.8	8.6	23.6	26.4
43.1	6.2	6.7	26.8	28
47	7.5	7.3	27.4	29.5
44.6	7	6.9	23.7	32.8
43.2	6.4	6.5	26.1	28.5
46.6	7	6.8	31.4	29.9
41.7	6.4	6.6	21.4	23.7
41.8	7.2	7.1	24.3	26.7
44	6.7	6.9	23.9	23.2
35.4	4.4	4.9	18.5	18.2
34.9	4.6	4.9	15.5	18.1
37	5.3	5.7	17.8	18.5
33.5	5.2	5.4	21.1	24.1
36.5	5.9	6.2		
40.1	6.4	6.2	25	25.5
34.6	6.2	6.7	18.2	21.9
32.6	6.2	6.3		
28.4	6.7	7		
41.6	6	6.1		
35.6	7.5	7.4		
35.5	6.6	6.5	19.3	17.7
34.7	6.2	6.6		
39.4	6.5	6.7		

28.7	5.4	5.5	15.7	13.9
28.8	5.5	5.8	10.5	10.9
30.9	5	5	16.3	16.8
37.7	6.7	6.6	22	24
37.4	6.7	6.4		
28.2	5.4	5.4	18.9	17.8
40.8	7	7.3	22.6	27.1
39.9	7.2	6.9	23	25.4
38.8	7.2	7.3	21.7	23.3
31.6	5.9	6	19.1	16.8
35.9	7.6	7.1		
27.2	4.3	4.5		
23.2	4	4		
25.5	5.4	5.4		
31.2	6	6.1		
33.8	6.3	6.2	22.6	20.1
32.6	6.3	6.2		
27.7	6.5	6.6	22.9	24.5
36.1	6.3	6.3	25.2	22.5
36.1	5	4.8	13.7	13.2
39.2	7	6.9	25.6	27.7
31.1	5	4.8	17.1	14.3
40.2	7.5	7.2		
23.2	4.4	4.2	15.2	14.4
28.9	5.6	5.8		
28.9	5.4	5.4		
Neohibolites minimus pinguis				
L	**Dlmax**	**Dvmax**	**xl**	**xv**
37.4	8.6	8.3	19.2	21.8
33.3	7.4	7	19.3	20.9
34.9	6.9	6.5	13.6	13.5
36.2	6.8	6.6	12.3	16.5
Neohibolites minimus submedius				
L	**Dlmax**	**Dvmax**	**xl**	**xv**
26.8	4	4	17.1	17.8
30.5	3.5	3.4	16.3	13.3
35.2	4.1	4.2	20.8	19.9
32.5	5.2	5.3	17.7	19.4
35.2	4	4.2	21.8	21.5
29.4	4.5	4.6		
24.6	4.2	4.4		
33.5	5.2	5.3	20.7	24.9

Neohibolites strombecki				
L	**Dlmax**	**Dvmax**	**xl**	**xv**
28.3	4.9	4.7	13.9	13.5
30.8	8.4	8	12.9	13
30.7	5.1	5	18.4	19.4
41.1				
43.3	4.5	4.6	18.1	16.3
Neohibolites semicanaliculatus				
L	**Dlmax**	**Dvmax**	**xl**	**xv**
43.7	8	8.2	26.3	28
51.9	8.4	8.9	32.1	30.4
41.2	7.7	7.7	21.9	21.4
36.9	6.5	6.5	20.7	16
45.8	7.4	7.1	22.5	21.1
47.4	9.9	10.8	29.2	30.9
49.4	8.2	7.9	29.3	35.9
33.2	5.2	5.3		
41	8.6	8.5	31	34.2
45.5	8.1	8.3	28.8	36.6
38.3	7.5	7.2	23	24.9
46.4	8.7	8.9	36.3	38.7
43.5	8.4	8.4	31.5	34.1
33.3	5.5	5.8	22.6	23
38.6	7.3	7.3		
44.9	7.1	7.2		
47.7	8.5	8.7	24.5	25.5
39.6	6.4	6.5		
37.7	7	7.2		
32.3	5.5	5.7		
36.5	5.5	5.6	20.4	19.3
40.5	7.6	7.6	31.9	31.2
40.6	7	6.9		
38	7.8	7.5		
32.8	4.8	5	28.9	23.5
31.4	4.4	4.6	17.3	14.6
31.6	5.3	5.6	17.9	17.8
29.4	4.6	4.9		
32.6	4.6	4.6	19.4	17.8
45.5	8.4	8.5	25.3	29
37	6.4	6.6	24.4	24.5
38.6	6.4	6.4		
45.5	6.9	7	21.6	32.8
48.5	9.5	9	30.2	31.9

Neohibolites ernsti

L	Dlmax	Dvmax	xl	xv
26.2	4.9	4.6	14	14.4
36	6.7	6.4	21.5	26.9
26.4	4.4	4.6	10	12.5
30	4.6	4.5	16.3	15.2
27	4.4	4.2		
30.7	6	6	17.5	17.9
25.4	3.9	4.1		
27.8	4.7	4.6	16.3	14
23.2	3.8	3.8		
28.4	4.8	4.6	16.2	16.2

Neohibolites spicatus

L	Dlmax	Dvmax	xl	xv
40.7	5.7	5.7	21.5	21.6
26.9	3.4	3.8	16.5	21.7
34.4	4.5	4.8	21.8	25.4
32.6	5	5.5	19.5	21.9
38.2	5.1	5.3	28.8	22
49.4	6.4	6.7	29.4	30.4
48.1	7	7.5		
42.3	5.9	6.1	30.8	30.1
40.8	5.3	5.5		
37.3	5.2	5.5	19.8	18.6
	5.8	5.9		
39.6	5.4	5.4		
36.6	4.8	4.9		18.9
33.6	4.3	4.7	19	21.3
30.3	73.8	77.3	20.3	231.9

Tetrabelus seclusus seclusus				
L	**Dlmax**	**Dvmax**	**xl**	**xv**
25	6	6.4	10.3	11
27.3	6.6	6.2	13.1	11.6
25.4	6.4	6.1	11.5	11.5
18.8	4	5	6.9	8
19.7	4	4.2	8	8.4
28.5	6	6.4	14	11.5
29.3	5.4	6	11	11.7
29	5.4	5.6	14	12.2
23.4	4.2	4.9	10.4	10.9
21.9	4.4	5	10.4	7.9
16.9	3.3	3.8	8.6	7.9
28.1	5.4	5.5	12.8	12.5
23.2	4.7	5.1	10.3	9.6
27.1	6.8	6.9	14	14.2
26.6	5.7	5.6	11.1	14
28.9	5.3	5.5	12.9	12.4
31.4	7	8.1	15	14
28.3	5	5.5	11.3	11.8
21.6	4.8	5.5	9.3	9.6
23	4.6	5.2	9	9.4
24.9	4.9	5.3	11.1	10.5
25.5	4.5	4.9	10	8.5
27.6	4.7	5	11.7	11.6
25.8	4.1	4.7	8.2	9.5
22.1	3.6	4.1	8	9.3
29.9	4.3	4.8	7.8	7.7
19.6	3.6	4	7.7	7.3
19.9	3.7	4.1	7.8	7.2
23.4	3.6	4.1	7.1	7.7
21.4	3.5	4.3	8.5	8.9
20.6	3.5	3.9	8	8.7
17.9	3.5	3.6	10	7.8
23.5	3.9	4.5	9.2	8.9
20.8	3.5	4.1	7.2	7
20	3.4	3.9	8.5	8.7
20.1	3.5	4.3	6.5	6.6
20.2	3.5	3.9	7.9	6.9
25.7	4.3	4.8	12.4	10.7
22.3	4	4.3	9.7	8.7
21.4	3.4	4	9.4	7.3
23	4.1	4.5	13.1	11.3
18.7	3.5	4.1	8	8.5
22.4	3.5	4.3	8.5	7.9
20	4	4.4	8.7	8.9
19.7	3.7	4.2	9.2	9.3
19.1	3.7	4.3	8	6.7
19.8	3.1	3.6	9.9	7.4

22.3	3	3.7	9.5	8
20.1	3.6	4.3	7.9	8.4
28.5	4.6	5	10.5	9.3
21.7	3.4	3.9	7.3	7.5
21.8	3.1	4	6.8	7.6
22.7	3.4	4.5	8.3	7.3
28.5	5	6.2	10.3	10.4
23.9	3.6	3.9	6.3	6.9
22.1	3.8	4.3	7	7.9
29.7	5.8	6.1	12.8	9.9
23.6	5.2	5.5	11.8	10.4
22.1	5.2	5.8	11.5	9.1
29	5.9	6.2	10	11.6
25.3	5.5	5.8	10.7	9.1
28	3.6	3.9	8.1	8.2
24.4	4.3	5	10.4	9.4
19.5	3.7	3.9	7.1	8
28.4	4.9	5.2	9.7	9.1
24.9	4.6	4.9	11.9	12.4
20.8	4.7	5.4	9.4	10.5
22	4	4.9	7.3	8.9
18.9	3.4	3.6	9.1	8.5
20.6	4.5	5	8.4	8.6
19.9	3.5	4	7.6	6.7
24.9	3.3	3.9	8.1	9
23.5	4.1	4.6	12.7	8.5
21.4	3.7	4.2	9.9	7.9
24.2	5	5	11.9	11.8
22	4.6	5.2	9.8	8.7
22.1	4.6	5		
23.5	4.7	5.5	8.3	10.9
18	3.5	3.8	6.7	5.9
25.6	5.7	5.9	9.6	14.7
20.4	3.8	4.4	9.6	10.1
24.7	4.9	5.1	10.4	10
24.3	4.2	4.7	8.1	8.1
23.8	4.5	4.9	8.9	7.8
28.9	5.2	5.8	12.4	11.4
26.6	4.9	5.2	12	10.9
23.7	4.7	5.2	15	13.3
26	5	5.5	11.2	11.3
22.8	5	5.3	11.1	11.9
17.4	3.4	3.9		
24.5	5	5.7	9.4	9.5
23	4.7	5.3	11.2	10
29.3	5.4	5.8	13	7
19.6	3.8	3.9	9.3	7.8
30.3	5.5	6.4	9.6	9
20.6	3.7	4.3	8.1	8.1
21.3	4.5	4.6	10	8.9

22.9	4.9	5.5	12.3	9.9
21.4	4.5	5	8	10.1
18.9	4.3	4.5	8.7	6.9
20	3.5	4.2	7.6	8.3
18.9	3.8	4.1		
27.9	5.3	5.6	13.7	12.5
26.4	5.6	5.8		
21.1	3.5	4.1	7.4	6.8
18.5	3.8	4.4	9.3	8
25.6	4.6	5.1	11.5	9.6
22.2	4.6	5.2	9.9	9.4
27.1	5.1	5.3	12.4	10.1
26.8	5.4	5.9	11.3	8.8
22.3	5.5	6	10.6	9
26.6	5.1	5.7	12.3	11.5
23	4.6	5.1	9.1	8.8
20.4	3.4	3.7	8.9	7.2
27.9	4.9	5.2	15.5	15.8
22.2	4.7	5.1	9.6	9.1
22.3	5	5.6	8.6	8.5
25.5	5	5.5	12.7	11.2
24.6	5.2	5.5	11	11.9
22.8	4.3	4.8	9.1	7.9
26.5	5.4	6	9.4	8.4
19.9	3.8	4.1	7.6	7.7
17.6	4.3	4.7	7.8	7.3
25.7	5.3	5.4	9.8	8.2
20.9	4.7	5.1	7	8.3
23.7	5.2	5.5	8.2	7.9
19.5	4	4.5	7.8	10.6
24.9	5	5.5	9.4	10.2
25.7	5.5	6	12.2	10.5
31.9	5.7	6.2	12.8	13.1
25.4	4.9	5.2	10.6	8.4
17.1	3.9	4.2	9.1	7.1
17.6	3.1	3.3	6	6.2
25	4.3	4.7	11.5	9.8
22.7	4.1	4.6	9.8	6.7
18.6	3.1	4		
21.5	3.8	4.5	8	7.9
20.3	3.5	3.8		
20.1	3.7	4.1	7.9	8.6
31.8	5	5.7	13.3	14.8
18.4	3.7	4.4	5	7.6
22.8	4.2	4.9	10.5	9.3
21.4	4	4.6	9.6	10.2
22	3	3.6	5.6	7
24.3	4.9	5.4	10.3	9.3
24.5	4.6	5.3	8.9	6.9
18.7	3.3	3.8	5.2	5.8

22.2	5	5.9	9.1	7.8
23.7	4.5	4.7	9.8	8.1
24.6	4.9	5.2	8.5	8.3
26.5	4.9	5.4	11	10.2
25.7	4.5	5	12.1	11.6
21.5	5.1	5.4	8.7	8.7
19.5	3.3	3.6	7.2	6.9
24.9	4.4	4.9	8.8	9.3
24.9	5	5.4	13.1	11.2
31.2	5.6	6.4	12.6	12.5
22.6	4.3	4.7	8.5	7.3
22.7	4.7	5	10	8.1
19.9	4.5	4.8	9	9
23.3	5	5.5	10.3	10.1
26.5	4.8	5.5	11.5	10.9
22.3	4.8	5.3	9.2	10
24.1	5.1	6.7	8.5	9.3
19.2	4	4	8.8	5.9
19.8	4	4.6	7.4	7.4
21	4.9	6.4		
28.6	6.5	5.7	10.5	8.5
27.3	5.4	6	8.7	10.3
22.8	5.5	6	10.2	9.1
23.2	5	5.6		
23.7	5	5.5	9.1	6.9
25.4	5.1	5.5	8.2	7.8
24.8	5.1	5.5	10	8.9
24.6	4.3	4.6	7	8.9
21.2	4	4.7		
20	3.7	4.4	7.3	7.3
29.3	4.6	5.6	10.8	8
31.6	5	6.1	11.9	13.3
20.8	3.6	4	8.7	8.5
23.2	4.4	4.8	10.5	9.1
25.6	4.9	5.6	10.9	11.3
30.7	5.5	5.9	12.9	11.4
16.9	2.9	3.2	6.2	6.3
27.4	4.5	5.4		
22.2	3.7	4	3.7	7.2
23.6	4.1	4.6	9.7	7.3
27.3	5.6	5.8	13.7	10.5
26.6	5.4	6	10	9
23.2	4.5	5	8.6	9
29.3	5.3	5.7	10.9	10.1
24.2	3	4.9	10.6	9.3
24.9	4.4	4.9	10.9	9.7
26	5.6	6.2	13.2	14.2
32	5.2	6	14.3	14.2
32.2	5.2	5.2	12.1	9.4
28.2	5.4	6.1	12.5	11.2

28.7	4.8	5.4	11.4	9
25.4	4.7	5.5	9.6	10.4
24.5	5.6	6.3	10.6	9.1
24.4	4.5	5.1	9.9	10.1
27.2	4.8	5.1	8	11.6
21.3	3.5	4.2	10	7.6
29.9	5.8	6.2	11	9.7
22.7	4.2	4.8	7.7	7.8
20.2	4.9	5.3	8.4	7.4
21.2	4.1	4.9	7	6.7
20.2				
24	4.4	5	9.7	8.4
26.9	4.8	5.4	10.5	10.5
19.8	5.4	5.9	9.3	8.5
28.7	5.7	5.8	12.4	11
21.6	4.9	4.9	9.9	8.8
25.9	5.8	5.7		
23.6	6.5	6.2	11.7	10
20.9	4.4	4.8	8.6	7.8
32.8	5.9	5.9		
22.1	3.8	4.1	7.2	7.3
25.1	4.9	5.3		
20.5	4.4	4.7	8	8.4
24.5	5	5.4	8.2	8.9
18.1	3.6	4.1	6.1	8.1
17.8	3.7	4	7.1	6.8
22.1	4.1	4.6	7.8	8.8
21.9	4.9	5	10.6	8.4
24.9	5	5.7		
22	4.9	5.2		
26	5	5.7	12.3	12.6
23.3	4.5	5	9.2	9.6
22.9	4.7	5.1	11.8	10
21.7	4.3	4.8	9.2	8
24.7	4	4.6	9.5	9
22.4	4	4.8		
22.9	4.1	4.3	9.6	7.9
22.9	4.1	4.8	8.6	8.9
25.2	4.1	4.9	10.5	11
25.2	4.3	5	10.9	10.4
23.4	4.6	5.5	11.1	12.6
25	6.2	6.5	10.9	12.6
29.6	5.7	6.4		
21.2	3.7	4		
24	5	5.5	9.9	10.8
27	5.5	5.8	13.1	9.9
26.9	4.6	5.6	14.8	11.2
25.7	4.2	5	12.7	12.9
30.3	6.3	6.8	11.5	14.3
19	4	4.3	11.1	9.1

22.2	3.9	4.5	10.6	12.4
22.8	3.3	4.4	9.3	10
19.5	3.2	3.8	7.9	10.3
25.2	5.1	6.2		
26.6	5.5	6.3	15.3	15.7
24.3	5.2	5.9	12.9	11.6
24.8	4.9	5.7	11.9	12.6
20.6	4.2	5	10.9	12
22.9	4.5	5.4	8.8	8.8
25	5.2	5.9	15.6	13.4
25.6	4.3	5.3	14.3	12.6
21.1	3.9	4.8	9.6	10.1
18.3	3.4	4.1	8.6	8.2
20.4	4	4.8	7.2	7.3
23.2	3.7	4.7	9.4	7.9
21.3	4.1	5.2	8.7	9.3
22	3.9	4.5		
21	4.3	4.7	7.8	9
20.7	3.8	4.5		
17.1	3	3.7	7.7	8.2
22.5	3.7	4.5	11.5	9.8
19.7	2.9	3.7	8.6	8.8
22.6	4.8	5	11	10.6
21.4	3.6	4.3	7.6	8.2
26.7	4.9	5.3	12	11
27.7	4.9	5.7	13.3	12.5
21.2	4.6	5.2	11	12.9
20.8	3.9	4.7		
22.8	3.9	4.5	9	10.6
18.8	4	5	8	8.8
29.5	6.4	7.3	16.5	13.7
26	6	6.6	15.9	15.3
23.1	5	5.9	12.9	11.7
28.7	5.2	6.1	13.4	10.7
21.1	4.3	5	7.3	8.8
19	3	3.5	6.2	6
17.8	3.7	4.3		
20	4.1	5	11.7	11.9
21.4	3.3	4.3	7.1	8.1
17.3	3.2	3.9		
23.6	3.8	4.5	10.5	10.4
23.7	3.9	4.8	10	9.6
21	4.3	4.9	10.9	10.2
32.4	6.7	7.3	16	16.5
19.4	4.1	4.5	9.1	7.8
18.7	4.5	5.4	8	9.7
24.8	4.7	5.5	12.2	12.7
23.6	4.8	5.9		
27.2	4.7	5.9	13.9	13.2
18.6	3.2	4.6	8.5	9.4

24.8	4.3	4.6	12.6	13.3
28.4	4.3	5.2		
27.4	3.7	4.8	10.8	10
29.4	5	6.1	11.9	11.3
16.4	3.6	4.6	7.1	6.9
26.6	5.5	6.3		
29.2	5.6	6.3	14.8	14.9
18.5	3.6	4.3	8.9	8.5
28.1	4.4	5.4	12.3	15.5
35	6.1	7	16.6	16.8
25.5	4.5	5.2	10.4	12.8
25.7	4.5	4.9	10	9.6
29.4	5	5.4	13.5	14.3
22.1	3.8	4.5	8.7	7.1
26.2	4.4	5.2	11.1	12.1
26.4	4.8	5.2	12.2	11.3
21.9	4.7	5	12	9.9
17.8	3.7	4.3	8.4	8.5
16.8	3.4	3.7	7.7	7.2
18.6	3.4	4	7.6	7
20.5	3.5	4.3	9.9	10.4
20.1	3.5	4.5	9	11.7
23.5	4	4.8	10.7	10.7
22.6	4.7	5.2	11.9	10.2
23.4	4.9	5.6	10.9	11.5
25.5	4.9	5.7	13.4	13.6
21.9	4.7	5	11.9	12.3
25.4	4.9	5.6	13	14.3
25.5	5.1	5.5	14.4	11.8
18.4	3.9	4.3	9	8.9
24.1	4.4	4.9	10.3	12.3
18.4	3.7	4.4	7.4	7.5
23.5	4.6	5.1	11.6	11.3
25.4	5	5.6	11.5	13.8
20.7	3.7	4.4	8.8	8.7
24	3.4	3.8	9.1	8.4
23.7	3.9	4.3	10.3	9.4
23.2	4	4.6	9.6	9.9
20.7	3.4	4	8.4	7.6
25.3	4.2	5	15.9	14.5
19.8	3.7	4.2		
25.5	4.5	4.9	12	12.7
19.4	4.5	4.9		
20.8	5.4	5.8		
18.8	4	4		
21.6	3.4	4.3	12	10.6
22	3.3	4	10.1	10.9
23.1	3.7	4.1	10.6	11.1
19.9	4.3	5.4	11.4	9.1
21.3	4.3	5	10.3	10.4

17.3	3.1	3.8	8.8	7.9
18.7	3.2	3.6	9	9.1
20.3	4.2	4.9	11.4	9.4
30.4	5.2	5.8	15.4	13.7
25.2	3.9	4.7	9.9	9.8
20.1	3.6	4.4	9.9	10.2
22.6	4.4	5.3	9.8	10.6
21.8	4.5	5.2	11.3	11.1
27.7	5	5.5	11.8	9.4
27.8	6.3	6	13.1	10.9
22.9	5	5.5	11.1	9.9
20.5	4.5	4.9		
22.6	4.5	5	8.7	8.9
17.8	3.4	3.9	9	9
24.2	3.7	4	11.6	9
22.9	3.9	4.5	9.9	9
23.3	5	5.9	12.9	11.4
27.8	5.4	6.2	13.8	15.7
23.9	4.6	5.3	11.7	11.4
18.7	3.3	3.8	7.2	8.6
22.8	3.8	4.2		
17				
24	4.6	5.2	11.6	10.5
19.6	3.5	4.2	9.8	9.6
21.7	4	5	9	9.9
20.9	2.8	3.3	8.9	9.1

Tetrabelus seclusus lawrencei				
L	**Dlmax**	**Dvmax**	**xl**	**xv**
22	5	5.9	11.5	11.1
25.8	5.3	6	12.2	12.5
25.9	5	5.6	10.3	11.7
21.5	3.9	4.1	8.4	9.2
24.4	5.1	5.7	11.2	9.8
23.5	3.7	4.3	10.4	9.9
28	5.4	6.5	10	10
21.9	3.9	4.3	7.8	8.2
25.3	5.2	5.6	9.7	9.1
21.7	4.2	5	9.2	9.7
19.4	3.8	4.3	8	6.3
24.9	4.6	4.9		
25.7	4.3	5	8.9	9.1
25.6	5	5.4		
26.4	4.8	5.8	11.4	12.8
26.7	4.4	5		
26.5	5	6.2		
20.9	3.8	4.4	7.8	8.1
20.6	3.4	4	8.8	8.8
29.6	5.2	5.9	10.7	10.8
19.9	3.2	3.6	6.9	7.2
21.8	3.5	4.1	7.6	7.3
18.4	3.9	4.8	7.1	6.8
24.4	4.3	4.6	9.9	11.1
30	5.9	6.2	14.9	12.8
28.1	5.5	5.8	13.4	12.6
20	3.2	3.6	8.9	8.7
27.2	5	5.5	13.9	11.8